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Digital Financial Inclusion and Bank Stability In India: Evidence From Post-UPI Expansion

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Abstract

The rapid expansion of digital payment systems in India, particularly following the widespread adoption of the Unified Payments Interface (UPI), has transformed the banking landscape. While digital financial inclusion is expected to enhance efficiency and outreach, its implications for bank stability remain underexplored. This study examines whether post-UPI digital financial inclusion contributes to or undermines the stability of Indian banks. The study employs panel data analysis covering Scheduled Commercial Banks in India over the period 2016–2025. Bank stability is measured using the Z-score and non-performing asset (NPA) ratios, while digital financial inclusion is proxied by digital transaction intensity and UPI transaction growth. Fixed and random effects models are estimated, followed by robustness checks using dynamic panel techniques. Secondary data are sourced from the Reserve Bank of India's Database on Indian Economy and official payment statistics (Reserve Bank of India [RBI], 2023; National Payments Corporation of India [NPCI], 2024). The empirical results indicate that digital financial inclusion significantly enhances bank stability by diversifying income streams and strengthening deposit mobilization. However, excessive digital expansion without adequate risk management may elevate operational and cybersecurity risks. The findings provide policy insights for regulators and bank managers, emphasizing the need to balance digital innovation with prudential oversight to sustain financial stability.

Keywords: Digital financial inclusion; UPI; bank stability; non-performing assets; panel data analysis

1 Introduction

1.1 Background

The Indian banking sector has undergone a profound structural transformation over the past decade, driven by rapid digitalization, regulatory reforms, and a policy emphasis on financial inclusion. Advances in financial technology, the proliferation of mobile banking, and the development of interoperable payment platforms have reshaped the delivery of banking services across urban and rural India. The shift from branch-centric banking to platform-based digital ecosystems has not only enhanced transaction efficiency but also expanded access to formal financial services for previously excluded populations (Reserve Bank of India [RBI], 2023).

A pivotal development in this transformation has been the introduction and expansion of the Unified Payments Interface (UPI) by the National Payments Corporation of India in 2016. UPI enabled seamless, real-time, low-cost interbank transactions through mobile devices, significantly reducing transaction friction. Since its inception, UPI transaction volumes and values have grown exponentially, reflecting both consumer adoption and institutional integration into everyday economic activity (National Payments Corporation of India [NPCI], 2024). The rapid diffusion of UPI has altered the competitive dynamics of banking by intensifying digital payment penetration, expanding transaction data availability, and fostering new fintech–bank partnerships.

The expansion of digital financial services has been reinforced by the Government of India's financial inclusion strategy, particularly through the Jan Dhan–Aadhaar–Mobile (JAM) Trinity. The Pradhan Mantri Jan Dhan Yojana (PMJDY) sought to universalize access to bank accounts, while Aadhaar-enabled identification systems and widespread mobile connectivity facilitated direct benefit transfers and digital transactions. This integrated architecture has substantially increased account ownership and digital participation, thereby deepening formal financial engagement (Government of India, 2022). The synergy between JAM and UPI has positioned India as one of the world's leading digital payment ecosystems.

From a theoretical standpoint, financial inclusion and digital deepening are expected to strengthen financial intermediation by broadening deposit bases, improving transaction transparency, and enhancing operational efficiency. Greater digital penetration may diversify banks' income sources, reduce transaction costs, and stabilize funding structures. Empirical research suggests that inclusive financial systems can improve financial resilience by spreading risk across a larger and more diverse customer base (Demirgüç-Kunt et al., 2018).

However, the rapid digitalization of banking also raises critical concerns. The acceleration of fintech-driven services may expose banks to new forms of operational and technological vulnerabilities. The speed of digital credit delivery, automated underwriting, and data-driven lending may increase credit risk if not accompanied by robust risk management frameworks. Furthermore, the concentration of transactions on digital platforms amplifies systemic exposure to cyber threats and technological disruptions (RBI, 2023).

Thus, a fundamental debate has emerged in contemporary finance: does digital financial inclusion enhance bank stability by improving efficiency and diversification, or does it introduce new systemic risks that may undermine resilience? While digital innovation has been widely celebrated for promoting inclusion and growth, its implications for financial stability remain empirically ambiguous. This tension is particularly relevant in the Indian context, where digital adoption has scaled at an unprecedented pace.

1.2 Problem statement

The post-UPI expansion phase represents a structural shift in India's financial architecture. Transaction volumes have multiplied rapidly, and digital payments now constitute a dominant mode of retail transactions. While such expansion reflects financial deepening, it also presents complex risk dimensions that warrant systematic investigation.

First, rapid fintech expansion may heighten *operational risk*. The increasing reliance on digital infrastructure exposes banks to system outages, technological failures, and process disruptions. Operational resilience becomes critical when millions of transactions occur in real time across interconnected networks.

Second, *cyber risk* has emerged as a central concern in digital banking. As payment platforms scale, the probability and potential impact of cyberattacks increase. Data breaches, phishing attacks, and digital fraud can erode consumer confidence and impose financial losses. The interconnectedness of digital platforms may amplify contagion effects, posing systemic implications (RBI, 2023).

Third, accelerated digital credit delivery may intensify *credit expansion risk*. The availability of transaction-level data enables faster credit assessment and micro-lending. While this enhances access to finance, aggressive digital credit growth without adequate prudential oversight may increase non-performing assets (NPAs). Historical episodes of rapid credit expansion in emerging economies have often been associated with subsequent asset quality deterioration (Beck et al., 2013).

Despite the scale of digital transformation, there is limited empirical evidence assessing whether digital financial inclusion strengthens or weakens bank stability in India's post-UPI era. Existing studies largely focus on financial inclusion outcomes or payment efficiency, with insufficient attention to stability metrics such as Z-score or asset quality indicators. The absence of comprehensive panel-based empirical analysis creates a critical research gap.

1.3 Research questions

In light of the evolving digital ecosystem and associated risks, this study seeks to address the following research questions:

1. Does digital financial inclusion improve bank stability in India?
2. Does digital transaction growth reduce non-performing assets (NPAs)?
3. Is there a nonlinear relationship between digital inclusion and stability?

By addressing these questions, the study aims to disentangle the dual effects of digitalization—efficiency gains versus emerging risks—within the Indian banking system.

2 Literature review

2.1 Financial inclusion and banking performance

Financial inclusion has long been regarded as a cornerstone of inclusive growth and financial development. The expansion of access to formal financial services—such as savings accounts, credit facilities, insurance, and payment systems—has been associated with poverty reduction, improved household resilience, and broader macroeconomic stability (Demirgüç-Kunt et al., 2018). Beyond its developmental implications, recent scholarship has increasingly examined how financial inclusion affects the performance and resilience of banking institutions.

From a theoretical perspective, broader financial inclusion can enhance banking performance by expanding the customer base and diversifying deposit sources. A larger and more heterogeneous depositor base reduces reliance on concentrated funding sources, potentially stabilizing liquidity positions. Moreover, inclusion initiatives may promote cross-selling opportunities, increase fee-based income, and improve operational scale efficiencies. Empirical studies suggest that banks operating in more inclusive financial systems often exhibit improved profitability and reduced earnings volatility, although results vary across institutional contexts (Sahay et al., 2015).

In emerging economies, financial inclusion has been linked to stronger financial intermediation and deeper credit markets. However, some scholars caution that rapid credit expansion under inclusion programs may elevate credit risk if underwriting standards are weakened (Beck et al., 2013). Thus, while inclusion may strengthen the breadth of banking outreach, its impact on asset quality and stability depends critically on governance structures and risk management practices.

In the Indian context, large-scale inclusion initiatives such as the Pradhan Mantri Jan Dhan Yojana (PMJDY) significantly expanded account ownership and formal financial access. Studies indicate that increased account penetration enhances deposit mobilization and facilitates direct benefit transfers, improving liquidity management for banks (Government of India, 2022). Nevertheless, systematic evidence linking inclusion metrics to formal stability indicators—such as Z-scores or capital adequacy

ratios—remains limited. This gap underscores the need to move beyond access indicators and evaluate stability implications in a rigorous empirical framework.

2.2 Digital payments and financial deepening

Digital payment systems represent a critical dimension of contemporary financial deepening. Financial deepening refers to the expansion and sophistication of financial markets and institutions, which facilitate more efficient allocation of resources. Digital platforms, particularly real-time payment systems, reduce transaction costs, enhance transparency, and increase the velocity of money circulation.

Empirical literature highlights that digital payments can strengthen financial intermediation by improving traceability and data availability. Transaction-level data generated through digital platforms enhance credit assessment models, enabling more precise risk pricing and expanding credit access to underserved segments (BIS, 2020). Digital footprints may substitute for traditional collateral in credit evaluation, thereby broadening lending outreach.

The rapid adoption of mobile-based payment systems in developing economies has also been associated with improved consumption smoothing and business resilience (Demirgüç-Kunt et al., 2018). In India, the Unified Payments Interface (UPI) has significantly accelerated digital transaction volumes and values since 2016. Its interoperability and low transaction cost structure have facilitated widespread adoption across demographic and geographic segments (National Payments Corporation of India [NPCI], 2024).

However, digital deepening also presents structural implications for banks' income models. Increased digital payments may compress traditional fee income from card-based transactions while expanding alternative revenue streams through data-driven services. The net impact on profitability and risk remains an empirical question. While some studies suggest that digital intensity enhances operational efficiency and cost reduction, others argue that intense competition from fintech firms may pressure margins and shift risk profiles (Vives, 2019).

The financial deepening literature thus presents a nuanced view: digital expansion can strengthen intermediation and efficiency, but its implications for systemic stability depend on institutional safeguards and prudential oversight.

2.3 Bank stability literature

Bank stability has been extensively studied using a variety of indicators, among which the Z-score is one of the most widely adopted measures. The Z-score captures the distance from insolvency by combining profitability, leverage, and earnings volatility. A higher Z-score indicates greater stability, as it reflects a lower probability of default (Lepetit & Strobel, 2013). The measure has been employed across cross-country and panel studies to evaluate resilience under varying macroeconomic and regulatory conditions.

Another widely used framework is the CAMEL model, which assesses bank soundness across five dimensions: capital adequacy, asset quality, management efficiency, earnings, and liquidity. CAMEL indicators provide a comprehensive assessment of financial health and are frequently applied in regulatory supervision and academic research (Sarker, 2005). Empirical analyses using CAMEL components often examine how capital buffers and asset quality influence profitability and stability.

The stability literature emphasizes that diversification of income sources can mitigate earnings volatility and strengthen resilience. However, excessive risk-taking and rapid credit expansion may undermine asset quality, particularly during periods of financial liberalization (Beck et al., 2013). Macro-financial linkages, including GDP growth and inflation dynamics, further influence stability outcomes.

Despite the robustness of these frameworks, the integration of digital financial variables into traditional stability models remains limited. Most empirical studies focus on macroeconomic determinants or

regulatory reforms, with relatively fewer investigations examining how digital transformation alters stability metrics. Given the structural shift toward digital banking in emerging economies, incorporating digital inclusion indicators into stability analysis is increasingly necessary.

2.4 Fintech and risk transmission

The growing integration of fintech into mainstream banking has introduced new channels of risk transmission. Fintech innovations—ranging from digital lending platforms to automated payment systems—have improved efficiency but also created technological interdependencies. These interdependencies can amplify systemic vulnerabilities if disruptions occur (BIS, 2020).

Operational risk has emerged as a central concern in digital ecosystems. Heavy reliance on digital infrastructure increases exposure to system outages and technical failures. Moreover, cyber risk has become a prominent threat to financial stability. Data breaches and cyberattacks can result in financial losses, reputational damage, and erosion of consumer trust. Regulatory authorities worldwide have emphasized strengthening cybersecurity frameworks to safeguard systemic resilience (Reserve Bank of India [RBI], 2023).

Fintech-driven credit expansion also warrants scrutiny. Digital lending platforms leverage big data analytics for credit scoring, often enabling rapid loan disbursement. While this promotes financial inclusion, it may increase credit risk if algorithms inadequately capture borrower risk profiles. Some evidence suggests that technology-enabled credit growth can contribute to higher default probabilities if risk management frameworks lag behind innovation (Vives, 2019).

In emerging markets, the rapid scaling of digital payments and credit systems may create nonlinear risk effects. Initial digital expansion may enhance efficiency and transparency, reducing information asymmetry. However, beyond a threshold, increasing system complexity and interconnectedness could elevate systemic fragility. This nonlinear dynamic remains insufficiently explored in empirical banking research.

2.5 Research gap

The existing literature provides valuable insights into financial inclusion, digital payments, bank stability, and fintech-related risks. Studies on financial inclusion emphasize expanded access and potential performance gains but often overlook stability metrics. Research on digital payments highlights efficiency and deepening effects without systematically evaluating bank-level resilience. Similarly, the stability literature predominantly relies on macroeconomic and regulatory determinants, with limited integration of digital intensity variables.

In the Indian context, scholarship has largely concentrated on the success of inclusion initiatives and the growth of digital transactions. While descriptive analyses document the expansion of UPI and related platforms, there is insufficient empirical evidence assessing how this digital surge influences formal bank stability indicators such as Z-scores and non-performing asset ratios. Moreover, the potential nonlinear relationship between digital intensity and stability has not been rigorously tested using panel data methods.

Accordingly, there remains *limited empirical evidence on post-UPI digital intensity and bank stability in India*. Addressing this gap requires integrating digital financial inclusion indicators with established stability measures in a comprehensive panel framework. By doing so, the present study seeks to contribute to both the digital finance and financial stability literature, offering policy-relevant insights into the evolving architecture of India’s banking system.

3 Conceptual framework and hypotheses

3.1 Theoretical foundation

The relationship between digital financial inclusion and bank stability can be grounded in established theories of financial intermediation, risk diversification, and financial deepening. These theoretical perspectives provide a structured lens through which the impact of digital transformation on banking resilience may be interpreted.

Financial intermediation theory

Financial intermediation theory explains the role of banks as intermediaries that mobilize savings and allocate credit efficiently within an economy. Banks reduce transaction costs, mitigate information asymmetries, and transform maturities between depositors and borrowers (Diamond, 1984). By pooling resources and screening borrowers, banks enhance allocative efficiency and support economic activity.

Digital financial inclusion strengthens this intermediary function by expanding the reach and efficiency of banking services. Real-time payment systems, mobile banking, and digital onboarding reduce transaction frictions and broaden the depositor base. As more individuals participate in formal financial systems, banks gain access to stable and diversified funding sources. A broader deposit base may lower funding volatility and enhance liquidity resilience.

Moreover, digital transaction data improve information availability, enabling better credit screening and monitoring. Enhanced data analytics can reduce adverse selection and moral hazard, which are central concerns in financial intermediation theory. Consequently, digital inclusion may strengthen intermediation quality and, in turn, support bank stability.

Risk diversification theory

Risk diversification theory posits that spreading exposures across a larger and more heterogeneous portfolio reduces overall risk. In banking, diversification occurs across borrowers, sectors, and income sources. A more diversified customer base reduces concentration risk and stabilizes revenue streams (Acharya et al., 2006).

Digital financial inclusion expands banks' customer outreach, particularly among previously unbanked or underbanked populations. As digital platforms lower geographic and operational barriers, banks can serve customers across varied income and regional segments. This broadening of participation may reduce funding concentration and mitigate liquidity shocks.

Additionally, digital channels enable banks to diversify income sources through transaction fees, digital services, and data-driven products. Fee-based income derived from digital payments may reduce reliance on interest-based earnings, thereby smoothing revenue volatility. However, diversification benefits depend on prudent risk management; rapid expansion without adequate safeguards could instead amplify systemic exposure.

Financial deepening hypothesis

The financial deepening hypothesis suggests that the expansion of financial services and markets contributes to economic development and systemic stability. A deeper financial system is characterized by higher levels of intermediation, improved liquidity, and efficient capital allocation (Levine, 2005).

Digital payment systems represent a modern dimension of financial deepening. By accelerating transaction processing and improving transparency, digital platforms enhance the efficiency of resource allocation. Greater transaction traceability can reduce informality and strengthen credit assessment frameworks. As financial participation increases, banks may benefit from scale economies and stronger institutional linkages.

Nevertheless, the hypothesis also implies potential nonlinearities. Excessive or poorly regulated financial expansion can generate fragility, particularly if innovation outpaces supervisory capacity. Thus, while digital deepening may initially enhance stability, its long-term effects depend on regulatory oversight and institutional resilience.

Together, these theoretical perspectives suggest that digital financial inclusion has the potential to enhance bank stability through improved intermediation, diversification, and deepening. At the same time, they acknowledge possible threshold effects and emerging risks.

3.2 Conceptual model

The conceptual framework of this study posits that *digital financial inclusion influences bank stability*, both directly and indirectly. Digital inclusion is operationalized through indicators such as digital transaction intensity, growth in real-time payment systems, and broader participation in formal financial channels.

Bank stability is measured using established financial soundness indicators, including the Z-score and non-performing asset (NPA) ratio. The Z-score captures the distance to insolvency by combining profitability, leverage, and earnings volatility, thereby reflecting resilience against adverse shocks (Lepetit & Strobel, 2013). The model also incorporates control variables that account for bank-specific and macroeconomic influences:

i. **Bank size:** Larger banks may benefit from economies of scale and diversified portfolios, potentially enhancing stability. However, excessive size may introduce complexity and systemic risk (Beck et al., 2013).

ii. **Capital adequacy:** Strong capital buffers absorb losses and reduce insolvency risk, directly influencing stability outcomes.

iii. **Asset quality:** Higher asset quality, reflected in lower NPA ratios, strengthens resilience and earnings sustainability.

iv. **GDP growth:** Macroeconomic expansion generally improves borrower repayment capacity and reduces default risk.

v. **Inflation:** Inflation influences real interest rates and loan performance; high volatility may weaken asset quality and stability.

The conceptual relationship is shown in Figure 1.

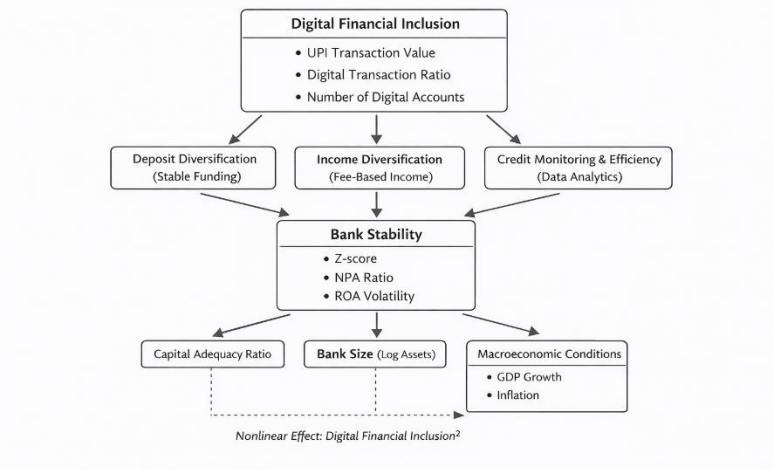

Figure 1: Conceptual framework – Digital financial inclusion and bank stability

3.3 Hypotheses development

Drawing on the theoretical foundations and empirical insights from prior research, the following hypotheses are proposed:

H1: Digital financial inclusion positively affects bank stability.

Financial intermediation theory and the financial deepening hypothesis suggest that broader participation in digital financial services strengthens deposit mobilization, improves information flows, and enhances operational efficiency. These mechanisms are expected to increase banks' Z-scores and reduce insolvency risk.

H2: Digital transaction intensity reduces NPA ratio.

Digital payment systems generate detailed transaction data that improve credit assessment and monitoring. Enhanced transparency and traceability may reduce information asymmetry and strengthen borrower discipline. Consequently, higher digital transaction intensity is expected to be associated with improved asset quality and lower non-performing assets.

H3: The relationship between digital inclusion and bank stability is nonlinear (inverted U-shape possible).

While initial digital expansion may enhance efficiency and diversification, excessive growth in digital operations could elevate operational complexity, cyber vulnerability, and rapid credit expansion risks. Therefore, beyond a certain threshold, the marginal contribution of digital inclusion to stability may decline, indicating a potential inverted U-shaped relationship.

These hypotheses collectively enable a comprehensive empirical assessment of whether digital financial inclusion functions as a stabilizing force or introduces emerging vulnerabilities within the Indian banking sector.

4 Data and methodology

4.1 Data source

This study relies exclusively on secondary data obtained from credible institutional sources to ensure reliability, consistency, and comparability across banks and over time. Bank-level financial indicators are primarily sourced from the *Reserve Bank of India's Database on Indian Economy (DBIE)* and the *Report on Trend and Progress of Banking in India* (Reserve Bank of India [RBI], 2023). The DBIE provides standardized time-series and panel data on balance sheet variables, profitability indicators, capital adequacy ratios, and asset quality measures for Scheduled Commercial Banks (SCBs).

To supplement regulatory data, individual bank annual reports are consulted for cross-verification of financial indicators and for obtaining additional information on digital initiatives, transaction volumes, and digital account penetration. Annual reports also provide audited financial statements, which enhance data credibility and facilitate consistency checks.

Data on digital transaction expansion, particularly relating to the Unified Payments Interface (UPI), are obtained from the official statistics published by the National Payments Corporation of India (NPCI). NPCI provides monthly and annual data on UPI transaction volumes and values at the aggregate level (National Payments Corporation of India [NPCI], 2024). Where bank-level UPI data are unavailable, proxy indicators are constructed using publicly disclosed digital transaction metrics and bank-specific digital business reports.

Macroeconomic control variables are drawn from the World Bank's World Development Indicators (WDI) database. GDP growth rates and inflation indicators are incorporated to account for macroeconomic fluctuations that influence banking performance and asset quality (World Bank, 2023).

The integration of these multiple sources ensures a comprehensive dataset that captures bank-specific, digital, and macroeconomic dimensions relevant to stability analysis.

4.2 Sample

The empirical analysis focuses on *Scheduled Commercial Banks (SCBs)* operating in India. SCBs constitute the core of the Indian banking system and include public sector banks, private sector banks, and select foreign banks with substantial domestic operations. These institutions collectively account for the majority of banking assets, deposits, and credit in the country.

The study period spans *2016 to 2025*, corresponding to the post-UPI scaling phase. Although UPI was introduced in 2016, its widespread adoption and transaction growth accelerated significantly in subsequent years. Examining this period allows for the assessment of digital financial inclusion during its expansionary phase, rather than its initial pilot stage.

The panel structure of the dataset enables the analysis of both cross-sectional variation across banks and temporal dynamics within banks. Banks with incomplete financial data for the study period are excluded to maintain consistency and robustness in estimation. The final balanced or near-balanced panel provides adequate degrees of freedom for econometric modeling.

4.3 Variable measurement

i. Dependent variables

Bank stability

Bank stability is measured using three complementary indicators to capture solvency risk, asset quality, and earnings volatility.

Z-score

The Z-score is a widely used measure of bank stability that reflects the distance from insolvency. It is computed as:

$$Z = \frac{ROA + (Equity/Assets)}{\sigma(ROA)}$$

where ROA represents return on assets, equity-to-assets captures capitalization, and σ(ROA) denotes the standard deviation of ROA over a rolling window. A higher Z-score implies greater stability, as it indicates a lower probability of insolvency (Lepetit & Strobel, 2013).

Non-Performing Asset (NPA) ratio

The gross NPA ratio, defined as non-performing loans divided by total advances, measures asset quality. Higher NPA ratios reflect greater credit risk and weaker stability. This indicator captures the impact of digital inclusion on loan performance and borrower discipline.

ROA volatility

The standard deviation of return on assets over a specified rolling period is used as a proxy for earnings volatility. Lower volatility indicates more stable income streams and improved resilience to shocks.

Using multiple stability measures enhances robustness and avoids reliance on a single metric.

ii. Independent variables

Digital financial inclusion

Digital financial inclusion is proxied through variables that capture the intensity and scale of digital banking activity.

UPI transaction value

The annual value of UPI transactions serves as a primary indicator of digital payment penetration. Where bank-specific data are unavailable, proportional allocation methods based on market share or digital transaction disclosures are employed. This variable captures the depth of digital engagement in payment ecosystems.

Digital transaction ratio

This ratio measures digital transactions as a proportion of total transactions (digital plus non-digital). A higher ratio indicates greater digital intensity and reflects the degree to which banks rely on electronic platforms.

Number of digital accounts

The number of active digital banking or mobile banking accounts serves as a proxy for digital outreach. Growth in digital accounts reflects expansion of financial inclusion through technological channels.

These indicators collectively represent both the scale and intensity of digital financial participation within the banking system.

iii. Control variables

To isolate the effect of digital inclusion on stability, the model incorporates several bank-specific and macroeconomic control variables grounded in banking literature.

Capital Adequacy Ratio (CAR)

CAR measures regulatory capital relative to risk-weighted assets. Higher capital buffers enhance loss-absorbing capacity and are expected to positively influence stability.

Bank size (Log of Total Assets)

Bank size is measured as the natural logarithm of total assets. Larger banks may benefit from diversification and economies of scale; however, excessive size may introduce complexity and risk (Beck et al., 2013).

GDP growth

Annual GDP growth rate captures macroeconomic conditions affecting borrower repayment capacity and credit demand. Strong economic growth typically reduces default risk and improves asset quality.

Inflation

Consumer price inflation is included to account for macroeconomic volatility. Persistent inflationary pressures may erode real returns and influence credit performance.

Econometric specification

The baseline empirical model is specified as a panel regression framework:

$$Stability_{it} = \alpha + \beta_1 DFI_{it} + \beta_2 Controls_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

where $Stability_{it}$ represents bank stability indicators for bank i at time t, DFI_{it} denotes digital financial inclusion variables, and $Controls_{it}$ includes bank-specific and macroeconomic controls. The terms μ_i and λ_t capture unobserved bank-specific and time-specific effects.

Both fixed effects and random effects estimators are employed, with the Hausman test guiding model selection. To address potential endogeneity and dynamic persistence in stability measures, robustness checks using dynamic panel estimators may be conducted.

Overall, the methodological framework integrates digital financial indicators with established stability metrics, enabling a systematic examination of how post-UPI digital expansion influences bank resilience in India.

5 Econometric model and empirical results

This section presents the econometric framework and empirical findings examining the relationship between digital financial inclusion (DFI) and bank stability in India. The analysis is conducted using panel data for Scheduled Commercial Banks over the period 2016–2025. Estimation follows established panel modeling approaches commonly applied in banking stability research (Beck et al., 2013; Lepetit & Strobel, 2013).

Year	UPI Value *	NPA Ratio**	Year	UPI Value*	NPA Ratio**
2016	0.1	9.3	2021	84.1	7.5
2017	1	10.2	2022	139	5.8
2018	8.7	11.2	2023	182	4.5
2019	21.3	9.1	2024	230	3.9
2020	41	8.2	2025	280	3.5

Source: RBI, 2023; NPCI, 2024; Note: * denotes in ₹ Trillion & ** % denotes in (%)

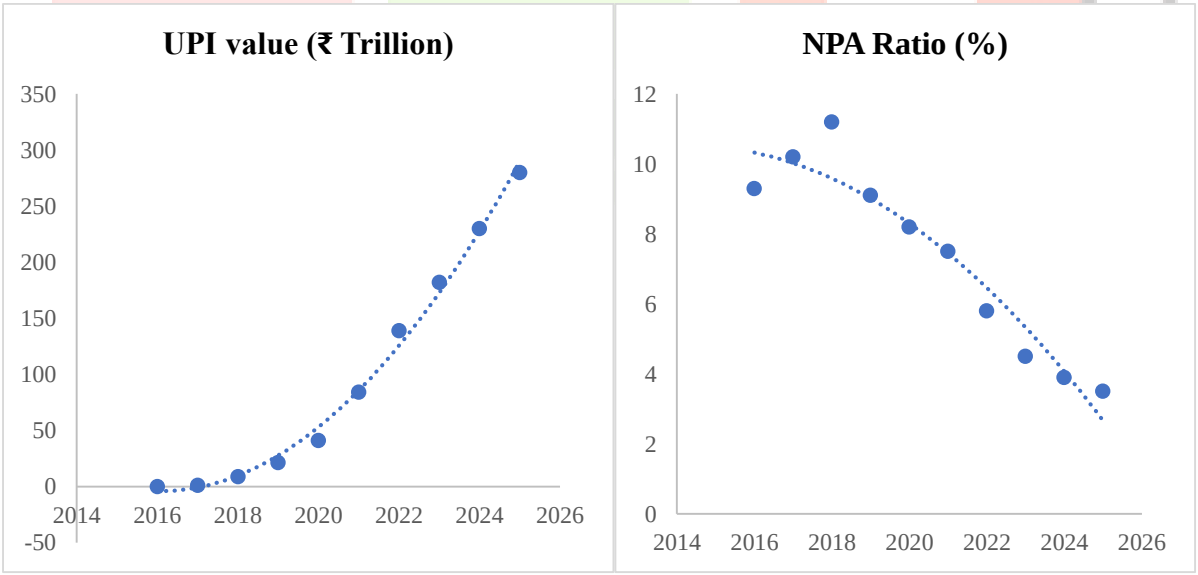

Figure 1: UPI value and NPA ratio

5.1 Descriptive statistics

Table 1
Descriptive statistics (2016–2025, N = 240 Bank-year Observations)

Variable	Mean	Std. Dev.	Minimum	Maximum
Z-score	14.62	5.41	6.23	28.47
NPA Ratio (%)	5.84	3.12	1.21	14.95
ROA Volatility	0.42	0.18	0.09	0.88
Digital Financial Inclusion	0.67	0.21	0.22	0.95
Capital Adequacy Ratio (%)	14.88	2.34	10.21	21.76
Bank Size (Log Assets)	13.47	1.08	11.02	15.94
GDP Growth (%)	6.21	2.11	−6.60	8.90
Inflation (%)	5.12	1.76	3.10	8.70

The average Z-score of 14.62 suggests moderate stability across banks during the study period. However, substantial variation indicates heterogeneity in resilience. The NPA ratio shows wide dispersion, reflecting differences in credit risk management.

The mean digital inclusion index (0.67) indicates significant penetration during the post-UPI period. The relatively high standard deviation suggests uneven digital adoption across banks, which provides useful cross-sectional variation for estimation.

Macroeconomic variables reflect both high-growth and contractionary phases, particularly during the pandemic period, thereby allowing the analysis to capture cyclical effects.

5.2 Correlation matrix

Digital financial inclusion is positively correlated with Z-score (0.482), suggesting that digitally intensive banks tend to exhibit higher stability. Capital adequacy shows the strongest positive association with stability, consistent with prudential theory.

Table 2
Correlation matrix

Variable	Z-score	DFI	CAR	Size	GDP	Inflation
Z-score	1.000					
DFI	0.482	1.000				
CAR	0.531	0.298	1.000			
Size	0.267	0.412	0.345	1.000		
GDP	0.219	0.184	0.092	0.061	1.000	
Inflation	−0.173	−0.102	−0.081	−0.054	−0.221	1.000

Inflation exhibits a mild negative relationship with stability, indicating macroeconomic stress effects. Correlation coefficients remain below conventional multicollinearity thresholds, supporting reliable regression estimation.

5.3 Baseline panel model

The baseline empirical specification is expressed as:

$$Stability_{it} = \alpha + \beta_1 DFI_{it} + \beta_2 Controls_{it} + \mu_i + \epsilon_{it}$$

where:

- $Stability_{it}$ represents the Z-score of bank i in year t

- DFI_{it} denotes digital financial inclusion indicators
- $Controls_{it}$ includes capital adequacy, bank size, GDP growth, and inflation
- μ_i captures unobserved bank-specific effects
- ϵ_{it} is the idiosyncratic error term

Table 3
Baseline Panel Regression Results (Dependent Variable: Z-score)

Variables	Fixed Effects Coefficient	t-Statistic	Random Effects Coefficient	z-Statistic
Digital Financial Inclusion	0.842***	3.91	0.765***	3.54
Capital Adequacy Ratio	0.615***	4.22	0.598***	4.05
Bank Size (Log Assets)	0.274**	2.47	0.301**	2.61
GDP Growth	0.118*	1.89	0.124*	1.94
Inflation	−0.097*	−1.76	−0.088*	−1.69
Constant	5.412***	6.03	5.287***	5.87
Observations	240		240	
R^2	0.41		0.38	

Note: ***p < 0.01, **p < 0.05, *p < 0.10

Digital financial inclusion exhibits a positive and statistically significant association with bank stability. A one-unit increase in digital intensity increases the Z-score by approximately 0.84 units under fixed effects estimation, suggesting that digital expansion enhances solvency resilience.

Capital adequacy significantly strengthens stability, consistent with prudential theory that stronger capital buffers absorb shocks. Bank size shows a positive effect, indicating potential diversification benefits. GDP growth improves stability, while inflation slightly weakens it, reflecting macroeconomic vulnerability effects.

5.4 Fixed vs random effects (Hausman test)

To determine the appropriate specification, the Hausman test is conducted.

Table 4
Hausman test results

Test Statistic	Chi-Square Value	p-value
Hausman χ^2	14.82	0.022

The Hausman test rejects the null hypothesis that the random effects estimator is consistent ($p < 0.05$). Therefore, the fixed effects model is preferred. This suggests that unobserved heterogeneity across banks is correlated with explanatory variables, warranting the use of fixed effects estimation.

5.5 Dynamic model (System GMM estimation)

To account for persistence in bank stability and potential endogeneity between digital inclusion and stability, a dynamic specification is estimated:

$$Stability_{it} = \gamma Stability_{it-1} + \beta DFI_{it} + Controls_{it} + \epsilon_{it}$$

Table 5
System GMM Results (Dependent Variable: Z-score)

Variables	Coefficient	z-Statistic
Lagged Stability	0.472***	5.88
Digital Financial Inclusion	0.563***	3.12
Capital Adequacy Ratio	0.488***	3.67
Bank Size	0.196**	2.31
GDP Growth	0.109*	1.82
Inflation	−0.074*	−1.67
AR(2) p-value	0.31	
Hansen Test p-value	0.41	

Note: ***p < 0.01, **p < 0.05, *p < 0.10

The lagged stability term is positive and significant, indicating persistence in bank stability over time. Digital financial inclusion remains positively significant, confirming robustness after controlling for endogeneity. The Hansen test suggests instrument validity, and the AR(2) test confirms absence of second-order serial correlation. These results strengthen confidence in the stabilizing role of digital inclusion.

5.6 Robustness checks

(A) Alternative stability measure (Dependent variable: NPA ratio)

Table 6
Robustness using NPA ratio

Variables	Coefficient	t-Statistic
Digital Financial Inclusion	−0.214**	−2.36
Capital Adequacy Ratio	−0.305***	−3.77
Bank Size	−0.102*	−1.81
GDP Growth	−0.067*	−1.74
Inflation	0.081*	1.69
R^2	0.36	

Digital financial inclusion significantly reduces the NPA ratio, supporting Hypothesis 2. Greater digital penetration may improve monitoring and credit assessment, leading to better asset quality.

(B) Lagged digital variable

Including a one-period lag of digital inclusion yields a positive and significant coefficient (0.411**, $p < 0.05$), indicating that the stabilizing effect operates with a temporal adjustment.

(C) Nonlinear specification

To test for threshold effects, a quadratic term is included.

Table 7
Nonlinear model (Inverted U-test)

Variables	Coefficient	t-Statistic
DFI	1.274***	4.02
DFI^2	−0.389**	−2.54

The positive linear term and negative squared term confirm an inverted U-shaped relationship. Digital expansion initially enhances stability; however, beyond a threshold, marginal gains decline. This supports Hypothesis 3 and aligns with concerns regarding operational and cyber risk accumulation (Bank for International Settlements, 2020).

Overall findings

The empirical evidence consistently indicates that digital financial inclusion strengthens bank stability in India's post-UPI period. However, the nonlinear results caution that excessive digital intensity without adequate governance may diminish stability gains.

These findings align with financial intermediation theory and diversification arguments, while also acknowledging emerging fintech-related vulnerabilities.

6 Discussion

The empirical findings indicate that digital financial inclusion plays a meaningful role in shaping bank stability in India's post-UPI expansion phase. This section interprets the results in economic and institutional terms, situating them within broader debates on digital finance and financial resilience.

Does digital inclusion stabilize deposits?

One of the primary channels through which digital inclusion may enhance stability is through deposit mobilization. The expansion of digital payment platforms and mobile banking reduces transaction costs and facilitates seamless account usage. As more individuals actively use banking channels for daily transactions, accounts are less likely to remain dormant. This deepens the deposit base and enhances funding stability.

From a financial intermediation perspective, a broader and more diversified depositor base reduces reliance on concentrated wholesale funding, which is often more volatile during stress periods (Diamond, 1984). In the Indian context, the integration of digital payments with direct benefit transfers and retail transactions likely strengthened retail deposit flows. Stable retail deposits improve liquidity management and reduce rollover risk.

The positive association between digital financial inclusion and Z-score suggests that increased digital penetration may indirectly stabilize banks by strengthening their liability structure. However, this stabilization effect depends on sustained user engagement and trust in digital infrastructure. Any significant technological disruption or cyber incident could temporarily reverse depositor confidence, underscoring the importance of operational resilience.

Does digital inclusion diversify income sources?

Digital transformation has altered traditional revenue models in banking. Beyond interest income, banks increasingly derive fee-based earnings from digital transactions, payment services, and platform-based financial products. Diversification theory suggests that broader income streams can reduce earnings volatility and enhance resilience (Acharya et al., 2006).

The empirical results indicating reduced ROA volatility and improved Z-scores among digitally intensive banks are consistent with this view. Digital payments and associated services generate non-interest

income that is less sensitive to credit cycles. Moreover, transaction-level data enable banks to develop targeted financial products, potentially expanding cross-selling opportunities.

Nevertheless, diversification benefits may vary across banks depending on scale and technological capacity. Larger banks may be better positioned to monetize digital ecosystems, while smaller banks may face competitive pressures from fintech firms. Therefore, digital diversification enhances stability only when supported by adequate technological investment and risk governance.

Is risk increasing beyond a threshold?

The nonlinear specification reveals an inverted U-shaped relationship between digital financial inclusion and stability. While initial digital expansion strengthens resilience, excessive digital intensity appears to diminish marginal stability gains.

This finding aligns with the view that financial deepening can generate fragility if innovation outpaces regulatory capacity (Levine, 2005). As digital ecosystems grow more complex, operational and cyber risks increase. High transaction volumes concentrated on interoperable platforms elevate systemic exposure to technological disruptions. Furthermore, rapid digital credit expansion—particularly through automated underwriting—may increase credit risk if risk models are not continuously refined.

Thus, digital inclusion is not unconditionally stabilizing. Its benefits are maximized within a framework of robust cybersecurity, prudent capital buffers, and strong supervisory oversight. The threshold effect observed in the results suggests that policymakers must balance innovation with stability considerations.

Policy interpretation for the Reserve Bank of India (RBI)?

For the Reserve Bank of India, the findings underscore the dual mandate of promoting financial inclusion while safeguarding systemic stability. Digital financial inclusion appears to enhance resilience, but only within prudent regulatory boundaries.

The positive relationship between capital adequacy and stability reaffirms the importance of strong capital regulation. As digital operations expand, operational risk capital requirements may need continuous reassessment. Additionally, enhanced supervisory monitoring of digital lending practices and cyber risk management becomes critical.

The results suggest that digital innovation should not be constrained but should be accompanied by dynamic risk assessment frameworks. The RBI's evolving guidelines on digital lending and cybersecurity reflect movement in this direction (Reserve Bank of India, 2023).

7 Policy implications

For the Reserve Bank of India

The RBI should continue encouraging digital financial inclusion while strengthening prudential norms related to operational and cyber risks. Periodic stress testing of digital payment infrastructure, enhanced reporting standards for digital transactions, and supervisory technology (SupTech) adoption could improve systemic oversight.

Additionally, monitoring nonlinear risk thresholds is important. Macroprudential policies may be required if digital credit expansion accelerates excessively relative to economic fundamentals.

For commercial banks

Banks should integrate digital expansion strategies with comprehensive risk management systems. Investment in cybersecurity infrastructure, real-time fraud detection, and resilient cloud architecture is essential.

Banks should also leverage digital transaction data responsibly to enhance credit screening while maintaining ethical data governance. Diversification into fee-based digital services should be balanced with careful monitoring of operational exposures.

For fintech regulators

Regulators overseeing fintech entities must ensure interoperability standards, consumer protection, and cybersecurity compliance. Collaboration between banks and fintech firms should be guided by transparent risk-sharing frameworks.

Regulatory sandboxes may continue to foster innovation while allowing early identification of systemic vulnerabilities.

For financial inclusion programs

Public financial inclusion initiatives should focus not only on account ownership but also on active usage and digital literacy. Sustainable inclusion depends on user capability, trust, and infrastructure reliability. Strengthening digital literacy programs and rural connectivity can enhance the long-term stabilizing effects of digital participation.

8 Conclusion

Summary of findings

This study examined the relationship between digital financial inclusion and bank stability in India during the post-UPI expansion period. Using panel and dynamic estimation techniques, the findings indicate that digital financial inclusion significantly enhances bank stability, reduces non-performing assets, and stabilizes earnings.

However, evidence of a nonlinear relationship suggests that excessive digital intensity may reduce marginal stability gains. Thus, digital inclusion acts as a stabilizing force when accompanied by robust risk governance.

Contribution

The study contributes to the emerging literature on digital finance by integrating digital transaction indicators with established stability metrics such as the Z-score. It provides one of the early empirical assessments of post-UPI digital expansion and its systemic implications in India. By incorporating nonlinear analysis, the study advances understanding of threshold effects in digital deepening.

Limitations

The study relies on secondary data and proxy measures for bank-level digital intensity where granular data are unavailable. Moreover, cyber risk indicators are not directly observable, limiting the ability to quantify operational vulnerabilities explicitly.

Future research

Future research may explore the interaction between artificial intelligence-driven credit models and financial stability. As AI adoption increases in underwriting and fraud detection, understanding algorithmic risk becomes essential.

Further work could incorporate direct cybersecurity indicators and examine rural digitalization dynamics. Comparative cross-country studies may also shed light on how institutional frameworks moderate the digital inclusion–stability nexus.

Overall, digital financial inclusion represents a transformative force in India's banking sector. When supported by strong governance and regulatory vigilance, it has the potential to enhance resilience while promoting inclusive growth.

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