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Digital Technology Adoption, Business Formalization, and the Uptake of Digital Financial Services Among India's Informal Enterprises

Naveen Kumar K
National Institute of Bank Management, Pune, India

Abstract:

India's informal enterprises appear to employ the overwhelming majority of the country's non-agricultural workforce, yet remain persistently excluded from the formal financial system. This paper examines whether the adoption of basic digital technologies by informal firms translates into greater uptake of digital financial services (DFS), and the mechanisms through which this relationship may operate. Using a nationally representative firm-level dataset of 10,672 informal enterprises across nine Indian cities, this paper constructs a novel Digital Technology Adoption Index, a Business Formalization Index, and a Digital Financial Services Index, and estimates record-keeping and budgeting practices mediate the technology and finance relationship, while owner gender and educational attainment moderate its strength. The analysis suggests that digital technology adoption may be strongly associated with DFS uptake, that roughly 9% of this effect is transmitted through improved business formalization practices, and that the relationship appears to be significantly stronger for women-owned enterprises and for owners with less formal education. Digital and financial engagement appear to be further associated with substantially higher odds of access to formal credit. The findings suggest that India's distinctive digital public infrastructure may foster the business formalization of informal enterprises and potentially extend these benefits to roughly 65 million informal enterprises.

Keywords: Informal enterprises; Digital technology adoption; Digital financial services; Financial inclusion; India.

1. Introduction

The informal economy may no longer be regarded as a marginal feature of Indian commercial life; for most Indian entrepreneurs, it appears to constitute commercial life itself. Household enterprises and own-account workers operating without business registration, formal bookkeeping, or a Goods and Services Tax (GST) number are commonly estimated to constitute a substantial majority of India's non-agricultural employment and a considerable share of gross domestic product (ILO, 2022; Florence et al., 2018). For decades, the dominant policy response to informality treated registration and taxation as the gateway through which informal firms would eventually access formal finance, larger markets, and legal protection (Soto, 2000).

Since 2014, India's digital infrastructure expansion appears to have complemented the extension of banking services to individuals and enterprises. The rollout of near-universal biometric digital identity Aadhaar, a real-time interoperable retail payments architecture the Unified Payments Interface, or UPI, and near-saturation mobile connectivity may enable an enterprise to transact digitally and to access at least basic digital financial services without ever registering for GST, obtaining a business Permanent Account Number (PAN), or otherwise entering the formal regulatory systems (Gupta, 2019).

This decoupling of digital inclusion from formalization consequently raises a question of central importance for scholars of business law, financial regulation, and development policy alike: Does digital technology adoption by informal firms actually translate into greater use of digital financial services? If so, through what mechanism and for whom? The question matters because Digital Financial Inclusion (DFI) may constitute a precondition for the kind of incremental "semi-formalization" that many regulators now favor over blunt registration mandates, a trajectory in which a firm first builds a transaction and repayment history, then becomes creditworthy in the eyes of formal lenders, and only later, if at all, enters the tax and labor registries. This paper seeks to address that question through an analysis of firm-level microdata from the World Bank Informal Sector Enterprise Survey of

India, a survey of 10,672 confirmed informal businesses across nine Indian cities conducted in 2021–22 (World Bank, 2021b).

This paper makes three contributions. First, it develops and empirically tests an integrated theoretical model combining the diffusion of innovations framework, the technology acceptance model, and financial inclusion theory that treats digital financial services adoption not as a direct consequence of technological access, but as a process mediated, in part, by a firm's internal record-keeping and budgeting practices. Second, this is the first study to formally test moderated mediation in this setting, suggesting that the technology–finance relationship may not be uniform across the informal sector but may be amplified for women-owned firms and less-educated owners. Third, it translates these findings into policy advocacy for financial and tax regulators, thereby addressing business and policymakers rather than economists alone.

Section 2 develops the paper's theoretical framework and hypotheses. Section 3 situates the analysis within India's regulatory architecture for digital payments and formalization. Section 4 describes the data and empirical methodology. Section 5 reports the results, along with Section 6 outlining their implications. Section 7 presents the policy implications, and Section 8 acknowledges the study's limitations along with conclusions.

2. Theoretical Framework and Hypotheses

A. Diffusion of Innovation and the Technology Acceptance Model

Everett Rogers's Diffusion of Innovations theory elucidates how a new practice diffuses through a population by reference to the innovation's relative advantage, compatibility with existing routines, complexity, trialability, and observability (Rogers, 2003). Applied to informal enterprises, the theory suggests that digital tools with low complexity and high compatibility with existing cash-based practices a smartphone-based payment app, for instance- may diffuse more rapidly than tools requiring substantial behavioral or organizational change (Beck et al., 2018). The Technology Acceptance Model (TAM) and its successor, the Unified Theory of Acceptance and Use of Technology (UTAUT). Sharpen this prediction by identifying perceived usefulness and perceived ease of use as the proximate determinants of a user's intention to adopt a technology (Davis, 1989; Venkatesh et al., 2003).

These frameworks were developed for individual technology adoption decisions within organizations, not for the two-stage adoption problem this paper studies. In this problem, an informal firm must first adopt general-purpose digital technology, such as a smartphone, a computer, or a point-of-sale application, and only then, as a distinct decision, adopt digital financial services (DFS) layered on top of that technology, such as a digital wallet, a Unified Payments Interface (UPI)-linked bank transfer, or a digital savings product. This paper's first theoretical claim is that these two stages may be linked but not identical, and that the link may be mediated, in part, by an intervening organizational change. The adoption of digital tools may increase the salience and ease of business record-keeping, which may in turn raise perceived usefulness and lower the transaction costs of engaging with digital financial products that depend on some form of transaction history or documentation.

B. Financial Inclusion Theory and the Informality Trap

A separate body of literature examines why informal firms are excluded from formal finance and what interventions might change that. The research suggests that informal firms may be excluded because they lack the collateral, audited records, and legal identity that formal lenders require to price and manage credit risk. A self-reinforcing ‘informality trap’ exists in which the absence of records excludes access to finance, and the absence of finance removes any incentive to keep records (Beck et al., 2007; Dev, 2006).

DFS have been advanced as a mechanism to break this trap without requiring formal registration as a precondition. The Kenyan experience with M-PESA mobile money may be the most extensively studied model in this respect. Suri and Jack (2016) reported that access to mobile money appeared to expand consumption, increase savings, and move a measurable share of Kenyan households out of poverty, primarily by lowering the cost of maintaining and drawing on informal risk-sharing networks.

India's Global Findex data suggest a comparable, policy-driven surge in account ownership and digital payment usage following the 2014 Pradhan Mantri Jan Dhan Yojana (PMJDY) financial inclusion campaign and the

subsequent expansion of UPI, though usage has historically been concentrated among individuals rather than unregistered firms (Demirgüç-Kunt et al., 2022).

This paper's second theoretical claim is that the mechanism identified in the household-level literature (Alok et al., 2024) digital payment histories substituting for the documentation formal lenders otherwise require may operate at the firm level as well, although its strength may depend on characteristics of the firm and owner that shape both the perceived need for formal financial services and the owner's capacity to translate digital engagement into such access. These considerations motivate the paper's moderation hypotheses, which are discussed below.

C. An Integrated Model: Mediation Through Business Formalization

Synthesizing these strands, this paper advances an integrated model in which Digital Technology Adoption (DTA), with ownership of a computer or smartphone and the use of that device for core business functions such as procurement, inventory tracking, and customer outreach, may affect DFS uptake. The enterprise's use of digital payments to pay suppliers, receive customer payments, save, pay utility bills, repay loans, or pay workers through digital channels. The direct channel reflects the platform effect of owning digital hardware and connectivity, like a smartphone that can run a payment app is, mechanically, a prerequisite for many DFS products. The indirect channel runs through Business Formalization practices including maintaining written business records, separating business and household accounts, preparing written budgets, and periodically producing profit-and-loss statements. Digital tools make such record-keeping less costly and more routine, while better internal records may make it easier and more attractive for enterprises to adopt DFS products that reward a demonstrable transaction and repayment history.

Hypothesis 1 (Main Effect): Digital Technology Adoption may be positively associated with Digital Financial Services uptake among informal enterprises.

Hypothesis 2 (Mediation): Business Formalization practices may partially mediate the relationship between Digital Technology Adoption and Digital Financial Services uptake.

D. Moderators: Owner Gender and Education

Two owner-level characteristics are theorized to moderate the strength of the DTA and DFS relationship. First, gender may moderate this relationship; the existing evidence suggests that women entrepreneurs in South Asia face disproportionate barriers to formal financial access, including mobility constraints, lower rates of independent asset ownership, and social norms restricting direct engagement with bank branches and loan officers. Where digital channels may be partially avoided by allowing transactions to occur privately, from the home-based premises where a large share of women-owned informal firms operate Balakrishnan & Ramachandran, 2009; Desai & Vanneman, 2020).

If digital tools disproportionately relax a binding constraint for women owners rather than merely substituting for a channel that was already accessible, the marginal effect of digital adoption on DFS uptake may be larger for women-owned firms than for men-owned firms.

Hypothesis 3 (Moderation – Gender): The positive relationship between Digital Technology Adoption and Digital Financial Services uptake may be stronger for women-owned informal enterprises than for men-owned enterprises.

Second, educational attainment warrants consideration. Two competing predictions are plausible ex ante. A complementary skills account holds that formal education may enhance owners' capacity to exploit digital tools, predicting a stronger DTA and DFS relationship among more educated owners. A "leapfrogging" or "substitution" account instead holds that digital tools may be most consequential precisely where they substitute for capabilities that formal education would otherwise have provided. For instance, a simplified mobile interface substituting for the numerical literacy that manual ledger-keeping demands, predicting a stronger relationship among less educated owners, for whom the marginal value of a low-complexity digital substitute is highest (Aker & Mbiti, 2010).

Hypothesis 4 (Moderation – Education): The relationship between Digital Technology Adoption and Digital Financial Services uptake may differ by owner educational attainment; because the direction is theoretically ambiguous, this hypothesis is tested without a directional prediction.

Finally, because DFS adoption and business formalization are both theorized to improve access to formal credit and, over time, firm performance, this paper also tests an extension hypothesis connecting the core model to firm-level outcomes.

Hypothesis 5 (Extension): Digital Financial Services uptake and Business Formalization may be positively associated with formal credit access; their association with short-run firm profitability is tested as an open empirical question given the cross-sectional design.

E. Conceptual Model

Figure 1 outlines the moderated mediation model examined in this paper. The DTA influences DFS uptake both directly (path c′) and indirectly through Business Formalization practices (BFP) (paths a and b), with the moderating effects of owner gender and education on the DTA→DFS relationship. At the same time, DFS and BFP may, in turn, be associated with an expanded set of firm-level financial and performance outcomes.

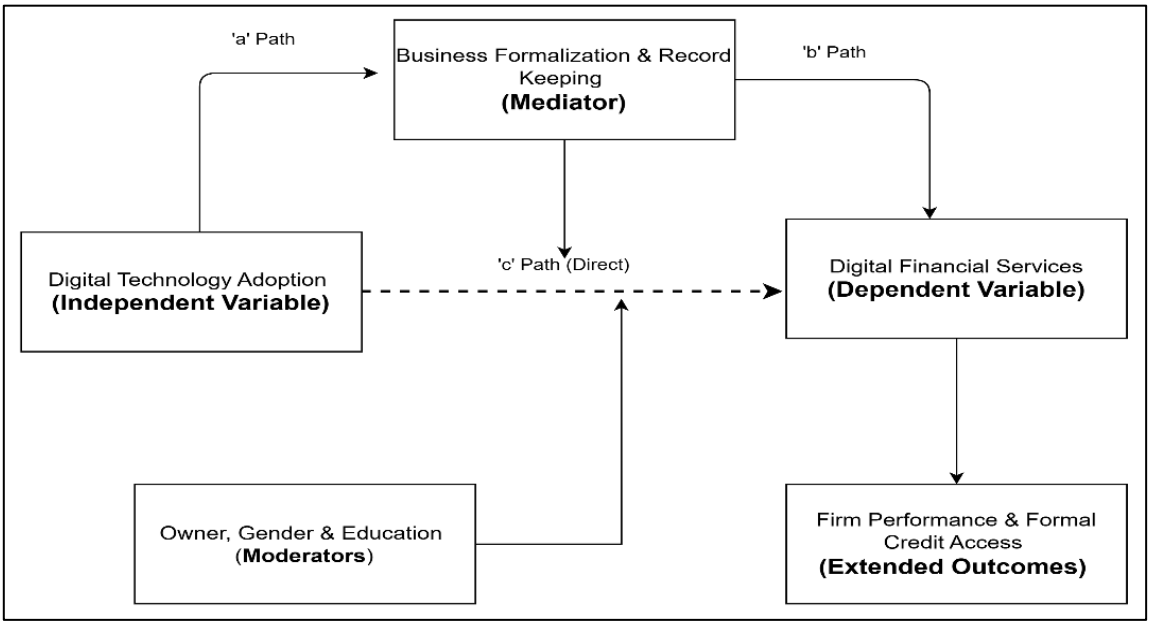


Figure 1: Conceptual Moderated Mediation Model.

3. The Regulatory Architecture of Digital Finance for India's Informal Firms

Three legal and infrastructural developments appear to delineate the environment in which the enterprises studied in this paper operate. The first is Aadhaar, India's biometric digital identity system, which the Aadhaar –a Targeted Delivery of Financial and Other Subsidies, Benefits and Services, Act, 2016, placed on statutory footing and which has become the de facto identity layer for opening a bank account and completing Know Your Customer (KYC) verification (Reserve Bank of India, 2019).

The second is the UPI, a real-time payment system built by the National Payments Corporation of India (NPCI) under the Payment and Settlement Systems Act, 2007, and regulated by the Reserve Bank of India, which appears to allow any bank account holder to send and receive funds instantly using a mobile phone number or a simple virtual payment address, without a merchant-acquiring relationship or point-of-sale hardware (Reserve Bank of India, 2007).

In practice, UPI's minimal onboarding requirements appear to permit an unregistered proprietorship to accept digital payments through the owner's personal bank account, without requiring a formal business registration. A

design choice that, irrespective of its origins, may have had the practical effect of decoupling digital payment access from formal business registration (Gochhwal, 2017).

The third pillar comprises the Goods and Services Tax (GST) regime established by the Central Goods and Services Tax Act, 2017, under which firms below prescribed annual turnover thresholds are exempt from mandatory registration (Central Goods and Services Tax Act, No. 12 of 2017). During the survey period, the threshold was generally ₹40 lakh for goods and ₹20 lakh for services, with lower thresholds in certain states. Most firms surveyed for this paper appear to fall below these thresholds and, consistent with the World Bank survey's sampling frame, report no GST number and no business PAN; informality, on this dataset, appears close to universal rather than a matter of partial compliance.

These three pillars are digital identity, an interoperable, no-registration-required payment channel, and a turnover-based rather than registration-based tax threshold. All these together constitute what this paper terms a diverged formalization pathway: a firm can become digitally and financially visible to banks and fintech lenders through its UPI transaction history well before, or entirely apart from, becoming legally formal in the tax and labor sense. Whether that bifurcation is a policy success permitting incremental, low-friction inclusion or a regulatory gap, leaving digitally active but legally invisible firms outside consumer protection, dispute resolution, and social security frameworks, is the question that this paper's empirical findings may help to address.

Formal credit, however, appears not to have been similarly decoupled from documentation. Priority Sector Lending guidelines and internal risk policies at scheduled commercial banks generally continue to require some combination of GST filings, income tax returns, or audited financials for loans above small-ticket size. The Reserve Bank of India's regulatory sandbox and Account-Aggregator (AA) initiatives, which permit consent-based sharing of digital transaction data, such as cash-flow-based lending instead of traditional collateral, appear to remain at an early stage of adoption among the small non-banking finance companies and fintech lenders most active in the informal-firm segment (Datta, 2023).

This institutional gap between a payments layer that requires no registration and a credit layer that still substantially does may help explain why DFS adoption, as measured in this paper, may not translate into short-run access to formal credit at anything like the rate suggested by the payments data alone, a possibility that Section 5 examines.

4. Data and Empirical Methodology

A. Data Source

This paper draws upon firm-level microdata from the World Bank Informal Enterprise Survey of India, 2021–22 across nine cities, namely Mumbai, Hyderabad, Surat, Jaipur, Kochi, Varanasi, Ludhiana, Tezpur, and Sehore, selected to capture regional and city-tier variation. The survey instrument was developed under the World Bank's Business Ready (B-READY) program and administered face-to-face using random-walk area sampling of business premises, including home-based enterprises, following listing and screening procedures intended to confirm informal status (World Bank, 2021a).

The analytic dataset comprises 10,672 informal enterprises. Consistent with the survey's design, registration variables show that the sample appears to be overwhelmingly unregistered; fewer than one percent of surveyed owners report holding either a business PAN or a GST number, suggesting that informality in this sample may reflect genuine non-registration rather than partial compliance. Because several outcome modules, predominantly the digital payments module were administered only to sub-samples or were conditioned on prior skip-pattern responses, the fully specified regression models below are estimated on the balanced analytic sub-sample of 4,735 firms with non-missing data on all core indices and controls. Table 1 reports how this sub-sample compares to the full sample on observable characteristics, and Section 5 reports weighted and alternative-specification robustness checks.

B. Construction of Composite Indices

Consistent with standard practice in the financial inclusion measurement literature, the paper constructs three cumulative composite indices rather than relying on any single survey item. Each index is scored on the unit interval as the mean of its component binary indicators (1 = yes, 0 = no) among the items answered by the respondent.

(i) Digital Technology Adoption (DTA) Index

The DTA index is calculated as the arithmetic mean of five binary indicators, such as whether the firm uses a computer or tablet; whether it uses a cell phone or smartphone; and whether it uses a phone or computer to buy inputs, to track inventory, or to reach customers through digital channels, e.g., messaging platforms or social media.

(ii) Business Formalization Practice (BFP) Index: Mediator

The BFP is constructed as the mean of five binary indicators of internal management formality that are analytically distinct from legal/tax registration, like whether the firm keeps written business records; whether the firm keeps business and household accounts separately; whether the firm has a written monthly budget; whether it prepares a cost budget for the following year; and whether it prepares an annual profit-and-loss statement. None of these five practices requires GST or PAN registration, which may enable the index to capture managerial formalization independent of the legal registration status that appears nearly invariant in this sample.

(iii) Digital Financial Services (DFS) Index: Dependent Variable

The DFS is constructed as the mean of seven binary indicators of digital-payment usage, namely – general use of digital payments, as well as their use specifically to pay suppliers, to save, to pay utility bills, to receive payments from customers, to repay loans, and to pay workers, including family workers.

C. Controls, Moderators, and Extension Outcomes

All models control for owner gender (1 = female), owner educational attainment (1 = completed secondary school or higher), owner age and years of business experience, firm size (number of persons who worked in the business in the last month), firm age (years since founding), three-category sector (manufacturing, retail, services), and city fixed effects, which may absorb differences in local infrastructure, banking density, and regional culture. Owner gender and the secondary-education indicator serve additionally as the study's moderating variables. The study uses two outcome variables: a binary indicator of business profitability in the last month – as reported by the owner, relative to a loss or break-even result, and a binary indicator of whether the firm currently holds a loan for the business.

D. Empirical Strategy

The core model is estimated by ordinary least squares with heteroskedasticity-robust (HC1) standard errors:

$$DFS_i = \alpha + \beta_1 DTA_i + \beta_2 BFP_i + \gamma' X_i + \delta_city + \varepsilon_i$$

where X_i is the vector of firm and owner controls described above, and δ_city denotes city fixed effects. DTA and BFP are standardized (mean zero, unit standard deviation), which may facilitate direct coefficient comparison in effect-size terms.

Mediation is assessed through the Baron and Kenny (1986) sequential-regression approach estimating the DTA→BFP path (path a), the BFP→DFS path controlling for DTA (path b), and the direct DTA→DFS path controlling for BFP (path c′), supplemented with a Sobel test (1982) of the indirect effect (a×b) and a nonparametric percentile bootstrap (2,000 resamples) of the indirect effect's confidence interval, which may be preferable because it does not require the indirect effect to be normally distributed and is increasingly regarded as a field-standard approach to mediation inference (Preacher & Hayes, 2008).

Moderation is assessed through the addition of interaction terms (DTA × Gender, DTA × Education) to the baseline specification. The extension models use logistic regression, given the binary nature of the profitability and loan-

access outcomes, with average marginal effects reported alongside coefficients. All models are additionally re-estimated (i) by applying the survey's strict-eligibility sampling weight and (ii) by using sector-stratified sub-samples, as robustness checks reported in Section 5. Variance inflation factors for all continuous regressors reported less than 2.6, well below conventional thresholds associated with the problem of multicollinearity (Wooldridge, 2001).

The analysis treats DTA and BFP as predetermined relative to DFS for identification purposes, but does not claim strict causal identification. Adoption of digital tools, formalization practices, and digital financial services are plausibly jointly determined by an owner's unobserved managerial orientation or risk tolerance, and the cross-sectional design may not fully rule out reverse causality (e.g., a lender's requirement that a borrower use digital repayment may itself induce DFS "adoption" rather than the reverse). The paper's claims are accordingly framed as theoretically grounded associations that are consistent with a mediation structure, not as experimentally identified causal effects; Section 7 returns to this limitation.

5. Results

5.1. Descriptive Statistics

Table 1 presents descriptive statistics for the balanced analytic sample (N = 4,735). The representative informal firm in the sample appears to score 0.33 on the five-item Digital Technology Adoption Index, 0.36 on the five-item Business Formalization Index, and 0.31 on the seven-item Digital Financial Services Index. This indicates that, on average, roughly one-third of the relevant digital, formalization, and digital-finance behaviors are present in a typical informal firm, with considerable room for growth on all three dimensions. Only 38.6% of sample firms report a dedicated business bank account, and just 12.3% report holding any business loan, which may underscore the persistence of the informality-finance gap that motivates this paper. Women appear to own only 9.6% of the firms in the analytic sample, which may reflect the well-documented underrepresentation of women as primary owners of registered and unregistered enterprises alike in urban India.

Table 1: Descriptive Statistics

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Digital Financial Services (DFS) Index	4,735	0.312	0.373	0.00	1.00
Digital Technology Adoption (DTA) Index	4,735	0.334	0.317	0.00	1.00
Business Formalization Practice (BFP) Index	4,735	0.360	0.347	0.00	1.00
Female business owner indicator (=1)	4,735	0.096	0.294	0	1
Secondary education completion by owner (=1)	4,735	0.434	0.496	0	1
Owner age (years)	4,735	40.36	8.86	17	86
Owner business experience (years)	4,735	11.38	7.84	1	60
Firm size (workers in the preceding month)	4,735	1.59	1.05	1	30
Firm age (years since founding)	4,735	10.71	7.88	0	63
Has business bank account (=1)	4,712	0.386	0.487	0	1
Active business-loan indicator (=1)	4,703	0.123	0.328	0	1
Profitability in the preceding month (=1)	4,550	0.428	0.495	0	1

Note: Total sample considered for the study is N = 4,735 out of total sample of 10,672

Source: Authors calculation from the World Bank – Informal Sector Enterprise Survey (India, 2021–22) with non-missing data on all core indices and controls.

5.2. Correlations Among Core Indices

Table 2 reports pairwise correlations among the three composite indices. All three indices exhibit substantial positive correlations (r = 0.50–0.55), consistent with the theoretical expectation that digital adoption, formalization, and digital finance uptake correlate. While appearing sufficiently distinct, no pairwise correlation seems to exceed 0.55 to warrant their treatment as conceptually separate constructs in the multivariate models that follow. Variance inflation factors for the standardized DTA and BFP indices in the full regression specification are 1.45 and 1.49, respectively, and remain well below thresholds conventionally associated with problematic collinearity.

Table 2: Pairwise Correlation Matrix of Composite Indices.

	DFS Index	**DTA Index**	**BFP Index**
DFS Index	1.000	—	—
DTA Index	0.496	1.000	—
BFP Index	0.539	0.552	1.000

Source: Authors calculation

5.3. Main Effect and Mediation

Table 3 presents the three sequential regressions that constitute the mediation test. Model 1 suggests the total effect of DTA on DFS adoption. A one-standard-deviation increase in the DTA Index is associated with a 0.11point increase (on the 0–1 scale) in the DFS Index, controlling for owner and firm characteristics and city fixed effects ($p < 0.001$), which may support Hypothesis 1. Model 2 (path a) indicates a substantive association between DTA and the mediator, BFP ($\beta = 0.107$, $p < 0.001$). Model 3 (paths b and c) demonstrates that, controlling for DTA, BFP remains positively associated with DFS adoption ($\beta = 0.090$, $p < 0.001$), while the direct effect of DTA appears to fall from 0.109 to 0.081, a reduction consistent with partial mediation.

Table 3: Main Effect and Mediation Models: Results from Ordinary Least Squares

	Model 1: DFS (total effect)	**Model 2: BFP (path-a)**	**Model 3: DFS (path b /c)**
DTA Index	0.1086*** (0.006)	0.1066*** (0.005)	0.0809*** (0.006)
BFP Index	—	—	0.0901*** (0.006)
Female ownership	-0.017 (0.014)		-0.013 (0.014)
Secondary or higher education	0.039*** (0.009)		0.016† (0.009)
Owner age	-0.0016** (0.001)		-0.0023*** (0.001)
Firm size	0.021*** (0.005)		0.013** (0.005)
Firm age	-0.0008 (0.001)		-0.0011* (0.001)
Sector and city fixed effects	Yes	Yes	Yes
Sample size (N)	4,735	4,735	4,735
R^2	0.387	0.401	0.418

Note: With robust heteroskedasticity-consistent (HC1) standard errors in parentheses.

*, **, *** Significant at the 10%, 5% & 1% level. All models include controls for owner age, experience, sector, and city fixed effects; abbreviated for space.

The indirect effect (a × b) is 0.0096 (SE = 0.0008), yielding a Sobel z-statistic of 11.64 ($p < 0.001$) and a percentile bootstrap 95% confidence interval of [0.0080, 0.0112] across 2,000 resamples, which excludes zero and suggests statistically significant mediation, thereby providing support for Hypothesis 2. The proportion of the total DTA and DFS effect transmitted through BFP is 8.8% (0.0096/0.1086). While this indirect share is modest in absolute size, it appears precisely estimated and substantively meaningful. It identifies business record-keeping and budgeting practices as a distinct, policy-actionable conduit through which digital adoption translates into DFI, separate from the direct hardware/connectivity channel that accounts for the remaining 91.2% of the total effect.

5.4. Moderation by Owner Gender and Education

Table 4 reports the moderation results. In Model 4, the interaction between DTA and female is positive and statistically significant ($\beta = 0.043$, $p = 0.004$), indicating that gender significantly moderates the relationship between digital technology and DFS adoption. The estimated marginal effect of digital technology adoption is 0.08 for male-owned firms, compared with 0.121 for female-owned firms. Representing an approximately 56% larger estimated effect among female-owned firms. These results support Hypothesis 3 and appear consistent with the theoretical prediction that digital channels disproportionately reduce mobility and norm-based constraints that otherwise limit women owners' direct engagement with formal financial institutions (Arora et al., 2026).

In Model 5, the interaction between DTA and secondary education is negative and statistically significant ($\beta = -0.029$, $p = 0.001$), indicating that secondary education negatively moderates the relationship between digital technology and DFS adoption. The marginal effect of DTA on DFS uptake is 0.096 for owners without a secondary education and falls to 0.066 for owners with secondary schooling or more, a 31% smaller effect among the more educated. This finding does not support the complementary skills argument and may instead be consistent with the leapfrogging or substitution mechanism proposed under Hypothesis 4.

The stronger inclusionary outcome of digital tools among enterprises with lower levels of formal education advocates a likely substitution mechanism, whereby low-complexity digital financial products may reward for limitations in formal numeracy and literacy rather than complement the existing skill set of the entrepreneur

Table 4: Moderation Results from Ordinary Least Squares

	Model 4 DFS (Gender × DTA)	**Model 5 DFS (Education × DTA)**
DTA Index	0.0774*** (0.006)	0.0955*** (0.007)
Moderator (Female / Secondary plus)	–0.010 (0.014)	0.016* (0.009)
DTA × Moderator	0.0434** (0.015)	–0.0294*** (0.009)
BFP Index	0.0900*** (0.006)	0.0892*** (0.006)
Sector/City (Controls) fixed effects	Yes	Yes
N	4,735	4,735
R^2	0.4186	0.4190

Note: Heteroskedasticity-consistent (HC1) standard errors in parentheses

*, **, *** Significant at the 10%, 5% & 1% level. All models include controls for owner age, experience, sector, and city fixed effects; abbreviated for space.

5.5. Extension: Firm Performance and Formal Credit Access

Table 5 reports two extension models, with Model 6 examining short-run business profitability. BFP remains a statistically significant predictor of reporting a profit last month, with an average marginal effect of 0.093 ($p <$

0.001). A one-standard-deviation increase in BFP is associated with a 9.3% higher probability of profitability. Neither DTA nor DFS, however, appears to be significantly associated with short-run profitability once BFP is controlled for. This null result may be informative rather than merely disappointing. It suggests that digital and financial engagement, on their own, are not short-run profit drivers. The results are consistent with an interpretation in which digital tools' primary benefit is inclusion and risk-smoothing (Suri & Jack, 2016) rather than an immediate productivity dividend (Wachira & Njuguna, 2023). It may therefore suggest caution against treating digital adoption as a sufficient condition for informal-firm performance.

Model 7 examines the probability of having a business loan or line of credit with outstanding, estimated on the larger sample (N = 9,510) for which loan status does not require the more heavily skip-patterned DFS dataset. Both DTA ($\beta = 0.842$, $p < 0.001$) and BFP ($\beta = 0.640$, $p < 0.001$) appear to be statistically significant, independent predictors of loan access. In odds-ratio terms, a one-standard-deviation increase in DTA is associated with 2.32 times the odds of having a business loan, and a one-standard-deviation increase in BFP with 1.90 times the odds, holding constant owner and firm characteristics. Women-owned firms appear to have significantly lower odds of loan access ($\beta = –0.498$, $p = 0.001$; odds ratio 0.61) even after controlling for DTA and BFP. It suggests that, notwithstanding the gender-moderation finding in Section 5, digital and formalization gains have not yet closed the credit-access gender gap at the point of loan origination, where lenders are still expected to depend on screening compliance requirements and collateral when deciding whether to provide a line of credit. Together, these results appear to provide partial support for Hypothesis 5. The DTA and BFP are strongly associated with formal credit access, but not, in the short run, with reported profitability.

Table 5: Extension Models: Firm Profitability and Business Loan Access

(Logistic Regression; Average Marginal Effects for Model 6, Coefficients for Model 7)

	Model 6: Firm Profitability (Logistic Regression, Average Marginal Effects)	**Model 7: Business Loan Access (Logistic Regression)**
DFS Index	-0.001 (0.009)	—
DTA Index	0.009 (0.009)	0.842*** (0.048)
BFP Index	0.093*** (0.010)	0.640*** (0.051)
Female ownership	-0.021 (0.025)	-0.498** (0.154)
Secondary or higher education	-0.068*** (0.015)	-0.016 (0.081)
Control variables: sectoral effects and city fixed effects	Yes	Yes
Observations	4,550	9,510
Pseudo R^2	0.071	0.322

Note: Robust Standard Errors in Parentheses. *, **, *** Significant at the 10%, 5% & 1% level.

5.6. Robustness

The main effect appears robust to the application of the survey's strict-eligibility sampling weight (weighted $\beta = 0.121$, $p < 0.001$, close to the unweighted estimate of 0.109), to estimating the model with a principal component-based alternative to the additive DTA index (first-component loadings all exceed 0.40, explaining 52% of joint variance among the five DTA items), and to re-estimation on sector-stratified sub-samples (retail, manufacturing, and services), each of which yields a positive, statistically significant DTA coefficient of similar magnitude. Probit re-estimation of the profitability model appears to yield substantively similar conclusions to the logit specification reported in Table 5. The BFP marginal effect significant at $p < 0.001$ in both specifications. These checks suggest

that the central findings may not be artifacts of functional-form choice, sample weighting, or index-construction method.

6. Discussion

In this study, three key findings stand out from the analysis. First, the mediation result reframes a common policy assumption. DFI strategies frequently treat mobile connectivity and hardware access as the binding constraint on informal-firm participation in DFS (Claessens, Stijn, and Liliana Rojas-Suarez, 2020). A Decision Tree for Digital Financial Inclusion Policymaking. Center for Global Development. (Claessens & Rojas-Suárez, 2020). Implicitly assuming that once a firm has a smartphone and a payment app, adoption may follow with limited friction. The finding is that approximately 9% of the DTA and DFS relationship runs through BFP and that this indirect channel is estimated with high statistical precision. This advocates that internal record-keeping habits may constitute a distinct and complementary channel rather than merely a by-product of digital access. From a policy advocacy and product design perspective, combining digital payment tools with simple compliance and mobile app-based bookkeeping features could be more effective. For example, transaction data could automatically generate a running ledger or basic profit-and-loss statement of the business, helping enterprises manage their finances while encouraging greater use of DFS. This approach may be more effective in promoting DFS adoption than simply providing payment application alone.

Second, the moderation results collectively suggest that digital technology functions as a potentially inclusionary rather than merely elite-reinforcing channel in this setting. If digital adoption's financial-inclusion dividend were concentrated among already-advantaged owners (male, more educated), that would suggest digital strategies risk widening intra-informal-sector inequality even while narrowing the formal and informal gap. The data appear to indicate an inverse pattern across both moderators. The DTA and DFS relationship is stronger for women owners and for less-educated owners, the two subgroups conventionally understood to face the steepest barriers to formal financial participation (Aterido et al., 2013). The findings are consistent with though, given the cross-sectional design, does not definitively establish a genuine substitution or leapfrogging dynamic in which digital tools function as an alternative pathway around, rather than merely combined with, conventional barriers to inclusion.

Third, the deviation between the DFS along with access to line of credit (loan) results and the profitability result is itself a policy-relevant finding. Digital and financial engagement appears to improve enterprises' access to formal credit. The relatively large odds ratios reported in Model 7 are noteworthy for firm-level cross-sectional analysis. However, in this cross-sectional data analysis, greater access to formal credit does not yet appear to translate into higher measured profitability.

Digital and financial engagement appear to open a door to formal credit; the odds ratios in Model 7 appear large by the standards of firm-level cross-sectional research, without yet, in this cross-section, showing up as higher measured profitability. Two non-exclusive explanations may conceivably account for this divergence. The credit-access effect may simply lead to any profitability effect in time, such that a longitudinal or panel design would find a delayed productivity payoff as digitally originated credit is deployed and matures. Alternatively, the loans accessed through digital and formalization channels may be predominantly working-capital or consumption-smoothing credit rather than productive investment credit, in which case a profitability effect would not be expected even in due course.

7. Policy Implications, Limitations and Conclusion

This section presents a concrete policy implication for government, banks and the financial sector to design the legal frameworks governing informal-sector digital finance elsewhere. The following are some of the major policy implications from this study.

7.1 Preserve and Formalize the Decoupling of Payments Access from Tax Registration

The divergent formalization pathway of informal enterprises, reflected in UPI access without GST or PAN registration, suggests that access to digital payments is associated with greater financial engagement. Significantly, this engagement appears to benefit disproportionately those enterprise owners who have historically been

unserved or underserved by the formal financial system. Proposals periodically floated to require GST or business PAN linkage as a precondition for merchant-side UPI features or to lower GST registration thresholds should be evaluated against this evidence. In the absence of a compelling revenue or anti-money laundering justification specific to a given product tier, the regulator and the GST Council may reasonably resist conditioning basic digital payment access on tax registration and could make that non-conditionality explicit and robust rather than leaving it as a by-product of current design choices that a future rule change could silently reverse.

7.2 Build High-tech and High-touch with Light Regulation Enterprise Formalization

Given the mediation finding, financial regulators and the NPCI could treat basic bookkeeping functionality, auto-generated transaction ledgers, simple profit-and-loss summaries, and inventory-linked payment records. As a natural and low-cost extension of the UPI ecosystem, potentially through NPCI's UPI Autopay and merchant-facing API layers for enterprise formalization. A modest regulatory nudge, for example, RBI guidance encouraging or incentivizing UPI merchant-application providers to offer a standardized, exportable transaction and ledger summary could operationalize this paper's mediation finding and could create the kind of transaction documentations, the lenders should be permitted to rely upon.

7.3 Extend Cash-Flow-Based, Documentation-Light Lending Standards to Small-Ticket Informal-Firm Credit

The gap this paper identifies between strong DFS-credit access associations at the population level and banks' continued reliance on GST filings and audited financials for underwriting suggests that the Reserve Bank of India's account aggregator and cash-flow lending frameworks may remain insufficiently extended to the informal firm segment. Priority Sector Lending guidelines and the RBI's digital lending guidelines could be amended to permit, for small-ticket working-capital loans below a defined threshold, underwriting based solely on a minimum period of verified UPI or digital-wallet transaction history, without requiring GST registration or formal financial statements. A standard that appears to be implicit in several fintech lenders' internal risk models, although not yet formally recognized or encouraged by prudential guidance. This paper’s findings suggest that women-owned firms may have significantly lower odds of loan access even controlling for digital and formalization variables. Any such reform could be paired with supervisory attention to whether cash-flow-based underwriting models themselves embed gender bias, for instance, by training on historical loan-book data that reflects past discriminatory lending patterns.

7.4 Closure of the Legal-Protection Gap for Digitally Active but Unregistered Firms

A firm that transacts extensively through UPI but holds no GST or PAN registration currently sits in a regulatory blind spot. It may constitute a substantial user of regulated payment infrastructure and, as this paper's findings suggest, an increasingly plausible borrower; it may nevertheless fall outside the consumer-protection, dispute-resolution, and grievance-redress mechanisms that formal registration typically triggers, and may remain outside the Digital Personal Data Protection Act, 2023's business-facing protections (Digital Personal Data Protection Act, No. 22 of 2023, 2023).

The Ministry of Micro, Small and Medium Enterprises' Udyam registration portal, already a lightweight, self-declaration-based registration mechanism distinct from GST, could be extended and actively marketed as a purely protective registration for informal firms. A business identity that provides dispute-resolution access under the Micro, Small and Medium Enterprises Development Act's delayed-payment provisions and eligibility for certain digital-lending consumer protections, without triggering GST liability for firms that remain below the statutory turnover threshold. Framing Udyam registration as strictly protective, and communicating that framing clearly to informal owners, could increase registration take-up among digitally active informal firms without requiring any change to GST policy itself (Government of India, 2006).

7.5 Gender-Targeted Digital Financial Literacy, Not Generic Financial Literacy

The strength of the gender-moderation finding suggests that digital-literacy and financial-literacy programs targeted at women informal-enterprise owners of the kind already funded through the Ministry of Skill

Development and Entrepreneurship and various state-level women's self-help group federations could explicitly prioritize digital-first financial tools over generic branch-banking literacy, on the basis that this channel may generate the largest marginal returns among women owners, as the data suggest.

7.6 Limitations and Directions for Future Research

Four limitations may qualify the paper's findings and conclusions. First, the design is cross-sectional; the mediation and moderation results are consistent with, but cannot definitively establish, the causal ordering this paper's theoretical model proposes. A panel extension of the World Bank informal-enterprise survey or a difference-in-differences design exploiting staggered UPI or bank-branch rollout across the surveyed cities, could strengthen causal identification and therefore constitute a plausible next step.

Second, all core indices appear to be predicated on self-reported binary indicators rather than administrative transaction data. Owners may over-report formalization practices they perceive as socially desirable, or under-report digital financial activity conducted through a family member's device or account. A particular risk for women owners given the mobility and asset-ownership constraints, which could bias the gender-moderation estimate in either direction depending on whether under-reporting is itself correlated with digital adoption.

Third, the sample, while large and geographically diverse, is drawn from nine urban centers and may not capture India's substantial rural informal enterprise sector, where connectivity, banking density, and gender norms differ in ways that could alter both the main effect and the moderation results in either direction.

Fourth, the profitability measure is a rough, self-reported, single-month categorical indicator rather than an audited or continuous financial metric, limiting the precision, with null performance result can be interpreted. A continuous sales or profit measure, collected longitudinally, could permit more discriminating tests of whether the credit-access gains documented in Model 7 eventually translate into measurable performance improvements.

Future research could also examine heterogeneity by sector at finer granularity than the three-category classification used here, assess whether the mediation and moderation patterns recur in other large developing-country informal-sector surveys within the World Bank's broader B-READY informal-sector program (World Bank, 2021b), and ideally evaluate the specific product-design intervention experimentally. Whether bundling lightweight bookkeeping functionality with digital payment applications could causally increase DFS uptake beyond what payment functionality alone would achieve.

7.7 Conclusion

Using firm-level data on 10,672 informal enterprises across nine Indian cities, this paper suggests that digital technology adoption is robustly associated with greater use of digital financial services. A meaningful share of this relationship may operate through improved business formalization practices, rather than through digital access alone, and that the relationship is significantly stronger for women-owned firms and for less-educated owners two groups that formal financial institutions have historically underserved. These digital and formalization gains may, in turn, be associated with higher odds of formal credit access, though not, in this cross-section, with short-run profitability. These findings may support a specific and, on the current evidence, underutilized regulatory strategy: rather than treating digital inclusion as a stepping stone toward eventual tax and labor formalization. India's financial regulators could preserve the current decoupling of digital payment access from GST and PAN registration, actively build lightweight formalization tools into the payments infrastructure itself, extend documentation-light, cash-flow-based underwriting standards to small-ticket informal firm lending, and offer a purely protective (non-tax-triggering) registration pathway for digitally active informal firms. For a legal and regulatory system still oriented around registration as the gateway to formal economic participation, the central lesson of this paper may be that, for India's tens of millions of informal enterprises (Dutta et al., 2023), the gateway may already have moved from the government’s registrar's office to the payment app and that financial and business law should adapt accordingly.

Appendix 1: Composite Index Construction

Index/Variable	Component Survey Items
Digital Technology Adoption (DTA)	Use of a computer or tablet; use of a cell-phone or smartphone; and use of a phone or computer for input procurement, inventory tracking, and digital customer outreach
Business Formalization Practices (BFP)	Maintenance of written business records; separation of business and household accounts; preparation of a written monthly budget, a cost budget for the subsequent year, and an annual profit-and-loss statement
Digital Financial Services (DFS)	Use of digital payments for general transactions, supplier payments, savings, utility bill payments, receipt of customer payments, loan repayment, and worker remuneration

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