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Bridging Inclusion Gaps through Digital Public Infrastructure: Evidence from UPI Adoption in India

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Abstract: The ongoing digital transformation presents both significant opportunities and complex challenges. While digital technologies have the potential to address a wide range of business and societal constraints, ensuring that this transformation is inclusive remains a persistent concern. In this context, Digital Public Infrastructure (DPI) has emerged as a promising framework for enabling inclusive digitalisation. However, empirical evidence on whether DPI-based systems translate into more inclusive adoption among firms has remained limited. This paper examines this question in the context of India's Unified Payments Interface (UPI), a flagship DPI-based payment system, and compares its adoption profile with conventional instruments such as credit cards and internet banking.Using primary survey data from 2,882 MSMEs across 14 states and five sectors, the analysis combines descriptive statistics with mode-specific binary logistic regression models. The results reveal significant gender, location, and size-based disparities in the adoption of credit cards and internet banking. In contrast, such disparities are not observed in the case of UPI adoption. The findings suggest that DPI-based systems can act as effective enablers of more inclusive digital participation.

***Keywords*:** Digital inclusion, UPI, Digital Public Infrastructure

1. Introduction

Digitalisation has become a distinguishing feature of the modern economy. Since the dawn of the twenty-first century, digital innovations have progressively permeated all aspects of human life, fundamentally transforming business practices and society. The widespread diffusion of Information and Communication Technology (ICTs) enabled innovations, ranging from basic high-speed internet and e-commerce platforms to advanced machine learning and artificial intelligence which have not only enhanced connectivity but also created new forms of interaction between individuals, firms, and markets. The gains from ongoing digitalisation

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are expected to go far beyond narrow productivity effects, with potential benefits spanning social inclusion, improved health outcomes, and environmental sustainability. There is consensus that digital technologies canfacilitate better monitoring of environmental impacts, more efficient use of energy and natural resources, and improved risk management across value chains (Yaqub and Alsabban, 2023; Leão & da Silva, 2021). At the social level, digital tools have the potential to expand access to information, essential services, and economic opportunities, thereby supporting more inclusive and resilient development pathways (Uduji, Okolo-Obasi and Asongu 2019; Friederici et al., 2020).

For Micro Small and Medium Enterprises (MSMEs) the expected gains from digitalisation are immense. Digital tools and platforms have the potential to level the playing field for MSMEs by reducing transaction costs, enabling faster scaling, improving productivity, and facilitating entry into new markets. Addressing the longstanding barriers related to information, coordination, and geography, digital technologies can allow micro and small enterprises to expand their customer base beyond local markets and participate more effectively in domestic and global value chains (Hendrawan et al., 2024. Esselaar et al., 2007). These opportunities are particularly relevant for women-led and rural enterprises, which often face additional constraints arising from limited mobility, restricted market access, and weaker integration into formal business networks. Digital payment systems and online financial services can further enhance these opportunities. They can help in simplifying transactions, improving cash-flow management, and strengthening micro and small enterprises' links with formal financial institutions, thereby opening pathways to greater inclusion and enterprise growth (Friederici et al., 2020).

However, the benefits of digitalisation for MSMEs in general, and for women-led rural micro enterprises in particular, are not automatic. These enterprises generally lack the required financial and human resources, which could restrict their ability to fully leverage digital technologies (International Finance Corporation, 2025; Small Industries Development Bank of India, 2025; Saxena, 2025). In contrast to MSME, large firms possess far greater financial and human resources that enable them to adopt advanced technologies more rapidly, enter new markets with

ease, and sustain competitive advantages. While MSMEs do enjoy greater flexibility and adaptability, existing evidence clearly shows that innovation and scale advantages tend to favour firms with deeper financial resources (Webb & Schlemmer, 2006; Dean et al. 1998; Babina et al., 2024). Therefore, digital transformation, if left to market forces alone, can reinforce existing asymmetries not only between small and large firms but also across gender and rural-urban lines, rather than reducing them. Since MSMEs are major providers of employment and play vital role in economic growth and structural transformation, such exclusionary outcomes of digitalisation can have serious macroeconomic ramifications, especially for developing countries.

The challenges outlined above have prompted growing interest in institutional and technological approaches that can steer the digital transition in a more inclusive direction. Governments around the globe have been trying to develop an appropriate strategy to ensure a just and inclusive digital transformation.In this context, Digital Public Infrastructure (DPI) has emerged as a promising framework for enabling inclusive digitalisation (World Bank 2025). India provides the best example of DPI-led digitalisation. Starting from 2010, India has gradually built impressive digital public infrastructure to ensure inclusive digital transformation (Bhojwani et al., 2023). In this context, the Unified Payments Interface (UPI) represents one of the most significant DPI interventions. Introduced by the National Payments Corporation of India (NPCI) in 2016, UPI enables a real-time, low-cost, and interoperable digital payments system. Its design emphasises accessibility, interoperability, and ease of use, making it particularly relevant for expanding digital financial inclusion. As a key component of India's DPI architecture, UPI is often viewed as a transformative instrument for enabling inclusive digitalisation (Ministry of External Affairs 2024).

As UPI approaches a decade since its introduction, there is little doubt that it has transformed the digital payments landscape in India. Data from the National Payments Corporation of India (NPCI), along with existing studies (Haque, Azeez, & Akhtar, 2025), show a sharp and sustained increase in digital transaction volumes and adoption following

its rollout. However, the evidence on UPI adoption and the issue of inclusion, especially from enterprises perspective have remained scant. Much of the academic work, so far, has focused on consumer behaviour and household adoption, using technology acceptance frameworks, while studies that engage with MSMEs have adopted a broader lens on digitalisation or fintech usage rather than isolating UPI-specific adoption dynamics (Kumar et al., 2023; Singh &Rana, 2024). There have been only a couple of studies that have attempted to examine the adoption of UPI among MSMEs. However, these studies are based on very thin sample. Moreover, these studies have not made any attempt to compare the UPI adoption pattern with the adoption pattern of other modes of digital payment (NeoGrowth, 2023; Mahajan and Agarwal, 2023). More importantly, the literature has not systematically examined whether UPI has helped reduce structural disparities in digital payment adoption across enterprises. Although some studies acknowledge uneven adoption of UPI due to firm size, digital capability, and access constraints, there is little empirical work that quantifies differences between micro, small, and medium enterprises or evaluates whether UPI has narrowed these gaps. The literature gap is even more pronounced with respect to ownership characteristics, as gender-disaggregated analysis of UPI adoption among enterprises remains virtually absent. Against this backdrop, this paper is a modest attempt in this direction. Using primary survey data and logistic regression analysis, the paper evaluates whether adoption patterns of different digital payment instruments differ systematically across women-led, rural, and micro enterprises and examines whether disparities in adoption are relatively lower in the case of UPI. In doing so, the paper provides firm-level evidence, albeit indirectly, on how the design of digital public infrastructure is associated with more inclusive patterns of digital adoption.

The remainder of the paper is organised as follows. Section 2 presents the analytical framework. Section 3 describes the data sources and methodology. Section 4 examines descriptive patterns of digital payment adoption among MSMEs. Section 5 presents the econometric results. Section 6 concludes with policy implications and directions for future research.

2. Analytical Framework: DPI, UPI, and the Digital Inclusion of MSMEs

Firms can access digital payments through multiple instruments, including credit and debit cards, internet banking, digital wallets, bank transfers, and the Unified Payments Interface. Although these instruments operate within the same financial ecosystem, they differ significantly in infrastructure requirements, cost structures, interoperability, and capability demands. These differences shape their accessibility for enterprises with limited financial and technological resources. The adoption of digital payment systems can therefore be analysed as a function of four interrelated factors; fixed adoption costs, variable transaction costs, capability requirements, and interoperability. Payment modes that impose higher upfront investment, require specialised infrastructure, or demand advanced digital and financial skills are expected to see limited adoption by micro enterprises, rural firms, and women-led businesses as these enterprises face persistent constraints related to capital access, documentation, mobility, and digital capability (International Finance Corporation, 2025; Hasan et al., 2023).

Analytically, the adoption of the different modes of digital payment can be gauged from different theoretical perspectives. From a technology adoption perspective, particularly the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), adoption of technology is shaped by performance expectancy, effort expectancy, facilitating conditions, social influence, price value, and habit (Venkatesh, Thong, and Xu, 2012). These dimensions can be mapped to user-level constraints. For example, fixed and variable costs influence price value, capability requirements determine effort expectancy, and infrastructure availability reflects facilitating conditions. Social influence captures diffusion effects within business networks, while habit reflects repeated usage once adoption barriers are overcome. This framework has been widely used to understand the adoption of digital technologies. However, standard adoption models primarily focus on user perceptions and are less equipped to explain how the structural design of payment systems influences these determinants.

Platform ecosystem theory addresses this limitation. It emphasises the role of network effects, interoperability, and access conditions in shaping participation in digital systems (Adner 2017). This theory implies that payment platforms with closed or semi-closed architectures, such as digital wallets, create fragmentation and liquidity frictions, thereby increasing effective transaction costs and limiting usability across networks (Rana, Luthra, & Rao, 2022). Card-based systems, in contrast, exemplify a high fixed-cost model, requiring investment in point-of-sale infrastructure, compliance procedures, and stable connectivity. Their effectiveness further depends on consumer-side card penetration, which remains uneven across regions. Internet banking, although less hardware-intensive, still requires reliable connectivity and higher levels of digital literacy, limiting its accessibility for first-generation digital users. These characteristics raise adoption thresholds and disproportionately exclude smaller enterprises.

From an institutional infrastructure perspective, Digital Public Infrastructure (DPI) can be understood as a mechanism that reduces coordination failures and transaction costs by providing open, interoperable, and scalable systems (Rochet and Tirole 2003). Within this framework, UPI represents a distinct institutional arrangement. Unlike earlier payment systems, it reduces fixed adoption costs by eliminating the need for specialised hardware and lowering transaction charges, while its interoperable architecture enables seamless transactions across banks and applications. QR-based interfaces and simplified onboarding reduce technological and cognitive barriers, particularly for enterprises facing documentation, mobility, and digital literacy constraints (World Bank 2023). Minimal infrastructure requirements and lower dependence on high-bandwidth connectivity further enhance its suitability in rural environments. At the same time, its integration across multiple consumer-facing applications strengthens network effects, increasing its utility even for enterprises with limited customer reach.

These theoretical perspectives together suggest that digital payment adoption is not solely driven by user preferences but by the interaction between platform design and enterprise-level constraints. In this context, payment modes characterised by high fixed costs, limited interoperability,

and greater capability demands are likely to exhibit more uneven adoption patterns across firms. In contrast, systems such as UPI, which lower entry barriers and expand network access, are expected to be associated with more inclusive adoption patterns. This is particularly relevant for micro enterprises, rural firms, and women-led businesses, which face structural disadvantages in accessing digital technologies.

On this basis, the paper proposes the following hypotheses:

H1: Women-led MSMEs are expected to exhibit relatively lower disparities in adoption of UPI compared to other digital payment modes, as UPI is characterised by features associated with lower mobility, documentation, and technology-related barriers.

H2: Rural MSMEs are expected to exhibit relatively lower disparities in adoption of UPI compared to other digital payment modes, as UPI is associated with lower infrastructure requirements and transaction costs.

H3: Micro enterprises are expected to exhibit relatively lower disparities in adoption of UPI compared to other digital payment modes, as UPI is characterised by lower infrastructure and capability requirements.

Our framework conceptualises digital payment adoption as an outcome of institutional design interacting with enterprise-level constraints. The empirical analysis will test whether these structural characteristics are reflected in relatively lower observed disparities in adoption across MSME segments for UPI, rather than directly identifying causal mechanisms.

3. Methodology, Data Sourceand Limitations

To empirically test the hypotheses on the adoption of the Unified Payments Interface (UPI) and its association with digital inclusion among MSMEs, we employ binary logistic regression models, estimated separately for each digital payment mode. This approach allows for a clear comparison of how enterprise and owner characteristics are associated with the adoption of different digital payment instruments, without imposing the assumption that payment mode choices are mutually exclusive.Given the fact that enterprises may adopt multiple payment

modes simultaneously, estimating separate binary models enables us to capture mode-specific associations without constraining the relationship across payment instruments or imposing substitution patterns.

The baseline logistic regression equation can be specified as follow:

$$\Pr(UPI_i = 1) = \Lambda\,(\alpha_1 + \beta_1\,Female_i + \delta_1\,Rural_i + \theta_1 Micro_i + X_i'\gamma_1 + \varepsilon_{1i}),$$

$$\Pr(Card_i = 1) = \Lambda\,(\alpha_2 + \beta_2\,Female_i + \delta_2\,Rural_i + \theta_1 Micro_i + X_i'\gamma_2 + \varepsilon_{2i}),$$

$$\Pr(Internet_i = 1) = \Lambda\,(\alpha_3 + \beta_3\,Female_i + \delta_3\,Rural_i + \theta_1 Micro_i + X_i'\gamma_3 + \varepsilon_{3i})$$

Where $\Lambda(\cdot)$ denotes the logistic cumulative distribution function.For each enterprise i, adoption of digital payment instruments is captured through binary outcome variables:

- UPI_i =1 if the enterprise uses the Unified Payments Interface (UPI) for making or receiving payments, and otherwise
- $Card_i$ =1 if the enterprise uses debit or credit cards for making or accepting payments, and otherwise
- $Internet_i$ =1 if the enterprise uses internet banking (NEFT/RTGS) to make or receive payments, and otherwise

The primary explanatory variables of interest are defined as:

- $Female_i$ = 1 if the enterprise is owned or managed by a woman
- $Urban_i$ = 1if the enterprise is located in an urbanarea
- $Micro_i$ = 1 if the enterprise is classified as a micro enterprise[1]

Apart from the main variables of interest, the models also include a vector of control variables X. In our model, we use the age of the enterprise, the education level of the owner or manager, the age of the owner or manager as control variables. Additionally, the model also control's for state and industry fixed effects. These controls account for observable heterogeneity across sectorsand operating environments that may influence digital payment adoption.

The coefficients from these models are interpreted as mode-specific associations between enterprise characteristics and adoption outcomes. The analysis focuses on differences in the direction, magnitude, and statistical significance of coefficients across payment modes to assess whether UPI exhibits relatively lower disparities across enterprise groups.

Data Source

Estimation of the equations specified above requires firm-level information on the adoption of different digital payment modes by enterprises. Unfortunately, no existing secondary data source in India provides systematic and comparable information on the use of multiple digital payment instruments at the enterprise level. This study, therefore, relies on a primary survey specifically designed to capture the adoption of digital technologies, particularly digital payment modes, among Indian MSMEs.A structured field survey covering 2,882 MSMEs was conducted across fourteen major states: Andhra Pradesh, Assam, Delhi-NCR, Gujarat, Karnataka, Madhya Pradesh, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, and West Bengal. The survey collected detailed information on whether enterprises use digital modes to receive and make payments and, if so, the specific payment instruments adopted. In addition, the questionnaire captured enterprise characteristics and owner attributes relevant for examining gender, location, and size-based disparities in digital payment adoption. The survey covered five major industry divisions: food processing, wearing apparel, auto components, retail trade services, and food and beverage services. These sectors were selected to reflect the natural distribution and concentration of MSMEs across India.

In the absence of an up-to-date list of MSMEs operating in India, acluster-based sampling strategy was employed to conduct the survey. Using the latest economic census data, two to three districts with a high concentrationof MSMEs were identified in each state. Within these districts, enterprise clusters and industrial hubs were mapped using local intelligence, secondary research, and web-scraping techniques. Within each identified cluster, enterprises were selected using a consistent right-hand rule, starting from a randomly chosen geographical point and interviewing all eligible enterprises located on the right-hand side. This approach ensured systematic coverage while limiting interviewer discretion and selection bias. Screening questions were used to verify enterprise size, sector of operation, and respondent eligibility. Interviews were conducted exclusively with enterprise owners or managing directors using a detailed structured questionnaire.

Table 1: Sectoral Distribution of Surveyed Enterprises

Sector	Micro	Small	Medium	Total
Manufacture Food Products	195	189	98	482
Manufacture of Wearing Apparels	207	198	113	518
Manufacture Auto Components	213	146	104	463
Retail Trade Services (except motor vehicles)	431	310	178	919
Food and beverage services	226	173	101	500
Total	1295	1035	605	2882

The final sample comprises 1,295 micro, 1,035 small, and 605 medium enterprises, allowing for a clear examination of size-based differences in digital payment adoption (table 1). Sectorally, retail trade services account for 30 per cent of the sample, followed by food and beverage services (over 17 per cent), with the remainder distributed across the three manufacturing sectors. Regionally, the largest share of enterprises is drawn from Gujarat (12 per cent), followed by Tamil Nadu (10.9 per cent), Maharashtra (10 per cent), Karnataka (10 per cent), and Rajasthan (8.1 per cent), with the remaining enterprises spread across northern, eastern, and northeastern states.In terms of ownership, approximately 10 per cent of surveyed enterprises are female-owned or managed, with the share of female-headed enterprises marginally higher among micro enterprises than among small and medium enterprises. The sample also exhibits variation in owner characteristics, including education and age, which are relevant for understanding capability-related barriers to digital adoption. This diversity across gender, geography, and firm size provides a suitable empirical basis for testing whether the adoption of different digital payment modes, particularly UPI, varies systematically across structurally disadvantaged segments of MSMEs.

Table 2: Distribution of Sample by Gender of Owner / Managing Director

	Micro	Small	Medium	Total
Male	1,138	926	538	2,602
Female	134	90	56	280

Limitations

Given the absence of a comprehensive and up-to-date sampling frame for MSMEs in India, we have used cluster-based sampling. This sampling approach provides a practical and widely used approach to identify and survey enterprises. MSMEs in India tend to be geographically concentrated in identifiable industrial and commercial clusters, making this approach effective for ensuring coverage across sectors and regions while maintaining the feasibility of fieldwork. However, this strategy may introduce certain limitations which should be kept in mind. There is a possibility that enterprises located within dense clusters may differ systematically from more dispersed or standalone MSMEs in terms of visibility, market access, and exposure to digital technologies. In addition, the use of the right-hand rule for respondent selection, while ensuring procedural consistency, may lead to an overrepresentation of more visible or easily accessible enterprises within clusters. As a result, the sample may be more reflective of MSMEs operating in commercially active clusters. Therefore, the findings of this paper should be interpreted with this scope in mind. Moreover, our empirical methodology facilitates comparison across payment modes, it does not constitute a formal statistical test of differences in coefficients across models. Therefore, the results of this paper should be interpreted as indicative of relative patterns rather than definitive cross-equation comparisons.

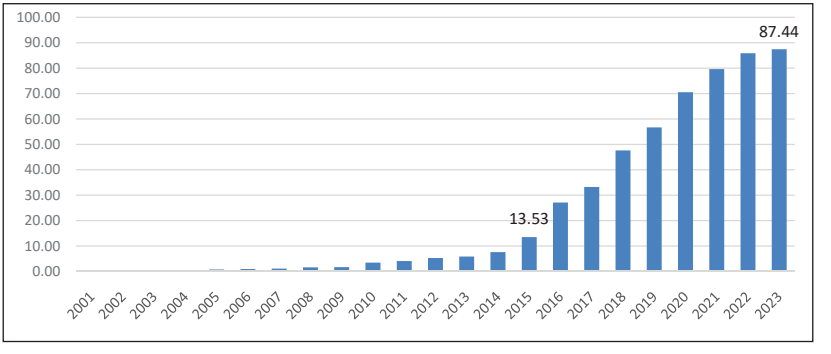
4. Trajectory of Digital Payment Adoption

Before turning to the econometric analysis, it is important to examine the digital payment adoption journey of Indian MSMEs. This section therefore presents a descriptive analysis of digital payment usage based on primary survey data, with the objective of contextualising the regression

results within the broader evolution of digitalisation among MSMEs. Documenting the progression of digital payment adoption over time and the relative uptake of different payment modes, the section attempts to identify key stylised facts that inform the subsequent empirical analysis.

Our survey data allows us to identify the year in which each enterprise first began using digital modes of payment. The tabulation of this information, presented in Figure 1, shows that none of the surveyed MSMEs reported using digital payments prior to 2002. Although the initial phase of payment digitalisation in India began in the early 1990s with the introduction of debit and credit cards, MSMEs appear to have remained largely insulated from this wave. Since Card-based payments during this period were primarily confined to select consumer segments and large formal enterprises, these results are perhaps not surprising. As per oursurvey data, adoption of digital payments among MSMEs started to increase gradually from the mid-2000s onward. However, uptake remained modest for an extended period. The share of MSMEs using digital payment modes, which was negligible until 2012, rose slowly to about 13.5 per cent by 2015. A sharp acceleration in adoption is observed in the post-2015 period. This inflection point coincides with the introduction of application programming interface (API)-based payment infrastructure, most notably the Unified Payments Interface (UPI). In other words, prima facie, it seems introduction of UPI has pushed the adoption of digital payments among MSMEs.

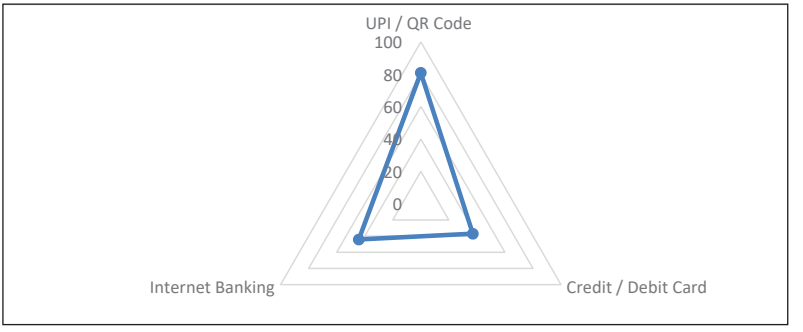
Figure 1: Timeline of Digital Payment Adoption in Indian MSMEs



Source: Authors' compilation from survey data

While Figure 1 traces the timing and pace of digital payment adoption among MSMEs, it does not reveal how this adoption varies across different payment instruments. In order to understand this, we estimated the penetration / use of different modes of digital payment; results are depicted in Figure 2. The results indicate a clear dominance of UPI and QR-code–based payment systems, which emerge as the most widely adopted digital payment instruments. Notably, the share of MSMEs using internet banking and debit or credit cards continues to remain extremely low compared to UPI-based payments.Our data suggest that less than 38 per cent of surveyed MSMEs have been using credit / debit cards to make or receive payment. The use of internet banking is relatively a bit higher, but it also continues to be very low. This pattern is consistent with the higher compliance costs, infrastructure requirements, and procedural complexity associated with these payment modes, which may be less compatible with the transaction volumes, customer profiles, and operational constraints faced by several MSMEs, especially the Micro and small enterprise. In contrast, more than 80 per cent of surveyed MSMEs have incorporated UPI in their business model to make and receive payments.

Figure 2: Digital Payment Penetration by Mode



***Source*:** Authors' compilation from survey data

In order to further explore heterogeneity in adoption patterns of digital payment, we disaggregate the use of digital payment modes by gender of the owner or manager, firm size, and enterprise location. The results reported in Table 3 show several notable patterns. First, gender-based

differences are evident in the adoption of credit cards and internet banking, with male-owned enterprises reporting substantially higher usage than female-owned enterprises. In contrast, adoption of UPI is high for both groups and the gender gap is extremelynarrow, indicating that low-cost and interoperable payment systems are perhaps more effective in reducing gender-based disparities than traditional banking instruments. Second, it is also clearly evident that adoption patterns vary systematically by enterprise size. As per our data, larger enterprises exhibit higher usage of credit cards and internet banking, reflecting greater formality, higher transaction volumes, and stronger integration with the banking system. In contrast, micro enterprisesdisplay limited adoption of these modes but very high reliance on UPI, underscoring the role of mobile-based, low-cost payment systems in facilitating digital participation among smaller firms. The relatively lower adoption of UPI among medium-sized enterprises suggests heterogeneity in transaction structures or partial reliance on alternative payment arrangements rather than a simple monotonic relationship between firm size and digital adoption. Interestingly, Table 3 shows that contrary to the general expectation, differences across location are comparatively modest, particularly for UPI, where adoption rates are almost identical for rural and urban MSMEs. This convergence suggests that digital payment infrastructure, especially UPI, has been effective in narrowing traditional rural-urban divides in access to digital payment systems. Modest differences persist for other modes, reflecting variations in institutional practices, transaction frequency, and infrastructure availability.

Table 3: Adoption of Digital Payment Tools by Location, Size, and Gender of Manager/owner

Characteristic	Category	Credit Card	Internet Banking	UPI
Gender	**Male**	38.24	46.93	80.82
	Female	26.43	27.5	79.79
Size of Enterprise	**Micro**	27.48	32.02	81.76
	Small	38.11	45.83	78.83
	Medium	38.46	41.76	69.23
	Large	50.25	61.03	82.83

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Location	**Rural**	36.8	46.79	80.71
	Urban	37.29	42.41	80.94

***Source*:** Authors' compilation from Survey Data.

The above descriptive evidence clearly highlights the central role of UPI in shaping digital payment adoption among Indian MSMEs. It shows that UPI has pushed the digital payment adoption among MSMEs and has also reduced gender, size and location gaps in adoption.

5. Results and Discussion

The preceding section documented aggregate patterns and stylised facts on the evolution of digital payment adoption among Indian MSMEs. While these descriptive patterns provide important initial insights, they do not account for heterogeneity across enterprises once multiple firm and owner-level characteristics are considered simultaneously. This section therefore builds on the descriptive analysis and employs multivariate regression techniques to examine whether the adoption of different digital payment modes varies systematically by gender of ownership, enterprise location, and firm size, after controlling for relevant characteristics of enterprises and their owners or managers.Using the methodology specified in Section 2, we estimated three equations, one each for the three modes of digital payment. The equations specified in Section 2 are estimated using maximum likelihood estimation under the binary logistic framework. The equations are estimated using robust standard errors to account for potential heteroskedasticity. The results are reported in Table 4. We have reported the estimated logit coefficients (β) alongside their corresponding odds ratios, which are obtained as the exponential transformation of the coefficients. While the coefficients reflect the direction and relative strength of associations, the odds ratios facilitate interpretation in terms of changes in the likelihood of adoption.

Before interpreting individual coefficients and odd ratios, it is useful to briefly assess overall model adequacy. It is evident from Table 4 that in all three specifications, the likelihood ratio chi-square statistics reject the null hypothesis that all coefficients are jointly zero, indicating that the equations are statistically well specified. The pseudo R^2 values, though

modest, are consistent with those typically observed in cross-sectional studies of firm-level technology adoption, suggesting that the included covariates explain meaningful variation in payment mode usage.

Turning to the results, the estimates for credit card adoption, reported in columns 1 and 2, reveal pronounced disparities across enterprise characteristics. Results show that Female-owned enterprises are significantly less likely to adopt credit cards for making or accepting payments (β = −0.557; Odd Ratio = 0.573), implying that the odds of adoption are approximately 43 per cent lower compared to male-owned enterprises, holding other factors constant. Similarly, micro enterprises exhibit significantly lower adoption (β = −0.640; Odd Ratio = 0.527), with nearly 47 per cent lower odds relative to other enterprise firms. In contrast, urban enterprises are significantly more likely to adopt credit cards (β = 0.166; Odd Ratio = 1.180), indicating higher adoption in urban areas. In other words, rural enterprises have significantly lower odd of adoption indicating rural-urban inequalities. Among the control variables, education of the owner / manager is positively and significantly associated with adoption (β = 0.308; Odd Ratio = 1.360), while the age of the manager shows a negative association (β = −0.180; Odd Ratio = 0.835). These results are on expected lines as more educated and young leadership is expected to be more tech-oriented. The age of the enterprise does not exhibit a statistically significant relationship.[2] Overall, our results show that credit card adoption is characterised by strong disparities across gender, firm size, and location.

Table 4: Coefficients and Odd Ratios from Logistic Regression on Digital Payment Adoption

Variable	Credit Card		Internet Banking		UPI	
	β Coefficients	Odd Ratio	β Coefficients	Odd Ratio	β Coefficients	Odd Ratio
Female-Owned Enterprise	-0.557* (0.159)	0.573* (0.091)	-0.626* (0.157)	0.535* (0.084)	-0.200 (0.159)	0.819 (0.130)

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Urban Enterprises	0.166* (0.091)	1.180* (0.107)	0.177 (0.088)	1.194 (0.105)	0.121 (0.107)	1.128 (0.121)
Micro Enterprise	-0.640* (0.093)	0.527* (0.049)	-0.758* (0.090)	0.469* (0.042)	0.082 (0.111)	1.086 (0.120)
Age of Enterprise	-0.052 (0.051)	0.949 (0.048)	0.003 (0.049)	1.003 (0.049)	0.109* (0.057)	1.115* (0.064)
Education (Manager/ Owner)	0.308* (0.041)	1.360* (0.056)	0.321* (0.039)	1.379* (0.054)	0.143* (0.046)	1.154* (0.053)
Age of Manager/ Owner	-0.180* (0.055)	0.835* (0.046)	-0.066 (0.052)	0.936 (0.049)	-0.124 (0.063)	0.883 (0.056)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2863		2863		2863	
Log Likelihood	−1,626.40		−1,690.10		−1,212.69	
LR χ^2	524.29		552.7		370.38	
Pseudo R^2	0.139		0.141		0.133	

Note: * significant at 1 per cent, robust standard error, clustered at the state level, reported in parenthesis

The results for internet banking adoption, reported in column 3 and 4, broadly mirror those observed for credit cards. Results show that female-owned / managed enterprises are significantly less likely to adopt internet banking ($\beta = -0.626$; Odd Ratio = 0.535), indicating approximately 46 per cent lower odds of adoption compared to male-owned enterprises. Micro enterprises also show significantly lower adoption ($\beta = -0.758$; Odd Ratio = 0.469), with about 53 per cent lower odds relative to larger firms. However, unlike credit cards, the effect of urban location is not statistically significant ($\beta = 0.177$; Odd Ratio = 1.194), suggesting that the rural-urban divide is not significant for internet banking. Among the control variables, education of owner / manager remains positively and significantly associated with adoption ($\beta = 0.321$; Odd Ratio = 1.379), while the age of the enterprise and the age of the manager do not exhibit statistically significant relationships. These results indicate that, although

Internet banking may be less dependent on physical infrastructure than card-based systems, it continues to exhibit disparities across gender and firm size.

In contrast to internet banking and credit / debit cards, the results for UPI adoption, reported in column 5 and 6, present a markedly different pattern. Our results shows that female ownership ($\beta = -0.200$; Odd Ratio = 0.819) and micro enterprise status ($\beta = 0.082$; Odd Ratio = 1.086) are not statistically significant, indicating no clear differences in adoption across these dimensions. Similarly, urban location does not exhibit a statistically significant association ($\beta = 0.121$; Odd Ratio = 1.128), suggesting absence of the rural-urban disparity in UPI adoption. Among the control variables, education remains positively and significantly associated with adoption ($\beta = 0.143$; Odd Ratio = 1.154), and the age of the enterprise shows a modest positive association ($\beta = 0.109$; Odd Ratio = 1.115). The age of the manager does not exhibit a statistically significant relationship. The absence of statistically significant differences across key enterprise characteristics suggests that UPI adoption is associated with relatively more uniform patterns across MSMEs.

Overall, the results provide strong support for the hypothesis that disparities in digital payment adoption across enterprise characteristics are absent in the case of UPI. While gender- and size-based disparities are evident in the adoption of credit cards and internet banking, such disparities are not observed for UPI. Location-based differences are also weaker in the case of UPI, although evidence is more limited. These findings suggest that UPI is associated with relatively more uniform adoption patterns across MSMEs.

Average Marginal Effect

While odds ratios provide useful information on the direction and relative strength of associations, their interpretation in terms of changes in predicted probabilities is not straightforward. Moreover, comparisons across models are complicated by the non-linear nature of the logistic function, which makes it difficult to interpret differences in coefficients or odds ratios consistently across payment modes. To address these limitations, we computed average marginal effects (AMEs) for the

key explanatory variables. AMEs translate the estimated coefficients into percentage-point changes in the predicted probability of adoption, averaged over the sample distribution of covariates. This provides a more intuitive interpretation and facilitates meaningful comparison across payment modes. The results are presented in Table 5. Notably, the AME estimates closely mirror the patterns observed in the odds ratio results. Female ownership is associated with a statistically significant reduction in the probability of adopting credit cards (10.8 percentage points) and internet banking (8.3 percentage points) which indicates persistent gender-based disparities. Similarly, micro enterprises face substantial reductions in adoption probabilities for these two payment modes, reflecting the higher fixed costs and operational complexities associated with traditional digital payment instruments. In contrast, the estimated marginal effects for UPI adoption are small in magnitude and statistically insignificant across gender and firm size. This suggests that, once other characteristics are controlled for, women-led and micro enterprises do not experience meaningful differences in the likelihood of adopting UPI relative to other enterprises. Importantly, these findings confirm that the weaker disparities observed in the logit estimates are not an artefact of odds-ratio scaling, but reflect genuinely smaller differences in predicted adoption probabilities.

Table 5: Average Marginal Effect from Logistic Regression on Digital Payment Adoption

Variable	Credit Card	Internet Banking	UPI
Female-owned enterprise	−0.108* (0.030)	−0.083* (0.021)	−0.020 (0.021)
Urban Enterprise	0.032* (0.017)	0.036 (0.018)	0.016 (0.014)
Micro Enterprise	−0.124* (0.017)	−0.153* (0.017)	0.011 (0.015)
Observations	2,863	2,863	2,863

Robustness Checks

The empirical results presented above indicate systematic differences in digital payment adoption across enterprise types, with a notably more uniform pattern observed for UPI relative to traditional payment modes. Given that these conclusions are based on non-linear probability models, cross-sectional survey data and cross-model comparisons, it is important to verify that the observed patterns are not sensitive to econometric specification, inference procedures, or scaling choices. One of the major issues with cross-sectional data is that it could have the problem of heteroskedasticity, which can lead to inconsistent standard error and unreliable statistical inference. In order to address this concern, we have estimated our equations using heteroskedasticity – robust standard error, clustered at the state level, which account for both heteroskedasticity and intra-state correlation in digital payment adoption. Another issue is the potential presence of multicollinearity among explanatory variables, which can inflate standard error and affect the stability of estimates. We examine the presence of multicollinearity among the explanatory variables using variance inflation factors (VIF). The results, reported in Table 6, indicate that multicollinearity is not a concern. VIF values are well below 3 and the mean VIF is 1.82. It suggests that the estimated coefficients are not driven by linear dependence among regressors and can be interpreted as stable partial associations.

Table 6: Variance Inflation Factors

Variable	VIF	1/VIF
Female-Owned / Managed Enterprise	1.05	0.95
Urban Enterprise	1.08	0.929
Micro Enterprise	1.06	0.945
Age of Enterprise	1.18	0.85
Age of Manager / Owner	1.01	0.99
Age of Manager/Owner	1.07	0.93
State Dummies	1.45 – 2.61	—
Sector Dummies	1.73 – 2.11	—
Mean VIF	1.82	—

Continued...

Finally, to assess sensitivity to functional form, as a robustness check,we estimated our baseline specifications using a probit model and the results are reported in Table 7. Notably, probit model yielded qualitatively identical results in terms of coefficient signs and statistical significance. In particular, the central finding that there are no statistically significant disparities in UPI adoption across gender and firm size continues to hold. This indicates that the main results are not driven by the choice of the logistic specification.

Table 7: Results - Probit Regression on Digital Payment Adoption

Variable	Credit Card	Internet Banking	UPI
Female-Owned Enterprise	-0.329* (0.091)	-0.391* (0.092)	-0.125 (0.091)
Urban Enterprises	0.104*** (0.057)	0.111 (0.055)	0.076 (0.067)
Micro Enterprise	-0.400* (0.058)	-0.474* (0.056)	0.051 (0.069)
Age of Enterprise	-0.033 (0.032)	0.002 (0.031)	0.068 (0.036)
Education (Owner/ Manager)	0.192* (0.026)	0.201* (0.024)	0.089*** (0.029)
Age of Manager	-0.113* (0.034)	-0.041 (0.033)	-0.078 (0.039)
State FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	2,863	2,863	2,863
Pseudo R^2	0.139	0.141	0.133

Note: Significant at 1 per cent, robust standard error, clustered at the state level, reported in parenthesis

6. Conclusion

Digitalisation has increasingly been viewed as a critical instrument for expanding access to markets, finance, and public services. However, digital transformation does not automatically translate into inclusion. When digital systems are built around high fixed costs, proprietary platforms, or demanding capability requirements, they risk reproducing or even reinforcing existing economic and social exclusions, particularly for women-led enterprises, rural firms, and smaller businesses. In this context, the design of digital systems becomes central to determining whether digitalisation promotes inclusion or exclusion. Digital Public Infrastructure (DPI) has emerged as a distinct approach to addressing these challenges. Scholars have argued that DPI can create digital ecosystems that are accessible to a broad range of users rather than a narrow segment of firms or consumers. India has championed the cause of DPI. It has put in place a sound DPI in the form of India Stack. India's Unified Payments Interface (UPI) represents one of the most prominent examples of DPI in practice, offering a useful case to examine whether public digital architecture can reshape patterns of inclusion in digital financial systems.

Against this backdrop, this paper examined whether adoption of UPI is more inclusive for women-led, rural, and micro MSMEs relative to traditional digital payment instruments such as credit cards and internet banking. The empirical results show a clear and consistent pattern. Based on in-depth econometric analysis, the paper shows that gender-, location-, and size-based divides are strongly present in the adoption of credit cards and internet banking, with women-led enterprises, rural firms, and micro enterprises exhibiting significantly lower odds and lower probabilities of adoption. These divides, however, are absent in the case of UPI.It means women-led, rural, and micro enterprises do not face systematic disadvantages in adopting UPI once other enterprise and owner characteristics are taken into account. This contrast is substantively important. It indicates that UPI has effectively addressed barriers that continue to constrain adoption of traditional digital payment instruments. Rather than conferring an advantage to specific groups, UPI appears

to function as an equalising technology, removing penalties associated with gender, location, and firm size that are embedded in other payment systems. The findings suggest that UPI's low fixed costs, minimal infrastructure requirements, interoperable architecture, and simplified onboarding processes have weakened long-standing exclusionary mechanisms linked to documentation, scale, and access to formal banking infrastructure. However, it is important to interpret these results as conditional associations rather than behavioural choices or causal effects. The analysis does not imply substitution or complementarity across payment modes, nor does it suggest that UPI replaces other digital payment instruments. Instead, the findings highlight how institutional and technological design shapes who is excluded and who is not. Traditional digital payment modes continue to reflect structural constraints, while UPI's design reduces the salience of these constraints in adoption decisions.

From a policy perspective, the results underscore the importance of DPI-led approaches to digital inclusion. Our results underline the fact that expanding digital adoption among MSMEs requires more than scaling technology or promoting usage. It requires building digital systems that are inclusive by design. Our results suggest that Public digital infrastructure which lowers entry barriers, ensures interoperability, and minimises compliance burdens can play a decisive role in broadening participation, particularly among enterprises that have historically been marginalised from formal digital finance. Overall, the findings suggest that Digital Public Infrastructure can pave the way for more inclusive digitalisation, not by privileging specific groups, but by systematically reducing structural barriers that limit participation. As countries increasingly adopt digital solutions for economic development, India's experience with UPI provides important lessons on how public digital architecture can shape more equitable digital outcomes for small businesses.

Endnotes

[1] Enterprises operating with fewer than 10 employees are defined as micro enterprises

[2] Apart from the control variables reported here, we also experimented with the number of employees an additional control variable. However, its inclusion neither improves the explanatory power of the model nor changes the significance and magnitude of other variables.

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