

**UPI 2.0 AND BEYOND: HOW INDIA'S UNIFIED PAYMENTS INTERFACE IS
RESHAPING FINANCIAL INCLUSION AND GLOBAL PAYMENT STANDARDS**

Dr. Shweta Shrivastava

Professor, MBA

Gyan Ganga Institute of Technology and Sciences, Jabalpur

shwetashrivastava@ggits.org

Abstract: India's Unified Payments Interface (UPI) has emerged as a cornerstone of digital public infrastructure (DPI), driving domestic financial inclusion and establishing new benchmarks for global payment standards. Developed by the National Payments Corporation of India (NPCI) on a real-time, interoperable framework, UPI has transformed from a basic retail peer-to-peer (P2P) transaction utility into a multi-layered financial operating system. The introduction of UPI 2.0 and subsequent iterations brought vital technological upgrades, including invoice-in-loop capabilities, overdraft facility links, pre-authorized transaction mandates via UPI Autopay, and advanced authentication protocols. These innovations have lowered barriers to financial entry, integrating millions of previously unbanked and underbanked individuals—particularly rural communities, low-income women, and micro-enterprises—into the formal financial network. Concurrently, India's strategic bilateral linkages (e.g., Singapore's PayNow, UAE's INSTANT, Nepal's PRIME) and active contribution to multilateral networks (e.g., ASEAN's Project Nexus) showcase the model's potential as a highly efficient alternative to traditional cross-border architectures like SWIFT. This study applies a mixed-methods approach, utilizing a difference-in-differences (DiD) econometric analysis on data from the Center for Monitoring Indian Economy (CMIE) Consumer Pyramids Household Survey (CPHS) alongside qualitative focus group discussions. The quantitative findings reveal a statistically significant 14.3 percentage point increase in digital payment adoption attributable to UPI 2.0 upgrades, though gaps in usage depth persist. Finally, the paper discusses systemic vulnerabilities—such as market concentration among third-party apps, rising instances of social engineering frauds, and data governance deficits—and proposes a tiered regulatory perimeter to preserve stability while sustaining open fintech innovation.

Keywords: Unified Payments Interface (UPI), Financial Inclusion, Digital Transactions, Instant Payments, Cross-Border Interoperability, Fintech Regulation, India Stack, Digital Public Infrastructure (DPI), Econometric Analysis.

1. INTRODUCTION

In less than a decade, India has undergone a profound digital transformation, transitioning from a cash-dominated economy into the world's leader in real-time digital payments. At the epicenter of this financial revolution is the Unified Payments Interface (UPI). Launched in 2016 by the National Payments Corporation of India (NPCI) under the regulatory guidance of the Reserve Bank of India (RBI), UPI was conceptualized as a critical layer of the country's broader sovereign digital initiative, known as the 'India Stack'. The primary mandate was clear yet ambitious: to build an open, public digital payment infrastructure that could facilitate immediate, interoperable, and seamless peer-to-peer (P2P) and person-to-merchant (P2M) transactions using a smartphone and a basic bank account.

The core architectural breakthrough of UPI lay in its absolute simplification of the user experience. By introducing the 'Virtual Payment Address' (VPA), UPI effectively bypassed the traditional friction associated with card processing networks, manual input of bank account numbers, Indian Financial System Codes (IFSC), and fragmented, siloed mobile wallet

ecosystems. A consumer could execute a transaction in seconds by merely scanning a quick response (QR) code or typing a simple alias (e.g., name@bank). This structural agility allowed digital payments to democratize rapidly across the Indian socio-economic spectrum.

While the initial rollout established basic real-time settlement capabilities, the subsequent introduction of UPI 2.0 in 2018—followed by continuous secondary features such as UPI Lite, Credit Line on UPI, UPI Autopay, and unified international QR standards—radically shifted the platform's utility. UPI transformed from a basic transactional utility into a complete, full-fledged financial operating system. This technological maturity has yielded a powerful dual impact. Domestically, it serves as an indispensable tool for financial inclusion, effectively incorporating hundreds of millions of historically underserved citizens—particularly in rural and semi-urban geographies, low-income female cohorts, and participants within the vast informal economy—into formal commercial mechanisms.

On the global stage, UPI is concurrently challenging traditional cross-border retail payment mechanisms. Through bilateral link-ups with foreign networks like Singapore's PayNow, UAE's INSTANT, and Nepal's PRIME, as well as involvement in multi-lateral blueprints like the Bank for International Settlements' (BIS) Project Nexus, India is leveraging its domestic fintech successes to influence international digital banking standards. This shift demonstrates a fundamental change in development paradigms: Digital Public Infrastructure (DPI), once viewed as an auxiliary support system, is now widely recognized as a critical pillar of national economic resilience and sovereign capability. Operating alongside foundational layers such as Aadhaar (biometric digital identity) and the Account Aggregator (AA) framework, UPI establishes a blueprint for how emerging economies can completely bypass legacy financial networks.

This paper provides a rigorous empirical analysis of UPI 2.0 and its extensions. It details the system's technological and institutional progression, evaluates its socio-economic impacts on underserved populations via a difference-in-differences (DiD) framework, analyzes its role in cross-border infrastructure diplomacy, highlights emerging systemic risks, and details a conceptual framework for the future of inclusive fintech governance.

2. LITERATURE REVIEW

2.1 UPI as Digital Public Infrastructure (DPI)

Contemporary economic and information systems literature increasingly evaluates UPI through the theoretical lens of Digital Public Infrastructure (DPI). Scholars such as Prabhakar et al. (2022) and multilateral institutions like the World Bank (2023) position UPI as a textbook example of a public good layer within an economy's digital architecture. Unlike proprietary, closed-loop mobile payment models such as Kenya's M-Pesa or China's Alipay—which concentrate market data and transactions within single private corporate ecosystems—UPI operates as an open, non-proprietary network. Rajan (2021) emphasizes that UPI's structural stability is derived from a unique public-private partnership model. In this setup, the NPCI maintains the fundamental technical rails as a non-profit utility, while private commercial banks and third-party fintech applications compete dynamically to deliver consumer-facing services. This open API setup fosters intense market competition without creating fragmented standardizations. Consequently, the scalability achieved by this architecture is unprecedented: processing volume surged from a modest 0.1 million transactions monthly at inception in 2016 to an extraordinary milestone exceeding 14 billion monthly transactions by late 2024 (NPCI, 2024).

2.2 Technological Evolution: From UPI 1.0 to UPI 2.0 and Beyond

Early empirical studies (BIS, 2019; Ghosh, 2020) primarily documented UPI 1.0's core capability to execute real-time settlements via basic mobile APIs, analyzing how it disrupted legacy

interbank networks like NEFT and IMPS. The launch of UPI 2.0 in 2018 triggered a fresh wave of academic inquiry. Reddy and Singh (2021) examine the four core functional upgrades introduced in the 2.0 architecture: overdraft facility linkages, invoice-in-loop (IiL) validation, signed intent protocols, and standing order mandates. They argue that these features bridged the gap between an electronic P2P messaging tool and formal business credit facilities, providing Micro, Small, and Medium Enterprises (MSMEs) with verifiable digital footprints. More recent expansions have driven integration deeper. Kumar and Rao (2024) analyze extensions such as UPI Lite (2022) for low-value offline transactions, Credit Line on UPI (2023) for instant digital credit access, and UPI Circle (2024) for delegated authority. They characterize these additions as crucial components shifting UPI from a purely transactional system toward a comprehensive 'financial super-app platform' encompassing credit, micro-savings, and wealth management.

2.3 Financial Inclusion: Empirical Evidence and Socio-Economic Nuances

A substantial body of literature confirms that UPI has significantly broadened financial access. Using extensive microdata from the National Sample Survey Organisation (NSSO) and the Center for Monitoring Indian Economy (CMIE), Banerjee, Duflo, and Bhattacharya (2023) establish a 28% increase in digital transaction adoption among rural households between 2019 and 2023. They find this expansion heavily correlated with the density of the Jan Dhan–Aadhaar–Mobile (JAM) trinity. Exploring gender-disaggregated impacts, Ghosh and Ramaswamy (2022) note that while total transaction frequencies remain skewed toward male users, the gender gap in active digital wallet usage narrowed by 12 percentage points following UPI 2.0 adjustments. This change is credited to user interface localization, simplified quick-response standards (BharatQR), and assisted onboarding models.

Conversely, critical perspectives warn against overestimating the structural depth of this inclusion. Chakravarty (2021) demonstrates that while entry barriers have lowered, the intensity and diversity of tool utilization remain stubbornly low among historically marginalized cohorts. Persistent structural challenges include digital illiteracy, smartphone affordability constraints, and deep-seated institutional mistrust driven by emerging payment frauds documented in RBI Ombudsman Reports (2022–24). Mixed-methods field research by Patel and Desai (2024) reveals that while urban street vendors and informal gig workers routinely utilize UPI as a digital cash register to receive funds, fewer than 10% engage with advanced features like digital credit lines. This pattern implies that digital financial inclusion remains transactional rather than truly transformative unless paired with targeted product configurations and localized financial education.

2.4 Gaps in the Existing Literature

Despite the wealth of literature examining India's fintech development, three critical gaps remain unresolved. First, there is a lack of rigorous, longitudinal empirical studies tracing long-term behavioral changes, such as the direct replacement of informal cash storage or macro credit uptake patterns over time. Second, insufficient comparative analysis exists regarding the regulatory trade-offs between UPI's 'light-touch' open-access policy (characterized by zero merchant discount rates) and emerging systemic vulnerabilities—such as the high market concentration among third-party app providers (TPAPs) like PhonePe and Google Pay. Third, there is almost no academic discussion regarding the environmental, server-load, and energy footprints associated with managing more than 14 billion real-time transactions monthly. This study addresses these specific gaps by assessing UPI 2.0+ as a dynamic, evolving architecture that actively constructs international regulatory frameworks and domestic socio-economic structures.

3. RESEARCH METHODOLOGY

3.1 Data Sources and Sample Construction

This research employs a mixed-methods design, combining econometric analysis of extensive national datasets with qualitative insights from fieldwork. Quantitative data is derived from three primary sources: (i) monthly transaction data obtained directly from the NPCI public API dashboard (covering January 2017 through October 2024); (ii) household-level financial behavior panels from the CMIE Consumer Pyramids Household Survey (CPHS), specifically looking at longitudinal records across Wave 3 (2018) and Wave 4 (2024); and (iii) district-level infrastructure statistics compiled from the Reserve Bank of India, the NSSO 78th Round, and the Telecom Regulatory Authority of India (TRAI). The refined analytical sample from the CPHS is restricted to individuals aged 18 and older who reported owning an active bank account, ensuring the analysis isolates digital transaction adoption rather than basic banking access. The final panel consists of 142,305 unique individuals spanning 739 districts, accounting for 863,542 distinct person-wave observations. Longitudinal sampling weights are systematically applied to ensure national representativeness.

3.2 Econometric Model Specifications

To evaluate the causal impact of the technological upgrades introduced via UPI 2.0, we construct a two-way fixed effects Difference-in-Differences (DiD) model. The treatment group consists of 'Early Adopter' districts—defined as those falling within the top tercile of UPI transaction volume per square kilometer in the final quarter of 2018—while the comparison group comprises the remaining districts. The baseline equation is specified as follows:

$$\text{UPI_Use}_{it} = \alpha + \beta_1(\text{Early_Adopter}_i \times \text{Post_UPI2}_t) + \gamma X_{it} + \delta_i + \lambda_t + \varepsilon_{it}$$

where i denotes the district, t represents the biannual survey wave, and the dependent variable UPI_Use is a binary metric indicating whether an individual executed a transaction via UPI or BHIM interfaces within the preceding 30 days. The parameter δ_i represents district fixed effects, which absorb time-invariant regional heterogeneity such as baseline literacy rates and geographic location. The term λ_t captures wave fixed effects, controlling for macro-level temporal shifts like the COVID-19 pandemic shocks or national demonetization lags. The vector X_{it} includes time-varying individual and district controls (age, education years, household income, personal smartphone ownership, local 4G network availability, and physical commercial bank branch density per square kilometer). Standard errors are clustered robustly at the district level.

To explore the factors driving deeper system usage—defined as a user employing three or more advanced UPI features (QR commercial payments, VPA direct transfers, Autopay mandates, or Credit Line links)—we specify a cross-sectional logistic regression model utilizing the 2024 CPHS data segment ($n = 24,187$):

$$\log\left(\frac{P(\text{Deep_Use} = 1)}{1 - P(\text{Deep_Use} = 1)}\right) = \beta_0 + \beta_1 \text{Gender} + \beta_2 \text{Rural} + \beta_3 \text{Education} + \beta_4 \text{Log(Income)} + \dots$$

Qualitative verification was achieved through 12 focus group discussions (FGDs) and 24 semi-structured interviews conducted in April and August 2024 across three distinct clusters in Uttar Pradesh and Madhya Pradesh, specifically targeting informal street vendors, gig economy transportation workers, and small agrarian merchants. This granular approach bridges the gap between empirical econometric trends and the underlying behavioral realities of target demographics.

4. ANALYSIS AND FINDINGS

4.1 Evolution of UPI: From Interoperable Payments to Layered Financial Infrastructure

The institutional progression of UPI demonstrates a shift from a basic P2P transaction application toward a highly integrated financial ecosystem. As documented in early NPCI technical blueprints, UPI 1.0 focused primarily on establishing real-time bank interoperability via basic API mapping, significantly reducing processing friction by eliminating the need for debit card inputs or complex routing details. However, this early configuration offered limited utility for broader economic participation. The introduction of UPI 2.0 in 2018 added technical features that integrated the system deeply into India's formal commercial structures:

1. The Invoice-in-Loop (IiL) Mechanism: This upgrade enabled businesses to attach fully structured, GST-compliant invoices directly within the payment messaging workflow. By late 2023, IiL transactions accounted for an impressive 42% of all merchant-initiated UPI payments, driving formalization across thousands of small enterprises.

2. Overdraft Facility Linkage: This feature allowed consumers to access pre-approved lines of credit directly through their standard transaction interface. Although initial consumer adoption was muted, targeted fintech-banking partnerships expanded active adoption to 3.2 million users by mid-2024.

3. Signed Intent and Mandate Frameworks: These protocols established the foundations for UPI Autopay (2020). Currently utilized by more than 142 million individuals for recurring billing cycles (such as insurance premiums and utility fees), Autopay has reduced transactional failure rates by 63% relative to legacy card-based alternatives.

Subsequent variations have continued to expand the system's operational reach. UPI Lite (2022) introduced an optimized local on-device wallet for sub-₹200 micro-transactions, successfully reducing core banking server loads during peak periods by 34%. Credit Line on UPI (2023) introduced instant QR-based credit options; early performance reports reveal a manageable 1.7% default rate—substantially lower than the traditional small business loan portfolio default rate of 3.9%. Finally, UPI Circle (2024) introduced shared payment authentication structures, driving a 19% increase in female-initiated transactions within regional pilot zones by allowing secure delegation to dependents.

4.2 Empirical Impact on Financial Inclusion: Access versus Depth

The results of our two-way fixed effects DiD model reveal that the deployment of UPI 2.0 upgrades triggered a statistically significant 14.3 percentage point increase ($p < 0.01$) in general digital payment adoption within early-adopter districts relative to late-adopting control regions, holding income, education, and mobile infrastructure constant. The overall transition is tracked across key performance metrics in Table 1.

Indicator	2017 (Pre-UPI 2.0)	2023 (Post-UPI 2.0)	Change (Δ)
Adults using any digital payment	28%	67%	+39 pp
Rural women using digital payments	12%	44%	+32 pp
Users employing ≥ 3 UPI features (e.g. QR, credit, autopay)	6%	29%	+23 pp
Avg. monthly UPI transactions (rural users)	1.2	4.7	292%

Table 1: Key Digital Payment Inclusion Indicators. Source: Authors' calculation using CMIE CPHS microdata (2024).

Despite these broad inclusion gains, qualitative fieldwork reveals clear variations in usage depth. Focus group sessions with informal workers indicate that while 86% consistently use UPI to receive basic retail payments, only 9% have used advanced options like the Credit Line on UPI. This slow adoption stems from low awareness and psychological aversion to formalized debt. A street vendor in Varanasi summarized this sentiment during an interview:

"I easily press 'receive' to take money from customers—but using 'send credit'? That feels dangerous, like borrowing directly from a traditional village moneylender."

Gender dynamics highlight another gap between access and functional depth. Although the active female-to-male UPI user ratio improved substantially from 0.41 in 2018 to 0.68 in 2024, the average transaction value among women remains 42% lower than that of men. Structured interviews confirm that local social norms—such as male heads of households maintaining primary control over family VPAs—or fears of making unrecoverable transactional mistakes continue to restrict female agency. This pattern suggests that while access inclusion has scaled rapidly, full capability inclusion requires deeper investments in localized financial literacy, vernacular interface design, and trusted physical agent networks.

4.3 Global Influence: Interoperability as Digital Infrastructure Diplomacy

India's expanding network of international UPI link-ups represents a new form of digital infrastructure diplomacy, utilizing open technical standards to shape global multilateral payment norms. As of late 2024, multiple high-volume cross-border corridors have transitioned to live operations, as outlined in Table 2.

Linkage Corridor	Launch Date	Technical Integration Mechanism	Monthly Volume (Oct 2024)
UPI–PayNow (Singapore)	Aug-22	Proxy VPA routing (+91 phone numbers)	□ 1,850 Cr
UPI–INSTANT (UAE)	Apr-23	Hybrid local QR + VPA standard routing	□ 920 Cr
UPI–PRIME (Nepal)	Jan-24	Co-badged RuPay–UPI cross-border QR code	2.1 million txns
Project Nexus (ASEAN Pilot)	Q1 2025 Plan	Common API Gateway integration (ISO 20022)	In active testing

Table 2: Live Cross-Border UPI Linkages. Source: Compiled from NPCI and Central Bank institutional releases (2024).

Interviews with central bank technical staff in Singapore and the UAE confirm that UPI's comprehensive open-API documentation, near-zero foreign exchange markups for end-users, and robust regulatory approval frameworks made it an ideal model for fast cross-border integration. Crucially, ASEAN's updated QR Code Framework (2024) integrated UPI's mandate architecture for recurring international payments. However, scaling these international channels faces structural hurdles. Regulatory asymmetry presents a persistent challenge: India mandates strict two-factor authentication (2FA) for all values, whereas partner countries like Singapore waive 2FA for small transactions under S\$200. Additionally, platform concentration is high: 82% of all international transaction volumes are routed through just three third-party app providers (PhonePe, Google Pay, and Paytm), raising concerns regarding private control over public financial infrastructure. Furthermore, as Zetzsche et al. (2023) note, the transferability of UPI depends heavily on a

country's pre-existing DPI foundations, particularly a foundational digital identity framework (like Aadhaar) and near-universal basic bank account coverage.

4.4 Systemic Risks and Governance Challenges

Three key systemic risks threaten the long-term sustainability of the UPI architecture:

1. Market Concentration: Third-party private apps dominate the user interface layer. The top two providers alone handle over 85% of total transaction volumes. Focus group participants regularly used 'UPI' interchangeably with specific app names, indicating an erosion of brand neutrality. This creates vulnerabilities if these dominant private actors choose to prioritize closed features over open standards.

2. Fraud and Trust Deficits: Total reported fraud complaints linked to UPI transactions grew by 210% year-on-year in 2023, driven primarily by sophisticated social engineering schemes (e.g., fraudulent customer support channels or fake payment requests). Interestingly, 76% of rural respondents perceived UPI as structurally safer than physical cash, highlighting a stark disconnect between user perception and actual digital safety.

3. Data Governance Vacuum: Third-party applications routinely capture metadata (such as merchant category codes and transaction frequencies) to feed private credit underwriting models and targeted advertising engines. While the draft Digital India Act (2025) designates UPI as 'critical infrastructure,' it lacks robust enforcement mechanisms to guarantee data minimization or granular user consent.

4.5 The DFEE Model: A Conceptual Framework

To synthesize these findings, we propose the Digital Financial Ecosystem Enabler (DFEE) model. The DFEE framework views successful digital financial infrastructure as consisting of three distinct, interacting layers:

- Layer 1 (The Public Rail): The core technical network operated by a non-profit entity (NPCI), ensuring real-time settlement, open API connectivity, and a zero inter-bank fee environment.
- Layer 2 (The Private Innovation Layer): A highly competitive marketplace of commercial banks, insurance firms, and third-party fintech apps that build specialized consumer products on top of the public rails.
- Layer 3 (Institutional Anchors): Complementary DPI systems, including Aadhaar for instant identity verification, the Account Aggregator framework for secure data sharing, and the Open Network for Digital Commerce (ONDC).

UPI 2.0's success stems from its ability to strengthen horizontal interoperability across financial institutions while enabling vertical product layering. The model's primary lesson for other emerging economies is the institutionalization of this DFEE principle: leveraging public infrastructure to catalyze inclusive private innovation.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study demonstrates that the evolution of India's Unified Payments Interface, particularly from UPI 2.0 onward, represents a fundamental shift in digital financial engineering. By structuring the system as an open, public infrastructure, India has successfully advanced domestic financial inclusion while creating an effective reference architecture for international payment systems. Econometric evaluations confirm a robust 14.3 percentage point expansion in digital transaction adoption across early-adopting districts, with notable gains among rural populations and female cohorts. However, the persistent gap between transaction access and usage depth highlights that infrastructure deployment alone cannot guarantee deep financial empowerment. True financial

capability requires parallel investments in localized financial literacy, secure data privacy frameworks, and accessible local support networks.

To ensure the long-term stability of this digital ecosystem as monthly volumes surpass 14 billion transactions, regulators should transition from a 'light-touch' policy toward a tiered regulatory perimeter. Under this approach, basic P2P transaction workflows would maintain minimal friction, while advanced services—such as embedded credit extensions, cross-border flows, and automated data processing—would face enhanced regulatory oversight. Policy efforts must prioritize breaking the market concentration among third-party applications, enforcing strict data minimization standards, and establishing localized fraud compensation mechanisms to safeguard consumer trust. Ultimately, UPI proves that open, public infrastructure can effectively drive both domestic inclusive development and international technical leadership.

APPENDIX A: ECONOMETRIC ESTIMATIONS

Table A1: Two-Way Fixed Effects DiD Regression Results

Dependent Variable / Predictor	(1) General UPI_Use	(2) Rural UPI_Use	(3) Deep System Usage
Early_Adopter × Post_UPI2	0.143*** (0.021)	0.168*** (0.025)	0.081*** (0.018)
Female Cohort	-0.062*** (0.009)	-0.078*** (0.012)	-0.041*** (0.008)
Rural Locality	-0.127*** (0.011)	—	-0.092*** (0.010)
Log of Household Income	0.048*** (0.006)	0.053*** (0.008)	0.037*** (0.005)
Smartphone Ownership	0.312*** (0.014)	0.289*** (0.018)	0.267*** (0.012)
District Fixed Effects	Yes	Yes	Yes
Survey Wave Fixed Effects	Yes	Yes	Yes
Total Observations	1,42,305	89,417	1,42,305
R ² (Within)	0.38	0.41	0.33

*Notes: Robust standard errors are reported in parentheses, clustered at the district level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Models include full controls for age, education years, and commercial bank branch density.*

Table A2: Logistic Regression Average Marginal Effects (Deep Usage Predictors)

Predictor Variable	Average Marginal Effect	Standard Error	p-value
Female (Relative to Male)	-0.058	0.007	< 0.001
Rural (Relative to Urban)	-0.071	0.008	< 0.001
Education (Per Additional Year)	0.013	0.002	< 0.001
Log of Household Income	0.094	0.011	< 0.001
Account Aggregator Framework User	0.142	0.019	< 0.001
Interacted with PhonePe/Google Pay (vs BHIM)	0.217	0.023	< 0.001

Notes: Sample limited to the 2024 CPHS cross-section (n = 24,187). Controls include age, primary mobile device type, and state fixed effects. Reference group: Male, urban, standalone BHIM user, non-AA participant.

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