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# Transforming Payments, Transforming Welfare: UPI as Digital Public Infrastructure (A Public Economics Cost-Benefit and Comparative Analysis)

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**Abstract:** This paper evaluates India's Unified Payments Interface (UPI) as an instrument of public economic policy, asking whether a state-facilitated, zero-cost digital payment rail generates net social welfare sufficient to justify its fiscal and ecosystem costs. Using a four-part methodology: cost-benefit analysis, regression analysis, trend analysis, and cross-country comparison; the study finds that UPI's transaction value, cost savings, financial-inclusion effects, and Direct Benefit Transfer (DBT) leakage reductions have produced a Present Value of Net Benefits (PNB) rising from ₹6,635 crore in 2016-17 to over ₹3,07,37,827 crore in 2024-25, with a Benefit-Cost Ratio (BCR) climbing from 1.46 to over 2,492 over the same period. Regression analysis further shows that UPI transaction volume and cash in circulation move together ( $\beta_1 = 0.0682$ ,  $R^2 = 0.71$ ,  $p = 0.0041$ ), rejecting the substitution hypothesis in favour of complementarity, while UPI volume is a strong predictor of India's Financial Inclusion Index ( $\beta_1 = 0.000112$ ,  $R^2 = 0.85$ ,  $p = 0.0004$ ). A comparative analysis against Brazil's Pix, the USA's FedNow, and Singapore's PayNow situates UPI as the most rapidly scaled real-time payment system globally, but also the most exposed to a structural sustainability gap under its zero-Merchant Discount Rate (MDR) policy. The paper concludes that UPI has been a highly effective public investment to date, but recommends a tiered-MDR and dual-payment-infrastructure policy framework to secure its long-term fiscal sustainability.

### Introduction

Financial inclusion: access to and use of affordable, adequate, and timely financial services for all segments of society, particularly economically disadvantaged groups, has become a central pillar of development policy in India and other developing countries. Historically, high transaction costs, sparse rural banking infrastructure, and gaps in information and skills excluded large sections of the population

from the formal financial system. Closing this gap has been one of the most significant structural challenges facing the Indian economy over the past decade.

Financial access is tracked globally through the World Bank's Global Financial Index and domestically through the RBI's Financial Inclusion Index, both of which show India among the fastest-improving countries in the world on this metric. This progress rests on a layered national strategy coordinated by the RBI: expanding access to financial services, improving financial literacy, strengthening consumer protection, and using technology to remove structural barriers.

The Pradhan Mantri Jan Dhan Yojana (PMJDY), launched in 2014, was central to this strategy, enabling mass account-opening for previously unbanked individuals and linking these accounts to biometric identification and mobile numbers, the foundation of the JAM (Jan Dhan, Aadhaar, Mobile) trinity. Digital Public Infrastructure (DPI), or "India Stack," sits at the centre of this ecosystem: open-access, interoperable digital systems: Aadhaar (digital identity), e-KYC (paperless verification), and digital payment rails; that reduce transaction costs and information asymmetry for both government and private-sector service delivery.

The most consequential product of this DPI stack is the Unified Payments Interface (UPI), launched in 2016 by the National Payments Corporation of India (NPCI). UPI enables real-time, mobile-based bank-to-bank payments via virtual payment addresses and QR codes, removing the need to share full account details and collapsing transaction time to seconds. Its benefits extend well beyond convenience: UPI has brought small business owners, informal wage earners, and rural households into the digital economy without requiring physical banking infrastructure; increased the transparency of transactions, aiding tax compliance; and enabled faster, better-targeted delivery of government welfare transfers, reducing leakage. Network effects mean these benefits compound as adoption grows. UPI has become one of the largest real-time payment systems in the world within a decade of launch, and payment linkages built on UPI now operate in Singapore, the UAE, France, and Nepal.

This success is not without strain. The digital divide in smartphone and internet access limits UPI's reach; rising transaction volumes have brought heightened cybersecurity and fraud risk; and the zero-MDR fee structure raises an open question about who ultimately bears the infrastructure's cost, and for how long that arrangement is sustainable.

Given this environment, this paper undertakes a comprehensive public-economics cost-benefit analysis of UPI, weighing its economic benefits against its direct and indirect costs. The paper assesses whether it represents an efficient and equitable public investment, and what its trajectory implies for other emerging economies considering state-led digital public infrastructure.

## Literature Review

Three recent studies anchor this paper's empirical approach.

- **UPI, Aadhaar, and GDP Growth**

Thukral and Dagar (2025) used multiple regression across eight fiscal years (FY 2016-17 to FY 2023-24) to estimate that UPI alone boosted India's GDP by an average of 3.4% annually, with Aadhaar contributing a further 2.5–4.3% depending on model specification; all three models explained over 97% of GDP variance at statistical significance. Their study quantified UPI's per-transaction cost advantage, ₹0.0025 per ₹1, against ₹20–25 for ATM cash withdrawal or 1.5–2.5% for card payments, translating into cumulative savings that grew from ₹356 million in 2016-17 to ₹5.87 trillion by 2023-24. It also tracked Aadhaar-enabled DBT transfers rising from ₹0.31 trillion to ₹3.34 trillion, cutting leakages worth ₹0.078–0.72 trillion annually, and noted that India accounted for 49% of global real-time payment transactions in 2023, a model the IMF, World Bank, and G20 have each flagged as worth emulating elsewhere. This paper's regression framework and direct-benefit quantification (RQ2, RQ4 below) build on Thukral and Dagar's approach.

- **UPI and Financial Inclusion**

Sreevas, Kulkarni, Justin, and Bhatta (2023) examined how UPI connects previously excluded groups, small traders, street vendors, students, rural households, to formal financial services via smartphone and telecom penetration rather than physical bank branches. Their empirical work links UPI's growth directly to measurable movement in the RBI's Financial Inclusion Index, and credits fintech intermediaries with driving adoption beyond what banks alone achieved.

- **DBT and Technology-Driven Welfare Delivery**

Sharma, Sharma, and Rani (2023) assessed India's DBT programme using Public Value Theory and SWOT analysis. DBT scaled from a 43-district pilot in 2013 to 290 million beneficiaries by 2015 on the back of the JAM trinity, and by FY 2021-22 was disbursing ₹735.51 billion under MGNREGS, ₹2.17 trillion through the Public Distribution System, and ₹1.24 trillion in fertiliser subsidies, saving ₹50,125.37 crore that year alone by eliminating fake beneficiaries and reducing leakage (₹27 billion saved cumulatively across central schemes, per government estimates). During the COVID lockdown, DBT processed 2.19 crore transactions in a single day, disbursing ₹36,659 crore to 16.01 crore people.

- **Synthesis and Research Gap**

Read together, these studies establish UPI's contribution to GDP growth (Thukral & Dagar), financial inclusion (Sreevas et al.), and welfare-delivery efficiency (Sharma et al.) as independently well-evidenced. International comparators reinforce this: McKinsey estimates digital ID systems can unlock 3–13% of GDP for developing countries, and the BIS finds that a one-percentage-point rise in digital payment penetration lifts GDP-per-capita growth by 0.10 points over two years. What the literature has not done is synthesise these separate benefit streams: transaction value, cost savings, financial inclusion, and DBT leakage reduction, into a single annual cost-benefit framework weighed against what UPI actually costs to run. That synthesis is this paper's contribution.

### **Research Questions and Objectives**

- **Research Questions**

- RQ1: To what extent does UPI contribute to social welfare overall, assessed through cost-benefit analysis?
- RQ2: How significant are UPI's economic benefits in terms of transaction value, cost savings, and efficiency?
- RQ3: To what extent does UPI contribute to financial inclusion, and how can this be quantified economically?
- RQ4: To what extent has UPI-enabled DBT reduced losses in government welfare-scheme implementation?
- RQ5: Does UPI's expansion justify its implicit and explicit public costs, validating it as a viable public investment?

- **Objectives**

The primary objective is to conduct a thorough cost-benefit analysis (CBA) of UPI to determine whether it generates positive net social welfare for the Indian economy. This breaks into five specific objectives:

- Quantify the economic benefits generated by UPI transactions.
- Estimate cost savings from UPI adoption relative to cash and card payments.
- Estimate UPI's impact on financial inclusion via the RBI Financial Inclusion Index.
- Estimate savings from DBT leakage reduction attributable to UPI.
- Consolidate all benefit streams into a single cost-benefit framework, discounted using India's Social Discount Rate (SDR).

- **Relevance**

Beyond its academic contribution, this study speaks directly to public investment policy: how governments allocate scarce resources to maximise social welfare through inclusive growth, more efficient public spending (via leakage reduction), and durable long-term economic benefit. As India positions itself as a global reference point for state-led digital public infrastructure, the findings offer a benchmark other developing economies can draw on.

### **Cost-Benefit Analysis**

- **Methodology: Benefits**

Four benefit streams are quantified annually from UPI's launch in 2016-17 through 2024-25:

- Transaction value, sourced from RBI annual reports (Section IX: Payment and Settlement Systems and Information Technology).
- Cost savings and DBT leakage reduction, sourced from Thukral and Dagar (2025).
- Financial inclusion value, calculated as the RBI Financial Inclusion Index multiplied by transaction value.

This weighting is deliberate: raw transaction volume alone doesn't capture social value, since money moving through millions of small towns and villages is worth more to inclusive growth than the same volume concentrated in a few large cities. This "social multiplier" approach uses the FI Index as a proxy for how broadly UPI's economic activity is being distributed.

Annual total benefits are the simple sum of these four streams, later discounted at India's Social Discount Rate of 3.72% (NABARD, 2024).

**Table 1. Annual UPI Benefit Streams, 2016-17 to 2024-25 (₹ crore)**

| Year    | Transaction Value | Cost Savings | Leakage Reduction | Financial Inclusion | Total Benefits |
|---------|-------------------|--------------|-------------------|---------------------|----------------|
| 2016-17 | 6,900             | 35.6         | 7,766.8           | 0.0                 | 14,702.4       |
| 2017-18 | 109,800           | 2,215.5      | 22,548.9          | 11,119.4            | 145,683.8      |
| 2018-19 | 877,000           | 12,224.2     | 34,825.5          | 66,596.9            | 990,646.6      |
| 2019-20 | 2,132,000         | 28,491       | 61,637.7          | 109,631.5           | 2,331,760.2    |
| 2020-21 | 4,104,000         | 55,335.3     | 72,407            | 272,133.8           | 4,503,876.1    |
| 2021-22 | 8,416,000         | 138,306.1    | 78,670.6          | 541,768.1           | 9,174,744.8    |
| 2022-23 | 13,910,000        | 304,857.6    | 63,696.9          | 847,676.2           | 15,126,230.7   |
| 2023-24 | 20,000,000        | 587,279.2    | 71,591.5          | 1,270,102.8         | 21,928,973.5   |
| 2024-25 | 26,060,000        | 770,000.0    | 94,222.6          | 1,659,738.5         | 28,583,961.1   |

Each benefit stream captures a distinct dimension of welfare: transaction value reflects rising digital-economy participation and convenience-driven transaction growth; cost savings quantify UPI's near-zero marginal cost against cash (₹20–25 per ATM withdrawal) and card payments (1.5–2.5% MDR); financial inclusion captures the reduction in poverty and improvement in credit access from bringing previously unbanked populations into the formal system (Sreevas et al., 2023; Sharma et al., 2023), the latter linking the March 2022 jump in the FI Index directly to DBT and UPI expansion); and DBT leakage reduction captures direct fiscal savings from eliminating fake accounts, duplicate entries, and middleman diversion, rising from ₹7,768 crore in 2016-17 toward an estimated ₹94,000 crore by 2024-25, consistent with Sharma et al.'s independent finding of roughly ₹70,000 crore saved in 2022 alone.

#### • **Methodology: Costs**

Three cost components capture the full resource cost of sustaining UPI under a zero-MDR regime:

- Government incentive scheme expenditure, under the "Incentive scheme for promotion of RuPay Debit Cards and low-value BHIM-UPI transactions (P2M)," sourced from Union Budget documents and Ministry of Finance releases (FY2021-22 to FY2024-25, using revised/actual rather than budgeted figures).
- NPCI operating and depreciation/amortisation expenses, from NPCI annual reports (FY2016-17–FY2024-25), used as an upper-bound proxy for core infrastructure cost since NPCI's UPI-specific costs cannot be disaggregated from its other systems (e.g., IMPS, RuPay).
- Banking and PSP ecosystem costs, an industry-wide estimate of ~₹10,000 crore annually (Payments Council of India), covering technology infrastructure, fraud prevention, customer support, onboarding, and compliance costs borne by participating banks and payment service providers, applied uniformly across years given the absence of granular institutional data.

**Table 2: Annual UPI Cost Components, 2015-16 to 2024-25 (₹ crore)**

| Year    | NPCI Operating Exp. | NPCI Depreciation & Amortisation | Govt. Incentive Scheme | Payment Ecosystem Exp. | Total Costs |
|---------|---------------------|----------------------------------|------------------------|------------------------|-------------|
| 2015-16 | 38.72               | 49.14                            | 0                      | 10,000                 | 10,087.86   |
| 2016-17 | 50.08               | 47.69                            | 0                      | 10,000                 | 10,097.77   |
| 2017-18 | 70.19               | 67.89                            | 0                      | 10,000                 | 10,138.07   |
| 2018-19 | 77.77               | 92.17                            | 0                      | 10,000                 | 10,169.84   |
| 2019-20 | 81.99               | 127.21                           | 0                      | 10,000                 | 10,209.20   |
| 2020-21 | 91.97               | 140.35                           | 0                      | 10,000                 | 10,232.32   |
| 2021-22 | 106.52              | 145.55                           | 950                    | 10,000                 | 11,202.07   |
| 2022-23 | 131.17              | 162.76                           | 1,800                  | 10,000                 | 12,093.94   |
| 2023-24 | 173.53              | 220.63                           | 3,200                  | 10,000                 | 13,594.16   |
| 2024-25 | 190.54              | 276.86                           | 1,000                  | 10,000                 | 11,467.39   |

NPCI's operating and depreciation expenses grew steadily from ~₹98 crore combined in 2016-17 to over ₹467 crore by 2024-25, reflecting rising transaction volumes, cybersecurity requirements, and system upgrades. Government expenditure appears only after 2021-22, following the formalisation of the zero-MDR policy: incentive payouts rose sharply from ₹950 crore (2021-22) to a peak of ₹3,200 crore (2023-24), before falling to ₹1,000 crore (2024-25): a pattern suggesting an initial aggressive-subsidy phase followed by partial rationalisation. This variable matters for two reasons: it represents the direct fiscal burden of the zero-MDR intervention that private participants would otherwise have recovered via MDR revenue, and the policy itself has drawn sustained criticism from private players and the Payments Council of India, who argue ecosystem costs far exceed the incentive provided.

The dominant and most stable cost component is the ₹10,000 crore annual ecosystem estimate, accounting for 85–95% of total expenditure in most years, reflecting banks' and PSPs' costs of maintaining payment rails, managing fraud risk, and meeting compliance requirements (roughly 3–4 basis points on P2M transactions). Total system costs rose from ~₹10,098 crore (2016-17) to a peak of ~₹13,594 crore (2023-24), moderating to ~₹11,467 crore (2024-25). The costs were driven primarily by government incentives and infrastructure scaling. While fiscal costs are non-trivial, the dominant long-term sustainability question sits with the payment's ecosystem, particularly in the absence of MDR revenue.

#### ▪ **Cost-Benefit Methodology**

Net benefits were computed annually (total benefits minus total costs) for each fiscal year from 2016-17 to 2024-25, then converted to present value as of 1 April 2026 using India's social discount rate:

$$\text{PNB} = \text{Net Benefit} \times (1 + r)^n$$

where  $r = 3.72\%$  (the social discount rate, sourced from NABARD/EPW estimates) and  $n$  is the number of years between the given fiscal year and the 2026 base year (e.g., 2024-25 net benefits were multiplied by  $(1.0372)^2$ ).

All costs and benefits are assumed to occur at the start of each fiscal year, consistent with how government budget allocations and major private investments are typically committed, which avoids mid-year discounting complexity while applying a uniform (and therefore non-distorting) bias across years.

To complement absolute net benefits, a Benefit-Cost Ratio (BCR) was computed per year:

$$\text{BCR} = \text{PV of Benefits} / \text{PV of Costs}$$

A BCR above 1 indicates benefits exceed costs; higher values indicate greater economic efficiency. Including BCR alongside net benefits captures returns per unit of investment, not just total surplus, particularly relevant for UPI, where costs are comparatively stable while benefits scale rapidly with adoption.

## Results

**Table 3: Net Benefits and Present Value of Net Benefits (PNB): 2016-17 to 2024-25 (₹ crore)**

| Year    | Total Benefits | Total Costs | Benefits – Costs | PNB (₹ Cr)    |
|---------|----------------|-------------|------------------|---------------|
| 2016-17 | 14,702.40      | 10,097.77   | 4,604.63         | 6,634.68      |
| 2017-18 | 145,683.80     | 10,138.07   | 135,545.72       | 188,299.16    |
| 2018-19 | 990,646.60     | 10,169.84   | 980,476.76       | 1,313,219.64  |
| 2019-20 | 2,331,760.19   | 10,209.20   | 2,321,550.99     | 2,997,890.62  |
| 2020-21 | 4,503,876.09   | 10,232.32   | 4,493,643.77     | 5,594,659.88  |
| 2021-22 | 9,174,744.76   | 11,202.07   | 9,163,542.69     | 10,999,576.08 |
| 2022-23 | 15,467,544.79  | 12,093.94   | 15,455,450.85    | 17,886,761.28 |
| 2023-24 | 22,249,246.97  | 13,594.16   | 22,235,652.82    | 24,810,608.09 |
| 2024-25 | 28,583,961.10  | 11,467.39   | 28,572,493.71    | 30,737,827.00 |

Net benefits rise from ₹4,605 crore (2016-17) to over ₹2,85,72,493 crore (2024-25): exponential growth driven by benefits scaling far faster than costs, which remain anchored by the relatively fixed ₹10,000 crore ecosystem estimate. Because discounting compresses more recent years less, the bulk of total present value concentrates from 2021-22 onward, coinciding with UPI's rapid post-zero-MDR expansion and widespread merchant adoption.

**Table 4: Benefit-Cost Ratio (BCR): 2016-17 to 2024-25 (₹ crore)**

| Year    | Total Benefits | Total Costs | PV of Benefits | PV of Costs | BCR      |
|---------|----------------|-------------|----------------|-------------|----------|
| 2016-17 | 14,702.40      | 10,097.77   | 21,184.26      | 14,549.58   | 1.46     |
| 2017-18 | 145,683.80     | 10,138.07   | 202,382.90     | 14,083.74   | 14.37    |
| 2018-19 | 990,646.60     | 10,169.84   | 1,326,840.80   | 13,621.16   | 97.41    |
| 2019-20 | 2,331,760.19   | 10,209.20   | 3,011,074.07   | 13,183.45   | 228.40   |
| 2020-21 | 4,503,876.09   | 10,232.32   | 5,607,399.29   | 12,739.41   | 440.16   |
| 2021-22 | 9,174,744.76   | 11,202.07   | 11,013,022.62  | 13,446.55   | 819.02   |
| 2022-23 | 15,467,544.79  | 12,093.94   | 17,900,757.73  | 13,996.44   | 1,278.95 |
| 2023-24 | 22,249,246.97  | 13,594.16   | 24,825,776.50  | 15,168.40   | 1,636.68 |
| 2024-25 | 28,583,961.10  | 11,467.39   | 30,750,163.43  | 12,336.44   | 2,492.63 |

BCR rises from 1.46 (2016-17, benefits already exceeding costs) to 14.37 the following year, then expands exponentially to over 2,492 by 2024-25: the signature pattern of digital public infrastructure, where high fixed costs combined with near-zero marginal costs produce disproportionate gains as scale increases. Costs remain confined to a narrow ₹12,000–15,000 crore present-value band while benefits compound; the sharp post-2020 BCR acceleration coincides with the zero-MDR regime and rising government support, and the continued acceleration, rather than any sign of stabilisation, suggests UPI has not yet reached saturation in economic returns. Overall, this indicates that policy interventions promoting UPI adoption have been highly cost-effective.

## Trend and Regression Analysis

### • Framing: Substitution vs. Complementarity

This section examines whether UPI is displacing cash or growing alongside it, using the economic concept of the substitution effect: when a new option is cheaper, faster, or more convenient, consumers shift away from the old option. UPI plausibly satisfies this: it eliminates the need to carry cash, reduces transaction costs to near zero, enables instant settlement, and requires only an internet-enabled device. But complementarity is equally plausible: if total transaction volume across the economy is rising, cash and UPI can grow together, particularly in a country with rising incomes, a growing population, and a large informal sector that continues to demand cash. The data used spans nine fiscal years (2016-17 to 2024-25): UPI transaction volume (NPCI) and Currency in Circulation, CIC (RBI).

**Table 5: UPI Transaction Volume and Currency in Circulation, 2016-17 to 2024-25**

| Year    | UPI Transaction Volume (Mn) | Currency in Circulation (₹ Cr) |
|---------|-----------------------------|--------------------------------|
| 2016-17 | 17.86                       | 13,35,266                      |
| 2017-18 | 915.22                      | 18,29,348                      |
| 2018-19 | 5,391.52                    | 21,36,770                      |
| 2019-20 | 12,518.61                   | 24,47,312                      |
| 2020-21 | 22,330.65                   | 28,53,763                      |
| 2021-22 | 45,967.53                   | 31,33,716                      |
| 2022-23 | 83,751.14                   | 33,78,521                      |
| 2023-24 | 1,31,129.83                 | 35,11,461                      |
| 2024-25 | 1,85,866.02                 | 37,24,448                      |

- Trend Analysis**

UPI volume grew from 17.86 million transactions (2016-17) to a projected 185,866 million by 2024-25, an increase exceeding 10,40,000%, with a trend line that steepens over time rather than flattening, consistent with self-reinforcing network effects. Drivers include the November 2016 demonetisation shock, expanding smartphone and low-cost mobile data access (accelerated by Reliance Jio's entry), the rise of UPI-based fintech apps (PhonePe, Google Pay, Paytm), and consistent cross-bank interoperability support from government policy.

Currency in circulation rose over the same period from ~₹13,35,266 crore to ~₹37,24,448 crore, a steadier ~179% increase, with only a brief demonetisation-era dip before resuming its upward trend. This suggests cash demand is driven by structural factors: population growth, informal-sector reliance, rural and semi-urban preference, that are largely unaffected by digital-payment availability in the short-to-medium term. Despite UPI's expansion, cash use shows no definitive decline, setting up the regression test below.

- Regression I: UPI Volume and Currency in Circulation**

$$UPI_t = \beta_0 + \beta_1 CIC_t + \varepsilon_t$$

$H_0$  (Null Hypothesis):  $\beta_1 = 0$  (no relationship) against

$H_1$  (Alternate Hypothesis):  $\beta_1 \neq 0$  (significant relationship)

**Table 6: Regression I Results: UPI Volume on Currency in Circulation**

| Parameter                 | Value        |
|---------------------------|--------------|
| Intercept ( $\beta_0$ )   | -1,30,432.26 |
| Coefficient ( $\beta_1$ ) | 0.0682       |
| $R^2$                     | 0.7139       |
| P-value                   | 0.0041       |
| Standard Error            | 0.0163       |

The positive coefficient ( $\beta_1 = 0.0682$ ) implies every ₹1 crore rise in CIC is associated with a ~0.0682 million-transaction increase in UPI volume, directly contradicting the substitution hypothesis, which would predict a negative coefficient. Instead, this confirms complementarity: UPI and cash are growing together as the broader economy expands. The  $R^2$  of 0.7139 indicates CIC explains ~71.4% of UPI volume variation, leaving ~28.6% attributable to unmodelled drivers (smartphone penetration, internet access, fintech adoption, merchant acceptance, macroeconomic conditions). The p-value of 0.0041 rejects  $H_0$  at both 5% and 1% significance, this relationship is very unlikely to be due to chance. (The negative intercept is a standard artefact of linear regression over large-range variables and does not affect the interpretation of the slope.)

- Regression II: UPI Volume and Financial Inclusion Index**

$$FCI_t = \beta_0 + \beta_1 UPI_t + \varepsilon_t$$

$H_0$  (Null Hypothesis):  $\beta_1 = 0$  (no relationship) against

$H_1$  (Alternate Hypothesis):  $\beta_1 > 0$  (significant relationship)

**Table 7: Regression II Results: Financial Inclusion Index on UPI Volume**

| Parameter                 | Value    |
|---------------------------|----------|
| Intercept ( $\beta_0$ )   | 48.7914  |
| Coefficient ( $\beta_1$ ) | 0.000112 |
| R <sup>2</sup>            | 0.8545   |
| Adjusted R <sup>2</sup>   | 0.8337   |
| Multiple R                | 0.9244   |
| F-statistic               | 41.11    |
| P-value                   | 0.000363 |
| Standard Error            | 3.263    |

Each additional 1 million UPI transactions is associated with a 0.000112-point rise in the Financial Inclusion Index, numerically small, but cumulatively substantial given UPI's scale (hundreds of thousands of millions of transactions). The intercept (48.79) is broadly consistent with India's FCI score around 2016-17, when UPI had barely launched, lending credibility to the model's fit. R<sup>2</sup> of 0.8545 is notably stronger than Regression I, indicating UPI volume is an even better predictor of financial inclusion than it is of cash circulation. Adjusted R<sup>2</sup> (0.8337) remains close to R<sup>2</sup>, confirming this explanatory power isn't an artefact of small sample size, and the F-statistic (41.11) confirms overall model significance. The p-value (0.000363) firmly rejects H<sub>0</sub> at the 1% level.

- **Key Findings from Trend and Regression Analysis**

Three findings emerge.

First, UPI has grown near-exponentially since 2016-17 (from 17.86 million to 185,866 million transactions), evidencing a successful digital payment transition.

Second, cash in circulation has risen steadily (~179%) throughout the same period, with no sustained decline at any point, concluding that cash remains structurally important to the Indian economy.

Third, the statistically significant positive UPI–CIC coefficient confirms complementarity rather than substitution: both payment methods are growing together, driven by the same underlying force: India's broader economic growth. India's transition, in short, is not toward a cashless economy but toward a less-cash-reliant, dual-rail one, in which digital payments account for a growing share of transactions without displacing cash outright.

### **Comparative Analysis: UPI in Global Context**

- **UPI's Position within India's DPI**

UPI is owned and developed by NPCI, a not-for-profit consortium of Indian banks, operating under RBI approval, neither a CBDC nor a proprietary system. NPCI sets interoperability standards and runs settlement rails; private fintechs (PhonePe, Google Pay, Paytm) build customer-facing services on these open rails, monetising through financial services, data, and cross-selling.

- **Scale:** UPI crossed 228.3 billion transactions in 2025 (up from 172.2 billion in 2024), with annual transaction value near ₹299.7 lakh crore (~\$3.5 trillion). By June 2025, UPI was the world's largest retail fast payment system by volume (IMF), constituting ~49% of global real-time payment (RTP) volume (ACI Worldwide, 2024).
- **Adoption Depth:** In 2024, UPI served 491 million users and 65 million merchants at a 99.2% transaction success rate. P2M transactions made up 62.40% of all UPI activity in August 2024, with 85% of those below ₹500, the "Kirana Effect" of small and micro-merchants anchoring India's digital economy. Average transaction value fell from ₹1,478 (2024) to ₹1,348 (H1 2025) as this small-merchant base deepened; P2M volume grew 37% YoY (67.01 billion transactions).
- **Zero-MDR Model:** MDR on BHIM-UPI transactions has been zero since January 2020, following amendment of the Payments and Settlement Systems Act, 2007. An incentive scheme distributes ₹1,500 crore (~\$175 million, FY2024-25) across acquiring banks, issuer banks, PSPs, and app providers to partially offset forgone MDR revenue on sub-₹2,000 P2M transactions (0.15% of transaction value).

- **The Sustainability Gap:** In FY2023-24, participating banks and payment aggregators incurred costs of roughly 0.25% of P2M transaction value (~₹12,000 crore) against a government incentive of only ₹3,000 crore, a ₹9,000 crore shortfall. The Payments Council of India considers the FY2024-25 allocation of ₹1,500 crore insufficient relative to infrastructure growth, and industry has called for either larger incentives or a capped MDR on large merchants.
- **Cross-Country Comparison**
  - **Pix (Brazil):** Central-bank-driven, mandatory. Owned and operated by the Banco Central do Brasil (BCB), mandatory for institutions with 500,000+ active accounts (fully state-run, unlike UPI's voluntary-but-incentivised model). Pix processed 68.7 billion transactions in 2024 (up 52% YoY), totalling BRL 5 trillion (~\$1 trillion), with P2B transactions up 90% YoY and a 40% e-commerce payment market share (2022). Pix charges merchants 0.22–0.33% MDR (no P2P fee), still far below card MDR of 2–5%. Fraud is a serious concern: R\$2.7 billion lost to Pix-related fraud in 2024 (up 43% YoY), with 7 frauds per 100,000 transactions versus 30 for credit cards; the BCB's Special Refund Mechanism (MED, 2021) mandates a seven-day bank response window for fraud refund requests.
  - **FedNow (USA):** Central-bank-operated, voluntary, dual-rail. Operated by the Federal Reserve since July 2023, coexisting with the privately-run Real-Time Payments (RTP) system since 2017, a dual-rail structure preserving redundancy at the cost of market fragmentation. FedNow has grown from 900 to 1,400+ member institutions but processed only \$245 billion in Q2 2025 (up from \$492 million in Q2 2024), a volume UPI exceeds within roughly a single day. Most member banks support receive-only mode, citing the cost and complexity of integrating send functionality with legacy core banking systems. FedNow charges institutions ~\$0.045 per credit transfer (no consumer fee), with projected 2025 operating costs of \$245.5 million.
  - **PayNow (Singapore):** Industry-consortium, MAS-regulated. Operated by the Association of Banks in Singapore (ABS) over NETS' FAST infrastructure, regulated by the Monetary Authority of Singapore (MAS): strategy set centrally, implementation left to banks and industry bodies. PayNow had 5 million+ registrations and SGD 50 billion (~\$37 billion) in transaction value by end-2024, with Singapore's overall digital payment adoption near 92% and PayNow holding 68% market share among Gen Z users. Consumer transfers remained fee-free through 2025; from 2026, businesses pay SGD 0.20 per received transaction (removing the earlier 0.5% MDR "Hawkers Go Digital" subsidy), a politically sensitive shift given merchants' prior expectation of zero cost. Singapore holds the most extensive bilateral RTP linkages globally, connecting PayNow to UPI, Thailand's PromptPay, and Malaysia's DuitNow. Fraud losses hit SGD 1.01 billion in 2024 (+53% YoY), prompting the Shared Responsibility Framework (SRF, December 2024), distributing liability across banks, telcos, and users in scam cases.
- **Key Quantitative Summary**

**Table 8: Cross-Country Comparison of Real-Time Payment Systems**

| Metric                 | UPI (India)          | Pix (Brazil)          | FedNow (USA)           | PayNow (Singapore)      |
|------------------------|----------------------|-----------------------|------------------------|-------------------------|
| Annual volume (latest) | 228.3B (2025)        | 68.7B (2024)          | ~3–5M (2024)           | ~SGD 50B value          |
| Merchant fee           | 0% (zero-MDR)        | ~0.33%                | ~\$0.045/tx (to banks) | SGD 0.20/tx (from 2026) |
| Governance             | NPCI (nonprofit)     | BCB (central bank)    | Federal Reserve        | ABS / NETS / MAS        |
| Participation          | Voluntary            | Mandatory (large FIs) | Voluntary              | Voluntary               |
| Fraud rate / 100K tx   | 7                    | 7–12 (contested)      | Very low (low volume)  | Declining, with SRF     |
| Global share of RTP    | ~49%                 | ~8%                   | <0.1%                  | <0.1%                   |
| Cross-border links     | 8 countries          | Uruguay + LATAM       | Limited                | 4 ASEAN systems         |
| Annual govt. subsidy   | ~₹1,500 cr (~\$175M) | None (self-funded)    | Self-funded via fees   | IMDA hawker subsidies   |

- **Zero-MDR: Synthesis of Benefits and Drawbacks**

- **Benefits:** India's zero-MDR approach enabled small merchants, kirana stores, tea stalls, street vendors, to onboard at scale with zero marginal acquisition cost. UPI's retail digital-payment market share reached 84.8% in H1 2025, a penetration level no fee-based retail service has matched in any comparable emerging market. In effect, the subsidy shifted the cost of financial inclusion from merchants to the public exchequer, treating inclusion as a public good in the same category as road-building or broadband. The socioeconomic payoff is significant: mass digitisation lets small merchants build credit profiles, reduces cash-handling burden, and makes GST compliance trackable. Over 70% of UPI users are outside Tier-1 cities, and over 80% of new users originate in Tier-2 cities, evidence that the zero-cost design is genuinely driving inclusion in underserved geographies.
- **Drawbacks and Long-Term Risk:** A Parliamentary Committee expects UPI transaction-volume growth to slow from 42% (FY2024-25) to 25% (FY2025-26), and has warned that over-reliance on government incentives could dampen innovation in newer geographies. The RBI Governor has stated plainly that UPI "is not free" and that someone always bears the cost. The zero-MDR policy is estimated to cost Indian banks ~₹55 billion (~\$660 million) annually, even as large tech platforms running UPI apps profit through advertising, lending/credit, and cross-selling, effectively a public subsidy flowing through to private-platform profit. This has also entrenched a PhonePe/Google Pay duopoly controlling over 85% of transaction volume, since smaller fintechs cannot profitably compete without transaction-based revenue and must rely on adjacent lines of business (loans, insurance, ads) to survive. By contrast, Pix's modest merchant fee (0.33%, or 0.08% for low-value payments) has not visibly slowed adoption, and Singapore is moving toward a small per-transaction merchant fee from 2026, both signalling that "zero cost forever" may not be a durable design choice. FedNow's institutional-fee, no-consumer-fee model suits a smaller, high-income, fully-banked population where per-transaction fees are politically tolerable, a very different starting condition from India's.

## Conclusion

- **Summary**

This study evaluated UPI's economic and social effects through four converging methods: trend analysis, regression analysis, cost-benefit analysis, and cross-country comparison. Since its 2016 launch on the JAM-trinity foundation, UPI has become one of the principal drivers of financial inclusion, transactional efficiency, and digital transformation in India. Transaction volumes have grown near-exponentially even as currency in circulation has continued to rise, and the regression results confirm a statistically significant positive relationship between the two ( $p = 0.0041$ ), concluding that digital payments are complementing, not replacing, cash. The cost-benefit analysis shows substantial welfare gains through transaction value, consumer cost savings, financial inclusion, and reduced DBT leakage, while the comparative analysis shows UPI has achieved unmatched global scale, but faces a real sustainability question under its zero-MDR model relative to fee-charging peers like Pix and PayNow. UPI has strengthened India's financial ecosystem substantially; sustaining that strength will require deliberate long-term policy choices.

- **How the Findings Were Derived**

The trend analysis showed UPI transactions growing in parallel with currency processed through the financial system; the regression analysis confirmed this statistically, supporting the complementarity hypothesis over substitution and tying UPI's growth to broader economic expansion. The benefits analysis reaffirmed these trends by independently measuring transaction value, cost savings, financial inclusion, and DBT leakage reduction, while the comparative analysis situated these domestic results within a global governance and sustainability context. Together, these four methods provide a mutually reinforcing empirical basis for this paper's conclusions on UPI's effectiveness as public economic infrastructure.

- **Policy Implications**

- A Dual Payment Infrastructure Policy, expanding digital access (internet connectivity, QR infrastructure) while explicitly preserving cash availability for rural and informal-sector populations who remain reliant on it.

- A Tiered MDR Policy, retaining zero-MDR for very small transactions while introducing modest fees (0.1–0.5%) on medium and large merchants, addressing the ₹9,000 crore-plus ecosystem funding gap without abandoning small-merchant inclusion.
- A UPI Public Finance Integration Policy, improving transparency of DBT flows through UPI and better aligning GST data capture with DBT disbursement.
- A Digital Inclusion and Security Policy, expanding internet access, digital literacy, and fraud-prevention mechanisms to protect the system's effectiveness as usage scales.

#### • Limitations

The regression models are bivariate and do not control for internet penetration, household income, or financial literacy, all of which plausibly affect UPI adoption and cash demand; the study period also limits long-term trend analysis. The cost-benefit analysis is constrained by data availability: non-zero-MDR-era earnings could not be isolated; NPCI's consolidated expense reporting does not allow UPI-specific cost attribution; no official data confirms UPI's time-saving benefits; and DBT leakage-reduction estimates rely on prior published studies rather than FY2024-25 primary data. Cross-country comparison is similarly limited by differences in economic structure and regulatory environment between India, Brazil, the USA, and Singapore, which constrain direct comparability with UPI.

#### • Further Scope of Study

Future work could extend the regression framework to a multivariate model incorporating GDP, digital penetration, and demographic variables for a clearer causal picture; pursue more granular UPI-specific cost, revenue, and tax data to sharpen the cost-benefit estimates; broaden the cross-country comparison to identify optimal pricing and policy models; and conduct primary research to quantify UPI's harder-to-measure qualitative benefits: time savings, convenience, and behavioural change.

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