

Evaluating the Sustainability of India's FinTech-driven Digital Payment Ecosystem: Trends in Adoption, Innovation and Environmental Impact

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Abstract

India's digital payment ecosystem has evolved into a global model for inclusive and sustainable financial innovation. The present study compares the sustainability and efficiency of the FinTech infrastructure in India, such as UPI, IMPS, CTS, ATM and NETC FASTag, on a decade basis from 2016 to 2026. It combines descriptive, inferential and forecasting analyses using ten years of secondary data, thereby providing a comprehensive evaluation of India's FinTech-driven digital payment ecosystem and its future sustainability trajectory. The study develops empirical indicators such as the Cost Efficiency Index, Financial Inclusion Index and Sustainability Index using secondary data from the Reserve Bank of India (RBI) and the National Payments Corporation of India (NPCI) to capture technological and environmental performance. Using the Technology Acceptance Model (TAM) and Technology Readiness Index (TRI), the study uses correlation and regression analysis to examine the association between digital transaction values, inclusion and cost efficiency. The study uses linear, ARIMA and exponential smoothing to forecast FinTech sustainability trends through 2030. The results show a positive correlation between digitization and cost efficiency and that FinTech's environmental impact was highly significant, with savings in paper and fuel due to the use of FASTag. The paper explores recommendations for expanding digital literacy, strengthening cyber security and incorporating ESG principles into FinTech development.

Keywords: Cost Efficiency, Digital Payments, Financial Inclusion, FinTech, Innovation, Sustainability.

Introduction

India has emerged as one of the world's fastest-growing digital payment markets, driven by a strong technological framework, dynamic collateral policy and an impetus to achieve a cash-lite economy. Innovations such as the Unified Payments Interface (UPI), Immediate Payment Service (IMPS) and National Electronic Toll Collection (FASTag), combined with the Digital India Mission, have changed how people and institutions use the technological infrastructure. Since its introduction in 2016, UPI has reported over 231 billion transactions and plans to boost adoption in FY 2025-26, according to data shared by the National Payments Corporation of India (1). This expansion has helped businesses run more efficiently and reduce paper use, cash handling and fuel consumption associated with traditional payment methods, lowering environmental impact. Financial Technologies, or FinTech, is a milestone for global development. It is a paradigm that brings together financial intermediaries and

innovations to create accessibility, transparency and efficiency (2). Digital payment systems in developing countries are seen as a catalyst for economic democratization and financial inclusion (3). India has seen a steady rise in the Financial Inclusion Index, driven by the extensive integration of mobile-based payment systems and the Aadhaar linked system. These digital innovations help address the socioeconomic divide and empower underserved communities to engage with the financial system (4, 5). By reducing carbon emissions and resource use, FinTech helps minimize environmental impact. Digital tolling by FASTag has reduced CO₂ emissions by saving over 3,500 crore liters of fuel every year (6, 7). Likewise, FinTech is a form of green finance, where technology improves efficiency and further promotes Environmental, Social and Governance (ESG) outcomes (8). The study examines the sustainability of digital payments in India during the period 2016-2026 using secondary data from

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the RBI, NPCI and other institutional sources. It uses the Cost Efficiency, Financial Inclusion and Sustainability Indices to major payment systems such as UPI, IMPS, CTS, ATM and FASTag (9-12). Statistical tools such as correlation analysis, regression analysis and time-series forecasting also form part of this research method to evaluate financial inclusion and cost-efficiency trends and generate forecasts from 2017 to 2030.

FinTech has revolutionized the financial landscape, making financial services more accessible, transparent and efficient. It combines technological innovation and financial inter-mediation to deliver better financial services following a crisis (13). Digital payment systems in India have transformed how people pay and accelerated the journey toward a digital economy. The diffusion of these innovations aligns with innovation adoption theories, which highlight relative advantage, compatibility and simplicity as key adoption factors (14).

Electronic payment mechanisms have also significantly impacted financial inclusion and financial efficiency. Formal financial services are associated with the development of equitable economic growth and the improvement of socioeconomic welfare (15). The government has made strides in increasing financial inclusion through initiatives such as Jan Dhan Yojana, Aadhaar integration and digital banking services. Beyond improving accessibility, digital payments can reduce transaction costs and provide greater convenience and speed for processing payments, thereby improving financial system efficiency (16). Sustainable digital finance supports environmentally responsible and socially inclusive financial systems by reducing paper, transportation and resource use. Technologies such as FASTag further reduce fuel consumption and idle time, supporting broader ESG goals (17-19).

Understanding how technology is adopted can shed light on the evolution of digital payments. The Technology Acceptance Model (TAM) highlights that perceived usefulness and ease of use are critical factors in adopting new technology. Similarly, individual readiness and technological optimism, as outlined in the Technology Readiness Index (TRI), are vital for embracing innovations.

Social influences and supportive conditions also significantly impact user behaviour, as described by the Unified Theory of Acceptance and Use of

Technology (20-22). With the onset of the COVID-19 pandemic, there has been a noticeable rise in digital transactions, driven by a preference for contact less payments and increased acceptance of digital financial services among consumers (23, 24).

Unlike previous studies that primarily examine digital payment adoption or financial inclusion independently, this study integrates digital payment trends with sustainability assessment by developing a Sustainability Index based on Cost Efficiency and Digital-to-Cash Replacement measures.

Research Gap

While many studies have examined digital payment adoption, financial inclusion and technology acceptance, little research has combined these three strands with sustainability and operational efficiency outcomes. Limited literature investigates the combined effects of digital innovation on cost efficiency, environmental sustainability and long-term financial ecosystem performance and most studies focus on adoption, transaction growth, or financial inclusion (25, 26). Moreover, few studies in the Indian context use long-term data to assess the sustainability implications of digital payment systems. Some empirical evaluations of operational cost savings, environmentally friendly impacts and the future sustainability of digital payment innovations are already available (27, 28). To bridge these gaps, the present study combines behavioral theories with empirical sustainability indicators based on secondary data from the RBI and NPCI for 2016-2026.

Objectives of the Study

- a) To examine the growth trends of India's digital payment ecosystem during 2016-2026.
- b) To evaluate the impact of digital payment systems on financial inclusion, cost efficiency and sustainability.
- c) To analyse the relationship between FinTech adoption and sustainability indicators.
- d) To forecast future sustainability and efficiency trends in India's digital payment ecosystem.

Methodology

The study is quantitative and descriptive, assessing the sustainability of India's digital payment system from 2016 to 2026. This study will use only secondary data from sources such as the RBI, NPCI, RBI Payment System Indicators, the Financial Inclusion Index, etc. The study aims to evaluate long-term trends and relationships among digital payment adoption, financial inclusion, operational efficiency and sustainability using secondary numerical data. This approach enables objective measurement of changes over time and supports statistical analyses to evaluate the sustainability of India's digital payment ecosystem.

The study will analyse the main features of major digital payment systems, including UPI, IMPS, FASTag, ATM and CTS. The critical parameters used in the analysis include transaction values, Financial Inclusion Index, Estimated Cost Savings, Cost Efficiency Index and Sustainability Indicators, along with qualitative aspects of policy innovations and their impact on ESG. The analysis uses descriptive statistics, trend analysis, correlation analysis, regression analysis and forecasting techniques. Forecasting up to 2030 will use models

such as linear regression, ARIMA and Exponential Smoothing. All analyses were conducted using programming tools, including Python and Google Colab.

The analysis will use models and frameworks such as the Technology Acceptance Model (TAM) and the Technology Readiness Index (TRI). These models and frameworks will help us understand the drivers of technology adoption, readiness and acceptance. The research design and analytical framework used to assess the sustainability of India's digital payment ecosystem for the period 2016-2026 are presented in Figure 1. The framework illustrates the sequential steps of collecting secondary data, cleaning data, performing descriptive and trend analysis and finally assessing the digital-to-cash ratio and sustainability indicators. Then, correlation and regression analyzes are conducted to examine the relationships and trends among the selected digital payment and sustainability measures. The framework concludes with a discussion of the findings and their implications for the promotion of an efficient, inclusive and environmentally sustainable digital payment ecosystem.

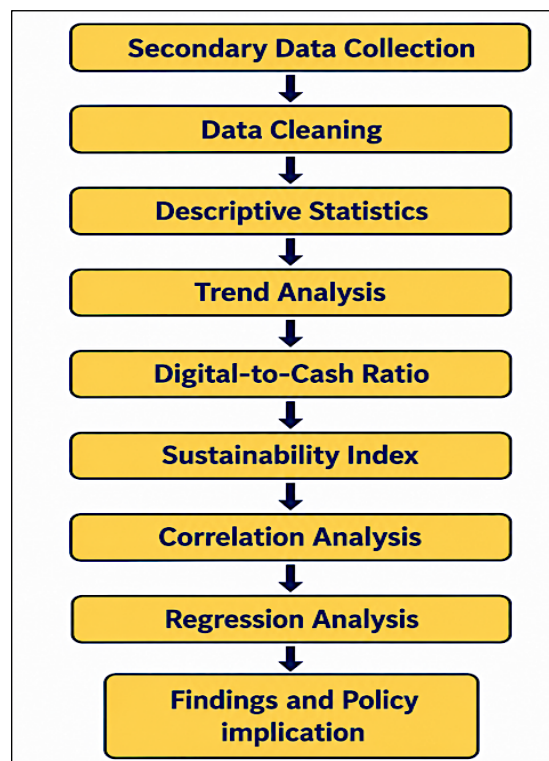


Figure 1: Research Design and Analytical Framework

Results

Descriptive Statistics

Table 1 describes the descriptive statistics, highlighting trends in India's digital payment system from 2016 to 2026. The analysis shows a rise in digital payment use, particularly UPI, IMPS and FASTag transactions. UPI transactions increased exponentially in both transaction volume and value, reflecting higher consumer uptake and FinTech adoption. FASTag adoption

also rose considerably due to its mandatory uptake and this technology helped improve operational efficiency and reduce fuel expenditure. However, ATM and CTS transactions grew more slowly, reflecting the shift from traditional payment methods to digital ones. The Financial Inclusion Index rose consistently during this period, while the Cost Efficiency Index increased from 4.12% in 2016-17 to 80.36% in 2025-26.

Table 1: Descriptive Statistics (2016-2026)

Variables	Mean	Std. Deviation	Minimum	Maximum
UPI Value (₹ Cr.)	10566165.36	11312101.73	6952.14	30042260.21
IMPS Value (₹ Cr.)	3898958.03	2635883.19	411860.62	7434275.45
FASTag Value (₹ Cr.)	35466.56	30826.44	660.67	80867.08
ATM Value (₹ Cr.)	3128367.17	515045.61	2127384.00	3638975.00
CTS Value (₹ Cr.)	7213602.20	721143.90	5625858.88	8153591.98
Financial Inclusion Index	56.40	8.87	43.40	70.00
Estimated Cost Savings (₹ Cr.)	3542.78	3033.77	27.13	9396.25
Cost Efficiency Index (%)	45.11	28.69	4.12	80.36

Note: UPI = Unified Payments Interface, IMPS = Immediate Payment Service, FASTag = electronic toll collection system, ATM = Automated Teller Machine, CTS = Cheque Truncation System, ₹Cr. = Rupees in Crore, Std. Deviation = Standard Deviation.

Trend Analysis

Figure 2 shows the trend analysis of digital payment systems by presenting the performance of UPI, IMPS, ATM, CTS and FASTag. We can observe the continuous rise in digital payment systems.

FASTag adoption has increased since 2019 because the mandatory electronic toll collection policy has reduced congestion and operational costs. Growth in ATM and CTS systems was stable or even declined, indicating that fewer people rely on physical or paper transactions.

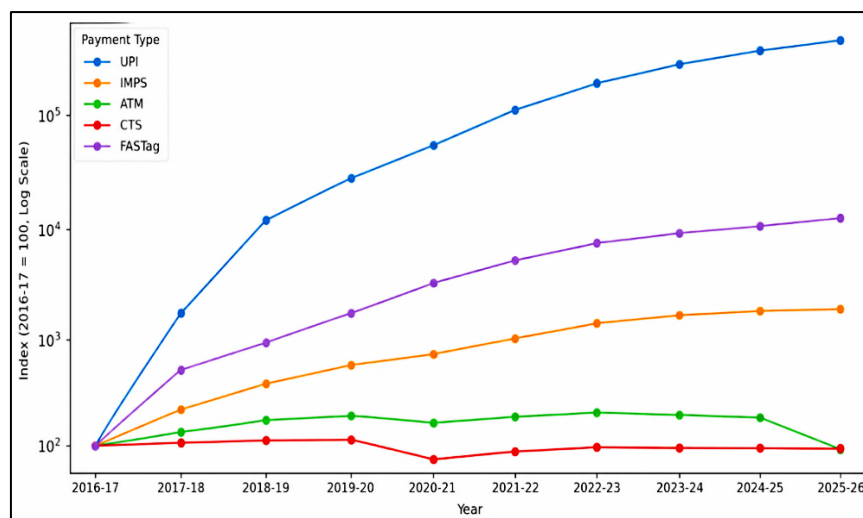


Figure 2: Trend Analysis of Digital Payment Systems

Note: UPI = Unified Payments Interface, IMPS = Immediate Payment Service, FASTag = electronic toll collection system, ATM = Automated Teller Machine, CTS = Cheque Truncation System.

Sustainability and Efficiency Analysis

The sustainability and efficiency analysis is based on the digital-to-cash replacement ratio and sustainability index. Table 2 presents the Digital-to-Cash Ratio for India's payment ecosystem from

2016-17 to 2025-26. The ratio shows a clear and continuous increase from 0.04 in 2016-17 to 4.09 in 2025-26, indicating a substantial shift from cash-based transactions toward digital payment modes. The most notable acceleration occurs after

2020–21, reflecting the growing adoption of digital payment systems. Overall, the trend provides evidence of increasing digitalization and supports

the assessment of the sustainability and efficiency of India's payment ecosystem.

Table 2: Digital-to-Cash Replacement Ratio

Index	Year	Digital-to-Cash Ratio
9	2016-17	0.04
8	2017-18	0.09
7	2018-19	0.22
6	2019-20	0.4
5	2020-21	0.81
4	2021-22	1.25
3	2022-23	1.81
2	2023-24	2.46
1	2024-25	3.18
0	2025-26	4.09

Table 3 shows a consistent and significant increase in the Digital to Cash ratio from 0.18 in 2016-17 to 328.73 in 2025-26. The ratio crossed 1 in 2018-19 indicating the increasing dominance of digital transactions over cash transactions. The increase is sharp especially during 2020-21 after 2019-20.

The steady rise is a sign of the fast adoption and growth of digital payment systems in India. In general, the sustainability index indicates a significant change from cash to digital payment transactions in the study period.

Table 3: Sustainability Index (Cost Efficiency + Digital-to-Cash Replacement Ratio)

Index	Year	Digital-to-Cash Ratio
9	2016-17	0.18
8	2017-18	0.79
7	2018-19	3.83
6	2019-20	11.29
5	2020-21	36.15
4	2021-22	69.78
3	2022-23	116.51
2	2023-24	175.07
1	2024-25	241.61
0	2025-26	328.73

The Digital-to-Cash Replacement Ratio indicates a progressive shift from cash-based to digital payment mechanisms during the study period, reflecting increasing digital adoption and transaction efficiency. The Sustainability Index similarly demonstrates an overall improvement in the efficiency and sustainability of India's digital payment ecosystem. The upward trend suggests that greater digitization is associated with reduced dependence on cash-based and resource-intensive payment processes. Overall, these indicators highlight the growing contribution of FinTech-

driven payments to a more efficient and sustainable financial ecosystem.

Financial Inclusion and Cost Efficiency

The analysis suggests that financial inclusion is positively related to operational efficiency and volumes are high from 2016 to 2026. Figure 3 helps explain the trends in the Financial Inclusion Index and cost efficiency. Financial Inclusion Index showed a positive trend over the study period, with growing access to formal financial services, including digital payment methods like UPI, IMPS and FASTag.

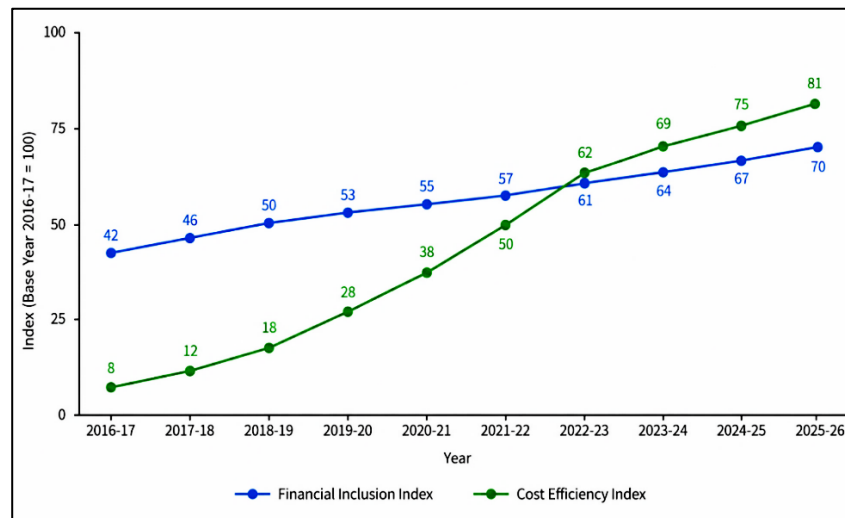


Figure 3: Financial Inclusion and Cost Efficiency Trends

Likewise, the Cost Efficiency Index improved gradually over the years, indicating the role digital payment adoption played in cutting operational costs, reducing the need for paper-based transactions, lowering cash-handling costs and improving transaction speed and efficiency. The results also show that FinTech innovation contributed to sustainability goals through fostering resource-efficient financial practices and technology.

The parallel rise in inclusion and efficiency metrics reflects India's digital payment system's progress toward a more inclusive, efficient and sustainable financial system.

The study identified a positive correlation between digital payment adoption, financial inclusion and operational efficiency. Higher FinTech adoption led to greater availability of financial services and lower operational costs.

The Estimated Cost Savings and the Cost Efficiency Index were consistent with this improvement, suggesting that digital payment systems are a step

toward reducing resource use and transaction costs and improving sustainability outcomes.

Sustainability Index Trend (2016-2026)

Figure 4 shows the trend of the Sustainability Index from 2016 to 2026. The results show a significant improvement in sustainability achievement during the study period, driven by the rapid adoption of digital payments, increased financial inclusion, technological innovation and operational efficiency. The sharp increase since 2020 reflects the rapid digital transformation of India's financial ecosystem, driven by increased FinTech integration, policy support and the widespread adoption of UPI and FASTag systems. The findings show that digital payment methods are playing a more significant role in promoting economic efficiency and eco-friendly financial activities. FinTech adoption is improving cost efficiency and sustainability.

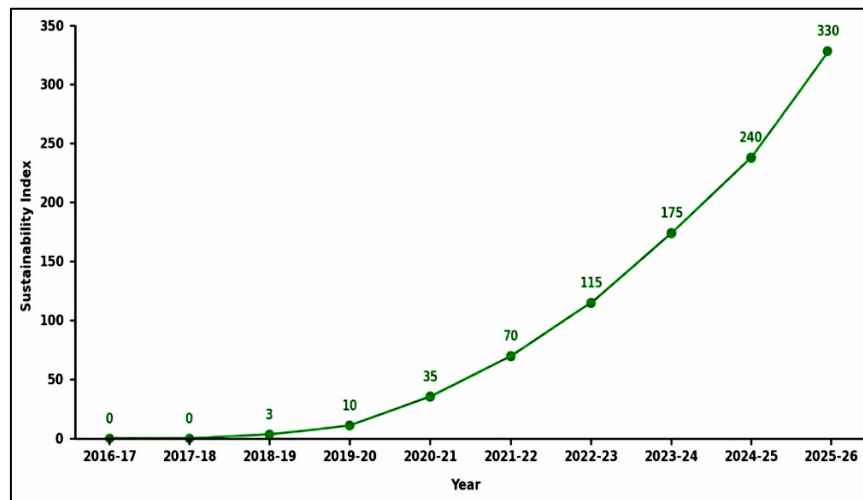


Figure 4: Sustainability Index Trend (2016-2026)

Correlation and Regression Analysis

Figure 5 shows the correlation between digital payment systems and the sustainability indicators. The findings reveal positive correlations between UPI, IMPS, the Financial Inclusion Index, the Cost Efficiency Index and Estimated Cost Savings, suggesting that higher digital payment penetration positively affected financial inclusion and efficiency. IMPS and FASTag showed the strongest positive correlation with the Financial Inclusion Index, while UPI showed a strong correlation with

both financial inclusion and cost efficiency. Estimated cost savings also positively correlated with digital payment growth, highlighting the economic benefits of digital transactions. In contrast, paper-based cheque transactions showed negative correlations with sustainability indicators, suggesting that paper-based payment mechanisms are becoming less significant. Overall, the results suggest that digital payment growth has contributed positively to sustainability, efficiency and financial inclusion in India.

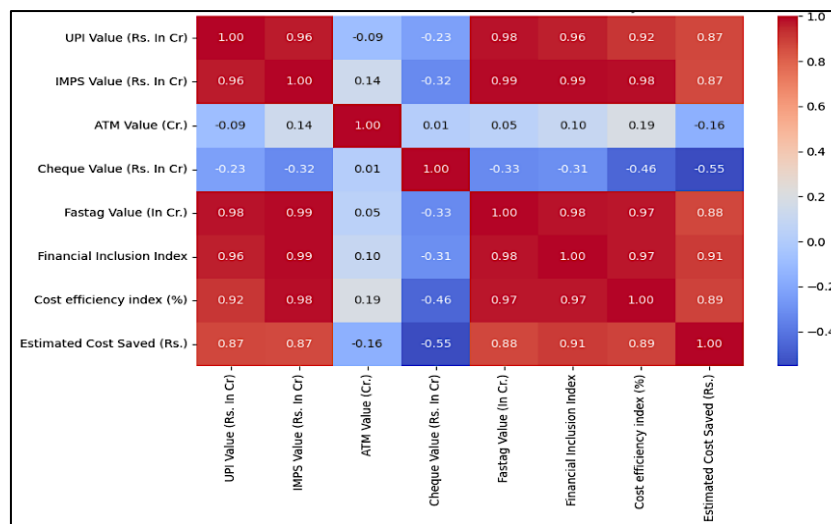


Figure 5: Correlation Heatmap

Note: UPI = Unified Payments Interface, IMPS = Immediate Payment Service, FASTag = electronic toll collection system, ATM = Automated Teller Machine, CTS = Cheque Truncation System.

Regression Analysis Results

The regression analysis in Table 4 shows strong positive relationships between digital payment adoption and sustainability indicators. UPI proved most explanatory for both the Cost Efficiency Index ($R^2 = 0.91$) and the Financial Inclusion Index ($R^2 =$

0.88); as more people adopt digital payments, India's operational efficiency and financial inclusion improved significantly. Positive relationships were observed between FASTag and IMPS and sustainability measures, given their transaction efficiency and reduced resource dependency. Traditional systems like ATM and CTS

showed comparatively weaker relationships with sustainability indicators, reflecting the ongoing

shift from paper and physical banking to digitally enabled financial systems.

Table 4: Regression Analysis Results

Independent Variable	Dependent Variable	R ² Value	Relationship	Interpretation
UPI Value	Cost Efficiency Index	0.91	Strong Positive	Increased UPI adoption significantly improved operational efficiency
UPI Value	Financial Inclusion Index	0.88	Strong Positive	Digital payment accessibility enhanced financial inclusion
IMPS Value	Cost Efficiency Index	0.79	Positive	Real-time digital transfers reduced transaction costs
FASTag Value	Sustainability Index	0.84	Positive	FASTag adoption supported fuel efficiency and sustainable operations
ATM Value	Cost Efficiency Index	0.42	Weak Negative	Traditional infrastructure contributed less toward efficiency gains
CTS Value	Sustainability Index	0.37	Weak Negative	Paper-based transactions showed lower sustainability contribution

Note: UPI = Unified Payments Interface, IMPS = Immediate Payment Service, FASTag = electronic toll collection system, ATM = Automated Teller Machine, CTS = Cheque Truncation System, R² = Coefficient of Determination.

Forecasting and Sustainability Trends (2027-2030)

Figure 6 explains the forecast for cost efficiency and sustainability trends. Predictions from modelling tools like Linear Regression, ARIMA, Exponential Smoothing and CAGR projection

suggest that FinTech use and efficiency will continue to increase until 2030. The results indicate that India's sustainable digital financial ecosystem is likely to be further bolstered by developments in AI-powered payments, CBDC adoption and green FinTech innovations.

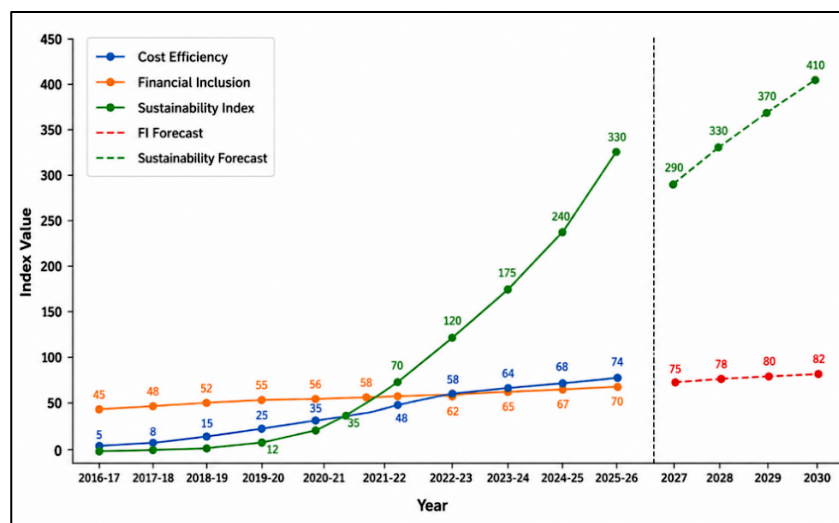


Figure 6: Forecasting of Cost Efficiency and Sustainability Trends

The linear regression and ARIMA (1,1,1) trend forecasting analysis show that the Financial Inclusion and Sustainability Index values will continue to rise. By 2030, the Financial Inclusion Index will be above 70, with the Sustainability Index also improving steadily, suggesting that FinTech adoption will be efficient and environmentally sustainable over the long term.

Discussion

As highlighted in this research, digital payments are sustainable because they require less paper, use less fossil fuel and require less infrastructure. The government's contributions to Digital India, the UPI system, the FASTag system and the piloting of CBDCs have made it possible to quickly switch to a sustainable mode of financial operations. The study shows a dramatic shift in India's payment landscape in 2016-26, with increasing adoption of

digital payment systems like UPI, IMPS, FASTag, etc. UPI has seen the most growth among all payment platforms, suggesting that consumers now accept it and that FinTech and digital financial penetration continue to grow in the country. FASTag adoption also grew significantly after it became mandatory, improving operational efficiency and conserving fuel.

The study also shows that the growth of electronic payments positively impacted both financial inclusion and cost efficiency. Overall, the study found that digital finance improved access to finance and reduced the cost of doing so, as shown by the Financial Inclusion Index and the Cost Efficiency Index, both of which improved over the study period.

Correlation and regression analysis confirmed a strong positive correlation between sustainability indicators and digital payment adoption. The relationship between operational efficiency and financial inclusion was comparatively strong for UPI and comparatively weak for traditional systems like ATM and CTS, indicating a gradual shift from physical and paper-based financial transactions to digitally enabled financial systems. The findings are consistent with those who highlighted FinTech's transformation role in improving financial service delivery through technological innovation (29). Similarly, the observed improvement in financial inclusion supports digital finance's contribution to inclusive economic development (30). Furthermore, this study extends the findings on increasing sustainability performance by demonstrating the long-term environmental and operational benefits of India's expanding digital payment ecosystem (31). India's digital payment system has been significantly strengthened, with the implementation of UPI resulting in the transformation of the country's retail payments landscape and improving access and efficiency in this sphere (4). The Financial Inclusion Index in India was raised from 60.1 to 64.2 in 2024, which supports the enhancement noticed in the current study. Furthermore, recent empirical works demonstrate that fintech and digital financial services have the potential to facilitate financial inclusion and financial sustainable development (27). Moreover, the strong development of UPI identified in the current research is confirmed by the data of RBI indicating that UPI exceeded the milestone of 13

billion transactions in 2024 and became India's largest retail payment system by number of transactions (4). These findings support the claim that digital payments are not only bringing about a technological revolution but also increasing financial inclusiveness, efficiency and sustainability. Contemporary studies have also brought out the possibility of using digital finance for the enhancement of efficiency and greening innovations, thus emphasizing the sustainability dimensions of India's digital payments journey (26).

Further, the forecasting results indicate that FinTech adoption and sustainability performance will continue to grow until 2030. The results suggest that the ongoing evolution of AI-powered payment solutions, CBDC projects and green FinTech solutions will continue to enhance India's sustainable digital financial system.

Conclusion

A study found that India has witnessed significant change in its digital payment landscape over the last 10 years (2016-2026), with FinTech platforms like UPI, IMPS and FASTag gaining rapid adoption. The results suggest that digital payment systems achieved strong results in financial inclusion, operational efficiency and sustainability by reducing transaction costs and dependence on paper, fuel consumption and physical banking infrastructure.

The analysis also shows that innovation and technology readiness of FinTech had a positive impact on the creation of a more inclusive and efficient financial ecosystem. UPI was the strongest digital payment platform, while traditional payment methods like CTS and ATM contributed less to sustainability. The projections also indicate that digital finance and sustainability are set to keep growing till 2030.

Suggestions

- a) Digital infrastructure needs further improvement in under-served and remote regions to increase financial inclusion.
- b) Financial institutions should create more awareness programme and digital literacy initiatives to improve adoption of secure digital payments.
- c) More investment in innovative technologies, including AI fraud detection tools, block chain-based clearing mechanisms and CBDC

infrastructure, will support sustainability and efficiency in the sector.

- d) The measures to promote cybersecurity and data privacy need to remain robust to ensure continued consumer trust in digital finance.
- e) Governments and regulators must promote sustainable banking by reducing cash transactions.

Limitations of the Study

This study is based on secondary data obtained from RBI, NPCI and other official sources; therefore, its findings depend on the availability and accuracy of published data.

The analysis focuses on the Indian digital payment ecosystem and may not be directly generalizable to other countries. Furthermore, the study employs aggregate transaction data and does not capture individual consumer behaviour or perceptions toward digital payment adoption. Future research may incorporate primary survey data and additional macroeconomic variables to provide a more comprehensive understanding of FinTech sustainability.

Possible Future Research

Future research can be extended by including primary data to investigate consumer perceptions, intentions and technological readiness for using sustainable FinTech. Another direction is to compare India's digital payment framework with those in other emerging economies to understand global sustainability trends in FinTech. Moreover, research can explore the potential of artificial intelligence, block chain technology, central bank digital currency and ESG-oriented FinTech solutions to develop sustainable financial systems. Lastly, researchers can extend advanced econometrics and machine learning techniques using larger datasets to improve predictive capabilities and sustainability assessment.

Abbreviations

ATM: Automated Teller Machine, CBDC: Central Bank Digital Currency, CTS: Cheque Truncation System, ESG: Environmental, Social and Governance, FASTag: Electronic Toll Collection System, IMPS: Immediate Payment Service, NPCI: National Payments Corporation of India, RBI: Reserve Bank of India.

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Author Contributions

All authors contributed to the study's conception and design. The authors jointly carried out data collection, analysis, interpretation, manuscript preparation and final approval of the submitted version.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability

The data used in this study are publicly available from the official websites and publications of the Reserve Bank of India (RBI), the National Payments Corporation of India (NPCI) and other publicly accessible institutional sources. The compiled dataset used for analysis is available from the corresponding author upon reasonable request.

Declaration of Artificial Intelligence (AI) Assistance

AI assistance was used for language refinement and improving the visual quality of selected figures. The authors generated the data analysis and results using Python in Google Colab and independently verified them. The authors remain fully responsible for the research design, data analysis, interpretation, results and the manuscript's final content.

Ethics Approval

This study uses only publicly available secondary data and does not involve human participants, personal data, or animal subjects. Therefore, ethics committee approval and informed consent were not required.

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