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Digitalization of financial transactions in Indian Agriculture: An empirical study of cashless adoption among farmers in Namakkal District, Tamil Nadu

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Abstract

Agriculture is undergoing a decisive shift as digital infrastructure and mobile-based financial tools reshape how farmers transact, save and access credit. This paper examines the transition of agricultural financial transactions from a cash-dominated system to one increasingly mediated by mobile banking, the Unified Payments Interface (UPI), digital wallets and internet-enabled trading platforms such as the National Agriculture Market (e-NAM). The study situates this transition within India's broader digital-governance ecosystem, including the Digital India Programme, BharatNet, the IndiaAI Mission and the Pradhan Mantri Gramin Digital Saksharta Abhiyan, and evaluates their bearing on rural livelihoods. To assess the ground-level uptake of these tools, a field survey of 120 farm households was conducted across six administrative blocks of Namakkal district, Tamil Nadu. Namakkal, Mohanur, Rasipuram, Paramathi, Tiruchengode and Komarapalayam using a structured interview schedule. Descriptive statistics, a composite adoption index, chi-square tests of association, Pearson correlation and a paired-comparison test were used to examine how location and socio-economic characteristics relate to smartphone ownership and UPI usage. The results show that overall smartphone ownership (41.7 per cent) exceeded UPI adoption (39.2 per cent), with wide inter-block variation: Namakkal recorded the highest adoption index (0.70 for smartphones, 0.55 for UPI) while Mohanur recorded the lowest (0.20 for both). The chi-square test confirmed a statistically significant association between block location and smartphone adoption ($\chi^2 = 13.440$, $df = 5$, $p = 0.020$), while smartphone and UPI adoption indices were very strongly and significantly correlated across blocks ($r = 0.960$, $p = 0.002$). Adoption was consistently associated with younger and middle-aged respondents, higher educational attainment and comparatively larger landholdings. Persistent constraints cyber-fraud risk, the cost of digital infrastructure, patchy rural connectivity, and gaps in digital literacy continue to slow uniform adoption. The paper argues that closing these gaps through targeted digital-literacy training, last-mile connectivity investment and trust-building safeguards is essential if digital finance is to translate into genuine and inclusive agricultural transformation.

Keywords: Digitalization, Unified Payments Interface (UPI), financial inclusion, e-NAM, rural agriculture, smartphone adoption.

1. Introduction

Farming has moved well beyond ploughs, seed and soil; it is now equally shaped by data, connectivity and financial technology. Across the developing world and in India in particular, the movement of money in the agricultural economy is being re-engineered around digital rails rather than paper currency. What was once described as a distant, futuristic idea a genuinely cashless rural economy has, over the past decade, become an operating reality for large segments of the farming population.

Digitalization, in this context, refers to the application of digital technologies to reorganize established practices in banking, trade, governance and communication into faster and more transparent systems. The pace of this transformation has been driven by falling data costs, near-universal mobile penetration and a policy environment that has actively promoted electronic payments over cash. For agriculture specifically, digital financial transactions carry

the potential to resolve chronic structural problems: the cost and time lost in travelling to distant bank branches, the opacity of cash-based produce transactions, and the difficulty small holders face in building a verifiable financial history.

1.1 Evolution of Financial Transactions

Financial transactions have passed through several distinct phases. In the earliest phase, cash, cheques and physical bank visits were the norm; withdrawing, depositing or transferring money required a branch visit and was often slow and paperwork-heavy. The second phase, built around Automated Teller Machines, debit and credit cards, reduced the need for physical visits while retaining a largely branch-anchored architecture. Internet banking then extended account access into the home, and the most recent phase driven by smartphone penetration has placed banking, bill payment, investment and merchant payment inside a single

mobile application. Contactless payments, QR-code scanning and instant payment rails have collectively compressed transaction time from days to seconds.

1.2 Objectives of the Study

Against this background, the present study was designed with the following objectives: (i) to trace the evolution of digital financial transactions and map the principal government schemes supporting digitalization in India; (ii) to assess the extent of smartphone ownership and UPI adoption among farm households in Namakkal district; (iii) to examine how socio-economic characteristics are gender, age, income, education and farm size relate to the adoption of cashless transactions; and (iv) to identify the constraints limiting wider adoption and to outline measures that could strengthen digital financial inclusion in agriculture.

1.3 Government Schemes Supporting Digital Financial Inclusion

India's push toward a digitally-enabled financial system rests on a cluster of interlinked initiatives. The Digital India Programme (launched 2015) is the umbrella initiative promoting digital infrastructure, e-governance and digital literacy. BharatNet extends optical-fibre broadband connectivity to Gram Panchayats, underpinning rural access to banking, telemedicine and online education. The IndiaAI Mission (2024) supports the application of artificial intelligence to agriculture, healthcare and public services. The Pradhan Mantri Gramin Digital Saksharta Abhiyan builds basic digital competence among rural citizens, while the Unified Payments Interface and the BHIM application provide the real-time payment rails that make instant, low-cost transfers possible. DigiLocker digitizes citizen document storage, the Open Network for Digital Commerce widens e-commerce access for small enterprises, the electronic National Agriculture Market (e-NAM) links farmers to markets nationwide, and the Government e-Marketplace formalises public procurement. Collectively, these schemes form the institutional scaffolding within which farm-level digital adoption is occurring.

2. Materials and Methods

2.1 Study Area

The study was conducted in Namakkal district, Tamil Nadu, an area characterized by a predominance of small and marginal agricultural holdings and a mixed rural-semi-urban economy. Six administrative blocks were purposively selected to capture variation in infrastructure and market access: Namakkal, Mohanur, Rasipuram, Paramathi, Tiruchengode and Komarapalayam.

2.2 Sampling and Data Collection

A multi-stage random sampling procedure was adopted. From each of the six selected blocks, 20 farm households were chosen at random, yielding a total sample of 120 respondents. Primary data were collected through a pre-tested, structured interview schedule administered face-to-face, covering demographic profile (gender, age, education, annual income, farm size), smartphone ownership, and the adoption of UPI-based digital payments. Secondary information on national and state-level digital finance schemes was compiled from government portals and published policy documents to provide contextual background for the primary findings.

2.3 Analytical Tools

Collected data were tabulated and examined using simple percentage analysis to describe the demographic profile of respondents and the extent of smartphone and UPI adoption across blocks. To allow direct block-wise comparison, a composite Adoption Index was computed for both smartphone ownership and UPI usage, expressed as the proportion of respondents in a block who had adopted the technology relative to the total number of respondents surveyed in that block (*Adoption Index = Number of adopters ÷ Total respondents in the block*). Cross-tabulations were used to relate adoption levels to gender, income, age, education and farm-size categories.

Beyond descriptive analysis, three inferential procedures were applied. First, the Pearson chi-square (χ^2) test of independence was used to test whether smartphone and UPI adoption were significantly associated with block location based on the 6×2 contingency tables of adopters and non-adopters; Cramer's V was computed alongside each test to indicate the strength of association. Second, the Pearson product-moment correlation coefficient (r) was used to examine the linear relationship between the block-wise smartphone-adoption index and UPI-adoption index, and, at the ecological (block) level, between adoption indices and the block-wise proportions of educated, younger, land-holding and income categories. Third, a paired t-test was used to determine whether the mean adoption index for smartphones differed significantly from that for UPI across the six blocks. All tests were conducted at the 5 per cent ($p < 0.05$) level of significance using Python (SciPy 1.x); ecological-level correlations ($n = 6$ blocks) are reported as indicative of area-level association and should not be interpreted as individual-level relationships.

3. Results and Discussion

3.1 Gender Profile of Respondents

Gender	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Male	15	14	7	10	7	10	63
Female	5	6	13	10	13	10	57
Total	20	20	20	20	20	20	120

Of the 120 respondents, 63 (52.5 per cent) were male and 57 (47.5 per cent) were female. Namakkal recorded the highest share of male respondents (15), while Rasipuram and Tiruchengode had the highest female representation (13 each); Paramathi and Komarapalayam showed an even split. Both genders are visibly engaged in farm-level activity in the study area, though male farmers appear to hold

comparatively greater access to smartphones and formal banking, largely because they are more directly involved in produce marketing and financial decision-making. Strengthening smartphone access and digital literacy among women farmers would broaden participation in cashless transactions and support more inclusive rural development.

3.2 Annual Income Distribution

Income (Rs.)	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Below 50,000	2	6	3	0	0	8	19
50,000–1,00,000	5	11	16	17	19	9	77
1,00,000–5,00,000	8	3	0	2	1	3	17
Above 5,00,000	5	0	1	1	0	0	7
Total	20	20	20	20	20	20	120

The majority of respondents, 77 (64.2 per cent), reported an annual income between Rs.50,000 and Rs.1,00,000, followed by 19 (15.8 per cent) earning below Rs.50,000. Only 7 respondents (5.8 per cent) reported an income above Rs.5,00,000. Tiruchengode and Paramathi contributed the largest numbers to the middle-income band, while Komarapalayam had the highest count in the lowest band and Namakkal the highest count in the top band. This concentration in the lower and middle-income groups

suggests that affordability continues to shape technology adoption: higher-income farmers are more likely to own smartphones, hold bank accounts and use UPI, whereas lower-income farmers are more likely to remain dependent on cash because of cost, device access and financial-literacy constraints.

3.3 Age Distribution

Age Group	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Below 45	4	4	8	2	7	7	32
46–60	13	8	8	14	8	9	60
60–90	3	8	4	4	5	4	28
Total	20	20	20	20	20	20	120

Half the sample (60 respondents, 50 per cent) fell in the 46–60 year age bracket, followed by 32 (26.7 per cent) below 45 years and 28 (23.3 per cent) between 60 and 90 years. Paramathi and Namakkal contributed the most middle-aged respondents, while Mohanur had the highest count of elderly farmers. Middle-aged farmers dominate agricultural decision-making and are comparatively receptive to digital tools; younger farmers tend to be the most digitally

confident, while elderly farmers more often continue with cash owing to limited digital exposure and concern over online fraud. Age therefore emerges as a meaningful determinant of cashless-transaction adoption in the study area.

3.4 Educational Status

Education	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Illiterate	6	10	2	10	9	6	43
Primary	2	6	3	7	3	6	27
Secondary	0	1	10	3	7	5	26
Higher Secondary	9	2	0	0	0	0	11
Graduate	3	1	5	0	1	3	13
Total	20	20	20	20	20	20	120

Illiterate respondents made up the largest single category (43, 35.8 per cent), followed by those with primary (27, 22.5 per cent) and secondary (26, 21.7 per cent) education; higher-secondary and graduate respondents accounted for 11 (9.2 per cent) and 13 (10.8 per cent) respectively. Mohanur and Paramathi had the highest numbers of illiterate respondents, while Rasipuram recorded the highest numbers with secondary and graduate qualifications. Education level is closely linked to comfort with

smartphone-based banking: more educated respondents transact independently and with greater confidence, while illiterate farmers often rely on family members or local intermediaries and remain hesitant to adopt UPI. These points to a clear case for targeting digital-literacy programmes at blocks with lower educational attainment.

3.5 Farm Size

Farm Size	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Marginal	3	4	6	8	5	5	31
Small	10	10	11	12	14	10	67
Large	7	6	3	0	1	5	22
Total	20	20	20	20	20	20	120

Small farmers formed the largest group (67, 55.8 per cent), followed by marginal (31, 25.8 per cent) and large farmers (22, 18.3 per cent). Tiruchengode had the most small farmers and Paramathi the most marginal farmers, while

Namakkal recorded the highest count of large farmers. This structure a preponderance of small and marginal holdings that transact frequently but in small amounts for seed, fertilizer and machinery hire is precisely the segment that

stands to benefit most from low-cost digital payment rails, though actual uptake still depends on device ownership, connectivity and awareness. Large farmers, with greater exposure to formal banking and commercial dealings, tend

to adopt digital payments more readily.

3.6 Smartphone Adoption

Smartphone Adoption	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Adopted	14	4	9	8	5	10	50
Not Adopted	6	16	11	12	15	10	70
Total	20	20	20	20	20	20	120

Overall, 50 respondents (41.7 per cent) owned a smartphone against 70 (58.3 per cent) who did not. Namakkal recorded the highest adoption (70 per cent), followed by Komarapalayam (50 per cent), while Mohanur recorded the lowest (20 per cent). Because a smartphone is the necessary gateway to UPI and mobile banking, disparities in ownership directly constrain access to digital finance; the

comparatively strong showing in Namakkal likely reflects better economic conditions and stronger digital infrastructure, while Mohanur's lower figure points to affordability and awareness gaps that would need targeted intervention.

3.7 UPI Adoption

UPI Adoption	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
Adopted	11	4	9	8	5	10	47
Not Adopted	9	16	11	12	15	10	73
Total	20	20	20	20	20	20	120

UPI had been adopted by 47 respondents (39.2 per cent), while 73 (60.8 per cent) had not yet used it. Namakkal again led with the highest adoption rate (55 per cent), followed by Komarapalayam (50 per cent), Rasipuram (45 per cent) and Paramathi (40 per cent); Mohanur (20 per cent) and Tiruchengode (25 per cent) trailed. The pattern broadly

mirrors smartphone ownership, reinforcing the view that infrastructure and awareness, more than willingness alone, govern the pace of adoption.

3.8 Adoption Index — Smartphone and UPI

Technology	Namakkal	Mohanur	Rasipuram	Paramathi	Tiruchengode	Komarapalayam	Overall
UPI	0.55	0.20	0.45	0.40	0.25	0.50	0.391
Smartphone	0.70	0.20	0.45	0.45	0.25	0.50	0.416

The composite adoption index reinforces the descriptive findings: the overall smartphone-adoption index (0.416) marginally exceeds the UPI-adoption index (0.391), indicating that owning a smartphone does not automatically translate into using it for digital payments. Namakkal recorded the highest index for both smartphones (0.70) and UPI (0.55), with Komarapalayam a close second (0.50 for both); Mohanur recorded the lowest index (0.20) for both indicators. The gap between smartphone ownership and UPI use in several blocks suggests that residual security concerns, limited confidence and gaps in transaction knowledge are holding back full utilization even where the hardware barrier has been cleared. Strengthening rural digital infrastructure and running targeted awareness

campaigns therefore remain necessary complements to expanding device access.

3.9 Statistical Analysis of Adoption Patterns

To move beyond descriptive percentages, three inferential tests were applied to the survey data. The first tested whether adoption of smartphones and UPI is significantly associated with block location; the second examined the strength of the relationship between the two adoption indices and between adoption and block-level socio-economic composition; the third tested whether smartphone and UPI adoption differ significantly in their overall extent. Results are summarized in Table.

Test	Statistic	df	p-value	Inference ($\alpha = 0.05$)
Chi-square: Block $\times$ Smartphone adoption	$\chi^2 = 13.440$	5	0.020	Significant
Chi-square: Block $\times$ UPI adoption	$\chi^2 = 8.149$	5	0.148	Not significant
Pearson correlation: Smartphone index $\times$ UPI index (n = 6 blocks)	r = 0.960	—	0.002	Significant, strong positive
Paired t-test: Smartphone index vs UPI index (n = 6 blocks)	t = 1.000	5	0.363	Not significant
Pearson correlation: Below-60 age share $\times$ UPI index (n = 6)	r = 0.874	—	0.023	Significant, strong positive
Pearson correlation: Below-60 age share $\times$ Smartphone index (n = 6)	r = 0.832	—	0.040	Significant, strong positive
Pearson correlation: Secondary+ education share $\times$ UPI index (n = 6)	r = 0.552	—	0.256	Not significant
Pearson correlation: Income above Rs. 50,000 share $\times$ UPI index (n = 6)	r = -0.092	—	0.862	Not significant

The chi-square test confirms that smartphone adoption differs significantly across the six blocks ($\chi^2 = 13.440$, df = 5, p = 0.020, Cramér's V = 0.335), indicating a moderate association between geographic location and device

ownership. UPI adoption also varies across blocks in the same direction, but the association falls just short of conventional significance ($\chi^2 = 8.149$, df = 5, p = 0.148, Cramér's V = 0.261); with only 120 observations spread

over six blocks and two categories, the test may simply lack the statistical power to confirm what the raw percentages already suggest namely, that UPI use tracks smartphone ownership fairly closely from block to block.

This tracking is confirmed directly: the smartphone-adoption index and the UPI-adoption index are very strongly and significantly correlated across the six blocks (Pearson $r = 0.960$, $p = 0.002$), meaning that blocks with higher device ownership almost invariably show higher digital-payment uptake as well. At the same time, the paired t-test finds no statistically significant difference between the mean smartphone-adoption index (0.416) and the mean UPI-adoption index (0.391) across blocks ($t = 1.000$, $df = 5$, $p = 0.363$). Taken together, these two results indicate that smartphone ownership and UPI use rise and fall together across the study area, and that the modest gap between them (visible earlier in Table) is not large enough, given the small number of blocks, to be treated as a systematic pattern rather than chance variation.

At the ecological level treating each of the six blocks as a single observation the proportion of respondents below 60 years of age is significantly and strongly correlated with both the UPI-adoption index ($r = 0.874$, $p = 0.023$) and the smartphone-adoption index ($r = 0.832$, $p = 0.040$), lending statistical support to the earlier observation that younger and middle-aged respondents anchor digital adoption in this population. By contrast, the block-wise share of respondents with secondary or higher education ($r = 0.552$, $p = 0.256$) and the share earnings above Rs. 50,000 annually ($r = -0.092$, $p = 0.862$) were not significantly correlated with UPI adoption at the block level, even though the individual-level percentage tables (Sections 3.2 and 3.4) point in the expected direction. This divergence is a reminder that block-level (ecological) correlations, computed from only six data points, are indicative rather than conclusive, and that the more granular, respondent-level patterns reported in Sections 3.1–3.5 remain the primary evidential basis for the study's socio-economic conclusions. A larger, individual-level dataset with joint recording of adoption and demographic status for each respondent would allow firmer inferential testing (for example, binary logistic regression of UPI adoption on age, education, income and farm size) and is recommended as a direction for future research.

3.10 Constraints in Digitalization of Agricultural Financial Transactions

The survey findings, read alongside the broader literature on digital finance, point to five recurring constraints. First, the rise of digital platforms has been accompanied by a corresponding rise in cyber-fraud phishing, counterfeit payment links and unauthorized account access which discourages cautious users. Second, building and maintaining digital financial infrastructure entails substantial investment in technology, cyber security and connectivity, a cost that weighs disproportionately on small institutions and, indirectly, on the farmers who rely on them. Third, digital-skill gaps, particularly pronounced among older and less-educated respondents, limit effective and confident use of banking applications. Fourth, inconsistent internet connectivity and periodic power interruptions in several blocks reduce the day-to-day reliability of digital payment systems. Fifth, low user confidence rooted in

concern over the safety of personal and financial data continues to slow adoption even where access is technically available.

3.11 Outlook for Digital Financial Transactions in Agriculture

Emerging technologies are likely to reshape this landscape further. Artificial intelligence and machine-learning tools are increasingly used to detect fraud and personalize financial services; biometric authentication fingerprint, facial and voice recognition is being layered onto existing payment systems to strengthen security; and several countries, India included, are exploring Central Bank Digital Currencies as a further evolution of digital money. As these tools mature, digital financial transactions in agriculture are likely to become faster, more secure and more accessible, provided that connectivity and literacy gaps are addressed in parallel.

4. Conclusion

This study set out to examine how digitalization is reshaping financial transactions in Indian agriculture, using a field survey of 120 farm households across six blocks of Namakkal district as an empirical anchor. The results confirm that digital adoption in this rural setting remains uneven: smartphone ownership (41.7 per cent) and UPI usage (39.2 per cent) trail well behind full penetration, and adoption is strongly patterned by block, income, age, education and farm size. Statistical testing corroborates these descriptive patterns: block location is significantly associated with smartphone adoption ($\chi^2 = 13.440$, $p = 0.020$), smartphone and UPI adoption indices move together very strongly across blocks ($r = 0.960$, $p = 0.002$) without a statistically significant gap between them (paired $t = 1.000$, $p = 0.363$), and the share of younger and middle-aged respondents is significantly correlated with both forms of adoption at the block level ($p < 0.05$). Namakkal block, with comparatively stronger infrastructure and economic conditions, recorded consistently higher adoption than Mohanur, where affordability and awareness constraints appear more binding.

These findings suggest that expanding digital financial inclusion in agriculture is not simply a matter of extending network coverage or subsidizing handsets; it requires a combined push on connectivity, targeted digital-literacy training, and trust-building measures that address the genuine fraud concerns of first-time users. Government programmes such as Digital India, BharatNet, PMGDISHA, UPI, BHIM and e-NAM already provide much of the institutional scaffolding needed for this transition; the task ahead is to ensure that this scaffolding reaches the blocks, age groups and income categories that currently lag behind. Future studies would benefit from a larger, individual-level sample permitting logistic regression analysis of adoption determinants. Done well, the shift from cash to digital rails promises not merely convenience but a more transparent, efficient and inclusive financial foundation for Indian agriculture.

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