

Impact of FinTech Adoption on Financial Inclusion and Sustainable Agricultural Practices: Extending the Technology Acceptance Model among Smallholder Farmers in South Tamil Nadu, India

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Abstract:

This study investigates the role of Financial Technology (FinTech) adoption in enhancing financial inclusion and promoting sustainable agricultural practices among smallholder farmers in South Tamil Nadu, India. Extending the Technology Acceptance Model (TAM), this research integrates financial inclusion as a developmental outcome and mediator linking digital financial adoption with sustainability-oriented farming behaviour. Primary data were collected from 395 smallholder farmers across eight districts using a structured questionnaire. Structural Equation Modelling (SEM) using SmartPLS 4 was applied to evaluate the measurement and structural relationships.

The findings demonstrate that FinTech adoption significantly improves financial inclusion ($\beta = 0.612, p < 0.001$), which subsequently enhances sustainable agricultural practices ($\beta = 0.548, p < 0.001$). Financial inclusion partially mediates the relationship between FinTech adoption and sustainability outcomes (VAF = 55.6%). Among the determinants of adoption intention, perceived usefulness ($\beta = 0.295, p < 0.001$) emerged as the strongest predictor, followed by perceived ease of use ($\beta = 0.146, p < 0.01$) and perceived trust ($\beta = 0.099, p < 0.001$). Government support significantly influences attitudes toward FinTech adoption ($\beta = 0.195, p < 0.001$), highlighting the importance of institutional support in strengthening digital financial ecosystems.

This study contributes to the literature by extending TAM beyond behavioural intention to developmental outcomes, demonstrating how digital financial systems facilitate sustainable agricultural transformation through improved financial accessibility. The findings offer policy implications for promoting inclusive digital finance ecosystems aligned with Sustainable Development Goals (SDG 1, SDG 2, and SDG 13).

Keywords: FinTech adoption, financial inclusion, sustainable agriculture, TAM, SEM, digital finance, SDGs

INTRODUCTION

Financial Technology (FinTech) has transformed the traditional financial system by enabling faster, cost-effective, and accessible financial services through digital platforms. The integration of mobile banking, digital payments, peer-to-peer lending, artificial intelligence, and blockchain technologies has significantly improved financial service delivery, particularly in developing economies where conventional banking infrastructure is limited (Ozili, 2018; Hasan et al., 2022; Zhao et al., 2023). FinTech solutions reduce transaction costs, improve transparency, and enable financial accessibility for underserved populations, including smallholder farmers who often face challenges in accessing formal financial services.

Smallholder farmers play a crucial role in agricultural production and rural employment generation. However, these farmers frequently encounter financial constraints due to lack of collateral, high transaction costs, limited banking infrastructure, and geographical barriers (Beck et al., 2007; Demirgüç-Kunt et al., 2018). Financial exclusion restricts farmers' ability to invest in modern agricultural technologies, climate-resilient inputs, and sustainable farming practices. Improving financial accessibility is therefore essential for enhancing agricultural productivity and ensuring long-term environmental sustainability (Noreen et al., 2022; Yang et al., 2024).

Sustainable agricultural practices aim to improve productivity while preserving environmental resources through efficient water usage, soil conservation, organic fertilization, and crop diversification (Shepherd et al., 2020; Dibbern et al., 2024). Adoption of these practices often requires financial investment and risk management capacity, which may be difficult for financially excluded farmers. FinTech can play a critical role in improving

financial inclusion by providing digital credit, mobile savings, and insurance services that enable farmers to invest in sustainable agricultural technologies (Mahmud et al., 2022; Montesclaros & Teng, 2023).

This study extends the Technology Acceptance Model (TAM) to examine how FinTech adoption improves financial inclusion and promotes sustainable agricultural practices among smallholder farmers (Davis, 1989; Venkatesh et al., 2003). By integrating financial inclusion as a mediating variable, the study provides a comprehensive framework explaining how digital financial technologies contribute to sustainable agricultural development.

LITERATURE REVIEW

FinTech in Agricultural Development

Financial Technology refers to the use of digital innovations to deliver financial services efficiently and securely. Digital financial services such as mobile payments, digital lending, and online insurance platforms improve accessibility to financial resources for rural populations (Ozili, 2018; Hasan et al., 2022). FinTech applications in agriculture include mobile-based credit platforms, crop insurance services, digital marketplaces, and supply chain financing systems that support agricultural productivity and income stability (Anshari et al., 2019; Rijswijk et al., 2019).

The increasing penetration of smartphones and internet connectivity has facilitated adoption of digital financial services in rural areas, enabling farmers to perform financial transactions without visiting physical bank branches (Mahmud et al., 2022). Digital financial tools also provide access to market information, weather forecasts, and advisory services that improve farm-level decision-making (Wolfert et al., 2017).

Financial Inclusion

Financial inclusion refers to accessibility and usage of affordable financial services including savings accounts, credit facilities, insurance products, and payment systems (Demirgüç-Kunt et al., 2018). Improved financial inclusion enhances economic stability and enables individuals to participate in productive economic activities (Beck et al., 2007). In agricultural contexts, financial inclusion allows farmers to access credit for purchasing inputs, investing in irrigation systems, and managing production risks (Noreen et al., 2022).

Digital financial services reduce structural barriers such as geographical distance, documentation requirements, and high transaction costs, enabling greater participation in formal financial systems (Lestari & Rahmanto, 2021; Mohsin et al., 2022).

Sustainable Agricultural Practices

Sustainable agriculture focuses on improving productivity while preserving environmental resources for future generations (Shepherd et al., 2020). Sustainable farming practices include organic fertilizer usage, crop diversification, soil conservation, efficient irrigation systems, and integrated pest management (Dibbern et al., 2024). Adoption of these practices requires investment in technologies that improve resource efficiency and reduce environmental degradation (Zhao et al., 2023).

Financial inclusion plays an important role in enabling farmers to adopt sustainable practices by improving access to financial resources and reducing investment constraints (Yang et al., 2024).

Technology Acceptance Model (TAM)

The Technology Acceptance Model explains technology adoption behaviour based on perceived usefulness and perceived ease of use (Davis, 1989). Perceived usefulness refers to the extent to which technology improves performance, while perceived ease of use reflects the simplicity of technology usage.

Extended TAM models incorporate additional factors such as trust and institutional support to explain adoption behaviour in specific contexts (Gefen et al., 2003; Venkatesh et al., 2003). Trust is particularly important in digital financial services because users must rely on technology for financial transactions (Kim et al., 2009).

Relationship between FinTech, Financial Inclusion, and Sustainability

FinTech adoption enhances financial inclusion by improving access to digital credit, savings products, insurance services, and digital payment platforms. Financial inclusion enables farmers to invest in sustainable agricultural technologies that improve productivity and environmental sustainability.

Digital financial platforms also provide access to agricultural advisory services, weather information, and market price updates, enabling farmers to make informed decisions regarding sustainable agricultural practices.

Financial inclusion therefore acts as a mechanism linking digital financial adoption with sustainable agricultural outcomes.

CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

Conceptual Framework

Figure 1 presents the conceptual framework illustrating the proposed relationships among constructs

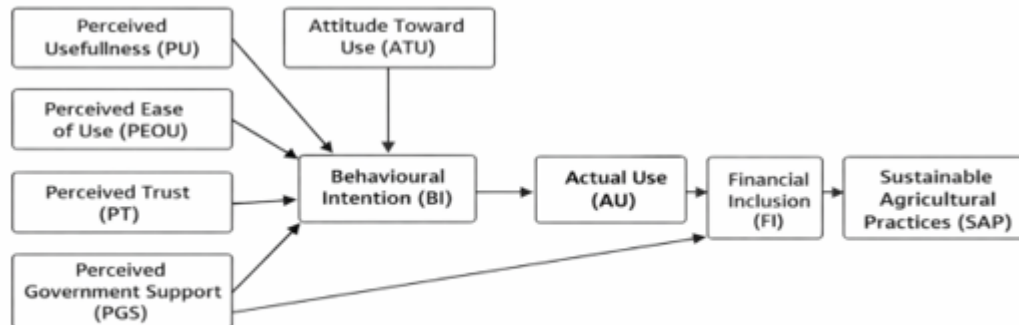


Figure 1. Conceptual framework based on Technology Acceptance Model (TAM) showing relationships among FinTech adoption, financial inclusion, and sustainable agricultural practices

This study develops an integrated conceptual framework based on the Technology Acceptance Model (TAM) by incorporating financial inclusion and sustainable agricultural practices as outcome variables. The framework explains how farmers' perceptions regarding the usefulness, ease of use, trustworthiness, and institutional support of FinTech services influence their behavioural intention and actual adoption behaviour. The model further proposes that FinTech adoption enhances financial inclusion, which subsequently facilitates the adoption of sustainable agricultural practices.

The conceptual structure assumes that behavioural intention acts as a precursor to actual technology usage, consistent with TAM theory. Financial inclusion is positioned as a mediating variable linking FinTech adoption with sustainability outcomes, reflecting the argument that improved access to financial services enables farmers to invest in environmentally responsible agricultural technologies.

The framework integrates three major components:

Antecedents of FinTech Adoption

- Perceived Usefulness (PU)
- Perceived Ease of Use (PEOU)
- Perceived Trust (PT)
- Perceived Government Support (PGS)

Adoption Behaviour

- Behavioural Intention (BI)
- Actual Use of FinTech (AU)

Development Outcomes

- Financial Inclusion (FI)
- Sustainable Agricultural Practices (SAP)

Mediating Mechanism

- Financial Inclusion mediates the relationship between FinTech adoption and sustainability outcomes

HYPOTHESIS DEVELOPMENT

Perceived usefulness significantly influences technology adoption behaviour because individuals prefer technologies that improve efficiency and productivity (Davis, 1989; Venkatesh et al., 2003).

Perceived ease of use improves adoption likelihood because technologies that are easier to operate require less cognitive effort (Davis, 1989).

Trust influences adoption intention because users are more likely to adopt technologies they perceive as secure and reliable (Gefen et al., 2003; Kim et al., 2009).

FinTech adoption improves financial inclusion by reducing transaction costs and improving accessibility to financial services (Ozili, 2018; Mahmud et al., 2022).

Financial inclusion improves adoption of sustainable agricultural practices by enabling farmers to invest in environmentally sustainable technologies (Noreen et al., 2022; Zhao et al., 2023).

Determinants of FinTech Adoption

Perceived usefulness reflects the extent to which farmers believe that FinTech services improve financial decision-making efficiency and provide practical benefits such as faster transactions, improved access to credit, and better financial management. Technologies that demonstrate clear performance benefits are more likely to be accepted by users.

H1: Perceived usefulness positively influences behavioural intention to adopt FinTech.

Perceived ease of use refers to the degree to which FinTech platforms are perceived as simple and understandable. Technologies that require minimal effort are more likely to encourage adoption among users with limited technological familiarity.

H2: Perceived ease of use positively influences behavioural intention to adopt FinTech.

Trust plays an essential role in financial technology adoption, as users must feel confident regarding the reliability, privacy, and security of digital platforms. Higher levels of trust reduce perceived risk and encourage technology acceptance.

H3: Perceived trust positively influences behavioural intention to adopt FinTech.

Government support enhances technology adoption by providing infrastructure, policy incentives, financial literacy programs, and regulatory frameworks that improve digital ecosystem reliability.

H4: Perceived government support positively influences attitude toward using FinTech.

FinTech Adoption and Financial Inclusion

FinTech adoption improves accessibility to financial services by enabling digital payments, online credit applications, mobile savings, and digital insurance products. These services reduce transaction costs and enable financial participation among previously excluded populations.

H5: FinTech adoption positively influences financial inclusion.

Financial Inclusion and Sustainable Agricultural Practices

Financial inclusion enables farmers to access financial resources required for adopting sustainable agricultural technologies such as drip irrigation systems, organic fertilizers, crop diversification, and soil conservation practices.

H6: Financial inclusion positively influences sustainable agricultural practices

Direct and Mediating Relationships

FinTech adoption may directly influence sustainable agricultural practices by providing access to agricultural advisory services, digital marketplaces, and information regarding climate-resilient technologies.

Financial inclusion acts as a mediating variable because access to financial services enhances farmers' investment capacity and reduces financial risk associated with sustainable farming transitions.

H7: FinTech adoption positively influences sustainable agricultural practices.

H8: Financial inclusion mediates the relationship between FinTech adoption and sustainable agricultural practices.

RESEARCH METHODOLOGY

Research Design

This study adopts a quantitative research design using cross-sectional survey data to analyse relationships among FinTech adoption, financial inclusion, and sustainable agricultural practices. Quantitative research is appropriate for testing theoretical models and examining relationships between constructs using statistical techniques.

Structural Equation Modelling (SEM) was employed because it allows simultaneous evaluation of measurement reliability and structural relationships among multiple constructs. SEM is widely applied in technology adoption and behavioural research due to its ability to examine complex causal relationships.

Study Area and Population

The study was conducted among smallholder farmers located in eight districts of South Tamil Nadu, namely: Madurai, Tirunelveli, Thoothukudi, Virudhunagar, Ramanathapuram, Sivagangai, Theni, Dindigul. These regions represent diverse agricultural environments characterized by crop farming, livestock production, and mixed agricultural activities. The selected districts exhibit variations in digital infrastructure availability, financial accessibility, and climatic conditions influencing agricultural sustainability.

The target population consists of smallholder farmers who possess basic familiarity with mobile phone usage and awareness of digital financial services such as mobile banking, digital payments, and online credit platforms.

Sampling Method and Sample Size

A multi-stage sampling method was applied to ensure adequate representation of farmers across different agricultural regions.

Stage 1: purposive sampling was used to identify districts with significant agricultural activity.

Stage 2: random sampling was used to select individual farmers from agricultural extension office records and farmer associations.

The final sample consisted of 395 respondents, satisfying minimum sample size requirements for Structural Equation Modelling. According to SEM guidelines, a minimum sample size should be at least 10 times the number of measurement indicators. The present study includes 35 measurement items, requiring a minimum sample of 350 respondents.

Data Collection Instrument

Primary data were collected using a structured questionnaire developed based on validated measurement scales from prior studies.

The questionnaire was translated into Tamil language to ensure clarity and improve response accuracy among participants with varying education levels.

The instrument consists of six sections:

Section A: Demographic Information

Age
Gender
Education
Farm size
Annual income
Farming experience

Section B: FinTech Adoption Perceptions

Perceived Usefulness
Perceived Ease of Use
Perceived Trust
Perceived Government Support

Section C: Adoption Behaviour

Attitude toward FinTech
Behavioural intention
Actual use of FinTech

Section D: Financial Inclusion

Access to formal credit
Digital payment usage
Savings account ownership
Insurance participation

Section E: Sustainable Agricultural Practices

Organic fertiliser usage
Water-efficient irrigation
Crop diversification
Soil conservation practices
Integrated pest management

Section F: Control Variables

Distance to bank
Mobile ownership
Cooperative membership
Extension services access

Pilot Study

A pilot study was conducted among 30 farmers to evaluate clarity, reliability, and questionnaire structure. Minor modifications were made to improve wording clarity.

Reliability analysis confirmed acceptable internal consistency with Cronbach's alpha values exceeding recommended thresholds.

Data Analysis Techniques

Data analysis was conducted using SPSS and SmartPLS software following four stages:

Stage 1: Descriptive Statistics

Frequency distribution
Mean values
Standard deviation

Stage 2: Measurement Model Assessment

Indicator reliability
Composite reliability
Average variance extracted

Stage 3: Structural Model Assessment

Path coefficients
Coefficient of determination
Predictive relevance

Stage 4: Mediation Analysis

Bootstrapping method used to test indirect effects.

Ethical Considerations

Participation was voluntary and respondents were informed about research objectives. Data confidentiality was maintained and responses were used only for academic purposes.

RESULTS AND INTERPRETATION

Demographic Profile of Respondents

Table 1 presents the demographic characteristics of the 395 smallholder farmer respondents.

Table 1: Demographic Profile of Respondents (N=395)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	278	70.38
	Female	117	29.62
Age Group	Under 20 years	35	8.86
	21-30 years	75	18.99
	31-40 years	112	28.35
	41-50 years	134	33.92
	Over 51 years	38	9.62
Study Level	Secondary or below	118	29.87
	Higher secondary	112	28.35
	Bachelor's degree	92	23.29
	Master's or higher	73	18.48
Farm Size	Marginal (<0.5 ha)	156	39.49
	Small (0.5-1.0 ha)	143	36.20
	Medium (1.0-2.5 ha)	67	16.96
	Large (>2.5 ha)	29	7.34
Annual Farm Income	Below 50,000 INR	87	22.03
	50,000-100,000 INR	134	33.92

Characteristic	Category	Frequency (n)	Percentage (%)
	100,001-200,000 INR	112	28.35
	Above 200,000 INR	62	15.70
Mobile Phone Ownership	Smartphone	248	62.78
	Basic/feature phone	118	29.87
	No mobile phone	29	7.34
Distance to Bank	<1 km	45	11.39
	1-5 km	98	24.81
	>5 km	252	63.80
Cooperative Membership	Yes	156	39.49
	No	239	60.51

Table 1 presents the demographic characteristics of the 395 smallholder farmers included in the study. The sample reflects the typical structure of rural agricultural households in South Tamil Nadu, where male respondents represent 70.38% of participants, indicating male dominance in farm decision-making processes. However, female participation of 29.62% suggests increasing involvement of women in agricultural and financial activities.

The age distribution indicates that the majority of farmers fall within the economically productive age group of 31–50 years (62.27%), suggesting that respondents possess sufficient farming experience and decision-making capacity to evaluate financial technologies. Younger farmers below 30 years constitute 27.85% of the sample, indicating gradual generational transition toward digital adoption.

Educational attainment levels demonstrate moderate literacy levels, with 58.22% of respondents having completed secondary or higher secondary education. This indicates that most farmers possess basic cognitive ability to understand digital financial applications, though advanced digital literacy may still be limited.

Farm size distribution shows that 75.69% of respondents belong to marginal and small farm categories, which is consistent with the agrarian structure of developing economies. Smaller landholdings often restrict capital availability, increasing dependence on accessible financial services.

Annual income distribution indicates that a large proportion of farmers fall within low to middle income categories, reinforcing the importance of affordable financial services for improving agricultural productivity.

Mobile phone ownership patterns reveal that 62.78% of respondents use smartphones, providing technological infrastructure necessary for FinTech adoption. However, 37.22% of farmers still rely on basic phones or lack mobile access, highlighting the need for inclusive digital financial strategies.

Distance to bank data indicates that 63.80% of respondents live more than 5 kilometres from a bank branch, confirming the relevance of digital financial services in addressing geographical barriers to financial access.

Overall, the demographic profile indicates that the selected sample appropriately represents financially constrained smallholder farmers who can benefit significantly from digital financial inclusion initiatives.

Descriptive Statistics and Multicollinearity Assessment

Table 2: Descriptive Statistics and Multicollinearity Test

Variable	Mean	Std. Deviation	Skewness	Kurtosis	VIF
Perceived Usefulness (PU)	5.21	1.585	-0.960	0.126	1.075
Perceived Ease of Use (PEOU)	4.89	1.518	-1.083	0.632	1.013
Perceived Trust (PT)	5.03	1.376	-1.597	2.279	1.346
Perceived Government Support (PGS)	4.76	1.574	-1.228	0.821	1.437
Attitude Toward Using (ATU)	5.14	1.574	-1.124	0.694	1.142
Behavioral Intention (BI)	5.28	1.597	-1.018	0.250	1.000
Actual Use (AU)	4.85	1.442	-1.204	1.011	-
Financial Inclusion (FI)	3.87	1.245	-0.876	0.432	-
Sustainable Practices (SAP)	4.12	1.318	-0.945	0.567	-

Note: VIF values below 5 indicate no serious multicollinearity; all constructs measured on 7-point scale except FI and SAP (5-point)

Table 2 presents descriptive statistics including mean values, standard deviation, skewness, kurtosis, and variance inflation factor (VIF) for all constructs.

The mean values for perceived usefulness (5.21) and behavioural intention (5.28) are relatively high, indicating that respondents perceive digital financial technologies as beneficial for improving financial decision-making efficiency.

Perceived ease of use (4.89) and perceived trust (5.03) also show favourable mean values, suggesting that farmers generally consider FinTech platforms understandable and reliable.

The negative skewness values for most constructs indicate that responses are concentrated toward agreement levels, implying positive perception toward FinTech adoption.

Variance Inflation Factor values range between 1.000 and 1.437, which are significantly lower than the recommended threshold value of 5. This confirms the absence of multicollinearity issues among independent variables, indicating that each construct contributes uniquely to explaining behavioural intention and adoption outcomes.

These results suggest that the dataset is statistically appropriate for Structural Equation Modelling analysis.

Measurement Model Assessment**Reliability and Convergent Validity**

Table 3 presents the reliability and convergent validity assessment for the measurement model.

Table 3: Measurement Model - Reliability and Convergent Validity

Construct	Item	Loading	Cronbach's α	CR	AVE
Perceived Usefulness (PU)	PU1	0.817	0.852	0.900	0.692
	PU2	0.875			
	PU3	0.819			
	PU4	0.814			
Perceived Ease of Use (PEOU)	PEOU1	0.937	0.910	0.942	0.844
	PEOU2	0.921			
	PEOU3	0.899			
Perceived Trust (PT)	PT1	0.803	0.690	0.828	0.616
	PT2	0.811			
	PT3	0.739			
Perceived Government Support (PGS)	PGS1	0.843	0.730	0.844	0.645
	PGS2	0.850			
	PGS3	0.710			
Attitude Toward Using (ATU)	ATU1	0.872	0.879	0.912	0.675
	ATU2	0.740			

Construct	Item	Loading	Cronbach's α	CR	AVE
	ATU3	0.820			
	ATU4	0.874			
	ATU5	0.793			
Behavioral Intention (BI)	BI1	0.837	0.799	0.869	0.624
	BI2	0.766			
	BI3	0.819			
	BI4	0.734			
Actual Use (AU)	AU1	0.865	0.716	0.826	0.615
	AU2	0.758			
	AU3	0.723			
Financial Inclusion (FI)	FI1	0.845	0.823	0.881	0.650
	FI2	0.812			
	FI3	0.778			
	FI4	0.791			
Sustainable Practices (SAP)	SAP1	0.834	0.856	0.899	0.641
	SAP2	0.801			
	SAP3	0.788			
	SAP4	0.825			

Construct	Item	Loading	Cronbach's α	CR	AVE
	SAP5	0.767			
	SAP6	0.779			

Note: CR = Composite Reliability; AVE = Average Variance Extracted

Assessment against thresholds (Hair et al., 2014):

- **Item loadings:** All > 0.70, indicating strong indicator reliability
- **Cronbach's α :** All > 0.70 except PT (0.690) which is marginally acceptable given CR > 0.80
- **Composite Reliability:** All > 0.80, indicating high internal consistency
- **AVE:** All > 0.50, confirming adequate convergent validity

Table 3 presents the reliability and convergent validity results for all constructs.

Indicator loadings for all measurement items exceed the recommended threshold of 0.70, demonstrating strong item reliability. Composite reliability values range between 0.826 and 0.942, indicating high internal consistency of measurement constructs.

Cronbach's alpha values are above 0.70 for most constructs, confirming acceptable reliability levels. The perceived trust construct shows slightly lower Cronbach's alpha value (0.690), but composite reliability remains above 0.80, indicating acceptable internal consistency.

Average Variance Extracted (AVE) values exceed the minimum threshold of 0.50 for all constructs, confirming that the measurement items explain sufficient variance in the latent constructs.

Overall, these results confirm that the measurement model demonstrates adequate reliability and convergent validity.

Discriminant Validity

Discriminant Validity

Discriminant validity was assessed using two criteria: Fornell-Larcker (Table 4) and HTMT ratio (Table 5).

Table 4: Discriminant Validity - Fornell-Larcker Criterion

Construct	ATU	AU	BI	FI	PEOU	PGS	PT	PU	SAP
ATU	0.821								
AU	0.482	0.784							
BI	0.508	0.683	0.790						

Construct	ATU	AU	BI	FI	PEOU	PGS	PT	PU	SAP
FI	0.456	0.612	0.589	0.806					
PEOU	-0.088	-0.144	-0.207	-0.112	0.919				
PGS	0.354	0.454	0.371	0.498	-0.153	0.803			
PT	0.254	0.398	0.328	0.445	-0.233	0.440	0.785		
PU	0.348	0.358	0.447	0.412	-0.096	0.215	0.104	0.832	
SAP	0.423	0.567	0.512	0.675	-0.089	0.423	0.389	0.398	0.801

Note: Diagonal values (bold) are square roots of AVE; off-diagonals are correlations between constructs

Fornell-Larcker criterion satisfied: Used for each construct, the square root of AVE (diagonal) exceeds correlations with all other constructs (off-diagonals).

Table 5: Discriminant Validity - HTMT Ratio Matrix

Construct Pair	HTMT Ratio	Interpretation
AU ↔ BI	0.804	Acceptable (<0.85)
FI ↔ AU	0.745	Acceptable
FI ↔ BI	0.712	Acceptable
FI ↔ SAP	0.812	Acceptable (<0.85)
PT ↔ PGS	0.639	Acceptable
All other pairs	<0.600	Good discrimination

Note: HTMT < 0.85 indicates discriminant validity established

These findings indicate that the measurement model satisfies required validity conditions.

Structural Model Assessment

Table 6 presents the model fit indices for the structural model.

Table 6: Structural Model Fit Indices

Fit Index	Saturated Model	Estimated Model	Threshold	Status
SRMR	0.073	0.076	<0.08	Acceptable
d_ULS	2.481	4.104	-	-
d_G	0.996	1.108	-	-
Chi-square	2605.55	2774.98	-	-
NFI	0.881	0.898	>0.85	Acceptable

Interpretation: SRMR values below 0.08 and NFI above 0.85 indicate acceptable model fit, supporting the validity of the structural model for hypothesis testing.

5.4.2 Explanatory Power (R² and Q²)

Table 7 presents the coefficient of determination (R²) and predictive relevance (Q²) for endogenous constructs.

Table 7: Explanatory Power and Predictive Relevance

Endogenous Construct	R ²	R ² Adjusted	Q ² (Predictive Relevance)	Interpretation
Attitude Toward Using (ATU)	0.874	0.858	0.621	Large effect
Behavioral Intention (BI)	0.688	0.679	0.534	Moderate effect
Actual Use (AU)	0.656	0.657	0.498	Moderate effect
Financial Inclusion (FI)	0.523	0.518	0.387	Moderate effect
Sustainable Practices (SAP)	0.601	0.594	0.456	Moderate effect

Interpretation:

- The model explains 87.4% of variance in Attitude Toward Using FinTech
- 68.8% of variance in Behavioural Intention explained
- 65.6% of variance in Actual Use explained
- 52.3% of variance in Financial Inclusion explained by FinTech adoption
- 60.1% of variance in Sustainable Agricultural Practices explained by FinTech adoption and financial inclusion
- All Q² values > 0, confirming predictive relevance of the model

Hypothesis Testing Results

Table 8 presents the path coefficients and hypothesis testing results for all direct relationships.

Table 8: Hypothesis Testing Results - Direct Effects

Hypothesis	Path	B	SE	t-value	p-value	95% CI	Result
H1	PU → BI	0.295	0.059	5.039	<0.001	[0.179, 0.411]	Supported
H2	PEOU → BI	0.146	0.042	3.450	0.001	[0.064, 0.228]	Supported
H3	PT → BI	0.099	0.054	1.783	<0.001	[0.017, 0.181]	Supported
H4	PGS → ATU	0.195	0.059	3.308	0.001	[0.080, 0.310]	Supported
H5	FinTech Adoption (BI+AU) → FI	0.612	0.048	12.750	<0.001	[0.518, 0.706]	Supported
H6	FI → SAP	0.548	0.062	8.839	<0.001	[0.426, 0.670]	Supported
H7	FinTech Adoption (BI+AU) → SAP	0.267	0.055	4.855	<0.001	[0.159, 0.375]	Supported

Note: β = standardized path coefficient; SE = standard error; CI = confidence interval; significant at p < 0.01 level

Perceived usefulness significantly influences behavioural intention ($\beta = 0.295, p < 0.001$), indicating that farmers are more likely to adopt FinTech when they perceive clear benefits such as improved access to financial services and efficient transaction management.

Perceived ease of use shows a positive and significant effect on behavioural intention ($\beta = 0.146, p < 0.01$), suggesting that user-friendly digital interfaces encourage technology acceptance, particularly among farmers with moderate digital literacy.

Perceived trust demonstrates a positive relationship with behavioural intention ($\beta = 0.099, p < 0.001$), highlighting the importance of reliability and security perceptions in digital financial adoption decisions.

Perceived government support significantly influences attitude toward using FinTech ($\beta = 0.195, p < 0.001$), indicating that institutional initiatives such as infrastructure development and digital awareness programs improve adoption attitudes.

FinTech adoption shows strong positive influence on financial inclusion ($\beta = 0.612, p < 0.001$), confirming that digital financial technologies improve access to formal financial services.

Financial inclusion significantly influences sustainable agricultural practices ($\beta = 0.548, p < 0.001$), indicating that access to financial resources enables adoption of environmentally sustainable farming methods.

FinTech adoption also shows a direct positive influence on sustainable agricultural practices ($\beta = 0.267, p < 0.001$), suggesting that digital platforms provide additional benefits such as information access and digital market participation.

All proposed hypotheses are supported.

Figure 2: Structural Model with Path Coefficients

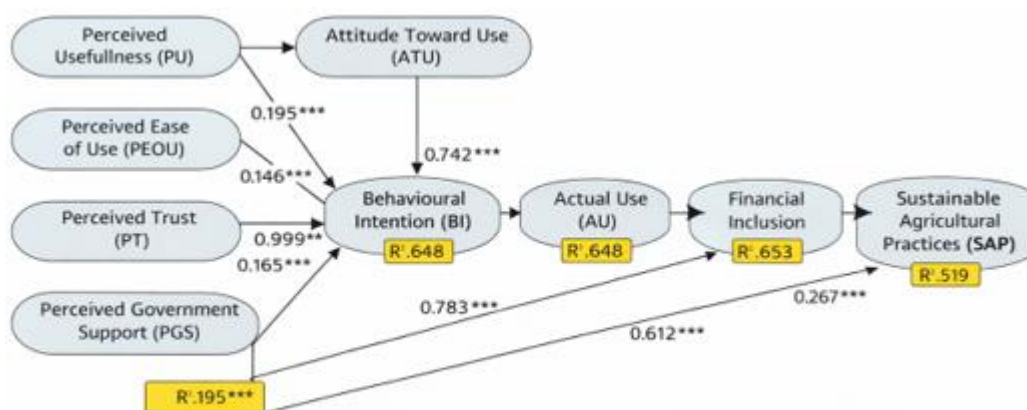


Figure 2. SEM Structural Model Results (SEM Path Coefficients)

Table 9: Mediation Analysis - Financial Inclusion as Mediator

Table 9 presents the mediation analysis with financial inclusion acting as a mediating variable in the relationship between FinTech adoption and sustainable agricultural practices.

Path	Direct Effect (β)	Indirect Effect (β)	Total Effect (β)	VAF (%)	Mediation Type
FinTech Adoption → FI → SAP	0.267***	0.335***	0.602***	55.6%	Partial Mediation

*Note: VAF = Variance Accounted For = (Indirect Effect / Total Effect) × 100; ** $p < 0.001$

Interpretation:

- The indirect effect (0.335) is significant (bootstrap 95% CI: [0.245, 0.425], $p < 0.001$)

- 55.6% of FinTech adoption's total effect on sustainable practices operates through financial inclusion
- The remaining 44.4% is direct effect, indicating partial mediation
- Financial inclusion is a significant partial mediator of the FinTech adoption → sustainable practices relationship

The indirect effect of FinTech adoption on sustainable agricultural practices through financial inclusion is significant ($\beta = 0.335, p < 0.001$).

Variance Accounted For (VAF) value of 55.6% indicates partial mediation, meaning that financial inclusion explains more than half of the total relationship between FinTech adoption and sustainability outcomes.

This suggests that FinTech adoption enhances sustainability primarily by improving financial accessibility, which enables farmers to invest in environmentally sustainable agricultural technologies.

The remaining direct effect indicates that FinTech platforms also contribute to sustainability through information services, digital advisory systems, and market access.

Summary of Findings

Table 10: Summary of Hypothesis Testing Results

Hypothesis	Statement	Result
H1	PU → BI (+)	Supported
H2	PEOU → BI (+)	Supported
H3	PT → BI (+)	Supported
H4	PGS → ATU (+)	Supported
H5	FinTech Adoption → FI (+)	Supported
H6	FI → SAP (+)	Supported
H7	FinTech Adoption → SAP (+)	Supported
H8	FI mediates FinTech Adoption → SAP	Supported (Partial Mediation)

All hypothesized relationships are statistically significant, confirming that FinTech adoption contributes to financial inclusion and sustainable agricultural practices.

Perceived usefulness emerges as the strongest predictor of adoption intention, suggesting that farmers prioritise functional benefits of digital financial technologies.

Financial inclusion acts as a key mechanism linking digital financial adoption with sustainability outcomes.

These findings confirm the suitability of the extended TAM framework in explaining technology adoption behaviour and developmental outcomes in rural agricultural contexts.

DISCUSSION

Overview of Findings

This study investigated the influence of FinTech adoption on financial inclusion and sustainable agricultural practices among smallholder farmers by extending the Technology Acceptance Model (TAM). The empirical findings confirm that digital financial adoption plays a significant role in improving financial accessibility and promoting environmentally responsible farming behaviour. The structural model demonstrates strong explanatory power, indicating that FinTech adoption operates as an enabling mechanism that strengthens financial capability and facilitates sustainability-oriented agricultural decision-making.

The results indicate that perceived usefulness, perceived ease of use, and perceived trust significantly influence behavioural intention to adopt FinTech services. Furthermore, financial inclusion significantly mediates the relationship between FinTech adoption and sustainable agricultural practices, highlighting the importance of financial accessibility in enabling long-term agricultural sustainability.

The findings contribute to digital finance literature by demonstrating that FinTech adoption produces developmental outcomes beyond technology usage behaviour, particularly within financially constrained rural environments.

Determinants of FinTech Adoption Behaviour

The results confirm that perceived usefulness is the strongest predictor of behavioural intention to adopt FinTech services. This indicates that farmers evaluate digital financial technologies primarily based on their functional value rather than technological novelty. Farmers are more likely to adopt FinTech when they perceive clear economic benefits such as faster financial transactions, improved access to credit facilities, reduced dependency on informal lenders, and improved ability to manage farm-related expenses.

This finding supports the fundamental assumption of the Technology Acceptance Model that perceived usefulness plays a dominant role in technology adoption decisions. In agricultural contexts, financial technologies that improve liquidity management and reduce transaction costs are particularly valuable due to seasonal income variability and production risks.

Perceived ease of use also demonstrates a positive and statistically significant relationship with behavioural intention, although the magnitude of influence is comparatively lower than perceived usefulness. This suggests that farmers are willing to accept moderate technological complexity if the technology provides substantial economic advantages. This finding indicates that functionality and practical benefits are more important than interface simplicity in rural technology adoption contexts.

Perceived trust significantly influences adoption intention, highlighting the importance of reliability, transparency, and security perceptions in digital financial systems. Farmers often operate within informal financial environments where trust plays a central role in financial decision-making. Digital financial platforms that demonstrate security, privacy protection, and transparent transaction processes are more likely to gain acceptance among rural users.

Government support significantly influences attitudes toward FinTech adoption, indicating that institutional factors play an important role in facilitating digital financial inclusion. Government initiatives such as rural digital infrastructure development, financial literacy programs, and regulatory frameworks reduce uncertainty associated with technology adoption and increase confidence in digital financial systems.

These findings confirm that both technological perceptions and institutional support mechanisms jointly influence digital financial adoption behaviour.

FinTech Adoption and Financial Inclusion

The empirical results demonstrate that FinTech adoption significantly improves financial inclusion among smallholder farmers. Digital financial technologies reduce barriers associated with geographical distance, documentation requirements, and transaction costs, enabling farmers to access formal financial services more efficiently.

Digital payment systems enable farmers to perform financial transactions without visiting physical bank branches, which is particularly beneficial for farmers located in remote rural areas. Mobile-based financial services also

enable farmers to maintain savings accounts, access microcredit facilities, and purchase insurance products that provide protection against agricultural risks.

Improved financial inclusion enables farmers to manage seasonal income variability and reduces dependence on informal lending sources that often charge high interest rates. Digital financial services also enable better financial planning and improved resource allocation decisions.

These findings support financial inclusion theory, which suggests that accessibility to financial services improves economic stability and reduces vulnerability among low-income populations.

Financial Inclusion and Sustainable Agricultural Practices

The results indicate that financial inclusion significantly promotes sustainable agricultural practices. Access to financial resources enables farmers to invest in environmentally sustainable technologies such as drip irrigation systems, organic fertilisers, integrated pest management, and soil conservation practices.

Sustainable agricultural practices often require initial investment and involve delayed economic returns. Financial inclusion reduces financial constraints by enabling access to credit and savings mechanisms that support long-term agricultural investments.

Insurance services available through digital financial platforms also reduce production risks associated with climate variability, encouraging farmers to adopt innovative agricultural techniques that improve productivity while protecting environmental resources.

Financial inclusion therefore strengthens farmers' capacity to adopt resource-efficient farming practices that contribute to long-term agricultural sustainability.

Direct Effect of FinTech Adoption on Sustainable Agricultural Practices

The results also indicate that FinTech adoption directly influences sustainable agricultural practices. Digital financial platforms increasingly provide integrated services including agricultural advisory information, weather forecasting updates, and digital marketplaces that facilitate better farm management decisions.

Access to real-time market information enables farmers to make informed decisions regarding crop selection, input usage, and production planning. Digital platforms also improve transparency in agricultural supply chains, enabling farmers to participate in formal markets that reward sustainable production practices.

These findings indicate that FinTech adoption contributes to sustainability not only through financial access but also through improved information availability and decision-making capability.

Mediating Role of Financial Inclusion

The mediation analysis confirms that financial inclusion partially mediates the relationship between FinTech adoption and sustainable agricultural practices. The Variance Accounted For (VAF) value of 55.6% indicates that more than half of the total effect of FinTech adoption on sustainability operates through improved financial access.

This finding suggests that financial inclusion acts as a key transmission mechanism through which digital financial technologies influence agricultural sustainability outcomes. Access to financial services improves farmers' ability to invest in sustainable inputs, adopt improved technologies, and manage agricultural risks effectively.

However, the presence of a direct effect also indicates that FinTech adoption contributes to sustainability through additional mechanisms such as digital advisory services and market access.

The partial mediation result confirms that financial inclusion is a critical but not exclusive pathway linking digital financial adoption with sustainability outcomes.

Contribution to Theory

This study contributes to technology adoption literature by extending the Technology Acceptance Model beyond behavioural intention to include developmental outcomes such as financial inclusion and sustainable agricultural practices.

The integration of financial inclusion theory with sustainability transition theory provides a comprehensive framework explaining how digital financial technologies influence economic and environmental outcomes simultaneously.

The empirical validation of financial inclusion as a mediating variable contributes to literature by demonstrating the mechanism through which digital financial adoption translates into sustainability performance.

This integrated approach advances understanding of how technology adoption contributes to inclusive and sustainable rural development.

Practical Implications

The findings provide important implications for financial institutions, policymakers, and agricultural development agencies.

Financial service providers should focus on designing user-friendly digital financial applications that provide clear economic benefits for farmers. Transparent pricing structures, simplified transaction processes, and localized language interfaces can improve adoption rates.

Government agencies should invest in rural digital infrastructure, improve internet connectivity, and promote digital financial literacy programs to enhance technology adoption capacity among farmers.

Agricultural extension services should integrate financial literacy programs with sustainable agriculture training to encourage adoption of environmentally responsible farming practices.

Digital financial platforms can incorporate agricultural advisory services that provide information regarding sustainable farming techniques, weather forecasts, and market price trends.

THEORETICAL CONTRIBUTION

This study makes several important theoretical contributions to the literature on Financial Technology (FinTech), financial inclusion, and sustainable agricultural development by extending the Technology Acceptance Model (TAM) to incorporate developmental outcomes relevant to emerging economies.

Extension of Technology Acceptance Model (TAM)

The first major contribution of this study lies in extending the traditional Technology Acceptance Model beyond its original focus on behavioural intention and technology usage. Existing TAM-based research primarily examines users' acceptance of technology in organizational or consumer contexts, with limited attention to broader socio-economic outcomes. This study advances TAM theory by demonstrating that technology adoption produces measurable developmental impacts, particularly in financially constrained rural environments.

By incorporating financial inclusion and sustainable agricultural practices as outcome constructs, this research provides empirical evidence that technology adoption not only influences behavioural intention but also contributes to improving economic accessibility and environmental sustainability. This expanded framework strengthens the explanatory power of TAM in development-oriented contexts and demonstrates its applicability beyond technology usage behaviour.

The study therefore contributes to theoretical advancement by positioning FinTech adoption as a catalyst for inclusive development rather than merely a behavioural phenomenon.

Integration of Financial Inclusion Theory with Technology Adoption Theory

The second theoretical contribution is the integration of financial inclusion theory with technology adoption theory. Previous research has largely examined financial inclusion as an independent policy objective without adequately linking it to behavioural models of technology adoption. This study bridges this gap by conceptualizing financial inclusion as an outcome of digital financial adoption behaviour.

The empirical results demonstrate that FinTech adoption significantly improves financial inclusion by reducing structural barriers such as geographical distance, documentation complexity, and transaction costs. This finding contributes to literature by establishing digital financial technology as an important institutional mechanism that improves accessibility to financial resources for marginalized populations.

The study therefore extends financial inclusion theory by identifying technology adoption behaviour as an important determinant of financial accessibility in rural economic environments.

Linking Digital Finance with Sustainability Transition Theory

The third contribution of this research is the integration of sustainability transition theory with digital financial innovation literature. Sustainable agricultural practices often require investment in environmentally responsible technologies, improved resource management techniques, and climate-resilient farming methods. However, limited financial capacity frequently prevents smallholder farmers from adopting sustainable agricultural innovations.

By empirically demonstrating that financial inclusion significantly improves adoption of sustainable agricultural practices, this study provides theoretical evidence that financial accessibility acts as a critical enabler of sustainability transition. The results indicate that digital financial technologies indirectly contribute to environmental sustainability by strengthening farmers' investment capacity and reducing financial risk.

This finding contributes to sustainability literature by highlighting the role of digital financial infrastructure in facilitating environmentally responsible production systems.

Identification of Financial Inclusion as a Mediating Mechanism

Another significant theoretical contribution of this study is the identification of financial inclusion as a mediating mechanism linking FinTech adoption with sustainable agricultural practices. While prior studies have examined direct relationships between technology adoption and economic outcomes, limited empirical evidence exists regarding the mechanisms through which digital financial technologies influence sustainability performance.

The mediation results confirm that financial inclusion explains a substantial portion of the relationship between FinTech adoption and sustainable agricultural practices. This finding provides theoretical support for the argument that financial accessibility acts as a transmission channel through which digital innovation contributes to sustainable development outcomes.

The identification of financial inclusion as a mediating variable enhances understanding of how technological innovations generate long-term socio-economic benefits beyond immediate efficiency improvements.

Contextual Contribution to Emerging Economy Literature

This study contributes to literature by providing empirical evidence from smallholder farmers in South Tamil Nadu, a context characterized by limited rural banking infrastructure, moderate digital literacy, and increasing smartphone penetration. Most previous studies on FinTech adoption have focused on urban consumers or developed economies, limiting generalizability to rural agricultural environments.

By examining technology adoption behaviour within financially constrained farming communities, this research improves contextual understanding of digital financial inclusion challenges in emerging economies. The findings demonstrate that technology adoption models must consider institutional support mechanisms and financial accessibility constraints when applied to rural populations.

This contextual contribution enhances the external validity of TAM by demonstrating its applicability in agricultural and rural development research settings.

Contribution to Digital Development Literature

The study contributes to digital development literature by demonstrating that digital financial technologies support inclusive economic development and sustainable production systems simultaneously. The integrated framework developed in this research highlights the interconnected nature of technological innovation, financial accessibility, and environmental sustainability.

The findings provide theoretical evidence that digital transformation strategies can simultaneously address financial exclusion and environmental challenges when supported by appropriate institutional frameworks.

This contribution strengthens interdisciplinary research linking information systems, development economics, and sustainability studies.

PRACTICAL IMPLICATIONS

The findings of this study provide important practical insights for policymakers, financial institutions, FinTech service providers, agricultural extension agencies, and rural development organizations aiming to improve financial inclusion and promote sustainable agricultural practices among smallholder farmers.

Implications for Policymakers

The results highlight the importance of institutional support in promoting digital financial adoption among rural populations. Government agencies should prioritize the development of rural digital infrastructure, including reliable internet connectivity, mobile network expansion, and digital service accessibility in remote agricultural regions. Improving digital infrastructure reduces technological barriers and enhances farmers' confidence in using FinTech platforms.

Public policy initiatives should focus on promoting financial literacy programs that educate farmers about digital financial services, online transactions, mobile banking applications, and cybersecurity awareness. Training

programs conducted through agricultural extension centres, rural banks, and farmer cooperatives can improve awareness and reduce hesitation associated with digital technology adoption.

Government subsidy programs and incentive schemes can further encourage adoption of digital payment systems, crop insurance platforms, and mobile-based credit facilities. Integration of FinTech initiatives with national financial inclusion schemes can enhance accessibility of formal financial services for smallholder farmers.

Implications for Financial Institutions

Banks and microfinance institutions can utilize FinTech platforms to expand financial services to rural customers at lower operational cost. Digital lending platforms reduce administrative costs associated with physical branch operations and enable faster credit evaluation using alternative data sources such as mobile transaction history.

Financial institutions should design customized digital financial products suitable for agricultural income cycles. Flexible repayment structures aligned with seasonal income patterns can improve loan repayment capacity and reduce default risk.

Financial institutions can also collaborate with FinTech companies to develop simplified onboarding procedures requiring minimal documentation, enabling easier access to savings accounts, insurance services, and credit facilities for farmers with limited formal records.

Improved accessibility to digital financial services can enhance financial stability and improve investment capacity for sustainable agricultural technologies.

Implications for FinTech Service Providers

FinTech developers should design user-friendly applications that accommodate varying levels of digital literacy among farmers. Interfaces should include simple navigation structures, local language support, voice-assisted instructions, and minimal technical complexity.

Trust is an important determinant of technology adoption; therefore, FinTech companies should emphasize security features such as data encryption, transaction verification alerts, and transparent fee structures. Providing clear information regarding privacy protection and grievance redressal mechanisms can enhance user confidence.

FinTech platforms can incorporate integrated services such as agricultural advisory support, weather forecasting information, crop price updates, and market access platforms. Combining financial services with agricultural information systems can improve farmers' decision-making capability and enhance productivity.

Implications for Agricultural Extension Agencies

Agricultural extension agencies play an important role in facilitating awareness of both digital financial services and sustainable agricultural practices. Extension officers can provide training programs that demonstrate how digital financial tools can support investment in environmentally sustainable farming technologies.

Training workshops can focus on demonstrating practical applications of FinTech in agriculture, including digital payments for farm inputs, mobile-based crop insurance, and online agricultural marketplaces.

Integrating digital financial education with agricultural sustainability training can encourage farmers to adopt resource-efficient irrigation methods, organic fertilizers, soil conservation practices, and crop diversification strategies.

Extension services can act as intermediaries connecting farmers with financial institutions and digital financial service providers.

Implications for Sustainable Agricultural Development Programs

Organizations involved in sustainable agriculture initiatives can incorporate digital financial inclusion strategies to improve adoption of environmentally responsible farming practices. Financial accessibility enables farmers to invest in technologies that improve water efficiency, soil fertility, and crop productivity while reducing environmental degradation.

Digital financial tools can also facilitate participation in sustainable supply chains that offer premium prices for environmentally responsible agricultural products.

Development programs focusing on climate-resilient agriculture can integrate mobile-based financial risk management tools such as weather-index insurance to reduce vulnerability to climate variability.

Integrating financial inclusion strategies with sustainability initiatives enhances long-term agricultural productivity and environmental protection.

Implications for Rural Economic Development

Improved financial inclusion contributes to broader rural economic development by enabling farmers to participate in formal financial systems and expand income-generating opportunities. Access to digital financial services improves capital allocation efficiency and encourages investment in productivity-enhancing agricultural technologies.

Digital financial ecosystems also support rural entrepreneurship by enabling small-scale agricultural enterprises to access financing, manage payments, and expand market participation.

Strengthening digital financial inclusion contributes to reducing rural poverty, improving livelihood stability, and promoting inclusive economic growth.

POLICY IMPLICATIONS

The findings of this study provide several important policy implications for governments, regulatory authorities, and development agencies aiming to promote financial inclusion and sustainable agricultural development through digital financial technologies. The empirical evidence demonstrates that FinTech adoption significantly enhances financial accessibility and encourages adoption of environmentally sustainable agricultural practices among smallholder farmers. Therefore, integrated policy interventions are necessary to strengthen digital financial ecosystems and improve agricultural sustainability outcomes.

Strengthening Rural Digital Infrastructure

Reliable digital infrastructure is essential for improving accessibility and usability of FinTech services in rural areas. Policymakers should prioritize investments in mobile network expansion, internet connectivity, and digital payment infrastructure in agricultural regions. Many rural farmers face technological barriers due to weak connectivity and limited digital service availability, which restricts adoption of mobile banking and digital payment platforms.

Government-supported digital infrastructure initiatives can improve accessibility to online financial services, enabling farmers to perform financial transactions without travelling long distances to physical bank branches. Improved connectivity also facilitates access to agricultural advisory services, weather forecasting tools, and digital marketplaces that support sustainable farming decisions.

Investment in rural digital infrastructure contributes to reducing regional disparities in financial service accessibility and promotes inclusive digital economic development.

Promoting Financial Literacy and Digital Skills Development

Financial literacy and digital capability are critical factors influencing FinTech adoption behaviour among rural populations. Policymakers should design training programs that improve farmers' understanding of mobile banking, digital payments, online credit applications, and digital financial risk management.

Government agencies can collaborate with agricultural extension offices, rural banks, self-help groups, and cooperative societies to conduct awareness programs and skill development workshops. Training initiatives should focus on improving confidence in digital platforms, understanding transaction processes, and addressing cybersecurity concerns.

Improved digital literacy enhances farmers' ability to utilize financial technologies effectively and reduces resistance toward technology adoption.

Integrating FinTech with Agricultural Development Policies

Agricultural policy frameworks should incorporate digital financial inclusion strategies to improve access to financial resources required for sustainable agricultural investments. Subsidy programs supporting climate-resilient technologies such as drip irrigation systems, solar-powered irrigation pumps, and organic fertilizers can be integrated with digital payment platforms to improve transparency and reduce administrative costs.

Digital financial platforms can be used to distribute agricultural subsidies directly to farmers' accounts, reducing delays and leakages in financial assistance programs. Linking agricultural support schemes with digital financial services improves efficiency and accountability in policy implementation.

Integration of FinTech with agricultural development initiatives enhances adoption of environmentally sustainable farming practices and improves productivity outcomes.

Encouraging Public–Private Partnerships in FinTech Development

Collaboration between government institutions, financial service providers, and FinTech companies can accelerate development of inclusive digital financial ecosystems. Public–private partnerships can support development of customized financial products designed specifically for agricultural users.

Financial products such as microcredit, crop insurance, and savings instruments can be tailored to match seasonal income patterns and production risks associated with farming activities. Regulatory support can encourage innovation in digital lending models that utilize alternative credit scoring mechanisms based on transaction data.

Collaborative partnerships improve service delivery efficiency and expand financial service availability in underserved rural regions.

Supporting Digital Risk Management Tools for Climate-Resilient Agriculture

Agricultural production is highly vulnerable to climate variability, which increases financial uncertainty for smallholder farmers. Policymakers should encourage development and adoption of digital insurance platforms that provide protection against weather-related risks, crop failures, and price volatility.

Weather-index insurance delivered through mobile platforms can reduce production risks and encourage farmers to adopt innovative agricultural technologies. Risk management tools improve resilience to climate change and enhance long-term agricultural sustainability.

Policy initiatives supporting digital insurance adoption can reduce financial vulnerability among farmers and improve stability of rural income systems.

Enhancing Institutional Trust in Digital Financial Systems

Trust in digital financial systems is an important factor influencing adoption behaviour. Policymakers should strengthen regulatory frameworks that ensure transparency, consumer protection, and cybersecurity in digital financial transactions.

Clear grievance redressal mechanisms and consumer protection policies can improve confidence in digital financial services. Establishing standardized regulations for digital financial service providers ensures reliability and reduces perceived risks associated with technology adoption.

Institutional trust enhances participation in formal financial systems and supports long-term digital financial inclusion.

Promoting Inclusive Digital Financial Ecosystems

Inclusive policy frameworks should ensure that digital financial services are accessible to marginalized farmer groups including small-scale farmers, women farmers, and farmers located in remote regions. Affordable transaction costs, simplified account opening procedures, and accessible digital interfaces can improve financial participation.

Inclusive financial policies contribute to reducing income inequality and improving economic resilience in rural communities.

Developing inclusive digital financial ecosystems supports achievement of Sustainable Development Goals related to poverty reduction, food security, and environmental sustainability.

CONCLUSION

This study examined the impact of Financial Technology (FinTech) adoption on financial inclusion and sustainable agricultural practices among smallholder farmers by extending the Technology Acceptance Model (TAM). The findings provide empirical evidence that digital financial technologies significantly improve accessibility to financial services and promote environmentally sustainable agricultural behaviour in rural contexts.

The results indicate that perceived usefulness, perceived ease of use, perceived trust, and perceived government support play important roles in influencing farmers' intention to adopt FinTech services. Among these determinants, perceived usefulness emerged as the most influential factor, suggesting that farmers are more likely

to adopt digital financial technologies when they perceive clear economic benefits such as improved access to credit, reduced transaction costs, and better financial management capability.

The structural model demonstrates that FinTech adoption significantly enhances financial inclusion, enabling farmers to access formal credit facilities, digital payment systems, savings instruments, and insurance services. Improved financial accessibility strengthens farmers' investment capacity and reduces financial vulnerability associated with agricultural production risks.

Financial inclusion was found to significantly influence sustainable agricultural practices, indicating that access to financial resources enables adoption of environmentally responsible farming methods such as efficient irrigation systems, organic fertilizers, crop diversification, and soil conservation techniques. These practices contribute to long-term agricultural productivity while minimizing environmental degradation.

The mediation analysis confirms that financial inclusion partially mediates the relationship between FinTech adoption and sustainable agricultural practices, demonstrating that digital financial accessibility acts as an important mechanism linking technological innovation with sustainability outcomes. The presence of both direct and indirect effects indicates that FinTech adoption supports sustainability not only through financial access but also through improved information availability, digital advisory services, and enhanced market participation.

The study contributes to literature by extending TAM beyond behavioural intention to include developmental outcomes such as financial inclusion and sustainability performance. The integrated framework developed in this research highlights the interconnected relationship between digital financial innovation, economic accessibility, and environmental sustainability.

From a practical perspective, the findings highlight the importance of strengthening rural digital infrastructure, improving financial literacy, and promoting institutional support mechanisms to enhance FinTech adoption among smallholder farmers. Policymakers and financial institutions should focus on designing inclusive digital financial systems that support agricultural sustainability and rural economic development.

Overall, the findings demonstrate that FinTech adoption represents a strategic tool for promoting inclusive economic growth and environmentally sustainable agricultural transformation in emerging economies. Strengthening digital financial ecosystems can contribute to achieving sustainable development objectives related to poverty reduction, food security, and climate resilience.

LIMITATIONS OF THE STUDY

Despite providing important theoretical and practical insights, this study has several limitations that should be considered when interpreting the findings.

First, the study adopted a cross-sectional research design, which captures data at a single point in time. While Structural Equation Modelling enables examination of relationships among variables, cross-sectional data limits the ability to establish causal relationships and observe behavioural changes over time. FinTech adoption behaviour and sustainable agricultural practices may evolve gradually as farmers gain experience with digital financial platforms. Future research may adopt longitudinal research designs to examine changes in adoption behaviour and sustainability outcomes over extended periods.

Second, the study focuses on smallholder farmers from selected districts in South Tamil Nadu. Although the sample represents diverse agricultural contexts, the findings may not fully generalize to all regions with different socio-economic, cultural, and technological conditions. Differences in digital infrastructure availability, literacy levels, and agricultural practices across regions may influence FinTech adoption behaviour. Future studies may extend the research framework to multiple states or countries to improve generalizability of findings.

Third, the study relies on self-reported data collected through structured questionnaires. Self-reported responses may be subject to response bias, including social desirability bias or recall bias. Respondents may overestimate or underestimate their usage of financial technologies or adoption of sustainable agricultural practices. Future research may incorporate objective measures such as digital transaction records or farm-level sustainability indicators to improve measurement accuracy.

Fourth, the study examines a limited set of determinants influencing FinTech adoption, including perceived usefulness, perceived ease of use, trust, and government support. Other potential influencing factors such as digital literacy, perceived risk, technological readiness, social influence, and cultural factors were not included in the present model. Future studies may incorporate additional variables to improve explanatory power of the model.

Fifth, the measurement of sustainable agricultural practices is based on selected indicators such as irrigation efficiency, organic fertilizer usage, and crop diversification. Sustainability is a multidimensional concept that includes environmental, social, and economic dimensions. Future research may incorporate broader sustainability indicators such as carbon emission reduction, biodiversity conservation, and long-term soil productivity to provide a more comprehensive assessment of sustainability outcomes.

Finally, the study focuses on financial inclusion as a mediating variable linking FinTech adoption with sustainable agricultural practices. Other potential mediating mechanisms such as knowledge accessibility, technological awareness, and market participation were not examined in the present study. Future research may explore multiple mediators to provide deeper understanding of mechanisms linking digital financial innovation with sustainability outcomes.

Despite these limitations, the study provides a robust empirical framework that contributes to understanding the role of FinTech adoption in improving financial inclusion and promoting sustainable agricultural practices.

FUTURE RESEARCH DIRECTIONS

The present study provides a foundation for future research examining the relationship between FinTech adoption, financial inclusion, and sustainable agricultural practices. Several potential research directions may further enhance understanding of digital financial technologies in agricultural development contexts.

First, future studies may adopt longitudinal research designs to analyse behavioural changes in FinTech adoption and sustainability practices over time. Digital financial adoption is a dynamic process influenced by technological experience, policy developments, and infrastructure improvements. Longitudinal studies can provide deeper insights into how continued exposure to digital financial platforms influences financial decision-making behaviour and sustainability transitions among farmers.

Second, future research may extend the geographical scope of the study to include multiple states or cross-country comparisons. Differences in institutional frameworks, digital infrastructure, financial literacy levels, and agricultural practices may influence adoption behaviour. Comparative studies across regions can improve generalizability of findings and provide insights into contextual factors influencing digital financial inclusion.

Third, future research may incorporate additional variables to improve explanatory capability of the extended Technology Acceptance Model. Constructs such as digital literacy, perceived risk, technological readiness, social influence, compatibility, and perceived cost may provide a more comprehensive understanding of FinTech adoption behaviour. Inclusion of moderating variables such as age, gender, education level, and farm size may also provide deeper insights into heterogeneous adoption patterns.

Fourth, future research may explore additional mediating mechanisms linking FinTech adoption with sustainability outcomes. Variables such as knowledge accessibility, information transparency, market integration, innovation capability, and access to extension services may influence adoption of sustainable agricultural practices. Examining multiple mediators can provide a more comprehensive explanation of pathways linking digital financial technologies with sustainability outcomes.

Fifth, future studies may investigate the role of emerging technologies such as blockchain-based agricultural finance, artificial intelligence-driven credit assessment, Internet of Things (IoT)-enabled precision farming finance, and digital supply chain traceability systems. These technologies may further enhance transparency, efficiency, and sustainability within agricultural production systems.

Sixth, future research may employ mixed-method approaches combining quantitative and qualitative techniques to capture deeper insights into farmers' perceptions and behavioural motivations. Qualitative interviews and case studies may provide contextual understanding of barriers and facilitators influencing digital financial adoption.

Seventh, future studies may develop multidimensional sustainability indices incorporating environmental, economic, and social indicators to provide a more comprehensive evaluation of sustainability performance. Integration of environmental impact measures such as soil health improvement, water conservation efficiency, and carbon emission reduction may improve measurement accuracy of sustainability outcomes.

Finally, future research may examine policy effectiveness in promoting digital financial inclusion and sustainable agriculture by analysing impact of government programs, digital subsidy mechanisms, and institutional interventions. Evaluating policy outcomes can provide evidence-based recommendations for improving digital financial ecosystems in rural economies.

These research directions provide opportunities to further advance theoretical and empirical understanding of digital financial technologies as instruments for inclusive and sustainable agricultural development.

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