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Digital Literacy and Innovation Diffusion in Agricultural Startups Across South Asia

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Abstract

Agricultural entrepreneurship in South Asia faces a defining technological transformation, with digital platforms, precision agriculture technologies, and agri-fintech solutions offering significant productivity and market access improvements while simultaneously creating adoption challenges rooted in digital literacy gaps, resource constraints, and institutional barriers. Grounded in Rogers' (2003) Diffusion of Innovation (DOI) Theory and the Unified Theory of Acceptance and Use of Technology (UTAUT2), this study investigates how perceived innovativeness attributes—relative advantage, compatibility, complexity, trialability, and observability—alongside digital literacy (DL) and institutional support (IS) influence technology adoption (TA) and subsequently agripreneur performance (AP). A two-stage sequential mediation model is tested using PLS-SEM (SmartPLS 4.0) on a sample of 612 agricultural entrepreneurs across India, Bangladesh, and Sri Lanka. Results confirm that relative advantage ($\beta = 0.312$, $p < .001$) and compatibility ($\beta = 0.267$, $p < .001$) are the strongest DOI predictors of technology adoption, while complexity negatively predicts adoption ($\beta = -0.198$, $p < .001$). Digital literacy significantly moderates the complexity–TA relationship ($\beta_{interaction} = 0.176$, $p < .01$), attenuating complexity's negative adoption effect among digitally literate agripreneurs. Technology adoption fully mediates the relative advantage–AP relationship (indirect effect = 0.218, 95% CI [0.163, 0.278]) and partially mediates the compatibility–AP relationship. These findings extend DOI Theory to agricultural entrepreneurship contexts and provide actionable guidance for agri-extension services, digital literacy programs, and agricultural startup support ecosystems in South Asia.

Keywords: agricultural entrepreneurship, technology adoption, diffusion of innovation, digital literacy, PLS-SEM, agripreneur performance, South Asia

1. Introduction

The agricultural sector across South Asia employs approximately 44% of the regional workforce and remains the primary livelihood source for over 600 million rural

inhabitants across India, Bangladesh, and Sri Lanka—yet it is simultaneously characterized by persistent productivity gaps, fragmented value chains, limited market access, and institutional barriers that collectively constrain agricultural entrepreneurs' capacity to generate sustainable livelihoods and contribute to national food security (FAO, 2023; World Bank, 2024). Digital agricultural technologies—encompassing precision farming sensors, mobile-based market information systems, agri-fintech platforms, drone-enabled crop monitoring, and AI-powered advisory services—offer transformative potential for addressing many of these structural challenges, but their adoption rates among smallholder agricultural entrepreneurs remain disappointingly low despite their technological availability and demonstrated productivity benefits (CGIAR, 2022; GSMA, 2023).

This adoption gap raises a fundamental research question: what cognitive, behavioral, and contextual factors determine whether agricultural entrepreneurs in South Asia adopt available digital technologies, and through what mechanisms does adoption translate into improved entrepreneurial performance? Rogers' (2003) Diffusion of Innovation (DOI) Theory, the most influential and extensively validated framework for analyzing technology adoption decisions, provides a comprehensive account of the innovation attributes—perceived relative advantage, compatibility with existing values and practices, complexity, trialability, and observability—that shape individual adoption decisions. Yet DOI Theory's original agricultural extension context, developed primarily through study of North American and European adoption patterns, requires contextual adaptation to adequately account for the digital literacy constraints, institutional barriers, and resource limitations that characterize South Asian agripreneur adoption environments.

The integration of digital literacy as a moderating boundary condition is theoretically motivated by the recognition that complexity—one of DOI Theory's five innovation attributes and typically a negative adoption predictor—may be differentially salient depending on the individual's digital skill level. For digitally literate agricultural entrepreneurs, the complexity of digital platforms may be a manageable challenge overcome through existing technological competencies, while for digitally illiterate entrepreneurs, the same complexity may constitute an insurmountable adoption barrier. This interaction has not been formally tested in a South Asian agricultural entrepreneurship context.

This study contributes to DOI Theory by: (1) providing cross-national validation of DOI innovation attributes in South Asian agripreneur contexts; (2) introducing digital literacy as a formal moderator of the complexity–adoption relationship; and (3) examining technology adoption as a full or partial mediator of the DOI attribute–performance relationship—thereby connecting DOI Theory's adoption model to the entrepreneurship performance literature.

2. Literature Review

2.1 Diffusion of Innovation Theory: Agricultural Applications

Rogers' (1962, 2003) Diffusion of Innovation Theory, developed originally through analysis of hybrid seed adoption among Iowa farmers in the 1940s and subsequently elaborated through decades of agricultural extension research, identifies five innovation characteristics that predict adoption speed and breadth: relative advantage (perceived superiority over prior practice), compatibility (consistency with existing values, practices, and needs), complexity (perceived difficulty of understanding and use), trialability (possibility of limited experimentation before full commitment), and observability (visibility of innovation results to others).

Agricultural technology adoption research has extensively validated DOI Theory's predictive power across diverse commodity systems, geographic contexts, and technology types—from irrigation technology and improved seed varieties (Mwangi & Kariuki, 2015) to mobile banking and digital market platforms (Aker, 2011) and precision agriculture sensors (Pivoto et al., 2019). Meta-analyses by Genius et al. (2014) and more recently by Belay and Mengiste (2021) confirm that relative advantage and compatibility are the most consistently positive adoption predictors, while complexity is the most consistently negative predictor, across the agricultural DOI literature.

In South Asian contexts specifically, DOI adoption research has been complemented by UTAUT-based analyses (Venkatesh et al., 2012) that incorporate social influence, facilitating conditions, and hedonic motivation as additional predictors—reflecting the social embeddedness of agricultural technology decisions in family farming systems where peer networks, community norms, and village-level demonstration effects play significant adoption-shaping roles.

2.2 Digital Literacy and Agricultural Technology Adoption

Digital literacy—defined as the ability to find, evaluate, create, and communicate information using digital technologies (ALA, 2013)—has emerged as a critical moderating condition in agricultural technology adoption research as digital platforms have increasingly replaced the analog technologies (radio, physical extension services, print media) that previously dominated agricultural information dissemination. Aker and Mbiti (2010) demonstrated that mobile phone ownership and basic digital literacy were strong predictors of market information utilization in African agricultural contexts. More recently, Zhu et al. (2021) found that digital literacy significantly moderated the adoption-intention relationship for precision agriculture technologies among Chinese smallholders.

In South Asian agricultural contexts, digital literacy distribution is highly heterogeneous—varying significantly across gender (women farmers exhibit lower digital literacy on average), age (younger farmers are substantially more digitally literate), educational attainment, and geography (rural-urban literacy gradients remain substantial). This heterogeneity creates a theoretically important moderating landscape: DOI adoption predictions should hold differentially for high vs. low digital literacy agripreneurs, with complexity's negative adoption effect being particularly susceptible to digital literacy moderation.

2.3 Institutional Support for Agricultural Technology Adoption

Institutional support for agricultural technology adoption encompasses government extension services, agricultural research institute technology demonstration programs, agri-fintech startup support initiatives, rural development bank technology credit products, and NGO-facilitated digital literacy programs. In South Asia, these institutional support systems are highly variable in quality and reach—with formal government extension services often under-resourced and over-stretched relative to the scale of their mandated client populations (Swanson & Rajalahti, 2010).

The role of institutional support as an enabling condition for technology adoption aligns with DOI Theory's emphasis on the change agent and communication channel dimensions of diffusion, which posit that adoption rates are significantly influenced by the quality and intensity of institutional promotion and support efforts. More recent UTAUT2 research (Venkatesh et al., 2012) positions facilitating conditions—including institutional infrastructure—as a direct adoption predictor and potential moderator of other adoption antecedents.

2.4 Technology Adoption and Entrepreneurial Performance

The relationship between technology adoption and entrepreneurial performance in agricultural contexts has been investigated primarily through productivity impact studies (Suri, 2011; Aker, 2011), which have consistently documented positive adoption–productivity relationships while acknowledging significant heterogeneity attributable to soil conditions, crop variety, irrigation access, and market connectivity. More recent research has examined technology adoption's effect on market access—the ability of smallholder farmers to obtain competitive prices for their produce—as a critical performance channel in fragmented agricultural value chains (Muto & Yamano, 2009).

For agricultural entrepreneurs specifically—defined as smallholder farmers who exhibit an entrepreneurial orientation in terms of proactive market engagement, innovation adoption, and risk-taking in production decisions (Boehlje et al., 2011)—technology adoption's performance effects may operate through multiple pathways: direct productivity enhancement through precision input application; market access improvement through digital platform participation; financial management improvement through agri-fintech adoption; and supply chain integration enhancement through traceability and quality certification technologies.

3. Research Gap

While DOI Theory has been extensively validated in agricultural technology adoption contexts, three gaps remain. First, digital literacy has not been formally modeled as a moderator of DOI innovation attribute–adoption relationships in South Asian agripreneur settings. Second, technology adoption has rarely been examined as a mediating mechanism connecting DOI innovation perceptions to entrepreneurial performance outcomes—most DOI studies treat adoption as the ultimate outcome rather than a performance pathway. Third, multi-country South Asian comparative studies examining DOI adoption dynamics across the region's institutional and digital literacy diversity are absent from the literature. This study addresses all three gaps.

4. Research Objectives

1. To validate DOI Theory innovation attribute effects on technology adoption among agricultural entrepreneurs in India, Bangladesh, and Sri Lanka.
2. To examine digital literacy as a moderator of the complexity–technology adoption relationship.
3. To investigate technology adoption as a mediator of DOI innovation attribute–agripreneur performance relationships.
4. To provide guidance for extension service design, digital literacy programs, and agritech startup support ecosystems.

5. Hypotheses Development

H1a–e: DOI innovation attributes (relative advantage, compatibility, complexity [negative], trialability, observability) predict technology adoption.

H2: Digital literacy negatively moderates the complexity–TA relationship, attenuating complexity's negative adoption effect.

H3: Technology adoption mediates the relative advantage–AP relationship.

H4: Technology adoption mediates the compatibility–AP relationship.

H5: Institutional support positively moderates the trialability–TA relationship.

6. Research Methodology

6.1 Sample and Data Collection

Stratified random sampling was employed to select 612 agricultural entrepreneurs across three countries: India (n = 218, Haryana and Karnataka states), Bangladesh (n = 198, Rajshahi and Chittagong divisions), and Sri Lanka (n = 196, Central and North-Western provinces). Eligibility criteria required respondents to be active agricultural entrepreneurs with cultivated land of 0.5–10 hectares and at least partial market orientation (>40% of production sold commercially). Face-to-face surveys with bilingual enumerators were administered.

6.2 Measures

DOI innovation attributes were measured using adapted versions of Moore and Benbasat's (1991) innovation diffusion instrument, contextualized to agricultural digital technology applications (20 items total). Digital literacy was assessed using a 10-item scale combining Eshet-Alkalai's (2004) digital literacy framework dimensions with agriculture-specific digital skill items. Institutional support was measured using a 12-item scale covering extension service quality, training access, credit availability, and network facilitation. Technology adoption was operationalized as a composite of adoption breadth (number of digital technology types adopted), adoption depth (intensity of use), and adoption recency. Agripreneur performance was assessed through a 14-item scale covering productivity improvement, income growth, market access enhancement, and supply chain integration. All scales used seven-point Likert formats.

6.3 Analytical Approach

PLS-SEM (SmartPLS 4.0) was employed for all structural model estimation. Two-stage assessment protocol followed Hair et al. (2022): (1) reflective measurement model assessment (CFA, reliability, validity); (2) structural model estimation with bootstrapped mediation and moderation tests. Moderation was tested using orthogonalized product-indicator interaction terms.

7. Data Analysis and Findings

7.1 Sample Profile

Table 1 *Sample Profile: Agricultural Entrepreneurs (N = 612)*

Characteristic	Category	N	%
Country	India	218	35.6
	Bangladesh	198	32.4
	Sri Lanka	196	32.0
Gender	Male	467	76.3
	Female	145	23.7
Education	Primary	198	32.4
	Secondary	264	43.1
	Tertiary	150	24.5
Farm Size	0.5–2 ha	287	46.9
	2.1–5 ha	213	34.8
	5.1–10 ha	112	18.3
Crop Type	Cereals	198	32.4
	Vegetables/Fruits	187	30.6
	Cash Crops	143	23.4
	Mixed	84	13.7
Smartphone Ownership	Yes	489	79.9
	No	123	20.1
Digital Literacy Level	Low	187	30.6
	Medium	241	39.4
	High	184	30.1

7.2 Measurement Model

Table 2 *Reliability and Validity of Constructs*

Construct	Items	α	CR	AVE	Loading Range
Relative Advantage	4	0.871	0.901	0.696	0.791–0.869
Compatibility	4	0.858	0.891	0.672	0.771–0.851
Complexity	4	0.841	0.878	0.643	0.748–0.831
Trialability	4	0.829	0.871	0.631	0.731–0.819
Observability	4	0.836	0.876	0.638	0.741–

Construct	Items	α	CR	AVE	Loading Range
					0.828
Digital Literacy	10	0.912	0.928	0.641	0.703–0.859
Institutional Support	12	0.921	0.934	0.618	0.681–0.847
Technology Adoption	8	0.904	0.922	0.632	0.694–0.852
Agripreneur Performance	14	0.938	0.948	0.621	0.679–0.864

7.3 Structural Model and Hypothesis Testing

Table 3 *PLS-SEM Path Coefficients: Technology Adoption Model*

Hypothesis	Path	β	SE	t	p	Decision
H1a	Rel. Advantage → TA	0.312	0.054	5.778	<.001	Supported
H1b	Compatibility → TA	0.267	0.057	4.684	<.001	Supported
H1c	Complexity → TA	−0.198	0.049	4.041	<.001	Supported
H1d	Trialability → TA	0.143	0.052	2.750	.006	Supported
H1e	Observability → TA	0.112	0.051	2.196	.028	Supported
H2	Complexity × DL → TA	0.176	0.063	2.794	.005	Supported
H5	Trialability × IS → TA	0.134	0.058	2.310	.021	Supported
—	TA → AP	0.487	0.052	9.365	<.001	—

Note. R^2(TA) = 0.521; R^2(AP) = 0.463. DL = Digital Literacy; IS = Institutional Support.

7.4 Mediation Analysis

Table 4 *Mediation Analysis: TA as Mediator of DOI Attributes → AP*

Pathway	Indirect Effect	95% CI	Direct Effect	Mediation Type
Rel. Adv. → TA → AP	0.218	[0.163, 0.278]	0.021 (ns)	Full
Compat. → TA → AP	0.189	[0.138, 0.247]	0.098**	Partial
Complexity → TA → AP	−0.141	[−0.191, −0.094]	−0.054 (ns)	Full
Trialability → TA → AP	0.101	[0.058, 0.149]	0.034 (ns)	Full
Observability → TA →	0.079	[0.032,	0.041	Full

Pathway	Indirect Effect	95% CI	Direct Effect	Mediation Type
AP		0.129]	(ns)	

Note. Full mediation (TA → AP) predominates, with compatibility showing partial mediation. All indirect effects significant (CIs exclude zero).

7.5 Moderation: Digital Literacy × Complexity Interaction

Table 5 *Complexity → TA at Different Digital Literacy Levels*

Digital Literacy Level	Complexity → TA (β)	95% CI
Low (−1 SD)	−0.341***	[−0.441, −0.241]
Mean	−0.198***	[−0.294, −0.102]
High (+1 SD)	−0.055 (ns)	[−0.143, 0.033]

Note. Digital literacy substantially attenuates complexity's negative adoption effect. At high DL, complexity's effect becomes non-significant, confirming the moderating hypothesis.

8. Discussion

The study's findings provide strong cross-national validation of DOI Theory in South Asian agripreneur contexts while simultaneously demonstrating the theoretically important moderating role of digital literacy. The strong technology adoption–agripreneur performance mediation (full mediation for relative advantage, compatibility, complexity, trialability, and observability) positions TA as the central performance-generating mechanism through which DOI innovation perceptions create entrepreneurial value—not merely an adoption decision endpoint. This full mediation finding implies that the performance benefits of favorable innovation perceptions are entirely channeled through actual adoption behavior, making technology adoption the critical intervention point for agripreneur performance improvement programs.

The complexity × digital literacy interaction (attenuation to non-significance at high DL levels) is practically and theoretically significant. It implies that digital literacy investment can effectively eliminate the primary adoption barrier posed by perceived complexity—transforming high-complexity innovations from adoption deterrents into neutral or positive adoption factors for digitally capable agripreneurs. This finding justifies prioritizing digital literacy programs in agricultural technology dissemination strategies as a complement to technology design improvements targeting complexity reduction.

9. Theoretical Implications

This study extends DOI Theory in three important ways. First, by demonstrating full mediation of DOI innovation attributes on performance through technology adoption, it formally integrates DOI Theory with the

entrepreneurial performance literature—connecting Rogers' adoption model to economic performance outcomes in a theoretically coherent pathway. Second, the digital literacy moderation finding advances DOI Theory by identifying a user-level boundary condition that determines the strength of the complexity–adoption relationship, contributing to the theory's contextual specification for digitally heterogeneous adoption environments. Third, the cross-national validation across India, Bangladesh, and Sri Lanka provides evidence for DOI Theory's applicability across diverse South Asian institutional contexts while highlighting country-level heterogeneity in adoption patterns attributable to differences in institutional support quality and digital infrastructure development.

10. Practical Implications

For agricultural extension services and agritech startups, the full mediation findings imply that innovation communication strategies should prioritize demonstrating relative advantage through credible pilot demonstrations, ensuring compatibility with existing farming practices through context-sensitive technology design, and reducing complexity barriers through user-friendly interface design and localized training materials. Digital literacy programs—including farmer digital skill training camps, peer digital coach networks, and agri-digital literacy apps—are justified not merely as digital inclusion initiatives but as economic performance enhancement investments that generate measurable agripreneur productivity and income improvements through their adoption-enabling effects.

11. Conclusion

This study has applied DOI Theory and PLS-SEM to examine technology adoption and agripreneur performance determinants across 612 agricultural entrepreneurs in India, Bangladesh, and Sri Lanka. Relative advantage and compatibility are the strongest positive adoption predictors; complexity is the strongest negative predictor but is significantly attenuated by digital literacy. Technology adoption fully mediates most DOI attribute–performance relationships, positioning it as the critical performance-generating mechanism. These findings extend DOI Theory to South Asian agricultural entrepreneurship contexts and provide actionable guidance for extension services, agritech innovators, and policymakers designing agricultural digital transformation programs. Future research should examine whether the technology adoption–performance relationship varies with technology type (mobile-based vs. sensor-based vs. platform-based) and whether panel data can establish the causal temporal precedence of adoption relative to performance improvement.

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