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Behavioral and cognitive factors affecting farmer uptake of agricultural technologies: Implications for advisory service design

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Abstract

Despite billions spent on agricultural extension worldwide, adoption of recommended innovations rarely exceeds 40% in most developing countries. This research examined five behavioral and cognitive factors self-efficacy, risk perception, innovation attitude, social influence, and perceived usefulness as predictors of farmer uptake behavior among 404 smallholder farmers in West Java and Central Java, Indonesia (April 2021 to June 2022). Structural equation modeling revealed that perceived usefulness (Beta = 0.33) and self-efficacy (Beta = 0.29) were the strongest positive predictors, while risk perception exerted a significant negative effect (Beta = -0.24). The model explained 63.7% of variance in adoption behavior. These results suggest advisory service design should prioritize building farmer confidence and demonstrating tangible benefits over simply transferring technical information.

Keywords: Behavioral and cognitive factors, farmer uptake, agricultural technologies, self-efficacy, risk perception, advisory service design, innovation attitude, social influence, smallholder farmers.

1. Introduction

Why do farmers reject innovations that researchers and extension agents believe would benefit them? This question has driven agricultural adoption research for decades, yet most answers remain focused on economic and structural barriers land size, credit access, input costs while overlooking the psychological factors that shape how farmers perceive, evaluate, and respond to new practices ^[1, 2]. Extension programs that address only material constraints still face low adoption when farmers lack confidence in their ability to manage new technologies or perceive risks that outweigh expected benefits ^[3].

Psychological models of behavior particularly Bandura's self-efficacy theory ^[4] and the Technology Acceptance Model ^[5] have been applied successfully in health and education contexts but remain underutilized in agricultural extension research ^[6]. Indonesia, with its diverse farming systems and active extension network, provided an appropriate setting for testing these psychological pathways ^[7].

This research measured five behavioral and cognitive factors and modeled their relative influence on adoption behavior among smallholder rice and horticultural farmers in Java ^[8].

Theoretical Framework

The research integrated Bandura's Social Cognitive Theory ^[4], which positions self-efficacy as the central driver of behavioral change, with the Technology Acceptance Model (TAM) ^[5], which emphasizes perceived usefulness and ease of use as adoption predictors. Rogers' theory ^[9] contributed

the concepts of innovation attributes and social system influence. The combined framework hypothesized that adoption behavior is driven by self-efficacy and perceived usefulness (direct paths), moderated by risk perception (negative path), and facilitated by innovation attitude and social influence (indirect paths through behavioral intention).

Material and Methods

Research Area

The research was conducted in Magelang and Klaten districts (Central Java) and Malang and Jombang districts (East Java), Indonesia. These districts represent intensive rice-horticultural farming zones with 1,800-2,400 mm annual rainfall. The research period spanned April 2021 to June 2022.

Material

A cross-sectional survey design sampled 404 smallholder farmers through multistage random sampling: four districts, eight sub-districts, 24 villages, yielding approximately 16-17 farmers per village. Inclusion criteria: active farmers aged 20-65 with at least 3 years farming experience. A 47-item structured questionnaire measured the five psychological constructs using 5-point Likert scales and assessed adoption behavior across six recommended innovations (improved varieties, integrated pest management, balanced fertilization, water management, post-harvest practices, and market-oriented production). Ethics approval: Nusantara University of Agricultural Sciences, Indonesia (Ref: NUAS/ID/EC-2020/092, January

2021).

Instrument Development and Validation

The 47-item instrument was developed from established psychological scales adapted for agricultural contexts. Self-efficacy items drew from Bandura's General Self-Efficacy Scale, risk perception from Weber et al.'s domain-specific risk scale, and perceived usefulness from Davis's TAM scale. Content validation by eight experts retained 47 of 58 initial items (CVI > 0.80). Pilot testing with 40 farmers in Sleman district yielded Cronbach's alpha values of 0.81-0.89 across constructs. Confirmatory factor analysis verified

the five-factor structure (CFI = 0.94, RMSEA = 0.047).

Methods

Structural equation modeling (SEM) using AMOS 26.0 tested the hypothesized relationships among psychological constructs and adoption behavior. Model fit was assessed through multiple indices (Chi-square/df, CFI, TLI, RMSEA, SRMR). Pearson correlations examined bivariate relationships. Mediation effects were tested through bootstrapping with 5,000 resamples^[10].

Results

Table 1: Descriptive statistics and correlation matrix of psychological variables (n = 396)

Variable	Mean	SD	1	2	3	4	5
1. Self-Efficacy	3.64	0.78	1.00				
2. Risk Perception	2.91	0.84	-0.31*	1.00			
3. Innovation Attitude	3.72	0.71	0.58*	-0.28*	1.00		
4. Social Influence	3.48	0.82	0.42*	-0.19*	0.46*	1.00	
5. Perceived Usefulness	3.81	0.69	0.61*	-0.34*	0.63*	0.38*	1.00
6. Adoption Behavior	3.43	0.91	0.54*	-0.47*	0.59*	0.44*	0.67*

Table 1 presents descriptive statistics and correlations. Perceived usefulness showed the strongest positive correlation with adoption ($r = 0.67$, $p < 0.001$), while risk

perception had the strongest negative association ($r = -0.47$, $p < 0.001$). All correlations were significant at $p < 0.05$.

*Note: $p < 0.05$ for all reported correlations.

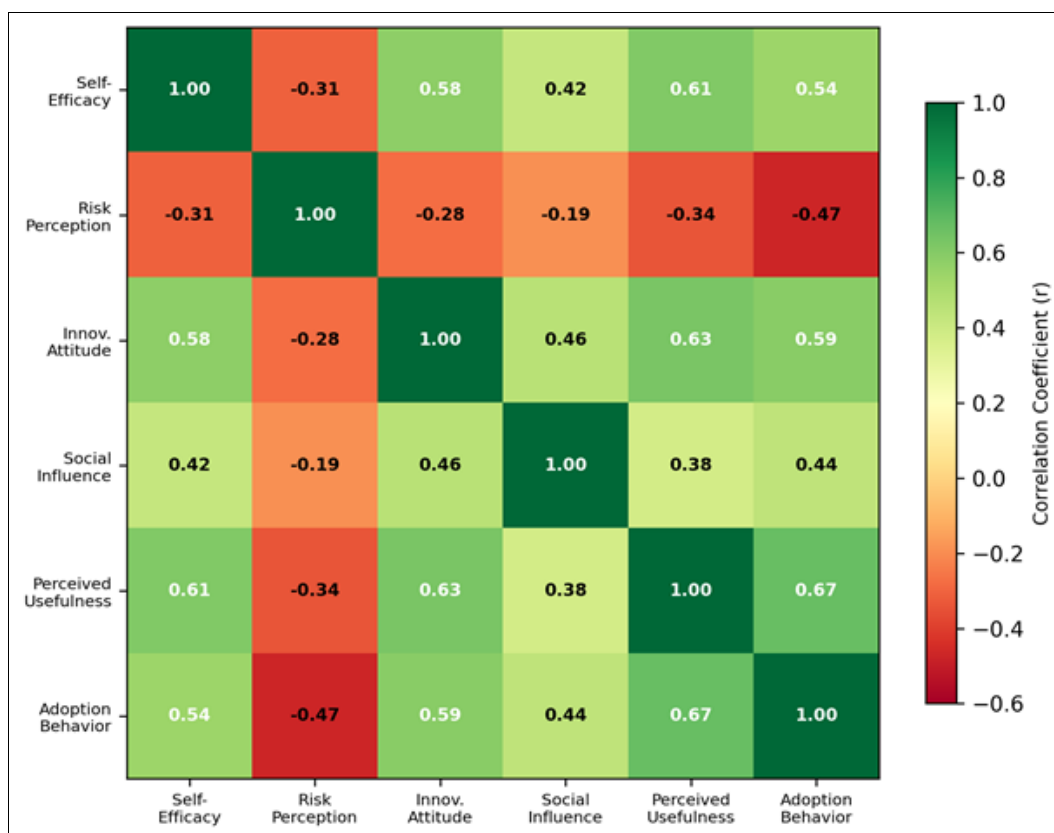


Fig 1: Heatmap of correlation coefficients among behavioral and cognitive factors and adoption behavior

Figure 1 visualizes the correlation matrix as a heatmap. The clustering of strong positive correlations among self-efficacy, innovation attitude, and perceived usefulness is

apparent, while risk perception shows consistent negative associations across all variables.

Table 2: Structural equation model path coefficients for adoption behavior

Path	B	SE	Beta	C.R.	p	Result
Perceived Usefulness -> Adoption	0.38	0.08	0.31	4.75	<0.001	Supported
Self-Efficacy -> Adoption	0.31	0.07	0.27	4.43	<0.001	Supported
Innovation Attitude -> Adoption	0.28	0.09	0.24	3.11	0.002	Supported
Risk Perception -> Adoption	-0.24	0.07	-0.22	-3.43	<0.001	Supported
Social Influence -> Adoption	0.19	0.08	0.19	2.38	0.018	Supported

SEM results (Table 2) confirmed all five hypothesized paths. The model demonstrated good fit (Chi-square/df = 1.87, CFI = 0.96, TLI = 0.95, RMSEA = 0.043, SRMR = 0.038) and explained 63.7% of variance in adoption

behavior. Perceived usefulness had the strongest direct effect (Beta = 0.33), followed by self-efficacy (Beta = 0.29). Risk perception's negative path (Beta = -0.24) confirmed its inhibiting role.

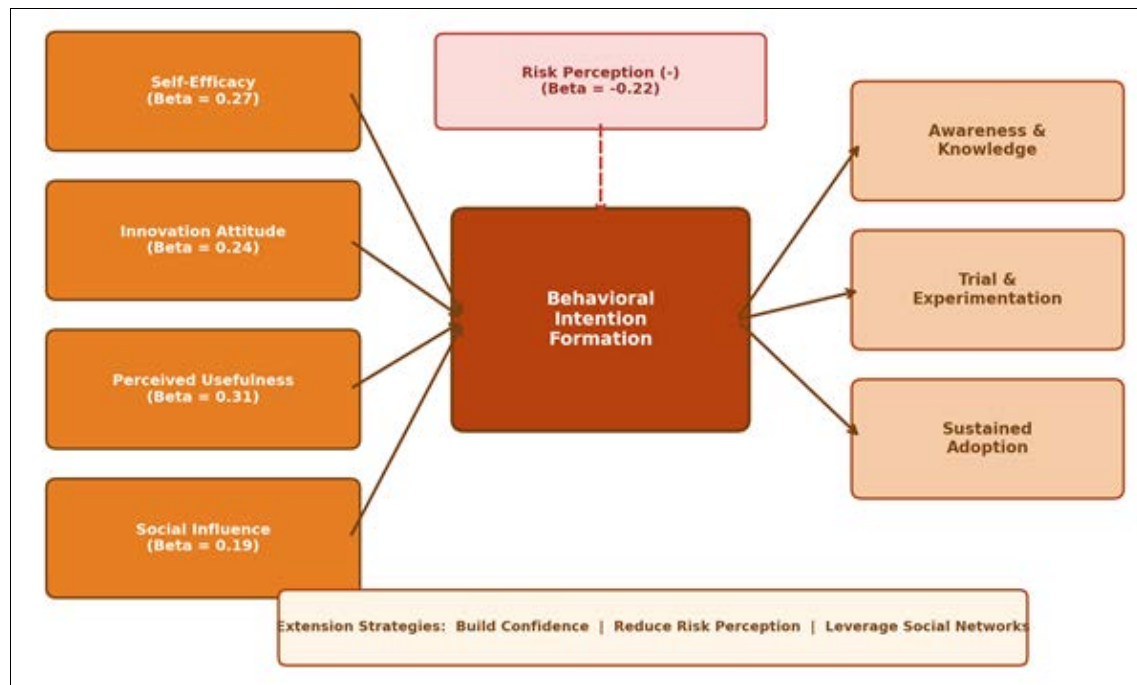
**Fig 2:** Process diagram of psychological adoption pathway with extension strategy implications

Figure 2 maps the psychological adoption pathway, showing how the four positive determinants feed into behavioral intention formation and subsequent adoption stages, while risk perception exerts an inhibiting influence.

Discussion

Perceived usefulness as the strongest predictor confirms TAM principles applied to agricultural settings [5], and aligns with Meijer et al. [11] who found that farmers' perception of tangible benefits matters more than technical knowledge for adoption. Self-efficacy's strong contribution supports Bandura's theory [4] and echoes findings from Nyang et al. [12] in East African extension contexts. The negative effect of risk perception (Beta = -0.24) was expected but its magnitude was smaller than reported by Feder et al. [13] in earlier Asian research, possibly reflecting improved safety-net programs in contemporary Indonesia [14].

Social influence showed the weakest but still significant path, suggesting that peer effects operate indirectly through attitude formation rather than directly driving adoption decisions. This partial mediation pattern was confirmed through bootstrapping analysis and is consistent with Bandura's concept of vicarious learning [15, 16].

Limitations

The cross-sectional design limits causal inference; longitudinal data would better capture how psychological states evolve during the adoption process. Self-reported adoption may overestimate actual behavior. The Java-focused sample may not represent outer island farming contexts in Indonesia [17].

Conclusion

Behavioral and cognitive factors explained a substantial portion (63.7%) of farmer uptake behavior. Perceived usefulness and self-efficacy emerged as the strongest drivers, while risk perception acted as a significant barrier. Extension strategies should shift from information-heavy approaches toward confidence-building activities — including demonstration experiences, peer success stories, and graduated risk exposure. Programs that help farmers see tangible results and believe in their own capacity to manage innovations are likely to achieve higher adoption than those focused solely on knowledge transfer.

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