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Modelling the adoption of agro-advisory mobile applications: a theoretical extension and analysis using result demonstrability, trust, self-efficacy and mobile usage proficiency

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Abstract

Purpose – This paper aims to explore the determinants of intention towards the use of agro-advisory mobile applications by extending the technology acceptance model (TAM) with addition of the following constructs: result demonstrability (RD), trust, self-efficacy (SE) and mobile usage proficiency (MUP).
Design/methodology/approach – The study employed a survey on farmers (n = 446), which was analysed through structural equation modelling using Analysis of Moment Structures (AMOS).
Findings – The results show that RD and farmer's trust on agro-advisory mobile apps (AAMA) positively impact their perceptions of usefulness. Also, farmer's SE and MUP positively affect their perceptions of ease of using AAMA. Further, interestingly, farmer's attitude towards the AAMA fully mediates the relationship between perceived usefulness and perceived ease of use on intention to use them.
Research limitations/implications – Understanding the antecedents of agro-advisory mobile application offers a unique contribution to policymakers, private firms, and non-government organizations by proving key insights on the acceptance of agriculture based mobile technologies in context of developing nations.
Originality/value – To the best of author's knowledge, this is one of the first research enquiries on the adoption of agro-advisory mobile applications. The new theoretical framework adds to the original TAM and offers novel insights that are helpful in augmenting the current understanding on AAMA and their acceptance by the beneficiaries.

Keywords Agriculture, Attitude, Agro-advisory mobile applications, Result demonstrability, TAM
Paper type Research paper

1. Introduction

In today's era, nations are confronting the problem of a growing population and depleting resources at the global level. The unprecedented growth in demographics, industrialization

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and demand puts limited resources under immense pressure, demanding an urgent need to boost agriculture and its allied sectors by developing inclusive and efficient food value chains. Agricultural development is considered a robust tool to improve people's living standards, thereby reducing extreme poverty, boosting prosperity and feeding an estimated 9.7 billion people by 2050 (World Bank, 2022). Sustainable growth in agriculture holds more relevance for the developing world as it acts as a mainstay of the economies due to its capacity to sustain a significant portion of the global population (Shetty *et al.*, 2014). Modern-day agriculture allows optimum infrastructure and technology usage required to optimize the limited resources. According to Mckinsey (2020), improving connectivity in agriculture could result in an additional $500 billion in value to the global gross domestic product (GDP) by 2030. An effective communication-based infrastructure in agriculture will bring improved farm productivity, enhanced resource utilization, effective time management and efficiency in marketing, logistics and quality management (Sørensen *et al.*, 2017). Agricultural communities have also comprehended that emerging information and communication technologies (ICTs) carry a vast potential to change the nature of work and can also bring a transformation (Jarial, 2022).

Especially smartphones have changed the way how people interact and exchange information (De Ridder, 2016). As per Statista (2021), approximately 70% of the world population uses a mobile phone, with total users exceeding six billion worldwide. It has provided a new scope of development to the existing businesses, including agriculture (Asongu and Asongu, 2017). However, a lack of resources and inadequate infrastructure have created an enormous gap between technical know-how and farming communities (Baloch and Thapa, 2014). Moreover, there is great potential to reduce this knowledge gap using ICT (Lahiri *et al.*, 2017), primarily through mobile phone-based applications. Due to the increased availability of smartphones, mobile applications have even surpassed text messages as the main method of information transmission (Kaske *et al.*, 2018). Several agriculture-related mobile applications, commonly known as agro-advisory mobile apps (AAMA), are available that offer a variety of service support to farmers. This informational support ranges from weather forecasting, market prices, farm practices, crops management and agriculture machinery amongst others. The prominence of mobile applications and their role in information exchange in agriculture concerning developing nations is well documented in the recent studies (Kuharić *et al.*, 2017; Fulton and Port, 2018; Khan *et al.*, 2019). Surprisingly, the prior research highlights mixed results regarding the significance of these applications to farmers (Patel and Patel, 2016; Petrellis, 2017; Inwood and Dale, 2019), the reason of which is primarily rooted into its poor use by the farmers (Barakabitze *et al.*, 2017).

The question persists whether the diffusion of mobile phones alone can be decisive in satisfying the agro-advisory needs to the farming communities. Although it acted as a stepping stone in this direction, but the farmers are still struggling to adopt the AAMA and therefore demands for more research in this regard (Thar *et al.*, 2021). Alternatively, there are individual level determinants that play a role in the adoption. A review of scholarly research reveals that the mobile application adoption literature has two main areas for improvement: Firstly, most of the research is product specific and needs to cover the broader issues related to agriculture. Secondly, the existing studies focus mainly on attitude (ATT)–intention or behaviour relationships. However, research capturing the antecedents of ATT towards these applications is less documented. To address this gap, the present study analyses the ATT–intention relationship and unearths factors determining the ATT towards AAMA. Given the above arguments, this study has a potential to contribute to the theoretical development from the users' perspective, which will help to improve the farming practices thereby making it more sustainable and future ready.

Furthermore, it is pertinent to mention that the diffusion of modern-day computer technologies is considered debatable as an individual's disposition and purpose to accept an

innovation is based upon psychological processes (Rogers, 1995). In addition, it is also well established that intention is the predictor of behaviour, and understanding pertinent antecedents of intention can help predict behaviour accurately (Gardner *et al.*, 2020). Therefore, to further improve our understanding of the adoption of AAMA, this study attempts to address two significant research questions (RQs):

RQ1. Do AAMA perceived usefulness (PU) and perceived ease of use (PEOU) determine users' ATT and intention?

RQ2. Does users' ATT influence their intentions to use AAMA?

This research intends to add and validate additional constructs: *result demonstrability (RD), trust, self-efficacy (SE)* and *mobile usage proficiency (MUP),* to the technology acceptance model (TAM) (Davis, 1989). A model to envisage mobile applications in agriculture context would contribute to the sustainability of the sector and supplement the growth of emerging economies primarily based on agriculture. The paper is structured as follows: Section 2 represents theoretical foundations and hypothesis development. Section 3 is dedicated to research methods, whereas Section 4 deliberates on the results. Section 5 presents discussions and implications. Finally, the paper summarizes the limitations and scope for further research.

2. Theoretical background and development of hypothesis

2.1 Technology acceptance model

To frame a theory-based design for this research, the TAM (Davis, 1989) was used because it is highly related to the acceptance of a particular information system. This adoption model intends to envisage the suitability of a tool and to pinpoint the changes which should be implemented in the system to make it suitable for users so that the new technology can be accepted. In the original TAM, the development of intention towards new technology is described through ATT, which is explained by PU and PEOU. The TAM has been rigorously validated and applied by researchers across several fields, such as information systems and technology (Ozag and Jurkiewicz, 2009), e-commerce (Van *et al.*, 2022), mobile news application (Mittal *et al.*, 2020) m-health applications (Mittal *et al.*, 2021), Internet banking (Chan and Lu, 2004) and microfinance platform (Amin and Li, 2014). Further, many scholarly articles (Folorunso and Ogunseye, 2008; Berhanu *et al.*, 2017; Salehi *et al.*, 2010) have tested the TAM in the agriculture domain and derived significant conclusions related to technology acceptance or rejection. However, the previous literature also systematically highlights its limitations, namely, self-reported usage (Venkatesh and Davis, 2000), student samples (Agarwal and Karahanna, 2000), low variance scores (Igbaria *et al.*, 1997) and small sample size (Gefen and Straub, 2000). Due to these limitations, the original TAM has been extended and validated with various causal factors within models to achieve better prediction across different fields (Venkatesh *et al.*, 2012). One such prominent extension came from Venkatesh and Davis (2000), where an attempt was made to elaborate the model to TAM 2 by incorporating social factors as predictors of PU. Also, Venkatesh and Bala (2008) further tried the extension to TAM 3 that combines determinants of the TAM 2 model with the inclusion of determinants of PEOU in the final theoretical model to check employees' adoption and usage of IT systems. All these extensions in the original TAM exclude the variable "attitude" but have focussed on the impact of PU and PEOU on the underlying intentions. While the status of mobile application-based services adoption amongst farmers is still in its early stage (Kumar and Karthikeyan, 2019), it is important to gauge the adoption of such apps. Therefore, this study uses the original TAM and incorporated potential antecedents to PU and PEOU as a part of the final theoretical model.

The existing literature also indicates that the pace of technology adoption in the context of emerging nations makes up an important facet of technology integration (Jamaluddin, 2013).

The use of the TAM to study the adoption of technology related to agriculture can be justified on the ground that advanced technologies are being introduced in this sector to boost the current agricultural output. Additionally, adopting technology would make this sector more sustainable and profitable for the farmers who belong to the marginalized sections of society. To ensure the inclusion of relevant factors that contribute to developing a positive intention towards AAMA, the TAM was used and validated in this study to test its significance in the Indian agriculture setting.

2.1.1 Perceived usefulness. PU for any IT system refers to the degree to which it is believed that using a technology would be beneficial to undertake a particular task (Davis, 1989). Many researchers have attempted to gauge the impact of PU in developing an intention, and therefore, it is viewed as a probability that the IT system will augment an individual's job or life performance (Davis, 1989). In line with Kleijnen *et al.* (2004) and Shin (2008), it is assumed that the PU of AAMA would impact the users' ATTs and beliefs. Previous research discovered PU to have a strong relationship with intentions (Sanchez-Franco and Roldan, 2005). Researchers have tried to gain meaningful insights into the consumers' ATTs to explore its utility in different research settings. Also, apprehension from users that app will benefit them and tend to have a favourable ATT towards the app (Lee, 2018). Thus, based on the arguments, the proposed hypothesis is as follows:

H1. PU of AAMA positively influences the farmer's ATT towards the apps.

2.1.2 Perceived ease of use. PEOU is the degree of comfort a prospective user expects towards using an information system or technology (Davis, 1989). PEOU determines the nature of technology or IT systems to be hassle free and uncomplicated. The more a new system is easy to use and needs less effort, the greater its tendency to generate positive ATTs (Davis, 1989). It is widely acknowledged that technology usage by individuals is attributed to perceived utilitarian and hedonic benefits (Kim *et al.*, 2016). Furthermore, PEOU is directly associated with PU (Teo, 2011; Chang *et al.*, 2014). A recent study on the role of PEOU explored that an application's ease of use is closely associated with users' ATTs towards the application (Wiese and Humbani, 2020). In the context of mobile commerce, PEOU significantly impacts PU (Revels *et al.*, 2010). This implies that the users perceive an easy-to-use technology as utility oriented. From the above arguments, we propose the following:

H2a. PEOU positively influences the farmer's ATT to use AAMA.

H2b. PEOU positively influences the farmer's PU of AAMA.

2.1.3 Attitude. ATT refers to the magnitude to which an individual has favourable or unfavourable disposition towards a point under consideration (Ajzen and Fishbein, 1980). ATT towards use can be explained as an evaluation of a person towards technology or specific behaviour linked with the technology usage (Scherer and Teo, 2019). An extant number of studies provide ample indication that ATT affects the intention of individuals towards the use of technology (Lee, 2009; Chiou and Shen, 2012; Dwivedi *et al.*, 2019). The TAM has proven predictive power in determining ATTs and intentions towards mobile payment systems and application adoption (Wiese and Humbani, 2020). In line with the arguments, an association links the ATTs of mobile application adopters and their intention. Thus, we propose the following:

H3. Farmer's ATT with the AAMA will positively influence the intention to use them.

2.1.4 Result demonstrability. RD is linked to the tangible aspects of using new technology or innovation which reflects through its observability and communicability (Moore and Benbasat, 1991). Consequently, this concept is a part of the cognitive instrumental process incorporated in TAM 2 (Venkatesh and Davis, 2000) and is yet to be explored deeper in information system/technology adoption context (Wu *et al.*, 2016). This construct is rooted into the premises

that the more an innovation is open to demonstration, its advantages would also be more evident. As highlighted by Venkatesh and Bala (2008), and reinforced by Yuen *et al.* (2020), RD is closely associated with the PU of technology. In view of above arguments, we hypothesize the following:

H4. AAMA's RD will positively influence farmers' PU towards the apps.

2.1.5 Trust. Rousseau *et al.* (1998) defined trust as "*a psychological state comprising the intention to accept vulnerability based on the positive expectation of the intentions and behaviours of others*". In the past, the association between trust and the TAM has been explored by assessing the relationship between PU, PEOU and trust (Gefen *et al.*, 2003). Trust is recognized as a predictor of PU as it ensures a positive frame of mind towards the perceived benefits of the technology (Pavlou, 2003). Moreover, researchers attempted to augment trust in different technology adoption settings (Patil *et al.*, 2020; Wang *et al.*, 2021) and described it as a significant driver of technology usage. In context of mobile application adoption, it is commonly seen that the user carries a sense of uncertainty and concern over the information being shared through the app usage (Muñoz-Leiva *et al.*, 2017) which can be resolved through trust (Rifon *et al.*, 2005). Therefore, trust plays a decisive role in explaining the perceived benefits of a technology. Based on the above arguments, it can be assumed that users' trust will affect the PU of AAMA. Therefore, we hypothesize the following:

H5. Farmer's trust on the AAMA will positively influences their PU to use them.

2.1.6 Self-efficacy. SE in the technology adoption milieu can be explained as a belief to accomplish a specific task which determines the intention to involve in a system (Compeau and Higgins, 1995). Earlier work proved that SE is a stronger influencer of an IT system adoption as it impacts ease of use (Brown, 2002). Therefore, it can be inferred that SE enables a person to use and control a technology, as also explicated by Hung *et al.* (2013). Studies in the past found a strong linkage between SE and PEOU in information system acceptance settings (Pavlou and Fygenson, 2006; Polites and Karahanna, 2012). Therefore, we too infer that individuals' SE directly impacts PEOU of these AAMA. Hence, the following is proposed:

H6. Farmer's SE positively influences PEOU in the usage of AAMA.

2.1.7 Mobile usage proficiency. MUP is the degree of expertise in using modern-day cell phones. As explained by the previous research, IT proficiency and its current understanding impacts the adoption of mobile phones in learning a system or technology (Balavivekanandhan and Arulchelvan, 2015). Proficiency is considered a vital aspect of technology adoption. In the case of MUP, it signifies the effortlessness in using new technology and also helps to remove barriers associated with the benefits of smartphone utilization (Petrovčič *et al.*, 2019). In this study, MUP has been added to observe the skills possessed by farmers to handle mobile-based applications. Therefore, the study puts forward the hypothesis:

H7. Farmers' MUP positively influences their PEOU of AAMA.

The available literature suggests PU as an antecedent of intention in various contexts, namely, e-learning (Lin and Wang, 2012), instant messaging (Wang *et al.*, 2011), Internet and m-banking (Martins *et al.*, 2014; Sharma, 2017), mobile wallets (Chawla and Joshi, 2020; Soodan and Rana, 2020), app adoption (Mehra *et al.*, 2020) and mobile commerce platforms (Shaw and Sergueeva, 2019). Some other studies further demonstrated that the ATT failed to mediate the effect of PU on intention towards technology usage (Davis and Venkatesh, 1996; Jamaluddin, 2013). It is, therefore, assumed that if farmers perceive the functional utility of agriculture mobile apps, they would be more likely to have a favourable intention. Moreover, a careful examination of prior TAM studies also suggested PEOU as an antecedent of intention development towards using

information technology (Gefen *et al.*, 2003; Thong *et al.*, 2006; Chiu and Wang, 2008). It is, therefore, expected that individuals feel optimistic towards ICT if it can be effortlessly used. Therefore, it would be appropriate to derive the hypotheses as follows:

H8. PU will positively impact farmers' intention to use AAMA.

H9. PEOU will positively impact farmers' intention to use AAMA.

2.2 Attitude as mediator

The TAM insinuates that factors like PU and PEOU are instrumental in determining ATTs towards the usage of technology, which ultimately can predict intentions (Davis *et al.*, 1989). In TAM-related studies, various scholars have replicated the role of ATT as a mediator. Researchers have highlighted the role of ATT in predicting intention towards mobile recommender systems (Choi *et al.*, 2014). Also, ATT is reported to mediate the association between PEOU and intention towards using social networking sites (Chang *et al.*, 2015) and ICT (Giovanis, 2011). Following this, the current work will test the role of ATT towards AAMA as a mediator between antecedent variables (PU and PEOU) and the outcome variable "Intention to Use" (ITU). Hence, the following hypotheses are proposed:

H10a. Farmer's ATT towards AAMA mediates the relationship between PU and intention to use them.

H10b. Farmer's ATT towards AAMA mediates the relationship between PEOU and intention to use them.

The existing literature helped to gain insights in framing the theoretical framework for the study (shown in Figure 1).

3. Research methods

This research incorporated a survey method to analyse the hypotheses. The survey was addressed to farmers in Punjab districts namely Ludhiana, Jalandhar, Kapurthala and Hoshiarpur. The sampling area was selected because of its position amongst the top food

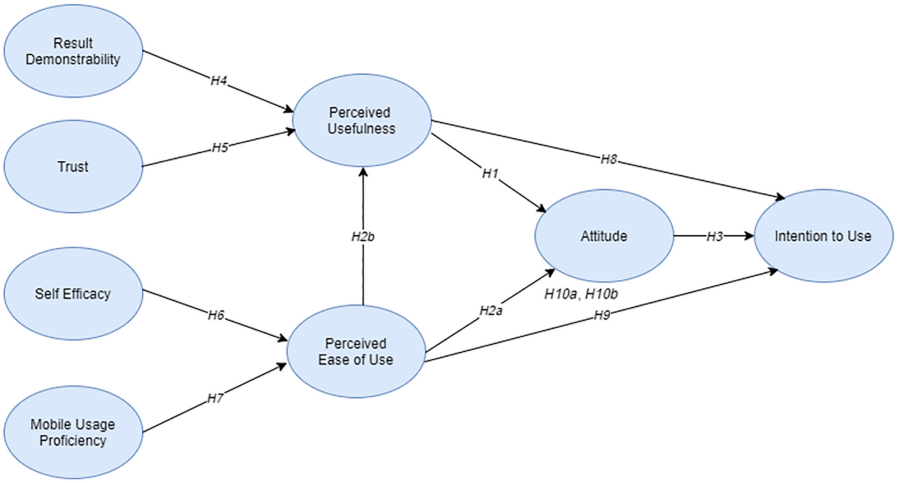

Figure 1.
Conceptual framework

Source(s): Adapted from Davis (1989)

grain cultivating areas with a high concentration of farms under crop cultivation. The study adopted a structured questionnaire for data collection. To seek insights into the technology acceptance nature of respondents, constructs from the TAM (Davis, 1989) were incorporated. Initially, a pilot survey was conducted to check glitches in the measurement scale items. A sample of 66 farmers was selected from the nearby villages of Phagwara (Punjab), and the collected data were statistically tested which showed no significant differences amongst the first and last 30 responses. The face validity of the questionnaire was checked through consultation with domain experts and feedback from the farmers during the pilot survey which resulted in modifications and deletion of some statements. The entire list of statements used in each construct is provided in Table 1.

To finalize the appropriate sample size, certain parameters and the existing literature were examined. Following Krejcie and Morgan's (1970) guidelines, the sample size was found out to be 384 at a desired 5% margin error and 95% confidence interval. Besides, for validation of the structural equation modelling (SEM)-based statistical model, a sample size of 200 and 300 can be considered as fair and good, respectively (Tabachnick and Fidell, 1996). Also, it is recommended that the sample size must be ten times more than the variables taken in the study (Roscoe, 1975). Complying with all these suggestions, sample size comprising 450 respondents was deemed fit for this study. But considering the constraints in getting a good response rate, we target to reach nearly 800 respondents.

We followed a purposive sampling approach to identify the respondents. Population for this study was farmers residing in the rural areas of the Punjab state of India. Typically, around 63% of the total population of Punjab lives in rural areas (Agriculture census, 2021), and hence, samples were identified based on the land use patterns and landholding in the abovementioned districts (Department of Agriculture and Family Welfare, 2014). In the first stage, only those farmers were included in the sample who were familiar with the AAMA. Also, necessary care was taken to ensure a relatively equal proportion of respondents from different landholding capacities. A total of 770 farmers were personally approached with bilingual questionnaires (Punjabi and English), and out of these, 446 questionnaires were received thereby aggregating the rate of response to 57.9%. The reason for the low response rate can be attributed to the harvesting season as the farmers were reluctant to participate in the survey citing their commitment towards crop harvesting. Out of all received responses, 427 responses were found fully appropriate for their final data analysis. The respondents were predominantly males (82.43%) with a median age of 46.36 years. Despite all selected respondents were familiar with the AAMA, 68.14% of them were using them on a regular basis. The reasons for using AAMA were mainly seeking information on farm practices (40.49%), weather forecasting (25.08%), market price (23.36%) and knowledge about government schemes and policies (10.65%). The collected data were subjected to analysis using Statistical Package for Social Sciences (SPSS) AMOS that involves exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and mediation analysis.

3.1 Measurement, reliability and validity

Before assessing the measurement model, it is important to check for endogeneity related issues in the model that mainly include common method variance (CMV) and measurement errors issues. We employed Harman's test to which a single factor solution amounted to nearly 32.4% of the variance in the model, which is significantly less than 50%, thereby signalling CMV is not a threat to the model Podsakoff *et al.* (2003). However, we also used some of the procedural solutions suggested by Podsakoff *et al.* (2003), which controlled endogeneity related issues. First, participation in the poll was entirely optional, and respondents were assured of the confidentiality and anonymity of their answers. Second, the sequence in which the questions were placed was random (Malhotra *et al.*, 2006). Third, to improve the survey's readability,

	Standardized loading (λ)
Perceived ease of use (Davis, 1989; Venkatesh, 2001)	
CR = 0.921, AVE = 0.795 and MSV = 0.286	
PEOU1: It is easy learn how to use these agriculture based mobile apps	0.895
PEOU2: It is very easy execute the activities I want to do by using these mobile apps	0.897
PEOU3: Overall, using these mobile apps to get information is not difficult	0.883
Perceived usefulness (Davis, 1989; Venkatesh, 2001)	
CR = 0.944, AVE = 0.849 and MSV = 0.286	
PU1: Agriculture based mobile apps improve my work efficiency	0.922
PU2: Agriculture based mobile apps help me to get the desired information	0.930
PU3: Overall, I find agriculture based mobile apps useful	0.912
Attitude towards mobile apps (Wu and Chen, 2005; Cheng *et al.*, 2006)	
CR = 0.940, AVE = 0.796 and MSV = 0.153	
ATT1: Agriculture based mobile apps will save me time	0.911
ATT2: Agriculture based mobile apps will facilitate my agriculture-related work	0.893
ATT3: Agriculture based mobile apps will save my money	0.879
ATT4: Usage of mobile apps will be good for me	0.886
Intention to use (Venkatesh and Davis, 1996; Venkatesh, 2001)	
CR = 0.944, AVE = 0.850 and MSV = 0.153	
ITU1: It is probable that I would use mobile apps to assist my agriculture activities	0.839
ITU2: I intend to begin or continuing using mobiles to facilitate my agriculture activities	0.962
ITU3: If mobile apps are accessible to me, I want to use them as much as possible	0.959
Trust (Lee, 2005)	
CR = 0.992, AVE = 0.975 and MSV = 0.146	
TRUST1: I feel the agriculture-related information shared by these mobile apps is reliable	0.990
TRUST2: I am sure that these mobile apps are widely acknowledged for their services	0.983
TRUST3: I believe that using these agriculture based mobile apps is safe	0.990
Self-efficacy (Schwarzer and Jerusalem, 1995)	
CR = 0.985, AVE = 0.956 and MSV = 0.182	
SE1: I believe that I can access the required information by using these mobile apps	0.965
SE2: I am good at interpreting all relevant info that these mobile app offers	0.995
SE3: I am assured in my ability to use mobile app for my agriculture activities	0.973
Result demonstrability (adopted from short form of general self-efficacy scale given by Venkatesh and Davis, 2000)	
CR = 0.976, AVE = 0.954 and MSV = 0.071	
RD1: I have seen that these mobile apps provide important and accurate info in the past	0.967
RD2: I get to know that lots of farmers have benefited by using these mobile apps	0.986
Mobile usage proficiency (adopted from short form of general MUP scale given by Roque and Boot, 2018)	
CR = 0.966, AVE = 0.935 and MSV = 0.075	
MUP1: I have no problem in going through different options in a cell phone	0.950
MUP2: I feel comfortable to use the different mobile Internet services over the cell phone	0.984
Note(s): Measured on a Likert five point scale: 1 – strongly disagree and 5 – strongly agree	

Table 1.
Measurement of constructs

accuracy, size and suitability for the respondents, the survey instrument was pretested by experts (academicians and practitioners) who ensured its content validity in the best way possible. Fourth, the topic on which the replies were requested was not one that would jeopardize the respondents' right to privacy. Additionally, we examined the variance inflation factors (VIFs) for which the values of all items fell below the 3.3 threshold, ranging from 1.082 to 2.915 (Kock, 2015), thus, ensuring the CMV was not a problem in our study.

Afterwards, the construct evaluation was conducted for their reliability and validity. The reliability was gauged using measures like composite reliability, whose required value must be higher than 0.6 for each construct. Furthermore, the psychometric properties of all latent measures were tested in AMOS using Maximum Likelihood estimation that assesses the

conceptual model through CFA (Anderson and Gerbing, 1988). Table 1 gives a general summary of the measurement instrument adopted for the study whereas Table 2 provides a detail of mean, standard deviation and inter-construct correlations. Reliability and construct validity are indicated by (1) acceptable values of the item to construct loadings ranging from 0.822 to 0.990, (2) satisfactory composite reliability values between 0.921 and 0.992, (3) values of average variance extracted (AVE) (between 0.797 and 0.975) and maximum shared variance values (ranging between 0.071 and 0.236) meeting the criteria of established threshold values (Anderson and Gerbing, 1988; Byrne, 2010). Moreover, the discriminant validity for all factors was also established by the fact that all the AVE values of all constructs go past the consequent squared correlations for the pairs of constructs (Fornell and Larcker, 1981).

3.2 Estimation and model fit

Table 4 provides the fit statistics of the conceptual model and the various statistics *namely:* Goodness-of-fit index (GFI) = 0.945, Adjusted goodness-of fit index (AGFI) = 0.924, Comparative fit index (CFI) = 0.992, Normed fit index (NFI) = 0.976, Tucker-Lewis index (TLI) = 0.99, Root Mean Square Error of Approximation (RMSEA) = 0.068. These were found to satisfy the acceptable measures (Bagozzi and Yi, 1986; Byrne, 2010). Therefore, the measurement model shows a good fit (χ^2 (202) = 299.796 and $p < 0.001$).

4. Results

The hypothesis H1 was accepted, as the effect of PU on ATT was significant ($\beta = 4.821$ and $p < 0.05$). Similarly, PEOU had a significant association with ATT ($\beta = 4.038$ and $p < 0.05$) and PU ($\beta = 11.105$ and $p < 0.05$), and thus hypotheses H2a and H2b were accepted. Also, the analysis revealed ATT as a determinant of intention to use ($\beta = 9.150$ and $p < 0.001$), thereby, accepting H3. The results revealed that each of the exogenous variables (RD, TR, SE and MUP) have significant effects on the endogenous variables (PU, PEOU and ATT) which in turn lead to intention development. The analysis explored one more significant path from RD to PU ($\beta = 2.92$ and $p < 0.001$) thus corroborating that RD has a substantial impact on PU, thereby supporting the hypothesis H4. As anticipated, trust had a significant relationship with PU ($\beta = 5.167$ and $p < 0.05$), and hence hypothesis H5 is accepted. Similarly, SE also had an association with PEOU ($\beta = 8.445$ and $p < 0.05$), so, hypothesis H6 was also supported. The findings stipulated that MUP significantly affects PEOU ($\beta = 2.596$ and $p < 0.001$). Therefore, hypothesis H7 is supported. However, the direct impact of PU and PEOU on intention to use was not reported as significant (PU → ITU, $\beta = 0.072$ and $p < 0.05$; PEOU → ITU, $\beta = 0.081$ and $p < 0.05$), thereby rejecting hypotheses H8 and H9. The description of all hypotheses is presented in Table 3.

	Mean	Standard deviation	OD	ATT	TRU	SE	ITU	PU	PEOU	MUP
RD	2.22	0.956	*0.977*							
ATT	3.18	0.935	0.109	*0.892*						
TRU	2.52	1.029	0.178	0.136	*0.988*					
SE	2.64	1.054	0.079	0.135	0.237	*0.978*				
ITU	3.46	0.971	0.085	0.391	0.114	0.070	*0.922*			
PU	2.62	1.070	0.267	0.362	0.382	0.291	0.089	*0.921*		
PEOU	2.58	1.132	0.254	0.343	0.342	0.427	0.072	0.535	*0.892*	
MUP	1.99	0.750	0.145	0.051	0.118	0.234	0.026	0.164	0.233	*0.967*

Note(s): Diagonal values (in italic) represent the square root of AVE for each construct

Table 2. Descriptive statistics and construct inter-correlations

4.1 Mediation effects testing

The study performed mediation analysis to gauge the nature of direct and indirect effects of the independent variable on the response variable (Table 4). For testing mediation effects, we followed the Baron and Kenny (1986) approach that involved four stages. First, the explanatory variable must affect the response variable. Secondly, the independent variable must exert an effect through the mediator on the response variable. Thirdly, the mediator must influence the response variable. Finally, after the introduction of the mediating variable, the effect of the independent variable on the response variable should be checked. As per our model, the direct effects impact of PU on intention towards usage of AAMA was insignificant (-0.072^{ns}). Also, the indirect effects of PU on ITU AAMA via ATT were reported significant (0.111^{***}) while the direct effect did not improve even in the presence of mediator "attitude", thereby demonstrating a clear indication of full mediation. Hence, H10a was rejected. Furthermore, PEOU also demonstrated an insignificant direct impact on intention to use AAMA (-0.081^{ns}). Also, the indirect effect of PEOU on intention to use AAMA through ATT was reported significant (0.144^{***}). But the direct effect of PEOU on ITU did not improve further in the presence of mediator "attitude" and found insignificant (-0.082^{ns}), thereby rejecting H10b.

Hypothesis sign	Path from → to	Estimates	SE	*t* value	Conclusion
H1	Perceived usefulness → Attitude	0.239	0.050	4.821^{***}	Supported
H2a	Perceived ease of use → Attitude	0.200	0.050	4.038^{***}	Supported
H2b	Perceived ease of use → Perceived usefulness	0.460	0.041	11.105^{***}	Supported
H3	Attitude → Intention to use	0.435	0.048	9.150^{***}	Supported
H4	Result demonstrability → Perceived usefulness	0.125	0.043	2.920^{**}	Supported
H5	Trust → Perceived usefulness	0.204	0.040	5.167^{***}	Supported
H6	Self-efficacy → Perceived ease of use	0.348	0.041	8.445^{***}	Supported
H7	Mobile usage proficiency → Perceived ease of use	0.152	0.059	2.596^{**}	Supported
H8	Perceived usefulness → ITU	−0.072	0.41	$1.024^{n.s}$	Not supported
H9	Perceived ease of use → ITU	−0.081	0.56	$0.998^{n.s}$	Not supported

Table 3.
Testing of proposed modelled relationships

Note(s): Model fit criteria: χ^2/df (14) = 3.317; RMSEA = 0.074; GFI = 0.973; AGFI = 0.931; NFI = 0.924; CFI = 0.944

Hypothesis sign	Hypothesized path	Direct effects	Direct effects with mediators	Indirect effects	Result
H10a	Perceived usefulness → Attitude → Intention to use	−0.072 ns(0.045)	−0.073 ns (0.048)	0.111***	Full mediation (supported)
H10b	Perceived ease of use → Attitude → Intention to use	−0.081 ns(0.072)	−0.082 ns (0.085)	0.144***	Full mediation (supported)

Table 4.
Mediation analysis

Note(s): Bootstrapping of 5,000 samples at 95% C.I. Entries are standardized estimates (standard errors)
*** = $p < 0.001$; ** = $p < 0.01$; ns = $p > 0.05$

5. Discussions and implications

5.1 Discussions

This research assessed the efficacy of the extended TAM in inducing the Indian farmers' intention to use AAMA in their farm practices. The findings exhibited that the model effectively elucidates the intentions of Indian farmers to use AAMA for better efficacy and increased efficiency of their farm practices. The study revealed that out of 12 hypothesized relationships in the model, ten were significant, and two were non-significant.

The results demonstrate that the PU of AAMA affects farmers' ATTs. It is well supported by the earlier literature (Herrero Crespo and Rodrí guez, 2008; Shin, 2008; Teo, 2011; Rafique *et al.*, 2014; Hussein, 2017). Hence, it is pertinent to mention that the usefulness of apps reflects contemplation of benefits that may arise from usage. Consequently, it can be stated that the use of AAMA determines the nature of ATT towards their usage. This finding is in line with the findings focussing on enriching the overall experience and creating a sense of being present and the ability to support knowledge about the system.

Similarly, PEOU of AAMA positively and significantly impacted ATT. This implies that perception related to applications' interactive interface and the readable content is instrumental in ATT development (Chen and Tan, 2004). The perusal of data revealed that PEOU plays a substantial role in shaping effortlessness in using AAMA. It reflects that internal motivation for using AAMA is influenced by the degree of the app's user-friendly interface having clear and simple instructions to be followed. This is consistent with the previous findings (Venkatesh and Davis, 2000; Mehra *et al.*, 2020).

Results also signify a significant relationship between the ATT of respondents and their intention to use AAMA. This outcome is contrary to the study results of Davis *et al.* (1989) and Teo and van Schaik (2009), where the role of ATT was found to be modest and insignificant. However, a range of studies found the relationship between the two variables significant, and studies validated the role of ATT in influencing the intention of technology users (Shin, 2008; Teo, 2011; Rafique *et al.*, 2014). Therefore, this adds to the result that a positive ATT towards app usage would lead to a positive intention and vice versa.

Moreover, the outcomes also reveal that RD also significantly and positively affects PU. This relationship shows that the tangible aspects (benefits) of mobile apps influence their PU amongst beneficiaries, thereby enhancing the likelihood of app adoption. Previous TAM studies have also found RD's impact on PU (Venkatesh and Davis, 2000; Gow *et al.*, 2019). The findings further signify a relationship between trust and PU. This indicates that farmers' trust towards mobile application's ability to perform accurately and free of errors significantly impact their PU. These findings corroborate the previous findings (Horst *et al.*, 2007; Mou *et al.*, 2016).

The results further recognized a determinantal role of SE in explaining PEOU. This strengthens the belief that farmers need to be self-efficacious enough so that they perceive the AAMA as easier to explore and use. Thus, these results find its relevance and further validate the existing literature (Hernandez *et al.*, 2009; Ong and Lai, 2006; Pituch and Lee, 2006). The significant association between MUP and PEOU confirms that expertise in using mobile handsets makes the AAMA and its benefits more fluid and easier to use by farmers. This can also be seen in a perspective, as given by Omar *et al.* (2021), that unless farmers are not ready to use a technology, the success of the same is not guaranteed. Therefore, it can be stated that expertise in mobile usage has a significant contribution to the acceptance of AAMA (Balavivekanandhan and Arulchelvan, 2015).

Interestingly, this study found an insignificant association between PU and intention to use AAMA but explored that PU influence intention indirectly via ATT. This outcome is an exception to previous research results that have recognized a significant role of PU in the intention to adopt a technology (Sharma, 2017). The finding corroborates partly with the research results of Kurnia and Chein (2003) and is well in line with the observations of Loketkrawee and Bhatiasevi (2018) and Lin *et al.* (2021). This direct insignificant relationship

confirms the role of ATT in strengthening farmers' intentions towards adopting these apps, which otherwise is not present.

Similarly, PEOU and intention to use AAMA share an insignificant relationship. Surprisingly, PEOU influences the intention indirectly, which is routed through ATT. This dominant role of ATT has been revealed in the context of PEOU and intention. This result fully replicates the results of Gefen and Straub (2000) and confirms its relevance with the scholarly findings. The study suggests that in adopting AAMA by farmers, the role of ATT stands apart from other variables. The reason can be attributed to the low diffusion of smartphones in rural areas and the lack of awareness towards the utility of such applications as compared to urban areas.

5.2 Theoretical contributions and implications

This study offers substantial implications for the agriculture sector. The TAM has been used to determine the usage of AAMA with a focus on additional factors having potential to impact adoption intention. By modifying the TAM for the purpose of research, this study has drawn detailed insights into the vital determinants of agriculture application usage. It can be said that the present study has significant potential to contribute to the already available scholarly literature related to the usage of mobile applications. The study generates new perspectives for AAMA adoption in India which has not been attempted before. The study reveals the role of ATT in shaping adoption intentions towards AAMA and underlines the importance of MUP, trust and RD.

In addition, by using SEM for analysing data, the current piece of research produced results which are not only valid in Indian context but can also be equally replicated in the perspective of other developing nations as well. Furthermore, this field study revealed that the TAM can significantly predict the adoption of AAMA and has further extended this highly validated model which confirms the robustness of the TAM in the context of agriculture application adoption.

5.3 Implications for practice

The use of mobile applications as an informational platform for farmers to avail utility services is still at a nascent phase of its inception. It is imperious for managers and policymakers to predict the degree of its perceived usability and acceptability amongst the farmers. Likewise, they must understand what motivates farmers to choose AAMA than relying on other sources of information for their agricultural activities. We believe that the result of our study delivers significant managerial implications. Based on study results, it can be inferred that those farmers who trust these mobile apps opine higher use of their information. Moreover, the farmers tend to focus more on their SE when thinking of using these mobile apps. Governments and marketers must exhibit a lot of public demonstrations and conduct workshops, training, etc. to render skill and knowledge about the usage of the AAMA so that a positive ATT about them can be developed. Surely, this has an inherent implication for the software developers to keep the easy-to-use features in designing the apps for the farmers. Therefore, augmenting the usefulness of information received through app usage and ease of use features in app design would be a viable strategy for the marketers to appositively develop intention to use these mobile apps.

From the perspective of a business practitioner, this research offers important inputs which can be used to augment current technology business. It is obvious that a large number of resources go into the development of mobile applications and its testing. Findings of this study can prove to be instrumental in designing mobile applications by keeping in mind the prominence of factors and enriching the overall user experience. Furthermore, this unique attempt empirically revealed the dominant role of ATT in context of the developing nation where awareness and access to prior information related to technology is low. Since most of the agriculture activities are performed in countryside, marketers and app developers should focus on ATT of potential users by keeping in mind their location and exposure to technology.

PEOU and PU are not related to intentions, or in other words, even if the individuals feel the ease and usefulness of these apps, they will not necessarily download or adopt. Marketers and app developers can focus on building awareness and should work on enhancing the visibility of these applications using social media promotions and content driven marketing strategies.

5.4 Limitations and future directions

Despite the crucial findings, current research is associated with few limitations. First, the area of study was confined to India, which prevents the generalization of findings to all other populations. Second, despite the significant modelled relationships amongst variables studied, the percentage of variance reflected by the predictors of PEOU and PU is rather low in comparison to some other studies. Therefore, future research shall try to incorporate new factors as antecedents of PU and PEOU to enhance the predicting power of the model.

Moreover, the spectrum and impacts of other potential variables namely outcome risks, Internet experience and demographic differences (educational, occupational, dispositional income, etc.) can be ascertained. Third, this study was limited to discover the potential predictors of intention to use mobile apps by farmers, keeping in view the antecedent factors. But does this intention lead to actual adoption of mobile apps still remains a question of ambiguity. Therefore, future research could examine the post-mobile app adoption behaviour of farmers using a longitudinal approach. Lastly, the future research may also explore how farmers behave in adopting specific mobile-based advisory services.

6. Conclusion

This research addressed the adoption of AAMA in sustaining Indian agriculture by using the much-validated TAM model. Results depict that perception of farmers about the efficacy and ease of use of mobile applications has a significant impact on ATT which in turn acts as an antecedent of intention. The study revealed no evidence in support of the direct association of PU and PEOU towards intention to use AAMA. Hence, it can be deduced that intention towards app adoption is routed through a favourable ATT, which in turn is determined by easy navigation and easy-to-understand instructions.

Due to an increase in the number of AAMA, users rely heavily on the trusted app source and evaluate the expected outcomes before adoption. The study also demonstrated that SE along with MUP envisages the ease of use of mobile applications. Thus, to advance the AAMA to the farmer's communities, the farmer's expertise on the mobile phone usage and the ability to retrieve all valuable information from the mobile apps must be enhanced. This shall be improved by creating awareness and launching digital literacy initiatives at the rural levels to integrate the stakeholders in the agriculture sector in a more profound way.

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