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FACTORS INFLUENCING THE DIGITAL AGRICULTURE ADOPTION: A RESEARCH MODEL FOR ASSESSING ROMANIAN FARMERS' MOTIVATIONS

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Abstract
This paper proposes a measurement model to be used to assess the Romanian farmers' motivations to adopt Agriculture 4.0 practices and technologies. The Unified Theory of Acceptance and Usage of Technology (UTAUT) provides a robust model for assessing the factors driving or inhibiting the adoption of digital farming technologies and practices. Extensions and enhancements of the UTAUT2 and UTAUT3 used in farmer studies internationally are discussed and also compared to the results of studies with a different architecture about farmers' motivations to use digital agriculture tools and systems. A proposed unified model will be used in subsequent quantitative measurements of Romanian farmers' motivations to embrace Agriculture 4.0. The paper is a premier in the literature about Romanian farmers. It is deemed a valuable tool for both researchers and developers of digital tools for farmers.

Keywords
Digital Agriculture/Agriculture 4.0; Technology Acceptance Models

Introduction

The extant literature review concludes that Agriculture 4.0 leverages the latest innovations in sensor technology, digital image processing as well as data analysis and visualization and relies on the interconnectedness offered by the Internet of Things (IoT) and the storage and computing power made accessible through cloud computing in service of a more productive, more efficient, and less environmental impactful farming (Abbasi et al., 2022; Albiero et al. 2020; Dayiloglu & Turker 2021; Elijah et al., 2018; Latino et al., 2021; Liakos et al., 2018; Roland Berger, 2015, 2017; Saiz Rubio & Rovira Mas, 2020; Zambon et al., 2019).

The links structure in the bibliometric maps analyzed in previous works of the author (Markovits, 2022, 2023) substantiates the narrative that Agriculture 4.0 is based on the Internet of Things and will bring solutions for climate and environment smart farming through digitally enhanced precision agriculture (Bucci et al., 2018; ISPA, 2019) leveraging especially the other industry 4.0 technologies: sensors, cloud computing and artificial intelligence (Braun et al., 2018; Kamilaris et al., 2017). These innovations made the rise of digital agriculture (aka Agriculture 4.0) possible, allowing farmers to better manage farms in general and the management of arable land and crops as well as water resources by means of digitally enhanced precision agriculture. These highly advanced technologies provide farmers with real-time data and data analytics while feeding decision support systems (Zhai et al., 2020) to improve productivity (Goedde et al., 2020; Klerkx et al., 2019), resource management, and sustainability in the crops management and farms' operations.

Understanding the factors that influence the acceptance and adoption of these relatively sophisticated Information and Computer Technologies (ICT) is essential for facilitating the effective implementation and utilization of digital agricultural solutions. Therefore, models about technology acceptance and usage seem the likely starting point to provide orientation and help assess the factors that determine the adoption of Agriculture 4.0 among Romanian farmers. This study aims to create a solid measurement model to be used in subsequent quantitative research among farmers in Romania.

Literature review

Field crops professional agriculture in Romania is done in farms that are overwhelmingly family firms, which most often built their scale through the family's joint exploitation of owned and rented arable land and relatively rarely through cooperatives (Dumitru et al., 2022). The relative recency of the creation of these farms also makes it very frequent that the founding figure would still be involved in the operation of the farm nowadays, aged 55+ or even 60+ (Rovný, 2016). The rising generation of professional farmers is coming primarily from inheritors as well as hired specialists, with the likelihood that they will be more inclined to use digital tools to manage their farms.

Despite the potential benefits and advancements brought by digital agriculture, the successful adoption and utilization of these technologies by farmers, old and new alike, remains a complex and multifaceted process (Gerli et al., 2022; Medvedev & Molodyakov, 2019). Adoption of digital farming practices and technologies is a typical knowledge management process within farms, implying knowledge acquisition, organizing, storing, retrieving, and sharing an organization's knowledge assets to facilitate decision-making, problem-solving, learning, and innovation (Brătianu, 2002, 2018, 2022). The generational change is likely to help digital farming adoption as it brings more ICT-savvy decision-makers to the helm of the farms in Romania. This could be a strong springboard for skills renewal at all farm decision-making and operational levels.

The *critical barriers to the adoption of Agriculture 4.0,* as identified throughout the literature review on digital agriculture (Bucci et al., 2018; Pierpaoli et al., 2013; Tey & Brindal, 2012), include *cost, lack of technical skills, resistance to change, limited access to technology due to infrastructure or connectivity issues, concerns about data privacy and security*.

Technology Acceptance Models (TAM/TAM2/UTAUT/UTAUT2/UTAUT3)

The interest of the research community in technology acceptance and drivers of technology usage goes back for decades (Wang et al., 2021) and accompanied the rise and adoption of computer-based technologies in a wide range of fields: commerce, telecommunications, medicine/telemedicine, banking/payments, education, home entertainment, smart houses, etc. (Marikyan & Papagianidis 2023, Moon & Kim, 2001).

The original technology acceptance model (TAM), proposed by F.D. Davis while at the University of Michigan in 1989 (Davis, 1989), suggests that the perceived usefulness (PU) and perceived ease of use (PEOU) of technology are the key determinants of user acceptance (Venkatesh & Davis, 1996). According to TAM, users are more likely to adopt a technology if they perceive it as useful and easy to use.

The Extended Technology Acceptance Model (TAM2) developed by Venkatesh and Davis (2000) extends the original TAM to the new TAM2. The two original core constructs of TAM, perceived usefulness (PU) and perceived ease of use (PEOU) were retained while two additional factors were added: social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability). The extended model was tested using longitudinal data collected at four organizations. Measurements were done at three points in time at each organization: pre-implementation, one-month post-implementation, and three months post-implementation. The extended model accounted for 40%–60% of the variance in usefulness perceptions and 34%–52% of the variance in usage intentions.

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is an evolved comprehensive model that seeks to provide a unified understanding of factors influencing the acceptance and use of technology. It was proposed in 2003 by V. Venkatesh (University of Maryland), M.G. Morris (University of Virginia), G.B. Davis (University of Minnesota), and F.D. Davis (University of Arkansas) by integrating and consolidating several existing technology acceptance models. In their paper, the authors reviewed user acceptance literature. They discussed eight prominent models at the time: Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), the Technology Acceptance Model (TAM) (Davis, 1989), the Motivational Model (MM) (Davis et al. 1989), the Theory of Planned Behavior (TPB) (Ajzen, 1985) a model combining the Technology Acceptance Model and the Theory of Planned Behavior (Taylor & Todd, 1995), the Model of PC Utilization (MPCU) (Thompson et al., 1991), the Innovation Diffusion Theory (DOI) (Rogers, 2003), and the Social Cognitive Theory (Bandura, 1986).

The *UTAUT model* identifies four critical determinants of technology acceptance:
Performance Expectancy refers to the degree to which individuals believe that using a particular technology will enhance their job performance or make tasks easier to accomplish.
Effort Expectancy represents the degree to which individuals believe that using technology will be free from effort and easy to use.
Social Influence reflects the influence of social factors and norms on an individual's decision to accept and use technology. This includes the influence of colleagues, supervisors, and other social relationships.
Facilitating Conditions refers to the degree to which individuals perceive that the necessary resources, support, and infrastructure are available to facilitate technology use.

UTAUT acknowledges that individual differences and contextual factors could moderate the relationships between the four key determinants and technology acceptance. These *moderating factors* include *gender, age, experience, and voluntariness of use*.

To validate the solidity of the new model, the authors used data from four organizations over a six-month period with three points of measurement and calculated the percentage of the variance in user intentions to use information technology. The eight models explained between 17 percent and 53 percent of the variance. Then they used their unified model, called the Unified Theory of Acceptance and Use of Technology (UTAUT), using the original data and found to outperform the eight individual models, explaining 77 percent of the variance in behavioral intention to use the technology and 52 percent of the variance in technology use (Venkatesh et al., 2016).

Therefore, UTAUT offers a relatively solid framework for understanding and predicting user acceptance and use of technology, providing valuable insights for practitioners and researchers in technology adoption. UTAUT has been widely applied and validated across various domains and technologies, including e-commerce, mobile technology, healthcare systems, and enterprise systems (Venkatesh et al., 2016).

One of the main limitations of the model was that it was constructed and validated for technology acceptance in organizational settings while non-organizational usage of technology was not studied, in other words, it was not considering that consumers would behave differently vs employees. It was explored in subsequent research and extensions, which refined and expanded the original model to address specific contexts and factors.

UTAUT2 (Venkatesh et al., 2012) is an extended version of the UTAUT model and includes additional constructs such as “hedonic motivation,” “price value,” and “habit” while removing “voluntariness” as moderating factors. The need for this new model mainly was to extend the model's validity for non-organizational settings (i.e., consumers). The new model recognizes that the use of technology by individuals is influenced by these three new constructs (hedonic motivation, price value, habit) moderated by age, gender, and experience. The “price value” construct is a valuable new addition as it accounts for the fact that, unlike in the organizational setting, there is a cost for adopting the behavior in the case of individuals. This is also an essential construct for our situation where farmers will most likely have to pay for at least part of the digital services, making UTAUT2 a better model to study farmers’ technology acceptance and usage in a very likely “freemium” type of business model.

Dwivedi (2017) made a critical review of UTAUT and emphasized the need to include “attitude” in the model to quantify the impact of the individual’s attitude on the behavioral intent and the actual (behavioral) usage of technology. Their review concluded with an amended UTAUT model where attitude partially mediates the effects of performance expectancy, effort expectancy, facilitating conditions, social influence on behavioral intent, and a direct effect on usage behavior.

The history of technology acceptance models to date also includes the extension of UTAUT2 to UTAUT3 (Farooq et al., 2017) with the introduction of the “personal innovativeness” construct. The Web of Science search for “UTAUT3” materials yielded five articles: 3 related to education (Tiwari et al., 2022; Gupta et al., 2022; Gunasinghe et al., 2020) and two related to payments (Chen et al., 2019; Saha et al., 2022).

Methodology

Online libraries and article repositories (Web of Science, Scopus, Taylor&Francis, Google Scholar), consulting firm reports (Goedde et al., 2020; Roland Berger, 2015, 2019), as well as references used in the doctoral school classes (Bratianu, 2022, Pînzaru et al., 2017, 2019, 2022) as well as thematic and author, searches on Research Gate (social network for scientists and researchers) were used to enrich the literature review for the keywords mentioned above and concepts with focus on barriers to adopting digital agriculture and tools to measure factors influencing adoption rates.

Results and discussion

The Uptake and Usage Theory

The Uptake Theory (Rose et al., 2016) was developed using a learning plot built on a baseline survey through 244 face-to-face quantitative interviews with farmers, a number of 78 semi-structured interviews with farmers and advisers, as well as a one-day workshop with 39 researchers, policymakers, and decision support manufacturers. The research was meant to understand better what could help increase the adoption of agricultural decision support systems both by farmers and their advisers. The study identified 15 factors influencing the adoption and usage of agricultural digital decision support systems. The Uptake Model affirms that usability, cost-effectiveness, performance, relevance to the user, and compatibility with compliance demands are the motivations that would persuade a farmer to adopt a certain decision support system. Age, type of farming, digital literacy level, and farm size (scale) might stimulate or inhibit adoption readiness. At the same time, the intensity of marketing activity and any help to fulfill compliance needs will further enhance the probability of adoption, as shown in Figure 3.

Although it did not start with any TAM or UTAUT model in mind, it yielded an architecture of constructs very similar to that of the UTAUT2 model. Core factors (performance expectancy, ease of use, peer recommendation, trust, cost, habit, relevance to user, and farmer-adviser compatibility) directly influence behavioral intent to use a specific decision support tool. The modifying factors (age, scale of farming, farming type, IT education) modify the strength of the core factor, which in turn affects uptake. The facilitating conditions (internet signal, compatibility with existing systems, fit within the workflow of the end user) are enabling factors. Notably, Rose et al. (2016) identified two driving factors: compliance (helping a farmer or adviser to satisfy legislative or market requirements) and level of marketing. In the discussion part of the article, the authors draw a direct similarity with the UTAUT2 model (Venkatesh et al., 2012).

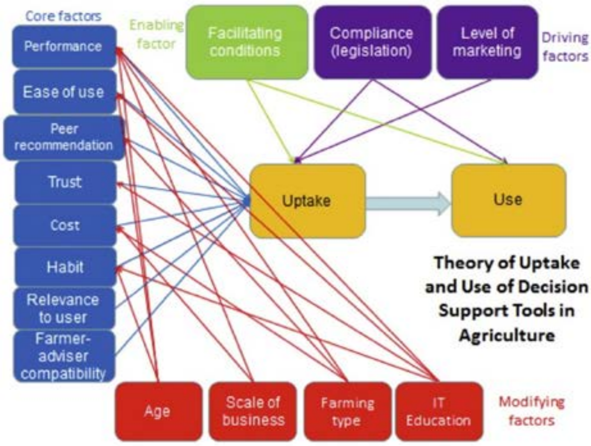

Figure 1. The Decision Support Tools in Agriculture Uptake and Usage Model
Source: Rose et al., 2016

UTAUT2 extension to assess willingness to pay for agricultural IoT

Shi and his team (Shi et al., 2022) examined the factors influencing the willingness of Bangladeshi farmers to adopt and pay for the Internet of Things (IoT) in the agricultural sector. The study was a cross-sectional quantitative study using the convenience sampling method and obtained data from 345 farmers (premium fruit growers) from the northern districts of Bangladesh. The questionnaire used the theoretical framework of the Unified Theory of Acceptance and Use of Technology 2 (UTAUT 2) from which Habit (HB) was eliminated and new constructs were added: Trust (TT), Government Support (GS), and Willingness To Pay (WTP) as shown in the model below:

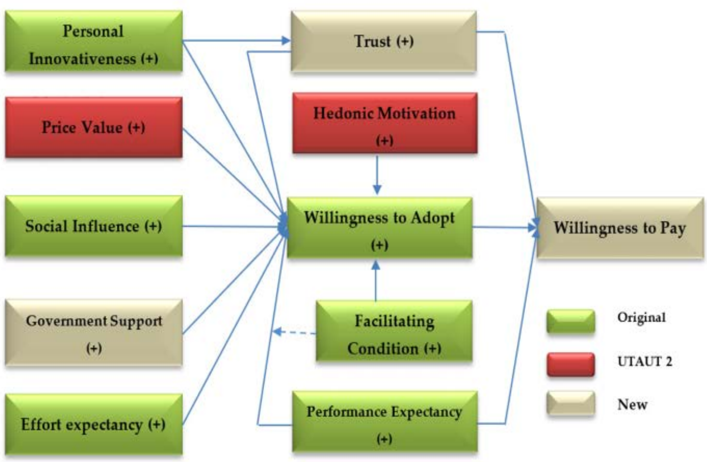

Figure 2. Conceptual model
Source: Shi et al., 2022

The data were analyzed using the Structural Equation Modeling (SEM) and confirmed that effort expectancy (EE), performance expectancy (PE), facilitating condition (FC), hedonic motivation (HM), government support (GS), price value (PV), personal innovativeness (PI), and trust influence the willingness of Bangladeshi farmers to adopt the IoT (WTA) that in turn determines the willingness to pay (WTP). Additionally, predictors such as trust (TT) and willingness to adopt (WTA) were observed to influence the willingness to pay for the IoT (WTP), while the construct "performance expectancy" (PE) produced no effect. The study also revealed that the willingness to adopt (WTA) moderates the association between performance expectancy (PE), price value (PV), and willingness to pay for the IoT (WTP).

This study brings several novelties. It studies the behavior of rural customers with respect to innovation adoption (IoT in agriculture), indicating precise reasons for the willing adoption of the IoT in agriculture. Using an extended UTAUT2 model that incorporates farmers' willingness to pay, it is among the first empirical studies examining whether farmers in a developing economy (such as Bangladesh) will adopt and pay for the agricultural IoT, a solid proxy for digital agriculture services.

Following the recommendation of the UTAUT author (Venkatesh et al., 2016), the UTAUT2 core model could be extended to fit the purpose of this study. The newly proposed model is constructed using the comparative table below:

Table 1. The unified model proposal (Source: Authors' own contribution)

Rose et al., 2016	**Shi et al., 2022**	**Venkatesh et al., 2016**	**Proposed Model**
Performance Does the tool perform a useful function and work well?	**Performance expectancy** I find IoT systems useful in crop yield rate analysis. Using an IoT system will assist in weather forecasting in crop production. I find IoT systems useful in field mapping using GPS systems in crop production.	**Performance Expectancy**	Yes
Ease of Use Is the user interface easy to navigate?	**Effort expectancy** The IoT is easy to learn for me. It is simple to become skillful at using the IoT. I find the IoT simple to use.	**Effort Expectancy**	Yes
Peer recommendation Is it peer-to-peer recommended?	**Social Influence** People who matter to me suggest I should utilize the IoT in agriculture. People who shape my behavior suggest I should utilize the IoT in	**Social influence**	Yes

	agriculture. People I respect desire that I employ the IoT in agriculture production.		
Trust Is the tool evidence-based, and does it have the trust of users?	**Trust** I believe that using the IoT is safe. I do not doubt the security of the IoT. The IoT can fulfill its task.		Yes
Cost Is there a cost-benefit, or is the initial cost too high?	**Price Value** The IoT system is reasonably priced. Usually, IoT systems are good value for money. With the current price, the IoT system provides good value.	**Price Value**	Yes
Habit Does the tool match closely with the existing habits of farmers?		**Habit**	Yes
Relevance to user Can the tool provide relevant information on an individual's farm?			No - Part of Perf. Expect.
Farmer-adviser compatibility Could the tool be targeted at advisers to encourage client uptake?			No
Age Does the tool match the skills and habits of the different age groups?			Yes
Scale of business How far is the tool applicable to all scales of farming?			Yes
Farming type How useful is the tool for different farming enterprises?			No
IT education Does the tool require good IT			Yes

skills to use?			
Facilitating conditions Is there internet access? Does it fit the farmers' workflows? Is their compatibility with the use of existing devices?	**Facilitating Condition** I am well equipped to put the IoT to work in agricultural productivity. I know how to apply the IoT in agriculture. When I encounter challenges in implementing the IoT in agriculture production, I can ask for assistance from others.	**Facilitating Conditions**	Yes
Compliance How can the tool help users to satisfy legislative and market requirements?			Yes, to be included as a Perf. Expect. item
Level of marketing How intensely is the tool being communicated/promoted?			No
Uptake	**Willingness to Adopt** I intend to use the IoT system in agricultural production. I plan to use IoT systems in agricultural production in the future. In the future, I believe I will employ an IoT system in agricultural production.	**Behavioral Intent**	Yes
	Hedonic Motivation IoT system usage is fun. IoT system usage is enjoyable. IoT system usage is entertaining.	**Hedonic Motivation**	No
	Personal Innovativeness I like to try new things. I would not hesitate to use new agricultural technology. Among other agri-entrepreneurs, I am usually the first to try out new agricultural technology.		Yes

	Government support The use of the IoT in agricultural production is encouraged and promoted by the government. The Internet infrastructure, including bandwidth, is enough for the IoT. The government has established solid rules and restrictions for using IoT systems in agriculture.		No – Consider formulating new items.
Usage	**Willingness to Pay** I will use IoT services in agricultural firming, even if the price increases somewhat. I am interested to pay a higher price for IoT services than similar agricultural technology. I will use IoT services via information technology devices, even if the price increases.	**New Conception of Acceptance and Use**	Yes

The proposed model would be the UTAUT2 extended model following the below conceptual framework:

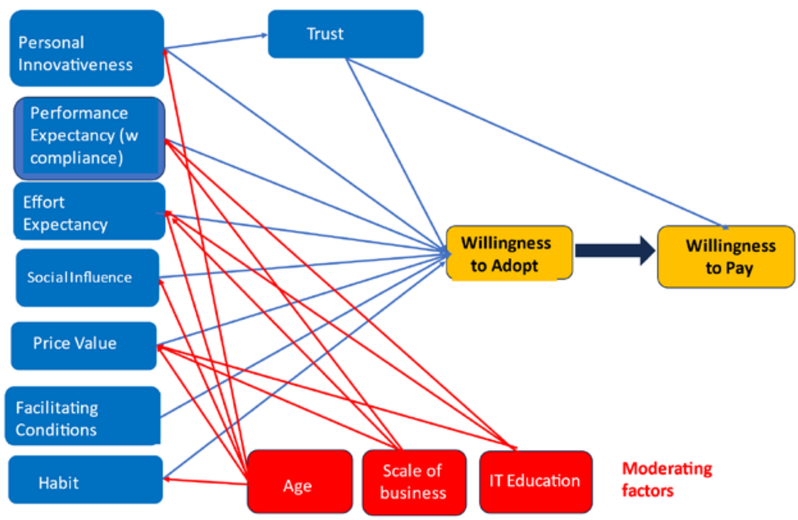

Figure 3. Proposed conceptual model
Source: Authors' own research results/contribution

Conclusion

As proven over time through its genesis and evolution, the UTAUT model (Venkatesh et al.., 2016) is a solid model (Tamilmani et al., 2021) that could be used in a research project that aims to understand the motivations of the Romanian field crop farmers (arable farming) to adopt digital agriculture technologies and practices and even explore their willingness to pay for these services. The intent is to use this model in subsequent quantitative measurements of Romanian farmers' motivations to embrace Agriculture 4.0. A preliminary qualitative consultation with practicing digital farmers is also planned.

The paper is a premier in the literature about Romanian farmers. It is deemed to be a valuable tool for both researchers as well as developers of digital tools for farmers.

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