

## 141. What factors shape farmers' intention to adopt new technologies? The case of the Italian vegetable sector

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### Abstract

This study examines the factors influencing the adoption of digital technologies among Italian farmers, focusing on the horticultural sector. The research employs the Extended Technology Acceptance Model (TAM) to analyze the determinants of technology adoption, integrating factors such as perceived usefulness, ease of use, social norms, and external pressures. A comprehensive survey of 250 farmers was conducted to obtain data on Italian farmers' intention to adopt new technologies, such as automated irrigation systems and predictive models. The results indicate that there are significant barriers to the adoption of digital technologies, with limited access to information and digital literacy being particularly noteworthy.

**Keywords:** digital technologies adoption, farmers' intentions, horticultural sector, sustainable farming, Technology Acceptance Model (TAM)

### Introduction

The agricultural sector faces many unprecedented challenges, including the need to develop sustainable resource management strategies to meet the growing demand for food and reduce the environmental impact of food production (Kapsdorferová, 2024). Given the increasing pressure on agricultural systems, especially on natural resources, it is crucial to identify effective measures to mitigate these negative impacts in line with the European Green Deal and the United Nations Agenda 2030 (Montanarella & Panagos, 2021; Peeters *et al.*, 2020). In this context, applying digital technologies and developing smart solutions have proven to be key strategies for improving efficiency, productivity, and sustainability in the agri-food sector (Yigezu *et al.*, 2018). Implementing innovations such as autonomous irrigation systems and predictive modelling has the potential to address significant challenges such as water scarcity and the impact of climate variability (Adeyemi *et al.*, 2017). Predictive modelling refers to using data-driven algorithms and statistical techniques to predict future conditions based on historical and real-time data. In relation to agriculture, and specifically irrigation systems, predictive modeling helps farmers anticipate water needs by analyzing factors such as weather conditions, soil moisture, crop water needs and climate variability (Adeyemi *et al.*, 2017). It is evident that despite the overall focus on ensuring a fair transition of farming practices to digital technologies, the diffusion of smart irrigation system remains uneven and heterogeneous between farmers. One of the major challenges small-scale agriculture faces is the limited adoption of autonomous irrigation systems integrated with predictive modelling, which has led to relatively low technology penetration in the sector (Senyolo, 2018). In this context, it is crucial to gain insights into farmers' behaviour, their propensity to adopt smart solutions and potential strategies to facilitate wider adoption of technologies in the agricultural sector (Mishra *et al.*, 2014; Cimino *et al.*, 2024). In the horticultural sector, which plays a crucial role in agricultural sustainability, little research has focused on the adoption of water smart technologies. Most studies on precision agriculture have examined large-scale cereal farming, neglecting horticultural systems where irrigation efficiency is a key factor (Adeyemi *et al.*, 2017).

This study aims to investigate the determinants influencing Italian farmers' adoption of digital smart-water technologies, focusing on horticultural crops. The technologies studied relate to intelligent water management through a three-stage technological complexity: the first stage is represented by the introduction of soil moisture sensors, which progresses to a system that combines sensors with an automated irrigation system, and in the last stage the sensors are connected to an automated system, which in turn is connected to and interacts with predictive models.

Horticulture has been considered for some reasons: first, because of the importance of this sector in the Italian agricultural system; secondly, for the relevance of the irrigation in this cropping system (Patle *et al.*, 2019); third because of the relevance of smart precision in horticulture (Adeyemi *et al.*, 2017).

## Literature review and theoretical background

As the existing literature indicates, the process of adopting new technologies is inherently complex and dynamic (Montes de Oca Munguia *et al.*, 2021). In particular, the decision-making process is influenced by various factors, which affect farmers' technology adoption rate (Osorf *et al.*, 2023). Some authors have highlighted the specificity of theories in modelling different aspects of the technology adoption process (Dissanayake *et al.*, 2022; Osorf *et al.*, 2023), while others have expressed doubts about the generalist ability of theories to represent different technologies and practises (Montes de Oca Munguia *et al.*, 2021). Indeed, there is still confusion about the analysis methods and the choice of explanatory variables that should be used to model the adoption process (de Oca Munguia and Llewellyn, 2020).

Since this paper aims to measure the intention of Italian farmers to adopt a technology, the Technology Acceptance Model (TAM), which is based on the Theory of Reasoned Action, was taken into account. TAM assumes that behavioural intention, attitude, perceived usefulness and perceived ease of use directly or indirectly influence the actual use of technology (Fishbein and Ajzen, 1975). Furthermore, the literature recommends TAM as the most appropriate basis for the theoretical construction of the Farmer Technology Acceptance Model (Amin and Li, 2014; Alambaigi and Ahangari, 2016; Thomas *et al.*, 2023). A modified version of the TAM, named TAM2, is based on the theory of planned behaviour (Ajzen, 1986; Venkatesh and Davis, 2000). The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, 2003) is the latest version of the model and, later on, an other extension of the original TAM, the TAM-3 version, was proposed by Venkatesh and Bala (2008). The TAM-3 extension introduces new constructs and determinants that affect the core variable Perceived Ease of Use (for the Perceived Usefulness the constructs are the same as in the TAM-2 version: subjective norm, image, job relevance, output quality, and result demonstrability) and proposes new relationships among the constructs. The factors that influence Perceived Ease of Use, in the TAM-3 version are: computer self-efficacy, perception of external control, computer anxiety, computer playfulness, perceived enjoyment, and objective usability. The other novelty introduced by this extension are represented by the new relationships proposed: (i) the correlation between the perceived ease of use and perceived usefulness, (ii) the correlation between the perceived ease of use and intention, and (iii) the anxiety.

## Data and method

Data collection took place in two phases. First, a preliminary explorative phase was conducted with qualitative unstructured interviews ( $n=10$  relevant stakeholders, such as agronomists, producers' organizations, interbranch organizations, and farmers) conducted in Italy in December 2023. In the second phase, a survey was carried out among a sample of Italian horticultural businesses. After an initial pilot phase ( $n=21$  interviews) for the testing of the questionnaire, the main survey was

carried out in October–November by an international market research company by means of CATI (Computer Assisted Telephone Interview). The survey lasted approximately 30 minutes.

The settled total sample involved was composed of 251 Italian farmers having the following features: farmers growing tomatoes with the following geographical distribution: 50% in the North of Italy and 50% in the South of the country and farmers growing fresh vegetables, melons, water melons etc. distributed in the North of Italy (30%), in the Centre (17%) and in the South (53%). The geographical split was settled to have a representativeness for all crops, and covering different administrative regions across Italy ensures a thorough understanding of farming practices in the whole country, elucidating also the different technological levels reached. For fresh vegetables, the split was calculated based on the data extracted from the Italian national statistical institute (Istat); for tomatoes, an equal share was established since there are no big differences in this specific crop distribution between the North and the South of the country.

The questionnaire was designed to test the model hypotheses together with the socio-demographic information and the descriptive indicators. A total of 14 constructs were included in the questionnaire with a total of 45 items. All items of the TAM3 were measured on a 7-point scale (ranging from 'strongly disagree' to 'strongly agree').

Some small adjustments to the original TAM-3 model proposed by Venkatesh and Bala (2008) have been adopted to better fit the purpose and the context of the analysis. Firstly, all the items constructs have been evaluated and considered in the context-specific setting: some aspects were considered highly significant and explicitly arose from the exploratory phase with stakeholders, such as, for instance, the technology self-efficacy and the output quality. Other features, such as (computer) playfulness or perceived enjoyment, were considered characteristic of the original conceptualization of the model related to information technologies but do not apply to the context of the current research and were therefore excluded from the model design. Secondly, some variables proved to be significant when considering sustainability issues (Gemtou *et al.*, 2024). Consequently, the SAFA aspects were assessed by four items (e.g., "By using this innovation, I could help reduce water consumption").

## Results

The sample is mainly composed of farmers who have not adopted any level of these technologies yet (69.7%); the ones who adopted one of these technologies rely on the first level (sensors: 17.1%), and few already employed automated irrigation systems or the most complex one with forecast models, respectively accounting for 6.4% and 6.8%. In light of these results, it is important to understand the motivation to adopt new technologies and the factors that hamper their adoption. In order to explore these questions, a TAM-3 model was designed.

To test the hypotheses about causal relationships among the chosen variables illustrated in Figure 1, a structural equation model managed with SPSS v. 29.0 and AMOS v. 29.0 statistical software (IBM, Armonk, NY, USA) was performed.

The fit indices, compared to more basic models with a restricted number of variables, show a poorer fit. Nevertheless due to the complexity of the whole theorization model they still suggest a good fit: the Comparative Fit Index (CFI) equals 0.950, the Root Mean Square Error of Approximation (RMSEA) is equal to 0.051, the Tucker–Lewis Index (TLI) is 0.942 and the Standardized Root Mean Square Residual (SRMR) results 0.054. The path coefficients are shown in Figure 1. The results indicate that the intention to adopt technologies affects the actual behaviour (i.e. the adoption of the technology itself), as postulated by the applied theoretical frames. Behavioural intention is positively affected by the perceived usefulness, which is one of the two core variables of the TAM-3. Regrettably, the perceived ease of use does not explain the intention to adopt technologies and it is an open point to be further reviewed and investigated. Subjective norm is also positively affecting the intention

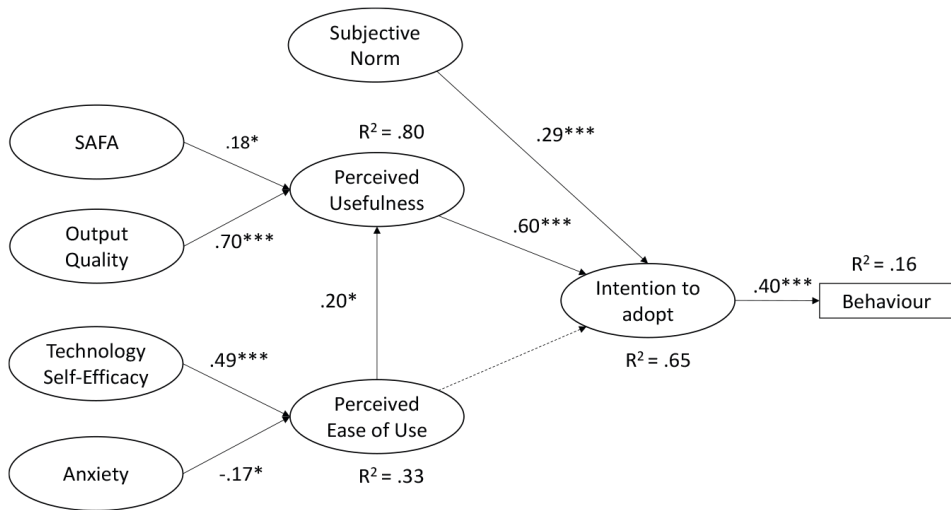


Figure 1. Proposed model based on TAM-3 theory.

to adopt technologies, showing that the perceived social pressure has an effect on the intention to adopt. The anxiety construct reveals a negative correlation toward the ease of use, attribute which is stimulating, when confirmed by a larger sample, and could open new ways to design and conceive modern technologies. Perceived ease of use, instead, is positively influenced by technology self efficacy. Perceived usefulness, in turn, is influenced by output quality (i.e. the perceived quality of the effects introduced by the use of the technology) and by the SAFA-based items.

### Conclusion

The implemented model, inspired by the TAM-3 conceptualisation, returns a good fit with real data collected for most of the constructs analysed. Because of the complexity of the model and the great numbers of items, an higher score in significance is complicated to be achieved. Nevertheless, extending the sample and collecting more questionnaires could be interesting for testing the validity of all the hypothesis included from the original theorisation. The perceived ease of use is the core variable which could be deeply analysed to understand wheter it is not relevant to explain the intention to adopt in the context-specific case study, or if the significance level is simply linked to the sample size. This aspect will shed light for technology-providers to better focus their attention and the implementation of their products and gives insights, on the other hand, to the features which could be strengthen to pursue a wider adoption of smart technologies. Obviously the study reflects not only a context-specific setting (farmers in horticultural sector), but also the national specificity, which could highly variate from country to country because of different normative and incentive frames, cultural practices, and, above all, technological infrastructures. For this reason it will be interesting to collect similar data in other countries to compare differences and similarities and to explore successful solutions already applied abroad. Moreover, the costructs which gives a negative correlation, could be codified and rephrased taking into consideration cultural peculiarities to check whether, changing the focus to slightly different aspects of the same domain, these exert their influence or not on the core variables of the model. In this way, a confirmation in line with literature or new categories and items to the existing model could be proposed for the sector analysed.

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