# Understanding the determinants of IT adoption in agriculture using an integrated TAM-TOE model: A bibliometric analysis

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## Abstract

This paper contributes to the understanding of the use of digital technologies in agriculture. It aims to highlight the different factors of the adoption of these digital technologies in agriculture. The theoretical framework of the research is based on two well-known models of adoption of new technologies (TAM and TOE). The authors propose a model combining the previous two. A bibliometric analysis of several articles dealing with digital adoption in agriculture was then conducted. It allows to refine the proposed model, by selecting the most relevant variables.

*Keywords :digital use, digital adoption, agriculture*

## 1. Introduction

The processes by which individuals adopt technologies in the workplace, and the factors that influence their usage remain a central focus of information systems research (Venkatesh et al., 2003) Information-based innovations are being introduced into the workplace at a rapid rate. Facilitating the introduction of IT (Information Technology) innovations requires an understanding of the factors that influence users' adoption and continuing use decisions. Such factors are important for both voluntary use systems and those mandatory ones (Jasperson et al., 2005).

In this paper, we seek to extend our understanding of the adoption of IT innovations, by developing an integrated model and identifying the factors that influence the adoption of digital services and IT solutions in agriculture. This is important because it will lead to an identification of the determinants facilitating an effective adoption in farms. First, a review of existing IT adoption models is provided, pointing out their advantages, domains of implementation and their limits. An integrated model is provided that overcomes some of these limitations while benefiting of main advantages of two well-known adoption models, namely the Technology Acceptance model TAM of Davis (1989) and the Technological-Organizational-Environmental (TOE) framework of Tornatzky and Fleisher (1990). Then, a bibliometric analysis of previous studies dealing specifically with the agricultural sectors is implemented. It allows the identification of adoption that have been explored and are pertinent for explaining IT adoption by farmers. These determinants are organized based on the integrated TAM-TOE model suggested in this paper, pointing out a set of factors that are appropriate for studying digital transformation in agriculture, and a set of factors for which more explorations is still needed.

## 2. Technology adoption models

The success of innovations can be measured by running an analysis of their adoption in the target markets by potential users. The literature is rich with many theoretical models which assist in making such analysis (Venkatesh et al., 2003; Venkatesh et al., 2012), such as the Diffusion of Innovations (DOI) theory (Rogers, 1995), the Theory of Reasoned Actions (TRA) of Fishbein and Ajzen (1975), the Theory of Planned Behavior (TPB) of Ajzen (1985), the Technology Acceptance Model (TAM) of Davis (1989), the Technology-Organization-Environment (TOE) framework (Tornatzky and Fleisher, 1990), the extended Technology Acceptance Model (TAM2) of Venkatesh and Davis (2000), and the Unified Theory of Acceptance and Use of Technology (UTAUT) of Venkatesh et al. (2003). Of all the aforementioned theories or models, Rogers' Diffusion of Innovations theory is very well established and the most used one (Tornatzky and Klein, 1982; Kapoor et al., 2013). The above technology adoption models used more or less similar types of explanatory factors as the DOI theory of Rogers (1995, 2003). For instance, the TPB model is an extension of the TRA model and shares similarities with TAM. TAM is regarded as an adaptation of TRA, and the main TAM constructs are similar to two of Rogers' DOI attributes. The TOE framework is consistent with DOI theory. Indeed, the DOI adoption predictors are comparable to those of the TOE framework (Baker, 2011). Based on an extensive literature review, this study paper introduces the basis of the DOI theory and more specifically presents the TAM model and the TOE framework. Then, a proposal for an integrated TAM-TOE model is suggested.

### 2.1 Diffusion of Innovation (DOI)

DOI is a theory of how, why, and at what rate new ideas and technology spread through cultures, operating at the individual and firm level. DOI sees innovation as being communicated through certain channels over time and within a particular social system (Rogers, 1995). Individuals are seen as possessing different degrees of willingness to adopt new technologies, and this it is generally observed that the portion of the population adopting is approximately normally distributed over time. Then, breaking this normal distribution into segments leads to the segregation of individual into five categories of individual innovativeness from earliest to latest adopters: innovators, early adopters, early majority, late majority, laggards (Rogers, 1995). However, the innovation process in organizations is much more complex, since it involves a number of individuals including both supporters and opponents of new ideas; each one playing a role in the innovation decision- making process. Since the first applications of the DOI theory to Information System (IS) research, the theory has been applied and adapted in various ways (Compeau et al., 2007; Oliviera and Martins, 2011).

Following DOI theory at the firm level, innovativeness is related to several independent variables that are individual or leader characteristics, internal organizational structural characteristics, and external characteristics of the organization (see. Fig 1.) ***Individual characteristics*** describe the leader attitude toward change. ***Internal characteristics of organizational structure*** includes observations regarding centralization, complexity, formalization, interconnectedness, organizational slack, and size. *Centralization* is the degree to which the power and control in a system is concentrated in the hands of a relatively few individuals. *Complexity* is the degree to which an organization's members possess a relatively high level of knowledge and expertise. *Formalization* is the degree to which an organization emphasizes its members' following rules and procedures. *Interconnectedness* is the degree to which the units in a social system are linked by interpersonal networks. *Organizational slack* is the degree to which uncommitted resources are available within the organization. Finally, *size* is the number of employees of the organization. ***External characteristics of the organization*** refers to the system openness (Rogers, 1995; Oliveira and Martins, 2011).

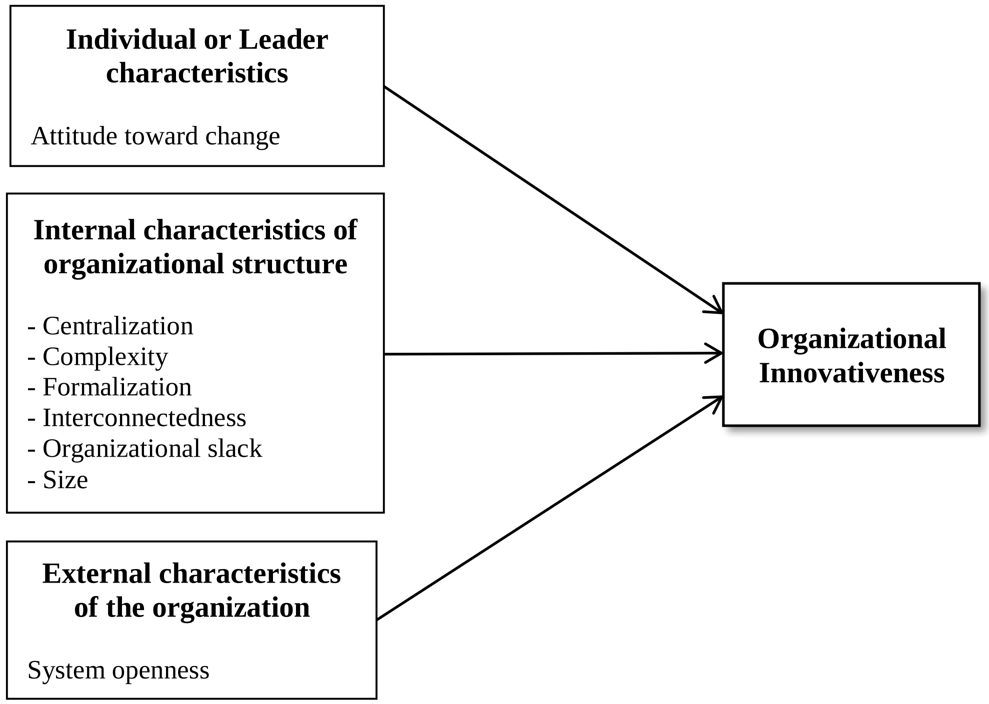


**Fig. 1**. Diffusion of innovations theory (Rogers, 1995).

Diffusion of innovations theory is possibly the principal theoretical perspective on technology adoption at both individual and organizational levels, offering a conceptual framework for discussing adoption at a global level. According to Rogers (2003), the following five attributes impact the diffusion of an innovation, which came to be recognized as *perceived attributes of innovations*: relative advantage, compatibility, complexity, triability, and observability are the most essential for examining technology adoptions. Besides, Rogers (2003) explained that these perceived attributes of innovations are an important explanation of the adoption rate of an innovation, and that most of the variance in the adoption rate (14% to 87%) is explained by these five attributes.

## 2.2 Technology Acceptance Model (TAM)

The TAM model is a widely accepted model for understanding IT adoption and use (or acceptance) processes. It explains the determinants of user acceptance of a wide range of technologies (Davis,

1989) and much of the variance in users' behavioral intention related to IT adoption and useacross a wide variety of contexts (Hong et al., 2006). Furthermore, TAM seeks to explain the relationship between technological acceptance and adoption, and subsequently, behavioral intention to use it (Autry et al., 2010). TAM considers the *perceived usefulness* (PU) and *perceived ease-of-use* (PEU) as the primary determinants of IT adoption (Gangwar et al., 2014). PU is defined as "*the prospective user's subjective probability that using a specific application system will increase his (her) job performance within the organizational context*" (Davis, 1989). PEU refers to "*the degree to which the prospective user expects the target system to be free of effort*" (Davis, 1989). The model also suggests that PEU influences PU (see. Fig 2.) because technologies that are easy to use can be more useful (Schillewaert et al., 2005). Implementations of TAM show that these two constructs consistently explain 40% of the variance in individuals' intention to use a technology (Autry et al., 2010).

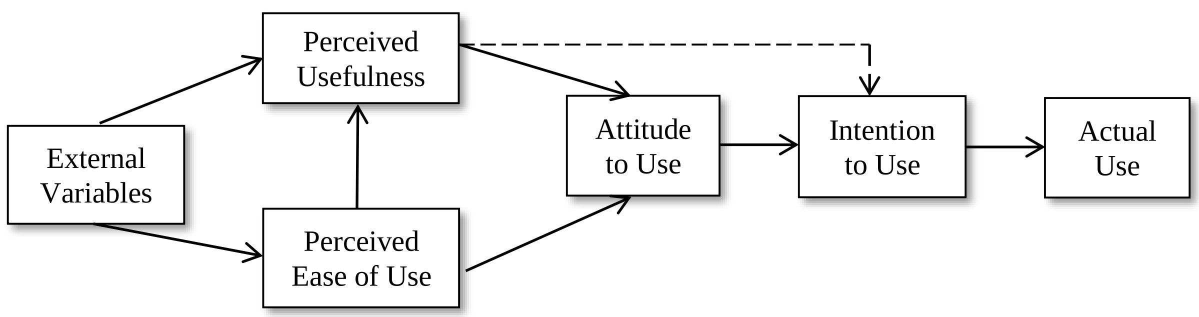


**Fig. 2**. Original technology acceptance model (TAM) (Davis, 1989).

Though TAM was originally developed to predict user's initial adoption of a new IT, it is also expected to explain and predict future user behavior (see. Fig 2.). TAM is an intention-based model, which stipulates that the intention to adopt a technology is a good predictor of a user's acceptance of information technology and its actual usage (Au and Zafar, 2008; Hong et al., 2006). TAM has been widely applied to a diverse set of technologies and users (Venkatesh et al., 2003; Williams et al., 2009). Researchers have utilized TAM for an initial exploration of factors influencing the adoption of many technologies such as Broadband (Dwivedi and Irani, 2009), e-mail (Karahanna and Straub, 1999), voice mail (Karahanna and Limayem, 2000), e-health systems (Wilson and Lankton, 2004), e-marketplace (Cloete and Doens, 2008), e-commerce (Chen and Tan, 2004), mobile commerce (Li et al., 2007), commercial web application (Lee et al., 2003), traceability systems (Theuvsen and Hollmann-Hespos, 2005), and precision agriculture (Adrian et al., 2005; Aubert et al., 2012).

However, studies on TAM have generated conflicting findings and led to confusion over moderating and external variables (Chen and Tan, 2004). Results coming from a TAM model should be generalized with caution. Indeed, Legris et al (2003) highlighted that TAM-based empirical studies do not produce totally consistent or clear results, calling for the inclusion of more factors into the TAM model. TAM contains a restricted number of constructs (Wu, 2011) and thus provides limited possibility of explanations (Garača, 2011). Thus, there is scope of extension for the TAM model as well as investigation of the role of certain variables such as technological influences, the role of firm size in the technology acquisition decision, trust, as well as evaluation of the consequences of technology usage on performance. Especially, the integration of the TAM model with other IT adoption models and theories is suggested as a need for improving its applicability (Gangwar et al., 2014).

## 2.3 Technological-Organizational-Environmental (TOE) framework

The TOE framework was developed by Tornatzky and Fleisher (1990) to examine adoption of various IT products and services at the firm level. It has emerged as a widespread theoretical perspective on IT adoption (Zhu et al., 2004). The TOE framework is an organization-level approach that explains that three aspects of an enterprise's context influence the process by which it adopts and implements a technological innovation: technological context, organizational context, and environmental context (see, Fig. 3).

The ***technological context*** describes both the internal and external technologies relevant to a firm. This includes current practices and equipment already integrated to the firm as well as the set of available technologies on the market place, but not currently in use in the firm (Oliveira and Martins, 2011). A firm's existing technologies are important in the adoption process because they set a broad limit on the scope and pace of technological change that a firm can undertake (Collins et al., 1988). The technological context is comprised of variables that influence an organization's adoption of innovation (Huang et al., 2008). Apart from innovation attributes derived from the Diffusion of Innovation theory (Rogers, 1995), studies found that system assimilation, triability, complexity, perceived direct benefits, perceived indirect benefits, and standardization are significant variables (Gangwar et al., 2014).

The ***organizational context*** refers to the characteristics and resources of the firm, including managerial structure, intra-firm communication and control processes, firm scope and size, along with the amount of slack resources and innovativeness of the organization (Baker, 2011; Dedrick and Wast, 2003; Oliveira and Martins, 2011). The significant variables in the organizational context include financial resources, firm structure, organizational slack, innovation capability, knowledge capability, operational capability, strategic use of technology, trust, technological resources, support for innovation, quality of human capital, organizational knowledge accumulation, expertise and infrastructure, and organizational readiness; the role of top management commitments varying form context to context (Gangwar et al., 2014).

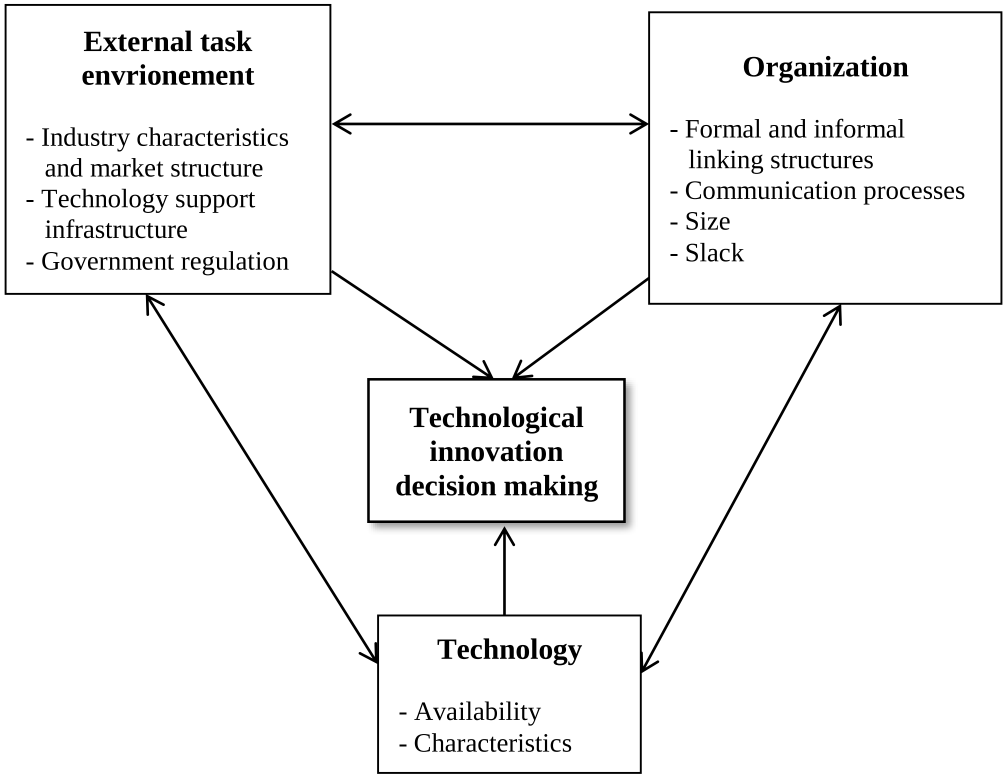


**Fig. 3**. The technology-organization-environment (TOE) framework (Tornatzky and Fleischer, 1990).

The ***environmental context*** focuses on areas in which a firm conducts its business operations, such as its industry structure, the presence or absence of technology service providers, and interactions with the government (Baker, 2011; Oliveira and Martins, 2011). It includes variables related to industry characteristics such as rivalry relations with buyers and suppliers as well as the stages of the industry life cycle (DePietro et al., 1990). With regard to industry life cycle, it is argued that firms in rapidly growing industries tend to innovate more rapidly. In mature and declining industries, however, innovation practices are not clear-cut (Tornatzky and Fleisher, 1990). Significant variables of the environmental context include customer mandate, competitive pressure, external pressure, internal pressure, trading partner pressure, vendor support, commercial dependence, environmental uncertainty, information intensity, and network intensity (Gangwar et al., 2014). Besides, the support infrastructure for technology also impacts innovation, and the availability of skilled labor and consultants or other suppliers of technology services fosters it as well (Baker, 2011). External factors influencing the industry such as government incentives and regulations are also of importance (Salwani et al., 2009), since they can have either a beneficial or a detrimental effect on innovation and they can either encourage or discourage it. When governments impose constraints on industry, adoption can be made mandatory (Baker, 2011).

Extant research has demonstrated that the TOE framework has broad applicability and possesses an explanatory power across a number of technological, industrial, and cultural contexts. It has been used to explain the adoption of inter-organizational systems (Mishra et al., 2007), e-business (Zhu and Kraemer, 2005), electronic data interchange (EDI) (Kuan and Chau, 2001), open systems (Chau and Tam, 1997), enterprise systems (Ramdani et al., 2009), and a broad spectrum of general IS applications (Thong, 1999). In each study, the three contexts have been shown to influence the way a firm identifies the need for, search for, and adopt new technologies. Besides, the TOE framework is consistent with the DOI theory of Rogers (1995) that emphasized individual characteristics and both the internal and external characteristics of the organization as drivers for organizational innovativeness. These are identical to the technology and organization context of the TOE framework, but the TOE also includes a new and important component that is the environmental context. The environmental context presents both constraints and opportunities for technological adoption. Thus, the TOE framework makes Rogers's innovation diffusion theory able to also explain intra-firm innovation diffusion (Hsu et al., 2006).

Studies based on the TOE framework have, however, several limitations. According to Dedrick and Wast (2003), the TOE framework is just a taxonomy for categorizing variables and does not represent an integrated conceptual framework or a well-developed theory, thus calling for a more robust framework to study organizational adoption. Besides, the TOE framework has a limited explanatory power of technology adoption, with less than 50% of adoption variance explained in the specific case of EDI adoption (Gangwar et al., 2014). Furthermore, Wang et al. (2010) mentioned that the TOE framework has unclear major constructs and that the variables used vary with contexts; thus, calling for other variables to be included in order to enrich the TOE framework, such as sociological variables, cognitive variables, technology readiness, knowledge management capabilities, ability to leverage IT investment through different channels, professional experiences and skills, managerial capabilities of change management, security concerns, government promotion and factors salient to the country context such as government policy/regulation, technology infrastructure and culture (Gangwar et al., 2014).

## 3. An integrated TAM-TOE model of IT adoption

Based on the literature review provided above, a proposal for an integrated TAM-TOE model is now suggested. Developing an integrated model allows us to not only investigate the technological, organization, and environmental contexts of IT adoption, but also individual factors; thus, combining the strengths of the TAM model in explaining individual behavior with the strength of the TOE framework in explaining organizational behavior.

The two construct of TAM (PU and PEU) explain about 40% of the systems' use (Legris et al., 2003), and the external variables in the extended models of TAM are not clearly defined yet. These external variables are often dependent on the context and thus, vary from one study to another. Therefore, TAM is described as a partial model of technology adoption (Riyadh et al., 2009). Subsequently, Legris et al. (2003) pointed out the need to integrate TAM with other innovation adoption models, especially those that includes variables related to human and social change processes. On the other side, the TOE framework has unclear major constructs (Wang et al., 2010) and is too generic (Riyadh et al., 2009). So, there is a need for the TOE framework to be strengthened by integrating models having clear constructs. Therefore, researchers have advocated the need of integrating TAM and TOE, so that the predictive power of the resulting model can be improved and some of their limitations can be overcome (Gangwar et al., 2014). Our proposition for an integrated TAM-TOE model is illustrated in Figure 3.

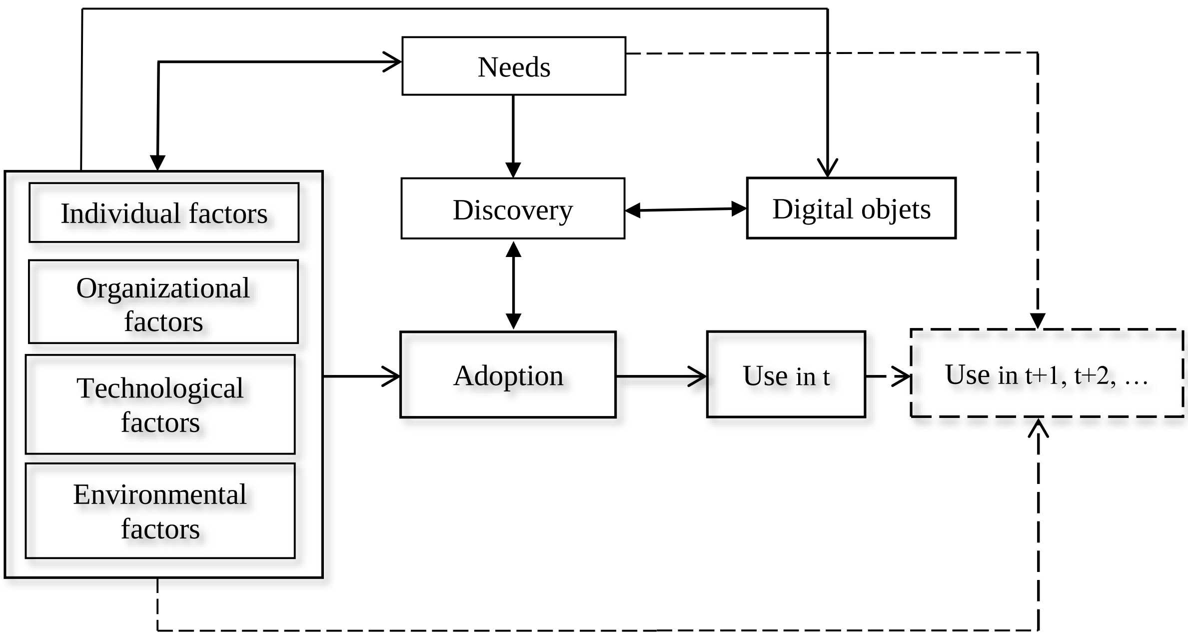


**Fig. 4.** An integrated TAM-TOE model of IT adoption

The proposed integrated TAM-TOE model is based on four major constricts that capture *the individual, organizational, technological* and *environmental* factors. Each construct is constituted of a set of explanatory factors that will be described hereafter. Besides, those constructs are considered as being constrained by the IT needs of the individuals, organizations, or the industry for their economic and commercial expansions that can be considered as voluntary as well as by the mandatory needs coming from regulations. Those *needs* imply a contact between the individuals or organizations with available IT solutions, through trials, experimentation, or observations, which constitute the stage of discovery of available IT solutions by potential users. Obviously, this *discovery* stage is constraint by available technologies and can evolve over time when new tools or solutions become available. The subsequent stage is the stage of *adoption* or non-adoption of available IT solutions by potential user. In case of non-adoption, individuals or organizations have to reconsider their needs and to expand their discovery phase of available technologies in order to select the right tools or solutions that match their needs as well as their culture and habits. When the technology is adopted, the last stage to be considered is its continuing *use* over time; a stage that is both influenced by the needs of individuals and organizations and this four factors of our integrated TAM-TOE model, namely individual, organizational technological and environmental factors.

Such an integrated model can serve as foundation for future studies and overcome shortcomings of existing models, while improving their strengths. The following integrated model has also some practical significance since it can help identify opportunities and risks associated with IT adoption and use, so that both individuals and organizations could be able to take effective course of actions in concerned areas.

## 4. Factors of the integrated TAM-TOE model explaining IT adoption

Based on the previous literature review., a selection of variables from implementing the integrated TAM-TOE model is now identified. They integrate some of the attributes of the TAM model and the TOE framework as well as some of those suggested bu the DOI theory.

### 4.1. Individual factors

*The perceived usefulness*

Usefulness is defined as the extent to which users believe that the new technology would provide them with access to useful information, a large variety of content, or help them connect. It defines the subjective idea that potential users have regarding IT in that using it improves operations (Lu et al., 2003). The way farmers perceived improvements in productivity is a strong factors of adoption. The performance of the new technology directly affects the decision-making process. Both farmers and advisers want new IT solutions or tools to improve both decision making and productivity (Rose et al., 2016).

**H1**. The perceived usefulness of an IT solution or tool positively impacts on the decision to adopt it.

*The perceived ease-of-use*

The perceived ease-of-use is defined as the extent to which users believe that the use of the targeted IT solutions or tools is free of effort. A technology that is easy to use impacts on the productivity of the user. Ease-of-use is an important support of IT adoption. Indeed, it influences the attitude toward the technology and eventually its use (Davis, 1993). Conversely, the degree to which a technology is difficult to use inhibits the adoption decision (Rogers, 2003). Rose et al. (2016) found that ease-of-use was one of the most influential reasons why a particular decision support tool was used or not.

**H2**. The perceived ease-of-use of an IT solution or tool positively impacts on the decision to adopt it.

*Age*

The age of the user is also considered as a factor explaining adoption (Chuang et al., 2007) In most technology-led markets, early adopters are commonly young (Lu et al., 2003). Age directly impacts on perceived usefulness and workers' performance of computer-based tasks. It is especially relevant to the farming context as younger farmers have a longer planning horizon (Läpple et al., 2015).

**H3**. Potential user's age negatively impacts on IT adoption decision.

*Education*

Education influences personal innovativeness, belief/value systems, risk-taking, cognitive preferences, and receptivity of an innovation. Low education levels are most often linked to risk aversion and threats to change, while higher education levels provide the skills required for experimenting new IT solutions or tools (McBride and Daberkow, 2003). Farmers with higher education levels are more open to adoption of IT solutions and tools for managing their farms (Kerr, 2004; Taragola and Van lierde, 2010; Auber et al., 2012).

**H4**. Potential user's education positively impacts on IT adoption decision.

*Innovativeness*

Besides, the propensity of potential users to seek and try out novelties can influence adoption. The individual's innovativeness i.e., his attitude towards new technologies that are not fully explored, greatly influences the adoption patterns (Thong, 1999). Innovativeness has a positive an impact on the adoption of precision agriculture (Aubert et al., 2012).

**H5**. Potential user's innovativeness positively impacts on IT adoption decision.

*Previous IT experience*

Previous experience is pointed out as a significant difference factor in technology acceptance research (Zmud, 1979). Favorable experience about new technologies influences adoption of similar ones. Indeed, people with prior experience about IT are more skillful and can simplify its complexities, thus improving its perceived usefulness.

**H6**. Previous IT knowledge and experience positively impacts on adoption decision.

*Perceived risk*

The potential users’ uncertainty about the quality of IT solutions or tools often causes anxiety and comes in the way of adoption decision (Ozaki, 2001). The expected probable social or economic loss resulting from the adoption of a given innovation is what constitutes perceived risk. Studies have found that lower risks positively impact users’ adoption intention.

**H7**. The perceived risk related to IT solutions and tools negatively impacts on adoption decision.

*Observability*

Rogers (1983) argued that observability of an innovation, i.e., “*the degree to which the results of using the innovation are visible to others*,” fosters faster innovation uptake. For an innovation that is easily seen, its diffusion will be quicker. For some innovations, the potential impact needs to be demonstrated, regardless of their visibility. Moreover, visibility of an innovation tends to encourage peer discussions, which collectively contribute toward achieving a better adoption rate (Rogers, 2003). Peer recommendation is pointed out by Rose et al. (2016) as a key determinant of IT uptake. Potential adopters looking for a solution use their existing networks of trusted peers. Shared experiences support the adoption decision-making process for solutions or tools other peers have praised or recommended to them about their availability and usefulness in supporting their activity.

**H8**. Observability of IT solutions or tools positively impacts on adoption decision.

## 4.2. Organizational factors

*Firm scope*

The greater the scope of business, the more likely a firm invests in IT. Zhu et al. (2003) describe the scope of business operations as an adoption predictor. Indeed, digitalization of operations reduces internal coordination costs, administrative complexities and information processing.

**H9**. The scope of business operations has positive impact on IT adoption decision.

*Farm size*

Much exists in literature which supports that firm size is a major factor affecting the adoption of technology, since size makes for resilience to environmental shocks. The uptake of internet and its infrastructure in business is slower in small than in larger firms (OECD, 2000). Adoption is slower amongst smaller institutions because of resistance to change, lack of education about ICT potential, lack of trust in security, lack of technological expertise and uncertainty about its benefits, and lack of economy of scale advantage and facilitating slacks as well as the strengths to bear the associated risks and to encourage trading partners to adopt technology with network externalities (Zhu et al., 2003).

**H10**. Farm size has positive impact on IT adoption decision.

## 4.3. Technological factors

*Cost*

The cost associated with IT solutions and tools affects its uptake by the end users. For Farmers ,even a small cost can be off-putting because of budget constraints. IT uptake is higher when grant funding are provided for its purchase. (Rose et al., 2016). Thus, costs play an important role on adoption deciosn.

**H11**. Lower costs have positive impact on IT adoption decision.

*Adaptability*

IT solutions or tools that fit more naturally with an individual's preferred way of working will be easier to adopt. *Habit* was a significant factor affecting use in Rose et al. (2016). A regular tendency to make a decision in a particular way holds back the uptake of new ideas, particular of new technologies. Most often, it is not the fact that a potential user cannot learn how to make decision in a new way that impeded adoption, but rather a kind of aversion regarding the fact of trying new things in the first place that prevent adoption. In the case of farmers, even those that have embrace software-based decision supports found it hard to more away from their current tools (Rose et al. 2016). Therefore, habit is probably one of the most difficult factors to overcome, as it will not be affected by designing more user-friendly systems that perform better.

**H12**. Adaptability to users' habit positively impacts on the decision to adopt IT solutions or tools

*Compatibility*

Rogers (2003) defined compatibility as "*the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters*." Perceived compatibility takes into account whether existing values, behavior patterns, and experiences of an organization and its employees are in the reconcilability of a new technology. The more compatible the technology is with the existing processes or work-practices (Compeau et al. 2007), the more relevant it is for an individual or an organization. Aspects of compatibility have been pointed out as one of the core issues experiences in the farming context (Kitchen, 2002). In the farming context where operations are characterized by a high degree of routine work and the uses of expensive machine equipment, the introduction of a technology that is not compatible with existing practices and infrastructure is likely to be perceived as difficult.

**H13**. The compatibility of the IT solutions and tools with exiting processes and practices positively impacts on the decision to adopt.

*Trust*

Trust in IT tools determined whether it is used in practice or not. Rose et al. (2016) pointed out that both farmers and advisers were keen to use tools from trusted sources, whilst advisers where particularly concerned with the evidence-based behind tool development, especially regarding robustness and transparency.

**H14**. Trust in IT solutions or tools positively impacts on the decision to adopt.

## 4.4. Environmental factors

*Triability*

Triability represents the perception that the individual has adequate opportunity to try out the innovation before adopting it. It reflects characteristics both of the technology itself and the implementation process by which it is introduced within the daily activities of the organization. While the act of trying out an innovation provides an opportunity to learn more about it, most often the adoption decision will be made more by what was learned than by the trial itself (Rogers, 2003). However, regardless of what is learned in trying out an innovation, the opportunity to try it out serves as a form of experience.

**H15**. The perceived triability of the IT solutions and tools positively impacts on adoption decision.

*Voluntariness*

Aubert and Hamel (2001) in explaining the influence of voluntariness pointed at the fact that the innovations introduced on a voluntary basis tend to received more acceptance than those that are mandatory. On the other hand, mandatory innovation adoptions have a tendency of only introducing resistance to adoption. Scheraga et al. (2000) mentioned the voluntary participation of the users in the implementation of a new technology as an important success factor. Moore and Benbasat (1991) explained that many studies tend to plainly assume that just because the innovations that they are examining are not mandatory, they have voluntary adopters for those innovations, but this may not always be the case. Indeed, it is often not the actual voluntariness, but the perception of voluntariness that influences the behavior of adoption. Perceived voluntariness reflects an important aspect of social influence. In a particular setting, an individual may in some way feel compelled to use a particular innovation. Such influences can operate through a mechanism of *compliance*, i.e. doing what is required because it is required, or *internalization* (Klein and Sorra, 1996). Internalization is similar to the effect proposed by Venkatesh and Davis (2000) of subjective norm, but they are not identical constructs. Both reflect normative pressure from one or more members of the individual's reference group. Indeed, the members of a social system generally tend to display a sense of belonging by being a part of the activities that are regarded as a norm within their social system (Ozaki, 2001) Social interaction and information exchange can play critical roles in promoting an innovation, and in turn motivating individuals to adopt it.

**H16**. Voluntariness positively impacts on the decision to adopt IT solutions.

*Resource availability*

The organizational literature has suggested in several studies that resources availability influences the technology adoption decision (Thong, 1999). Small firms find it harder to benefit from economies of scale provided by an innovation and the lack of resources leads firms to delay investments

**H17**. Resource availability has positive impact on IT adoption decision.

## 5. A bibliometric analysis in the context of agriculture

In this section of bibliometric analysis is undertaken focusing specifically on the agricultural sector in order to identify factors from our integrated TAM-TOE model that have already been identified regarding IT adoption as well as to defined new fields of exploration where a lack of information would be observed.

**Table 1.** Selected papers for the bibliometric analysis

| Authors | Title | Journal/Review | Country |
|---|---|---|---|
| Kerr (2004) | Factors influencing the development | *Artificial Intelligence Review* | Australia |
| Rolfe, Gregor and Menzies (2003) | Reasons why farmers in Australia adopt the Internet | *Electronic Commerce Research and Applications* | Australia |
| Taragola and Van Lierde (2010) | Factors affecting the Internet behavior of horticultural growers in Flanders, Belgium | *Computers and Electronics in Agriculture* | Belgium |
| Aubert, Schroeder, Grimaudo (2012) | IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology | *Decision Support Systems* | Canada |
| Perdersen et al. (2004) | Adoption and perspectives of precision farming in Denmark | *Acta agriculturae Scandinavica, Section B: Soil plan Sciences* | Denmark |
| Paustian and Theuvsen (2016) | Adoption of precision agriculture technologies by German crop farmers | *Precision Agriculture* | Germany |
| Botsiou and Dagdilelis (2013) | Aspects of incorporaton of ICT in the Greek agricultural enterpises: The case of a prefecture | *Procedia Technology* | Greece |
| Läpple, Renwick and Thorne (2015) | Measuring and understanding the drivers of agricultural innovation: Evidence form Ireland | *Food Policy* | Ireland |
| Edwards, Rue and Jago (2015) | Evaluating rates of technology adoption and milking practices on New Zealand dairy farms | *Animal Production Sciences* | New Zealand |
| Jago et al. (2013) | Precision dairy farming in Australasia: Adoption, risks and opportunities | *Anima Production Sciences* | New Zealand |
| Hansen (2015) | Robotic milking-farmer experiences and adoption rate in Jæren, Nora | *Journal of Rural Studies* | Norway |
| Rose et al. (2016) | Decision support tools for agriculture: Towards effective design and delivery | *Agricultural Systems* | United Kingdom |
| Warren (2002) | Adoption of ICT in agricultural management in the United Kingdom: The intra-rural digital divide | *Agricultural Economics* | United Kingdom |

## 5.1. Methodology

According to Harts (1998), papers for this bibliometric analysis were collected utilizing different combinations of sets of keywords in Science Direct, for example '*ICT adoption in arable farms*,' '*ICT adoption in agriculture*,' '*ICT adoption in rural business*,' '*ICT incorporation in agriculture*,' '*Decision support tools in agriculture*,' '*Precision agriculture/technology adoption*,' '*Using robots for agriculture*,' '*Drivers of technology adoption in rural farms*,' '*Drivers of technology innovation in agriculture*,' '*Decision support tool in cattle / dairy farmers*,' or '*ICT adoption in cattle/dairy industry*.' Research articles were filtered so as to select only studies covering the 2002 to 2016 period and developed countries such as Europe, Canada, Australia, New Zealand for assessing factors influencing ICT adoption in similar production contexts. Eventually, 13 studies were selected and are provided in Table 1, with details regarding the country and the selected approach.

## 5.2. Results

Results of the bibliometric analysis based on previous published papers are provided in Table 2. Almost all variables identified in Section 4 has been found, except one. Voluntariness is the only one factor that was not investigated in the selected studies. Otherwise, some factors not listed have been also identified as relevant for the agricultural sector, as farmer experience, off-farm activities, lack of time, location of IT use, information provided and farmer-adviser relationship.

In the literature, it was found that experienced farmers have a higher adoption rate of new technologies than less experienced ones. The main explanation is the longer time spent in managing their farms have allowed them to identify rooms for improvements and tasks than can be supported by new technologies, so as to improve their productivity by reducing their workload. Off-farm activities reduce the uptake of new technologies. This factor may be closely link to the lack of time for identifying needs regarding IT solutions and tools and for discovering those can match their working habits. Locations where IT are used deal with the connectedness of IT tools when on fields where Internet connection is not available. If the IT solutions or tools need such a connection, the uptake will be reduced in places where it is not available yet, but increased where it is provided; thus, the impact on adoption can be both sides. Information provided to farmers is also an important factor that impacts adoption decision, with a lack of information reducing adoption and enough information fostering it. Finally, a trusted relationship between farmers and advisors is pointed out has having a positive impact on IT adoption.

However, the bibliometric analysis, provided in Table 2, clearly show that not all factors have been explored in all the papers studied. Some have been often quoted as having an impact on IT adoption, such as perceived usefulness, farm size, education, ICT experience, type of farms. For some other factors, the impact is less strong, even though often quoted. It mainly concerns variables such as perceived ease-of-use, age, cost, adaptability, trust, information provided and farmer-adviser relationship.

**Table 2**. Factors influencing ICT adoption in agriculture

| | Frequency of quotation | | Importance of quotation | Hypotheses | |
|---|---|---|---|---|---|
| | ***nb*** | ***%*** | | **Expected effect** | **Validated effect** |
| **Individual factors** | | | | | |
| Perceived usefulness | 8 | 11 | high | + | validated |
| Perceived ease-of-use | 5 | 7 | medium | + | validated |
| Age | 4 | 5 | medium | - | validated |
| Education | 7 | 9 | high | + | validated |
| Innovativeness | 1 | 1 | low | + | to be confirmed |
| ICT experience | 7 | 9 | high | + | validated |
| Perceived risk | 1 | 1 | low | - | to be confirmed |
| Observability | 2 | 3 | low | + | validated |
| *Farmer experience* | *2* | *3* | *low* | | + |
| *Off-farm activities* | *2* | *3* | *low* | | - |
| *Lack of time* | *2* | *3* | *low* | | - |
| **Organizational factors** | | | | | |
| Firm scope/ Type of farms | 7 | 9 | high | +/- | undetermined |
| Farm size | 8 | 11 | high | + | validated |
| **Technological factors** | | | | | |
| Cost | 3 | 4 | medium | - | validated |
| Adaptability | 3 | 4 | medium | + | validated |
| Compatibility | 2 | 3 | low | + | validated |
| Trust | 3 | 4 | medium | + | validated |
| *Location of IT use* | *1* | *1* | *low* | | +/- |
| *Information provided* | *4* | *5* | *medium* | | +/- |
| **Environmental factors** | | | | | |
| Triability | 1 | 1 | low | + | validated |
| Voluntariness | - | - | - | + | non validated |
| Resource availability | 2 | 3 | low | + | validated |
| *Farmer-adviser relationship* | *3* | *4* | *medium* | + | *validated* |

Based on this analysis of the papers collected in the literature, two main results can be pointed out. First, individual factors are those that have been most often investigated in the literature regarding agriculture. They account for 55% of the explanation of adoption decision (see, Fig 4). It is followed by organizational factors for 20% and technological factors for 17%. Environmental factors count for 8% in adoption decision. They are the less explored factors. It can be explained by the fact that this factor is not taken into account in both the DOI theory and the TAM model; both of them constituting the majority of the framework used to investigate IT adoption in agriculture. Second, most of our hypotheses are supported by the bibliometric analysis. For some of them, the low number of publications quoting variables explaining adoption identified in Section 4 calls for more empirical studies.

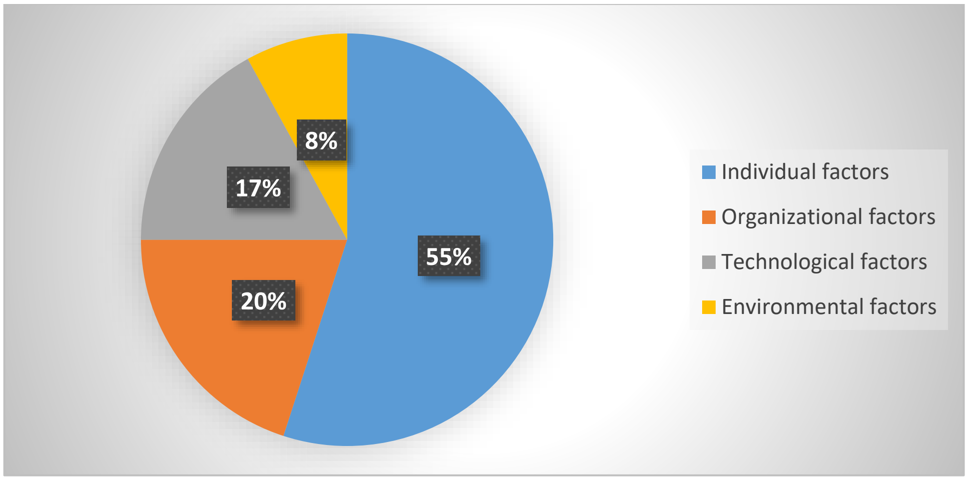


**Fig. 5** Main factors influencing ICT adoption in agriculture

## 6. Conclusion

The work presented in this paper is a first attempt to identify factors explaining IT adoption in agriculture. After a literature review related to available theories and models, an integrated TAM TOE model has been suggested for investigating adoption decision. Then, variables that can be used, especially in the agricultural context, have been characterized and tested based on a bibliometric analysis. Results show that individual and organizational factors are currently the most studied when considering IT adoption in agriculture. Technological and environmental factors appear having an impact, but are not investigated in all the papers studied.

Further extensions to this work are both theoretical and empirical. From a theoretical point of view, the model provides in this paper focuses only on the determinants of adoption. Usage and appropriation of IT solutions and tools over time are not investigated. Adding these elements to the current model will allow not only to investigate adoption but also to understand how IT solutions or tools are used and how users shape them differently over time. From an empirical point of view, the bibliometric analysis should be extended by implementing further research of studies, focusing on agriculture, on other publication platforms as well as by exploring publications based on the type of IT solutions or tools used by farmers; the latter extension allowing us to gain a deeper understanding of IT adoption in agriculture.

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