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Smart Farming Technologies adoption: which factors play a role in the digital transition?

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Abstract

Smart Farming Technologies (SFT) are smart devices part of a cyber-physical system able to improve farm management. Compared to other digital technologies' functionalities, SFT generate a multitude of data that once combined can be used not only on-farm but across the entire supply chain. Although recent studies highlighted how the lack of users' resources and competences might hinder the diffusion of digital agriculture technologies overall, few studies so far focused specifically on SFT. Moreover, the extant literature interprets the adoption decision mostly as "one-off binary" process, and limited attention is given to individual aspects of users and farms. Therefore, this study investigates the adoption of SFT analyzing various aspects of its complex nature; on the one hand, the analysis considers the multi-step nature of the adoption decision process: first, intention formation and then, actual adoption decision. On the other hand, the SFT adoption process is interpreted as being determined by several typologies of determinants beyond the most studied ones, with a particular focus on the role that organizational conditions and the supply chain governance structure play in influencing farmers' adoption of SFT.

An empirical analysis is run on a sample of 474 responses, collected through an on-line survey. Structural Equation Modeling (SEM) and a Zero-Inflated Poisson Regression (ZIP) were used to investigate respectively the intention to use and the actual adoption of SFT. Results show that farmers' intention to use mainly relies on technologies' performance expectancy, technologies' complexity and social influence exerted on farmers, while organizational supporting conditions do not play a significant effect. Nonetheless, when the actual adoption decision is observed, the likelihood that non-adopters intend to adopt SFT in their farms increases when formal integration along the supply chain is high and with the dimension of the farm (in terms of both land size and sales). When the adopters are analyzed instead, the decision to adopt is positively affected only by the individual intention to use and by farmers' specialization in the arable sector.

Findings reveal what factors need to be considered to guarantee a fairer and more inclusive agricultural digitalization, such as the role of social influence exerted by some figures around farmers and the still weak facilitating organizational conditions.
Keywords. Smart Farming; Technology adoption; Innovation diffusion; UTAUT; Chain Governance structures; Digital divide;

1. Introduction

Agri-food systems are on the verge of an on-going revolution based on the use of digital innovations throughout the supply chain (Giua et al., 2020; Klerkx et al., 2019; Wolfert et al., 2017). Scholars have defined this process of agriculture's digital transformation in different ways, including "digital agriculture", "agriculture 4.0" or "precision agriculture", in an attempt to describe its continuous evolution. In fact, the digital farming industry is experiencing a period of great development and dynamism in terms of technological supply. Over just a few decades, digital agriculture's applications have evolved from the mere use of devices for the technical conversion of analogue information into digital ones (*digitization)*, to a more complex socio-technical system surrounded by the use of a large variety of digital technologies (Autio, 2017; Rijswijk, 2020; Tilson et al., 2010). This more recent phase was named "*digitalization"* and is thought to have a much higher impact on social and institutional contexts that require and increasingly rely on digital technologies (Tilson, Lyytinen, & Sørensen, 2010). Indeed, digitalization goes beyond the application of digital technologies of a single business or entity, and it means for example using digital platforms to coordinate demand and supply in value chains, linking on- and off- farm data and managements tasks (Rijswijk, 2020; Tilson et al., 2010). The highly cited paper by Wolfert et al., (2017) defined this last technological evolution of agriculture as "Smart Farming" (SF), namely a "cyber-physical system" (pp. 70), where smart devices are the locus of control for the farm (Lioutas et al., 2019). Sensors, drones, weather satellites, intelligent software algorithms and robots, together generate data that, once combined, are able to provide not only agronomic but also historical, weather, market, logistic and benchmarking information.

When looking at the demand of such digital technologies, farmers are increasingly using different devices to carry out activities in their farms (Osservatorio Smart

Agrifood, 2019, 2020, 2021), although a widespread use of digital technology in agriculture is still a long way off. Important differences in rates of adoption can already be seen according to farm and farmers' characteristics (Gardezi and Bronson, 2020; Kolady et al., 2020; Paustian and Theuvsen, 2017; Pierpaoli et al., 2013) and, more widely, even at country-levels (Lawson et al., 2011). Indeed, despite the general attention for a fair digital agriculture's transition - expressed also in recent European policies (European Commission, 2020) - a well-balanced and homogeneous diffusion of these technological innovations among farms and farmers is far to be reached (Barnes, Soto, et al., 2019; Bronson, 2019; Pathak et al., 2019; Rotz et al., 2019).

The extant literature investigated the determinants of digital farming technologies adoption mainly focusing on aspects related to farm structure (size, sales, sector or land tenure) or farmers' socio-economic characteristics (age, education, experience) (Kernecker et al., 2020; Tey and Brindal, 2012), rarely going beyond the individual dimension of farmers (Giua et al., 2020; Pathak et al., 2019). Such an approach to the study of the diffusion of technological innovations presents two main limitations when the larger group of Smart Farming Technologies (SFT) is considered (Shang et al., 2021). Firstly, SFT are inherently interoperable and this implies a complicated adoption process: the collaboration between many different stakeholders who play different roles in the data value chain is indeed required (Wolfert et al., 2017).

However, such complexity has not been yet focus of research investigating the determinants of SFT adoption comprehensively, i.e. considering both individual characteristics of adopters and non-adopters and other factors, such as organizational factors. These are particularly relevant since the implementation of SFT is of optimal functionality when data can be transmitted along the value chain. Indeed, the existence of an organizational network underpinning the data value chain might be key for the efficient flow of information before and after the digitalization of the supply chain (Pesce et al., 2019; Verdouw et al., 2016). On the other hand, the existence of organizational facilitating conditions, able to equally support different types of farmers, might be particularly important to include even less technological and structured farms in such digital transition (Giagnocavo et al., 2017). Still, as recently pointed out by Shang et al (2021), organizational/institutional aspects are among the less investigated by previous literature.

A second aspect that deserves attention regards the research approach often used to frame the adoption of innovations (such as, digital technologies). In fact, the adoption is often analyzed as a one-off binary decision with a list of several variable directly affecting the final outcome (Sunding and Zilberman, 2001; Weersink and Fulton, 2020). In contrast, various scholars argue that innovations' diffusion in agriculture can rarely be seen as a result of a simple yes/no decision, being rather similar to a dynamic learning process with more phases (e.g. knowledge, information collection, persuasion, evaluation and similar, see Klerkx et al., 2012; Rogers, 2003; Sunding and Zilberman, 2001). Yet, few studies considered such a multi-step nature of the SFT adoption process, failing to include aspects such as attitudes, behavioral intentions and similar others in their analyses (Caffaro et al., 2020; Kernecker et al., 2020; Pivoto et al., 2019; Ronaghi and Forouharfar, 2020).

In the light of these considerations, the aim of this study is to contribute to the extant literature on the diffusion of digital technologies by comprehensively investigating the adoption of SFT, through the analysis of both its multifaceted and multi-step nature. In this regard, the role played by the organizational environment throughout the whole adoption process is addressed. The work is structured as follows; section 2 reports the conceptual framework, which stems from the literature review on adoption studies focusing on digital technologies at farm level. In the same section, the theoretical models used to investigate the adoption of SFT are presented and re-specified to be adapted to the context. Section 3 contains the methodology with the description of the empirical analysis conducted, while Section 4 presents the results obtained. Finally, findings are discussed and their implications indicated respectively in Section 5 and 6. Section 7 concludes and reports some limitations of the study.

2. Conceptual framework

2.1. Literature review

The conceptual framework adopted in the study draws from a literature review which considers the intersection between previous studies on the adoption of Precision

Agriculture Technologies (PAT) and more recent ones focusing on SFT. PAT are solutions able to "match agricultural inputs and practices to localized conditions within a field to do the right thing, in the right place, at the right time, and in the right way" (Pierce et al., 1994, pp. 17). These include technologies such as remote sensing, precision irrigation, variable rate technologies -VRT, etc. (Zhang et al., 2002), and started to be used since 1990s, especially in the arable sector and suitable productive territories (e.g. Unites States) (Pathak et al., 2019; Pierpaoli et al., 2013; Tey and Brindal, 2012). As reported in van der Burg et al. (2019), the main difference between PAT and SFT relates to the fact that "where precision agriculture is mainly taking in-field variability into account, smart farming goes beyond that by basing management tasks not only on location but also on data, enhanced by context and situation awareness, triggered by real-time events" (pp.2).

Revising the contributions that focused on PAT, the systematic literature review by Tey and Brindal (2012) categorizes the determinants of PAT adoption into six groups of factors, namely: socio-demographic/economic, agro-ecological, behavioral/farmers' perceptions, technological, informational and institutional factors. The more recent review from Pathak et al. (2019) proposes an extended, alternative classification with nine main adoption determinants' components (i.e. innovation features, communication and influence, outer context, adopter characteristics, system antecedents and readiness for innovation, linkage, assimilation and implementation process). Although the classifications provided do not identically coincide, both agree on the prevalence of some typologies of determinants: farmers and farm characteristics, technological factors (e.g. complexity, usability, etc.) together with informational/communication factors. Moreover, both studies come up with similar conclusions: previous research poorly considered the whole, multifaceted adoption process tending to focus more on singular aspects (mostly relative to individual farm and owner characteristics). Tey and Brindal (2012) underline how behavioral and social aspects are among the aspects more ignored, while Busse et al. (2014) state that "an examination of social and organizational innovations (…) would provide a broader understanding of innovation mechanisms." (Pathak et al., 2019, pp. 1310).

Similar evidence is reported in studies focusing specifically on the adoption of SFT (Giua et al., 2020; Shang et al., 2021). Knierim et al., 2019, investigate the SFT adoption in Germany following a multi-actor approach; different stakeholders are considered (farmers, experts and multi-actor constellations) and both qualitative and quantitative methodology (i.e. descriptive statistics) are applied. Socio-demographic characteristics as well as attitudes and expectations of farmers are analyzed. Although the study reveal interesting results from a qualitative perspective (i.e. they use the Agricultural Knowledge and Innovation System - AKIS conceptual framework), the quantitative approach do not cover the causality effects relative to the adoption determinants. Pivoto et al. (2019), investigate the same topic but in a different context (i.e. grain sector, Southern Brazil) and through a different methodology, namely logistic and Poisson regression models. Here SFT are considered as divided in four groups (as proposed in Fountas et al., 2015) and several determinants are identified (i.e. age, education, farm size) depending on the technology considered, although none of these are statistically significant when SFT are considered in an aggregated form. Moreover, a limitation of the study by Pivoto et al. (2019) is not considering the adopters' behavior as a possible adoption determinant. Attitudes, intentions and informational factors are instead considered in a recent study by Caffaro et al. 2020, where the SFT adoption is analyzed in Northern Italy. The Technology Acceptance Model (TAM - Davis, 1989) is used together with informational elements from the Diffusion of Innovation theory (DOI - Rogers, 2003) in order to investigate how different informational sources (i.e. personal-informal, personal-formal, impersonal) might affect attitudes and intentions regarding SFT. Results show that formal and informal sources of information have respectively a positive and a negative effect on the Perceived Usefulness (PU) that, in turn, positively affects the intention to adopt. Finally, the recent work from Ronaghi and Forouharfar (2020) estimates an extended adoption model using the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al., 2003. This model allows the Authors to consider not only expectations, attitudes and intention of respondents, but also social and environmental-organizational influences that might affect adopters, as well as individual socio-demographic factors. Results show that attitudes towards SFT as well as social-environmental conditions play a positive role in influencing intention to use and use behavior, whilst individuals' age, experience and income show a negative effect.

2.2. *Conceptualizing the SFT adoption model*

The adoption studies discussed so far highlight the need to extend the analysis of the process of SFT adoption to a wider set of determinants. This evidence was recently confirmed by Weersink and Fulton (2020), who highlight how farm-level adoption studies should not only consider the dynamic nature of innovation diffusion, but also the different role that some factors might play at different moments of this process. With the aim to delve into these research gaps, this section introduces the research questions and the specification of the model used to investigate the SFT adoption. The conceptualization follows two main phases. First, to appreciate the multi-step nature of the process, the factors affecting farmers' intention to use are investigated through the UTAUT model (green dashed box, Fig. 1). Secondly, the determinants of the actual adoption are studied, focusing on factors that might directly affect the adoption decision (red dashed box, Fig. 1).

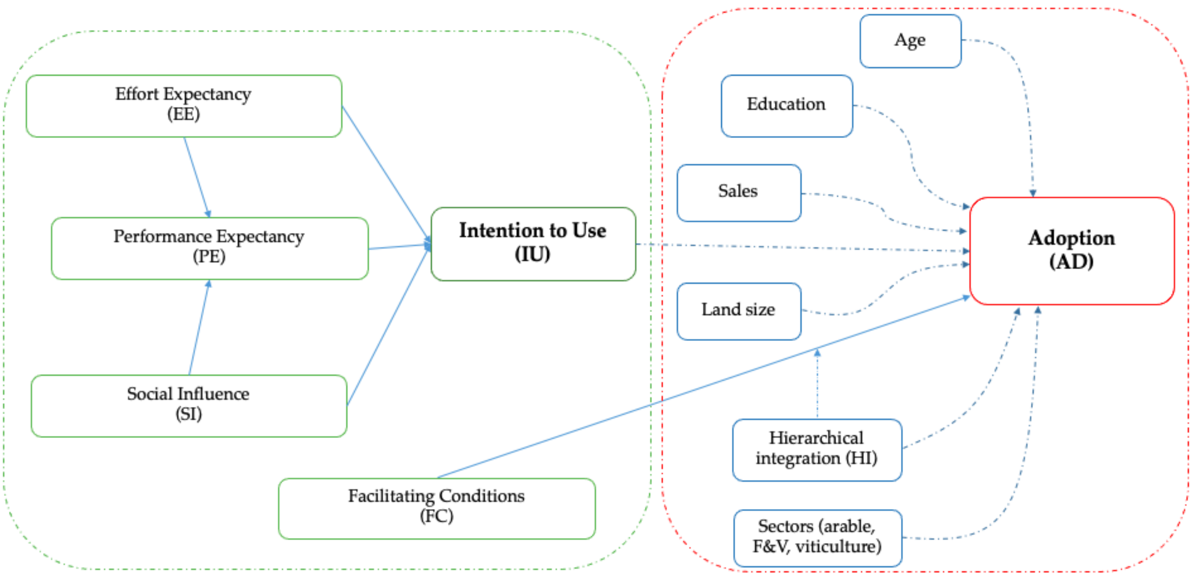

Figure 1 - Conceptual specification of the SFT adoption model (COLORS SHOULD BE USED)

On both phases, particular attention is paid to the role of organizational conditions in shaping the whole adoption process, with reference to facilitating supporting conditions and supply chain governance structures.

The remainder of this section presents, per each Research Question (RQ) addressed, the main assumptions and hypotheses behind both the Intention to use (IU) and the actual decision to adopt smart farming technologies (AD).

RQ1 - Which are the main factors affecting the intention to use SFT?

The completeness of the UTAUT model in exploring different attitudinal aspects of the innovation adoption process provides a useful theoretical framework to investigate the intention to adopt SFT. In their seminal work, Venkatesh et al. (2003), review eight principal theories[1] used to study technology adoption and merge them and the relative constructs into one unified theory of use and acceptance (UTAUT). In this model, the variables relative to the external, social-organizational environment are represented by two constructs denominated “Social Influence (SI)” and “Facilitating Conditions (FC)”. The former is defined by the Authors as the "degree to which an individual perceives that important others believe he or she should use the technology" (pp. 451). The latter is defined as the "degree to which an individual believes that an organizational and technical infrastructure exists that supports the use of the technology" (pp. 453). In our study, these variables are considered to capture the relevant effect played by the external organizational environment around farmers and their farms.

In addition to the SI and FC constructs, the UTAUT model considers two further important attitudinal factors. Performance expectancy (PE) is defined as "the degree to which an individual believes that using the technology will help him or her to attain gains in job performance" (pp. 447); Effort expectancy (EE) is defined as "the degree of ease associated with the use of the technology" (pp. 450).

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[1] These theories are: Technology acceptance model (TAM), the theory of reasoned action (TRA), Diffusion of innovation (DOI), the motivational model, the theory of planned behavior (TPB), a combined TPB/ TAM, a model of personal computer use and social cognitive theory.

Although the UTAUT model is originally applied to management and organizational innovation research, it has been already adopted in various studies concerning the agri-food sector. Beza et al. (2018) use the model to assess the mobile SMS technology acceptance from a sample of smallholder farmers. Additionally, Faridi et al., (2020) in their study in Rasht County, Northern Iran, incorporate the two models of UTAUT and Initial Trust Model (ITM) to assess water and soil conservation measures (WSCM) adoption. Finally, the above mentioned Ronaghi and Forouharfar (2020) and Michels et al. (2019) use the UTAUT models to investigate the adoption of different SFT, respectively IoT and crop management apps. Compared to its original version, the model used in this study presents some modifications in line with other studies found in the literature (Beza et al., 2018; Li et al., 2020; Ronaghi and Forouharfar, 2020).

Performance Expectancy (PE)

Expectations about the performance of SFT are investigated in previous studies through different constructs, such as the relative advantage derived from the DOI framework (Knierim et al., 2019) or the perceived usefulness derived from the TAM framework (Caffaro et al., 2020). For what concerns the UTAUT, PE is expected to be the strongest predictor of the intention to use (Venkatesh et al., 2003, pp.447). In the agricultural digital innovation adoption literature, the positive expectations of various decision makers about technologies are shown to affect positively their intention to adopt. On the base of such evidence, the following hypothesis is tested:

H1: ***Performance expectancy positively affects the intention to use SFT.***

Effort Expectancy (EE)

In their recent review, Shang et al. (2021) allege that technologies' attributes such as complexity, perceived usefulness and farmers' attitude towards technology "have the potential to be more useful predictors for adoption decisions than characteristics of farms and farmers" (pp. 7). In digital innovation studies, technologies' ease of use (or complexity) shows to positively (negatively) affect the adoption decision (Adrian et al., 2005; Pivoto et al., 2019; Vecchio, De Rosa, et al., 2020). Recently, Michels et al. (2020), shows how EE positively affects both IU and PE; with reference to the latter, it is expected that the higher the ease of use of a technology, the higher the performance expected by such technology (Davis, 1989; Michels et al., 2020).

H2: ***Effort expectancy positively affects the intention to use SFT.***

H2a: ***Effort expectancy positively affects performance expectancy regarding SFT.***

Social Influence (SI)

Social interactions are found to significantly affect innovation diffusion in agriculture (Kernecker et al., 2021; Klerkx et al., 2012; Ramirez, 2013; Scuotto et al., 2017). When the focus is on digital innovations' adoption, several actors are thought to exert social influence on decision makers. The support provided by consultants, extensionists or peers is found to positively affect the intention to adopt digital technologies (Knierim et al., 2019; Kutter et al., 2011; Pivoto et al., 2019), while the influence other farmers could play was found not always clear (see Shang et al., 2021). In our study, particular attention is paid to the influence organizations or associations to which farmers belong play as they are often believed to be the source of information and support that positively affects adoption decisions (Barnes, Soto, et al., 2019; Caffaro et al., 2020). Moreover, as found in Michels et al. (2020) social influence is expected to exert a positive influence also on the performance expectancy;

H3: ***Social influence positively affects intention to use SFT***.

H3a: ***Social influence positively affects performance expectancy regarding SFT.***

Facilitating Conditions (FC)

According to the original definition by Venkatesh et al. (2003), the construct 'Facilitating Conditions' should reflect both the organizational and infrastructural support to the use decision. When it comes to the adoption of SFT, the existence of digital infrastructures (e.g. broadband) is fundamental, as well as other financial and technical resources. Several authors analyze the effect of FC on both the intention to use and the actual adoption decision (Beza et al., 2018; Faridi et al., 2020; Michels et al., 2019; Schukat et al., 2019). However, in the recent work by Michels et al. (2019) the effect of FC on IU is found not significant in their structural equation model. In our study, the FC construct is considered to be representative of both the infrastructural and the organizational support that farmers and similar decision makers (i.e contractors, agricultural workers, etc.) might consider in the decision to adopt or not SFT. To this aim, the following hypothesis is tested;

H4: ***Facilitating conditions have a positive effect on the SFT adoption decision.***

Intention to use (IU)

The UTAUT model assumes that the intention to use may have a significant positive influence on the actual adoption (Beza et al., 2018; Faridi et al., 2020; Zeng et al., 2016). Hence the following hypothesis is tested;

H5: ***The intention to use SFT has a positive impact on the actual adoption decision.***

RQ2 - Which are the main factors affecting actual decision to adopt SFT?

Our study adopts the classification of SFT in 4 main typologies suggested by (Fountas et al., 2015; Knierim et al., 2019). As found in Adrian et al., 2005; Aubert et al., 2012, we consider the adoption decision (our observed variable - AD) as the sum of selected technologies which respondents declared to use. Looking at what determines the adoption of SFT, socio-demographic variables are considered as direct determinants, whereas in the original model by Venkatesh et al., 2003 they are considered to exert only a moderation effect on the variables affecting IU. Furthermore, acknowledging that organizational factors are among the aspects less investigated when it comes to digital technologies adoption (Shang et al., 2021) although relevant, our study adds them to the hypotheses tested in the model. With these premises, the following hypotheses are formulated.

Hierarchical integration (HI)

In this section, organizational factors are further analyzed - according to the neo-institutional economics lens - as the sets of rules and institutional arrangements which define product and process operational parameters within value chains (Bonanno et al., 2018; Gereffi and Fernandez-stark, 2016). As proxy of the nature and the characteristics of supply chain relationships, we refer to the notion of supply chain governance (SCG) as "the set of devices implemented within organizations, or among networks of organizations, to allocate and monitor assets and rights, providing the backbone to economic activities" (Ménard, 2018, pp. 143). As recently reported in Kataike et al. (2019), various researchers describe and "used different governance structures ranging within a continuum from market ("buy") to vertical integration ("make") to explain coordination in food chains" (pp. 1851). Raynaud et al. (2005) reports a classification of governance structures in six types, following a hierarchical sequence, namely: spot market, relational contract, relational contract with an approved partner, formal written contract, equity-based contract and vertical integration. The same framework is used by Wever et al., (2010) to study quality management alignments in EU pork supply chains and later on by Schulze et al., (2007), who studied attitudes of German farmers towards vertical integrated pork supply chains. Following this distinction, several authors explore how different forms of SCGs' hierarchical integration might affect innovation in the agri-food sector; Karantininis et al., (2010) show how vertical integrated food supply chains boost product innovation at firm-level in Denmark. More recently Martino et al. (2017; 2018) show how different contracting solutions in the Italian olive sector impact process innovation choices by olive millers. Finally, in the digital technologies' adoption literature, Carrer et al., (2017) prove that the existence of long-term production contracts at Brazilian citrus farm-level positively affect the decision of farmers to adopt farm management information systems. In our study, we draw from the classification proposed by Wever et al. (2010) and propose a measure of Hierarchical Integration (HI). In order to check whether HI might affect the SFT adoption decision, we attempt to detect whether the level of farms' commercial integration along the supply chain might: a) exert a moderating role on the relationship between FC and the adoption decision; b) directly positively affect the adoption decision, (Fig.2):

H6: ***Farms' hierarchical integration positively moderates the effect of FC on farmers' adoption decisions.***

H6.a: ***Farms' hierarchical integration positively affects farmers' decision to adopt SFT.***

Age

The age of decision makers has been extensively used as valid predictor of digital technologies' adoption and use in several studies (Batte, 2005; Daberkow and McBride, 2003). Often it is hypothesized that younger users are facilitated in dealing with digital technologies, especially when it comes to farmers (Tey and Brindal, 2012; Tiffin and Balcombe, 2011). For what concerns SFT, age generally showed negative effects on the adoption of SFT in several studies (Knierim et al., 2019; Pivoto et al., 2019; Ronaghi and Forouharfar, 2020). Accordingly, the following hypothesis is therefore formulated:

H7: ***Age negatively affects farmers' decision to adopt SFT.***

Education

Education seems to exert a potential positive effect on adoption (Barnes, De Soto, et al., 2019; Daberkow and McBride, 2003; Vecchio, Agnusdei, et al., 2020). The rationale behind this assumption is that farmers with a higher education level might better understand technologies' applications and usefulness. Since such a hypothesis has been recently contested (Shang et al., 2021), we test its validity:

H8: ***Farmers' education positively affects the decision to adopt SFT.***

Farm Size (land used)

Farm size is one of the factors most frequently positively associated with SFT adoption in past studies (Shang et al., 2021) for several reasons: larger farms might benefit more from efficiency due to economies of scale, their management is generally more complex and data to support decisions might be particularly useful. Moreover, these farmers have generally more resources to invest in technological modernization. For these reasons, several researchers state that digital technologies are primarily designed and available for larger farms. Thus, the following hypothesis is formulated:

H9: ***Size of land used for farm activities positively affects farmers' decision to adopt SFT.***

Sales

Measures of farms' economic dimensions (income, sales, off-farm income) are often considered as adoption determinants in several studies (Barnes, Soto, et al., 2019; Kolady et al., 2020; Toma et al., 2018). Similarly to the case of farm size, the high costs involved in the adoption of SFT might require solid financial resources to adopt and correctly implement digital technologies. In our study, the average annual turnover (*sales*) is considered as proxy of the economic dimension of farms; higher turnovers are expected to be positively associated with the decision to adopt SFT.

H10: ***Farms' annual turnovers (Sales) positively affect farmers' decision to adopt SFT.***

Sectors

Among agricultural sectors, the arable one has been the main focus of previous literature (Aubert et al., 2012; Kernecker et al., 2020; Michels et al., 2020; Paustian and Theuvsen, 2017): higher quality of land and land size's availability are associated with higher farm-level adoption of digital technologies. However, as noticed by Kernecker et al., 2020, fruit and vegetable (F&V) and viticulture see a greater adoption of farm management information systems in the European context. In order to detect whether a specific sector might be more likely to be associated with a higher SFT use by relative farms, the following hypotheses are formulated:

H11.a: ***Farms' specialization in the extensive arable sector positively affects the decision to adopt SFT;***

H11.b: ***Farms' specialization in the fruit and vegetable (F&V) sector positively affects decision to adopt SFT;***

H11.c: ***Farms' specialization in the viticulture sector positively affects the decision to adopt SFT;***

3. Materials and methods

3.1. Data collection

A questionnaire composed of 40 questions was tested before being administered in the period October 2020 - January 2021. Most of the questions are Likert-scale survey questions (25), which guarantees the compatibility with the UTAUT model and its statistical elaborations. The attitudinal constructs are built through specific items which result from a review of the literature, starting from the original UTAUT model by Venkatesh et al. (2012, 2003).Given their significant application to the agri-food and the digital technologies' adoption context, we adapt various items retrieved from previous studies (Beza et al., 2018; Diekmann and Theuvsen, 2019; Faridi et al., 2020; Michels et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012) (see appendix A.2 for more details).

Before the actual launch, the efficacy and comprehensibility of the whole survey was tested through pilot interviews with 8 farmers (from Emilia-Romagna, a region in North-East Italy). The pilot interviews were carried out via telephone and through different modalities; in some cases, the survey was filled out by the respondents assisted by one of the authors, the aim being to directly observe the interviewee's interpretation of questions and main concepts. In other cases, the survey was sent by email to the interviewees who were then asked to take notes and report any feedback. The pilot interviews process allowed us to considerably improve both the formulation of the questions and the overall flow of the survey. Subsequently, given that the research was carried out amidst the COVID-19 pandemic, the Computer Assisted Web Interviewing (CAWI) approach was used. In order to obtain the largest possible adhesion by farmers, we relied on existing databases to maximize farmers' reach and survey's responses. To this aim, we were granted access to one of the biggest private agricultural stakeholders' on-line community in Italy, run by the "Image Line" company[2]. Its community accounted for more than 250.000 registered users in January 2021, among which more than 50.000 are farmers.

The survey was launched in December 2020 and addressed 51.400 farmers. At the end of January 2021, the total number of responses collected (partial and complete) amounted at 945 (1.84% response rate). After the elimination of incomplete responses and an exploratory analysis, data were cleaned in order to avoid repetitive responses.

3.2. Data analysis

The analysis is based on a sample of farmers distributed in the whole country. Firstly, descriptive statistics are calculated for an overview of the farmers' characteristics in the sample (Table 1). When compared to the national population, the respondents participating in the study are on average younger, more educated, with larger farms and higher income. Such a difference is probably due to the types of farmers registered to the Image Line community, which are on average more technologically advanced.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
Age	20	44	53	51.56	60	83	12
Size (hectares)	0.6	8	20.50	53.56	59.50	768	100

[2] Image Line is a company that provides information, communication and technology services for agricultural sector, with an expertise in management information systems and agricultural databases' offer (Cristiano et al., 2020).

Education	-	second level secondary schools	second level secondary schools	-	bachelor/master degree	-	2
Income	-	€ 15.000 - 24.999	€ 50.000 - 99.999	-	€100.000-249.999	-	59

Table 1 - Sample descriptive statistics

In order to investigate the causal relationship between the variables and the constructs described above, two different methodologies are used and both analyses are carried out through R statistical software (version 1.4.1103). For what concerns attitudes and intention to use SFT, the Structural Equation Modelling (SEM) approach is adopted. The SEM is widely used in several disciplines such as management, socio-psychological, economics and organizational studies. It is a statistical method that allows to simultaneously analyze multiple causal relations occurring in a phenomenon. It consists of two main steps (Hair et al., 2019); firstly, the measurement model is set-up and analyzed to evaluate the reliability of the constructs used. Secondly, the structural model is run and results analyzed to infer about the causalities hypothesized.

For what concerns the actual adoption decision model, a Zero-inflated Poisson (ZIP) model is used to detect which variables act as determinants when it comes to both adoption or rejection choices and adoption of multiple technologies. In fact, adoption can be interpreted and analyzed in two ways; on the one hand, as a binary variable useful to codify the adoption decision - it is then equal to 1 when respondents adopted one of the SFT, 0 in the opposite case. On the other hand, the observed variable can be the sum of different technologies adopted, to reflect the adoption intensity for each observation. In this last case, when the observed variable is ordinal such that $y = i \; with \; i = 0, \dots, n$, the ZIP regression model allows to simultaneously investigate when $y_i = \begin{cases} y_i = 0 \\ y_i > 0 \end{cases}$ through two different estimation functions such that

$$\Pr(Y_i|y_i x_i, z_i) = \begin{cases} \varphi_i + (1 - \varphi_i)\exp(-\mu_i) & y_i = 0 \\ (1 - \varphi_i)\,\frac{\exp(-\mu_i)\mu_i^{y_i}}{y_i!} & y_i > 0 \end{cases}$$

where φ_i is the probability of the logistic distribution. With the SEM model, total complete responses account to 474 (only Likert-type and multiple choice questions considered). When the ZIP model is run, the total sample reduces to 341 observations to avoid missing values in socio-demographic variables.

Based on the methodological recommendations set out in the scientific literature concerning the estimation of SEM and ZIP models (Hair et al., 2019; Isgin et al., 2008) and considering the size of the samples used in similar works (Adrian et al., 2005; Beza et al., 2018; Caffaro et al., 2020; Gere et al., 2017; Karantininis et al., 2010; Ronaghi and Forouharfar, 2020), we argue that the sample selected is appropriate for the purposes of this study.

4. Results

4.1. Structural equation modeling (SEM)

Measurement model

A first complete measurement model - which included all the items proposed - was run, whose fit was however not sufficient. Therefore, in order to detect those items that performed poorly we relied on the completely standardized coefficients and modification indices obtained by the software analysis. After eliminating an item of the FC construct (FC1) that was relative to the basic knowledge necessary to adopt SFT, the overall fit indices of the measurement model improved. Nonetheless, when a reliability analysis of the construct was carried out, some items still did not perform acceptably. In particular, when the indicators' reliability, construct variability and convergence validity were checked, all the constructs apart from the FC one and the last item of the SI construct – SI4 (namely the perception of the support received by the organizations the farmers belong to) showed good reliability. In fact, when the indicators' reliability (standardized loadings) was analyzed, only the four items relative to FC together with the item SI4, showed loadings below 0.7, commonly considered as the ideal threshold for reliability. Importantly, these five items considered together represent the statements which asked to respondents whether they felt equipped (with necessary knowledge and resources) and supported by organizational facilitating conditions in the decision to adopt SFT. For what concerns the construct reliability, the Cronbach's alpha was checked and all the constructs showed values above 0.7 (Cronbach, 1951), apart from FC which had a value equal to

0,63. Finally, when convergence criteria were analyzed, the AVE - namely the variance that is shared by the construct and its indicators - was considered. All the constructs were above the minimum acceptable value of 0.5, apart from FC that displayed a value equal to 0.37. The same applies to Composite Reliability, with all the values exceeding the minimum acceptable value (0.7) apart from FC construct with a CR=0.64.
Due to their poor reliability, the FC construct and the SI4 item were dropped. The final model therefore presents four latent constructs rather than five as shown in figure 1. The model improved its fit and the other constructs are all reliable according to the indicators described above. As a final step, after an analysis of the modification index (MI) and the residuals (R2), also EE1 (item about the ease of interacting with SFT) is dropped, with the model improving considerably in its fit although the reliability analysis do not raise statistical problems with this item. The final measurement model shows adequate fits as shown in the tables 2 and 3.

Model fit indices	Recommended value (Hair et al., 2019)	Model results
Normed chi-square (CMIN/DF)	<3	2,37
Adjusted Goodness-of-Fit (AGFI)	≥0.8	0,93
Comparative Fit Index (CFI)	≥0.95	0,975
Root Mean Square of Approximation (RMSEA)	≤0.7	0,05
Standardized Root Mean Square residual	<0,1	0,038
(Tucker-Lewis Index)	≥0,90	0,967

Table 2 - Summary of fit indices for the final measurement model

Structural model

After assessing the measurement model, a structural model or path analysis is carried out. Firstly, the model as shown in figure 1 (the green dashed rectangular) is assessed with the exclusion of the FC construct (as it was not reliable). The measurement model results are confirmed (Table 3) and all the causal hypotheses are accepted (Table 4).

Item loadings, AVE, CR and alpha						
Factor	Item	Standardized Loadings	Z-value	AVE	Composite Reliability (CR)	Alpha
Performance Expectancy (PE)	useful	0.848	18.706***	0.596	0.86	0.858
	productive	0.785	17.262***			
	cost	0.748	16.361***			
	sustainable	0.708	15.392***			
Expected Effort (EE)	learn	0.847	21.208***	0.670	0.86	0.859
	use	0.764	18.511***			
	ability	0.850	21.318***			
Social Influence (SI)	colleagues	0.675	15.090***	0.555	0.78	0.780
	farmers	0.702	15.809***			
	trust	0.838	19.549***			
Intention to Use (IU)	programuse	0.947	23.582***	0.793	0.93	0.917
	intentuse	0.952	23.765***			
	alwaysuse	0.782	18.679***			

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.*

Table 3 - Final measurement model results

Latent Variables		Hypothesis	Estimate	Z-value
Performance Expectancy (PE)	~			
	Expected Effort (EE)	H2a (✓)	0.333	5.268***
	Social Influence (SI)	H3a (✓)	0.723	9.256***
Intention to Use (IU)	~			
	Performance Expectancy (PE)	H1 (✓)	0.599	8.457***
	Expected Effort (EE)	H2 (✓)	0.215	3.538***
	Social Influence (SI)	H3 (✓)	0.270	3.451***

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.*

Table 4 - Structural Model Results

As shown in table 4, PE is the strongest predictor of IU, followed by SI and EE. Importantly, hypotheses regarding PE's determinants are supported by the data. However, as shown in previous analyses (Michels et al., 2020), the estimated model do not capture environmental and organizational facilitating conditions (being FC and SI4 not reliable). Although hypotheses 5 and 6 cannot be tested nor accepted, when these evidences are considered with additional descriptive statistics coming from the survey[3], they show a condition of poor organizational support perceived by respondents. However, in accordance with our aim to thoroughly explore the supply chain's organization effect on the overall adoption decision process (hypothesis 6.a), the following section will investigate more in detail this aspect.

4.2. Zero-Inflated Poisson Regression Model

The second part of the empirical analysis deals with the actual adoption decision and results are obtained for both adopters and non-adopters. The same covariates are regressed on both categories (see Table 5) in order to see potential differences between the two groups. In addition to farm and farmers characteristics (size, sales, age, education and arable, fruit, vegetable and viticulture sectors), the obtained latent value representing the intention to use is included in the model (IU). Moreover, the supply chain organization is accounted for and included in the model through the HI indicator introduced in section 2.2. This measure is based on several binary questions regarding the existence of formal agreements and links between farmers and other actors along the supply chain (Table A.1, Appendix). In this way, the Hierarchical Integration (HI) indicator ranges from HI=0 (spot market transactions - loose formal link along the chain) to HI=5 (vertical integration, actors are formally linked, equity-based relationships). Before the regression analysis, multicollinearity is checked through the Variance Inflator Factors (VIF); only age is found with high VIF levels. Thus, age was transformed into a categorical variable (<45, 45-65, 65+) and multicollinearity checked again. Regression results are shown in Table 5.

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[3] At the question "Did you receive support by one or more of the organizations you belong to in adopting SFTs?" almost 80% of respondents answered negatively.

Inflation model - Logit: non adopters						Zero-inflated Poisson: adopters			
	Estimate	Odds-ratio exp (β)	Std. Error	P-value Pr(>|z|)	Hypothesis	Estimate	Odds-ratio exp (β)	Std. Error	P-value Pr(>|z|)
(Intercept)	3,059	21,306	1,765	0,083*		2,386E-01	1,269	2,3E-01	0,102
IU	-1,536	0,215	0,461	0,001***	H5(✓)	1,459E-01	1,157	5,8E-02	0,001***
sales	-0,024	0,976	0,013	0,060*	H9 (✓)	1,0E-04	1,000	6,3E-05	0,113
size	-0,101	0,904	0,052	0,051*	H10(✓)	5,553E-04	1,001	5,5E-04	0,316
+65	-1,500	0,223	1,312	0,256	H7 (X) not supported	7,9E-02	1,082	1,9E-01	0,668
45-65	1,469	4,345	1,235	0,234		2,751E-02	1,028	1,3E-01	0,831
highersc	-0,988	0,372	1,421	0,487	H8 (X) not supported	1,179E-02	1,012	1,7E-01	0,946
degree	0,237	1,267	1,520	0,876		-4,963E-02	0,952	1,9E-01	0,790
HI	-0,889	0,411	0,381	0,046**	H6.a(✓)	2,069E-02	1,021	3,9E-02	0,594
arable	-0,976	0,377	1,209	0,419	H11.a(X) not supported	2,934E-01	1,341	1,3E-01	0,024**
fruitveg	-1,352	0,259	1,160	0,244	H11.b(X) not supported	-2,8E-01	0,756	1,6E-01	0,094*
viticult	-0,500	0,607	1,127	0,659	H11.c(X) not supported	-8,727E-02	0,916	1,6E-01	0,600

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.*

Table 5 - Zero-Inflated Poisson regression model results

For simplicity, odds ratio (exponential transformation of estimates, exp(β)) are considered for interpretation. When for a certain covariate this ratio is higher than one, then it expresses the variable's effect on the farmers' likelihood to a) not adopt SFT in the case of binary logit model (left hand side of the table 5); b) adopt multiple SFT in the case of the inflated poisson regression model (right hand side of the table 5). Thus, for what concerns logit, results should be read in the opposite direction: for non-adopters farmers, IU is the strongest, significant factor affecting positively their likelihood to intend to become adopters. Dimensional variables such as annual average sales and land use size are the others significant factors positively affecting non-adopters likelihood to intend to adopt SFT, as well as their level of hierarchical integration along the supply chain (HI significant at 5% significance level). Surprisingly, farmers' age nor education do not show any significant effect on possible adoption, as well as the specialization in any of the sectors considered. When attention moves to adopters group, results are different; farmers specialized in arable sector are more likely to adopt more than one SFT, while those specialized in fruit and vegetable sector show a negative odds-ratio, thus lower likelihood to uptake more than one type of device. Finally, IU is the only other significant variable affecting adoption of multiple SFT.

5. Discussion

The first research question assessed in our study, i.e. "*Which are the main factors affecting the intention to use SFT?*" (RQ1), disclosed two main interesting results.

As a first result, farmers show stronger intention to adopt SFT that in their opinion (i) will deliver higher productivity, cost efficiency and sustainability performances, (ii) that are easy to use and (iii) whose use is supported by their social environment (trusted people, colleagues and other farmers). Most of the tested hypotheses are in fact supported by our model (table 4): expectations about the performances of such technologies (PE) are the most important drivers of the intention to use, as previously found by several scholars (Faridi et al., 2020; Michels et al., 2019; Venkatesh et al., 2003). Differently by Michels et al. (2019) though, the social influence around farmers (SI) seems to have a stronger impact than the perceived technologies' ease of use (EE) on both the expectations about SFT' performances and the intention to use them.

Especially for what concerns the perceived utility of these technologies at farm-level, the opinions and advices of peer farmers and trusted people might play a fundamental role. At the same time, EE's lower effect might be due to the technologically advanced nature of the online sample, probably more facilitated than the average with digital technologies.

As a second result stemming from RQ1, farmers seem to consider the organizational environment in which they (and their farms) are embedded as not facilitating the adoption of SFT. Although the facilitating conditions (FC) construct is not statistically reliable enough to be considered as a latent variable to test our fourth hypothesis (namely, that FC positively affects the SFT adoption decision), relying on the organizational support construct (item SI4) instead still indicates that the majority of respondents do not perceive that the organizations surrounding them were of any support in the process of deciding over the adoption of SFT. This evidence seems in conflict with several recent studies which highlight the important role played by numerous actors that are actively participating to the digital agriculture innovations systems - such as advisors, tech providers, professional associations etc. (Charatsari et al., 2020; Kernecker et al., 2021; Klerkx et al., 2019). Nevertheless, our results suggest that farmers seem to poorly perceive external support in the phase of knowledge/use intention, proving that the adoption process in these phases is still more individually driven.

As far as the second research question addressed in our study is concerned, i.e. “*Which are the main factors affecting actual decision to adopt SFT?*” (RQ2), additional useful insights on the adoption determinants are provided. Firstly, it is interesting to notice that all the variables related to the farms' size are significant and positively affect the non-adopters’ adoption decision, while no effect is observed for the adopters (table 5). Such evidence appears reasonable: while size (both in economic and land disposal terms) might be a decisive, necessary condition for non-adopters to intend to adopt SFT, for adopters who already use SFT and strive to integrate multiple technologies, financial resources and land disposal might not be discriminant conditions. Instead, IU seems to positively affect the adoption of more SFT, which supports the evidence that individual attitudes and intention to use seem to be crucial factors.

Secondly, our analyses indicate interesting differences between the non-adopters and the adopters also with regards to their sector of activity. On the one hand, the sectorial specialization seems not to affect SFT adoption by non-adopters. On the other hand, the F&V and arable sectors have different and opposed effects; the specialization in the F&V sector seems to negatively affect farmers' adoption of additional SFT. That might be explained with the current lower availability of specific SFT for the F&V sector (Kernecker et al., 2020). Indeed, the descriptive statistics indicate that only a few farmers belonging to this sector declared to have adopted more than one technology. In general, farmers in F&V sector seem to adopt mainly farm management information systems (FMIS), as the adoption of a logbook for pest treatment management required at national level indicates. The specialization in arable sector shows instead a significant positive effect on the uptake of multiple SFT. This result is in line with previous findings and seems to confirm that bigger, arable farms show a higher propension towards the use of SFT(Shang et al., 2021); on average, arable farmers benefit from the integrated usage of several SFT, as GPS-based devices and similar variable rate technologies (VRT) as well as FMIS and sensor-based technologies.

Further interesting results concern the influence of farmers' characteristics on SFT adoption. In fact, both age and education levels are found not statistically significant either for adopters and non-adopters. On the one hand, these results are in line with some findings of recent literature that confirms that being "young and educated" seems not to be a determinant for digital technologies' adoption at farm level (Pivoto et al., 2019; Shang et al., 2021). On the other hand, the nature of the sample – composed mainly by younger and more educated farmers than the national average – might have further downsized these sociodemographic effects.

Finally, when the focus is on supply chain organization, our elaborations show that on average, the farms' integration along the supply chain is associated with a higher intention to adopt SFT, although such formal integration do not explain the adoption of additional SFTs. Moreover, when various formal links are considered separately, farmers receiving support and resources by commercial partners (e.g. cooperative, consortium or similar producers' organizations) are more likely to intend to adopt SFT (i.e. the odds-ratio were less than one). This evidence contributes to recent studies that report how agricultural digitalization might be associated with supply chain hierarchical integration (Pesce et al., 2019). From an infrastructural perspective, a vertically integrated supply chain might more likely imply an entire and complete data chain which favors information flow. From governance perspective, to deal with data ownership and privacy issues, it might be fundamental for farmers to be able to rely on specific support figures. Generally, such favorable conditions are more likely to be available in hierarchically integrated supply chains.

6. Implications

The study has several implications for different agri-food systems' stakeholders.

To the best of our knowledge only a few contributions thus far have investigated the adoption of SFT through a comprehensive and exhaustive analysis of its determinants along the whole decision process, namely from the intention to adopt to the actual adoption. While the literature so far has looked at SFT adoption as the result of a simple binary (i.e. yes or no) decision, our study considers attitudes and intentions towards the use of technologies as the antecedents to the decision to adopt or not to adopt. By means of such an extended conceptual model, our study allows to analyze and consider additional potential determinants of the adoption, such as the organizational conditions.

In terms of theoretical implications, our results concerning the intention to adopt show that the usefulness of digital technologies needs to be clear to their potential users and that the social environment around farmers is key, more than the effort needed to use these technologies. For what concerns the first aspect, farmers convinced about the SFT usefulness in terms of higher productivity, cost efficiency and improved environmental sustainability show stronger intention to use and are more likely to finally adopt. Secondly, when looking more specifically at the influence the society at large exerts on the farmers decision makers, people that farmers trust seem to play a crucial effect, stronger than peer farmers and other colleagues. Finally, when looking at current adoption dynamics, our results show that highly motivated farmers, with bigger farms and higher levels of vertical coordination along the supply chain, are more likely to adopt SFT.

These results have also practical implications for various stakeholders in the agri-food system. First of all, we address policy makers who support farmers and other stakeholders (e.g contractors, agronomists, agricultural workers) in joining the digitalization process. Given the fragmented structure of the agricultural sector both in Italy and Europe, it is important that economic, training and support measures will be implemented to guarantee access to these technologies to small and medium farms, in order to avoid the risk of increasing the digital divide at the farm-level.

Our study offers interesting insights also for other stakeholders that might play an important role in facilitating the diffusion process of digital technologies along the supply chain. More specifically, we found that farmers perceive the organizational facilitating conditions as not supportive of their whole decision process. Actors operating at the supply-chain meso-level (e.g. producers' organizations, districts, farmers associations and similar) might be fundamental not only in supporting the adoption process, but also in the implementation and data management phases where trust becomes key to the adoption (Giagnocavo et al., 2017; Wolfert et al., 2017). The same applies to other industry actors (retailers, processors, etc.) that might have the potential to drive the future of the value chain digitalization. All these actors might find interesting insights on the possibility to guide a digitalization process that is currently mainly individual, thus disempowered. Furthermore, these readers might find useful suggestions on how to set a proper digitalization strategy from the farm level, by focusing on key adoption and diffusion determinants. Finally, these results might be of interest for technological providers and public/private support services, who might find useful insights regarding the key role of specific actors and technological attributes influencing the adoption and use of digital technologies.

7. Conclusions and limitations

The study comprehensively investigates the adoption of SFT in Italy. In order to analyze the multistep and multifaceted adoption decision process, different methodologies are used to analyze both the determinants of the intention to use and of the actual adoption. Various typologies of determinants are considered (behavioral, technological, relative to farms and farmers' characteristics), with a particular focus on the role the organizational environment around decision makers. To this aim, first the intention to use SFT is analyzed; on the one hand, our results highlight the key role the social environment around decision makers, as well as the technological features of SFT in terms of usability and performance expectancies, play in the adoption process. On the other hand, variables related to infrastructural/organization support perform poorly, indicating no average effect on the intention to use. Moreover, with the aim to further explore the role of organizational factors, the actual adoption decision is analyzed. In this case, in addition to the intention to use, farms' and farmers' characteristics are considered, as well as different variables measuring the level of farms' formal commercial integration along the supply chain. When looking at non-adopters, findings highlight that on average, larger farms, more integrated along the supply chain, are more likely to intend to adopt SFT, while both age and education are not statistically significant. When instead the focus moves to the adopters, only the users' intention to use seem to clearly, positively affect the final adoption decision.

Overall, this study partially confirm the key role that organized commercial networks can play as adoption drivers along the supply chain. In addition, our results indicate that the current SFT adoption process relies more on individual intentions, resources and existing formal relations along the supply chain. On the one hand, these findings highlight a consequential existing risk of digital divide for farmers and farms that might not be able to satisfy these requisites. On the other hand, they identify some important aspects that various stakeholders might consider to optimally support farmers in such digital transition, with particular reference to the role of social, organizational as well as technological factors in the moment of attitudes formation. Finally, the study highlights the great potentialities of SFT for farms showing high levels of commercial integration along supply chains, in terms of superior traceability, coordination and value distribution.

Limitations of the study and future research directions

From a conceptual point of view, although we extend the focus to more possible factors affecting adoption, our study does not include variables such as agro-ecological or informational factors. Moreover, for what concerns the UTAUT model, the FC construct do not perform as expected, as in other recent studies (see Michels et al., 2020). We recommend future research to pay particular attention to the adaptation of this construct to the agri-food context.

From an empirical point of view, a limitation of our analysis consists in the sample's nature; we refer to an existing on-line community of farmers, thus their attitudes towards technologies might differ from those of off-line farmers, probably less technologically advanced. Moreover, the study has a geographical limitation: it includes only farmers active in Italy. Our suggestion for future research on SFT adoption is to replicate multistep and multifaceted analyses, with samples more heterogeneous in terms of propension towards technology and geographical distribution.

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9. Appendix

SC Governance structures classification (Wever et al., 2010) and measurement of SC hierarchical integration	
Spot market contract. A contract (invoice) for instant exchange of goods or services	Q1. I*s the production and/or the commercialization ruled by legal enforceable contracts?*
Verbal agreement. Exchanges not formalized into written, legally enforceable contracts. Performance or behavioral standards are unlikely to be specified, but if so, they are not formalized	Q2. *Do you receive resources and/or support for some of your business activities (e.g. production commercialization, etc.) from commercial partners to which you belong (e.g. producers organizations, suppliers, buyers, etc.)?*
Formal contract. Legal enforceable, written contracts are used to govern the transaction. Performance and behavioral standards are specified in the contract	Q3. Is *your farm part of a cooperative, consortium or similar producers' organizations?*
Equity-based contract. A chain actor owns stock (and has the accompanying shareholder voting rights), but less than 50%, of (on of) its suppliers/buyers	Q4. *In the management of your farm, are you subject to control/monitoring from other actors of the supply chain you belong to?*

Vertical integration. A chain actor owns more than 50% of the stock (and has the accompanying shareholder voting rights) of (one of) its suppliers/buyers	Q5. *Do other actors from the supply chain you belong to own part your farm's property?*

Table A.1 - Governance structure classification and indicator of relative hierarchical integration

UTAUT constructs	Items	No.	Source
Performance Expectancy – PE	*I would find the use of SF technologies useful in my daily work*	PE1	Beza et al., 2018; Venkatesh et al., 2012, 2003
	I think the use of SF technologies makes my farm more productive	PE2	Beza et al., 2018; Caffaro et al., 2020; Faridi et al., 2020
	I think that the use of SF technologies makes the cost management of my farm more efficient	PE3	Michels et al., 2020
	I think that the use of SF technologies makes the management of my farm more environmentally sustainable	PE4	Michels et al., 2020
Effort Expectancy – EE	*My interaction with SF technologies is clear and understandable*	EE1	Beza et al., 2018; Michels et al., 2020 Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012, 2003
	I think learning to use SF technologies is easy for me	EE2	Faridi et al., 2020; Beza et al., 2018; Michels et al., 2020 Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012, 2003
	I think that SF technologies are easy tools for me to use	EE3	Beza et al., 2018; Faridi et al., 2020;

			Michels et al., 2020 Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012, 2003
	I think it is easy for me to become proficient in using SF technologies	EE4	Beza et al., 2018; Faridi et al., 2020; Michels et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2003
Social Influence – SI	*People I work with on the farm (agronomists, consultants, salesmen etc.) think I should use SF technologies*	SI1	Faridi et al., 2020; Michels et al., 2020; Venkatesh et al, 2012, 2003
	On average, other farmers I know think I should use SF technologies (2)	SI2	Beza et al., 2018; Faridi et al., 2020; Michels et al., 2020
	People I trust think I should use SF technologies (3)	SI3	Venkatesh et al, 2012, 2003
	In general, the organization (one or more) I belong to has/have supported the adoption of SF technologies (4)	SI4	Venkatesh et al, 2012, 2003
Facilitating Conditions - FC	*I think I have the necessary basic knowledge to adopt SF technologies*	FC1	Beza et al., 2018; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012, 2003
	I think I have the necessary resources (economic, technical, infrastructural, etc.) to adopt SF technologies (2)	FC2	Beza et al., 2018; Faridi et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2003, 2012
	SF technologies are compatible with other technologies I already use (3)	FC3	Beza et al., 2018; Faridi et al., 2020; Ronaghi and Forouharfar, 2020;

			Venkatesh et al., 2003, 2012
	If I am in difficulty with the use of SF technologies, there are people (or a group of people) who would provide me with assistance and/or support (4)	FC4	Beza et al., 2018; Faridi et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2003, 2012
Behavioral Intention – BI	*I plan to use or continue to use SF technologies in the future (1)*	BI1	Beza et al., 2018; Michels et al., 2020 Faridi et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2003, 2012
	I intend to use or continue to use SF technologies (2)	BI2	Beza et al., 2018; Michels et al., 2020 Faridi et al., 2020; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2003, 2012
	I always try to use SF technologies in the daily management of my company (3)	BI3	Beza et al., 2018; Ronaghi and Forouharfar, 2020; Venkatesh et al., 2012, 2003

Table A.2 - UTAUT constructs and measurement items