Technological Forecasting & Social Change 186 (2023) 122106

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Adopting new technologies during the crisis: An empirical analysis of agricultural sector

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ARTICLE INFO

Keywords:
Technology adoption
Crisis
Extended theory of planned behaviour
Entrepreneurs
Farmers

ABSTRACT

Research and development in agricultural sector are becoming a crucial issue, especially to answer to growing global market needs and, in general, for rural innovation development. The innovation process involves stakeholders of all levels and rural development requires both personal farmers' characteristics along with favourable socio-political and infrastructural environment. Many countries and governments have executed innovation projects for agricultural firms, involving a number of actors from the public and private sectors. However, the literature lacks of studies that investigate the identification of the main factors that determine the agricultural entrepreneurs' probability to adopt new technologies during a crisis context. Thus, through the adoption of the Extended Theory of Planned Behaviour, this study aims at filling this lack. More specifically, the exploratory empirical analysis focuses on a sample of 130 agricultural entrepreneurs operating in a rural developing Italian region, during the historical context of global pandemic crisis of COVID-19. The results provided several insights showing the factors that influence the adoption of technologies, such as the Attitude to Environmental-Economic Sustainability and the Planned Behavioural Control. An important role is also assumed by the past farmer's technological experience. The paper offers implications for entrepreneurs and public government.

1. Introduction

Agricultural entrepreneurs have to deal with growing challenges across the world and meet changed production requirements (Sørensen et al., 2021). In this context, many agricultural entrepreneurs see in the adoption of new technologies, a flywheel to change direction and transform their businesses, adapting them to market expectations. "*Agricultural technology*" is a broad term that is used to describe equipment, genetic material, farming techniques, and agricultural inputs that have been developed to improve the effectiveness of agriculture in terms of health, welfare, and sustainability outcomes (Ruzzante et al., 2021).

In the last years, research and development in agricultural sector are becoming a crucial issue, especially to answer to growing global market needs and, in general, for rural innovation development. The definition of innovation is something of man-made design which is new or unique and never before created (at least on historical record). More concretely, innovation can relate to any idea, practice or material artefact which is regarded as novel by members of a social system (Herbig and Kramer, 1993, pag1). Although all types of innovation have played a part in creating the society within which we now live in, this article focuses on *technological innovations*. The innovation process involves stakeholders of all levels, and rural development requires both constructive socio-political and infrastructural environment (macro factors) and personal farmers' characteristics (micro factors). Many countries and governments have executed innovation projects for agricultural firms, involving a number of actors from the public and private sectors and these projects involve a large amount of human and economic resources. More concretely, in this study we use the term "*technological adoption*" to indicate the adoption of new improved technologies by individual agricultural entrepreneurs in a given area (Feder and Umali, 1993), and "*technological diffusion*" to refer to the widespread adoption of new technologies by a greater number of agricultural entrepreneurs in larger areas (Takahashi et al., 2020). The phenomenon of new technology adoption in agriculture has been receiving much attention in recent years (Calisti et al., 2020; Wang and Fan, 2021; Hackfort, 2021; Tenakwah et al., 2022). It is a complex issue that invokes a wide range of factors that could influence the decision to adopt or not a given technology. Different theoretical models were proposed, to explain the

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https://doi.org/10.1016/j.techfore.2022.122106
Received 8 February 2022; Received in revised form 26 August 2022; Accepted 16 October 2022
Available online 4 November 2022

phenomenon of intention to adopt new technologies in the agricultural field. However, more studies are needed, especially to explore the phenomenon during a crisis context, in rural developing local settings (Apostolopoulos et al., 2021).

Specifically, coherently with this field of literature, we attempt to explore the factors that determine entrepreneurs' probability to adopt new technologies especially in a rural developing region, during the COVID-19 pandemic, which is representing one of the most serious challenges of the last century. Stemming from an analysis of the literature on technology adoption in agriculture, the paper proposes a conceptual extension of the theoretical model of Theory of Planned Behaviour (TPB) (Ajzen, 1991), that includes all the following variables: Behavioural Attitude, Subjective Norm, Perceived Behavioural Control, Information and Knowledge Acquisition and Access to External Financial Resources. This study is one of the earliest studies related to a developing Italian region and offer different insight to the literature.

Referring to the effect of the variables included in the extended model, the empirical analysis shows a positive effect of Behavioural Attitude to Environmental and Economic sustainability on the intention to adopt new technologies. Specifically, when choosing to adopt new technologies, agricultural entrepreneurs consider not only those technologies that allow a reduction in terms of costs and an increase in productivity, but also technologies that can have a low environmental impact. Also, the Planned Behavioural Control has a positive effect on the intention to adopt new technologies. The added variables related to Information and Knowledge Acquisition and Access to External Financial Resources are to be not significative for the intention of agricultural entrepreneurs to adopt new technologies. Along with the variables included in the extended TPB model, the empirical analysis considers also some control variables; among the others, the experience of agricultural entrepreneurs shows a negative role in the intention to adopt new technologies in the future.

The paper is organized as follows: the second section illustrates the literature and the theoretical background. In the third section, methods and materials are analysed. The fourth section illustrates and discusses the results. Finally, the fifth section discusses the conclusions, limitations and future research.

2. Literature review

2.1. The thematic analysis

In recent years, several studies in the literature have focused on the topic of technology adoption (Zamani, 2022; Singh et al., 2021; Wang and Fan, 2021Technology adoption represents a crucial theme in the scientific literature of recent years. In order to complete our understanding of the in-depth topic, we conducted an analysis of the literature on technology adoption in agricultural sector. Specifically, we start with the approach suggested by Cobo et al. (2011). We downloaded from web of science 233 papers derived from the keyword search on "technology adoption" AND "agriculture" AND "determinant*" AND "factor*"[1] with reference to topics on title, abstract author keywords and logical keywords (plus). The thematic map (Fig. 1) based on density (y-axis) and centrality (x-axis). Centrality measures the importance of the selected topic and density measures the development of the selected topic. The chart is divided into four parts: the themes that appear in the lower left are emerging or declining themes; the themes found in the lower right part of the theme map are the basic themes; the upper left part represents high density but low centrality, these developed but isolated themes; the upper right part represents high density and high centrality. The themes in this part are driving themes, which are developed and essential. The size of the theme map corresponds to the factors within

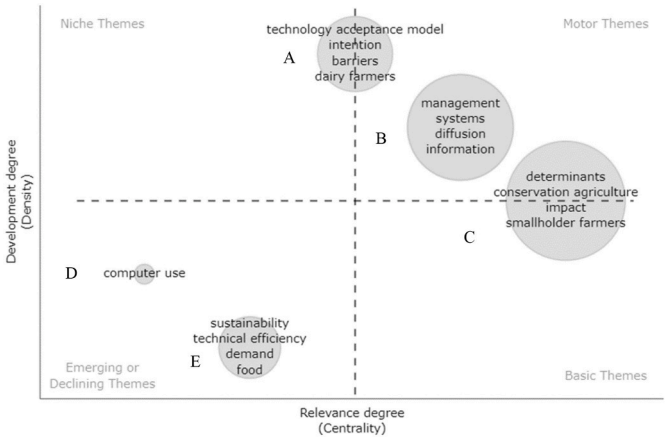

Fig. 1. Thematic map.
Source: our elaboration from Bibliometrix.

the theme and was constructed based on a time span from 1994 to 2022. The 100 most important keywords were used, but the elements shown in the clusters are set to the minimum frequency of 10 within the treated papers downloaded from web of science. The number of representative words for each theme was set at 4. The method used to extract the results is the Walktrap clustering algorithm (Pons and Latapy, 2006). The analysis was carried out by removing words that contributed to the formation of the dataset such as adoption, agriculture, technology adoption, technology, technologies, farmer, farmers. This was done in order to have as a result the true determinants that do not pertain to macro words such as technology or adoption. The result shows the literature on technology adoption and the respective factors.

The driving themes are represented by the following clusters: A, B, C, which result in part with basic and niche themes, but together with other clusters such as D and E, focus on some variables that could be considered in empirical studies, such as: sustainability, information, efficiency and intention.

Fig. 2 shows the Thematic evolution that represents the projection of the historical development of the literature on technology adoption in agriculture. To do this, the Walktrap algorithm was used with the top 500 words with a minimum frequency of five in the respective papers pertaining to the clusters. This temporal segmentation is based on the subjective judgment of the authors and in the concentration of the two periods of greatest crisis in recent decades such as the financial and pandemic crisis. The themes have evolved over time, starting from simple agriculture in the first 15 years, to transformation into determinants, models, investments, and holdings to result in climate-change, systems, attitudes, innovation, information, security, and collective action.

This literature analysis offers interesting insight on the main "hot topics" proposed in the specific field of literature, that need to be developed.

From the analysis of the 233 studies coming from the above review, it come out that very few works propose an empirical analysis of technology adoption during the strong pandemic period. Furthermore, although several studies are focused on the rural developing local context, few of these are developed in the Italian setting.

Thus, stemming from the literature, this paper attempts to answer the following research question: *which are the main factors that determine the probability of farmers to adopt new technologies during the period of global strong crisis, in rural developing local Italian contexts?*

2.2. The intention to adopt new technologies: some proposed theories

From the Thematic map (Fig. 1) comes out that "intention" and "determinants" are considered motor themes in the specific literature.

[1] The symbol (*) is used to not exclude from the results words with the same matrix but different final part

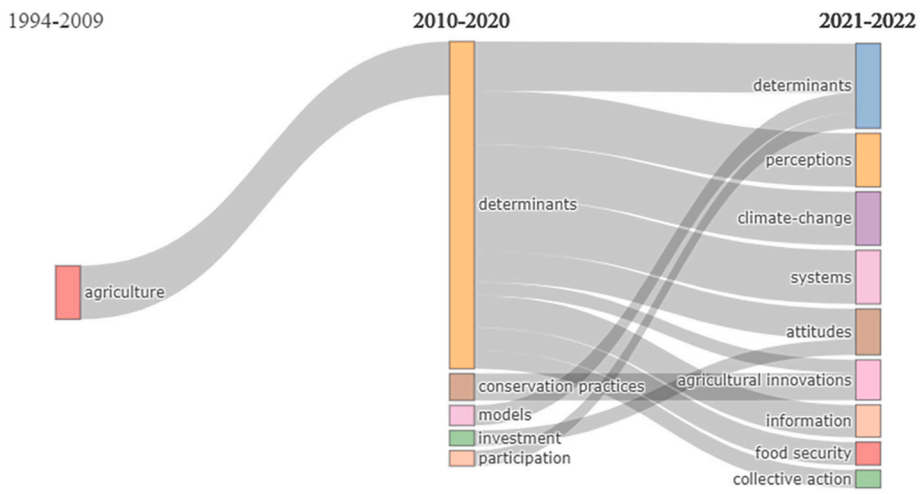

Fig. 2. Thematic evolution.
Source: our elaboration from Bibliometrix.

Moreover, from the Thematic evolution (Fig. 2) emerges that the concept of "models" is a crucial topic, moreover, across the years, it flows to the concepts of determinants. Thus, it is important to identify a theoretical model to explain the phenomenon of intention to adopt new technologies in the agricultural field. Technology adoption is a complex nonlinear process influenced by multiple factors. Different works in the literature (Sok et al., 2021; Bagheri and Teymouri, 2022; Cobelli et al., 2021), identified specific determinants and models, which consistently explain farmers' decisions to adopt innovation. Some studies were developed in the field of social psychology, and they describe adoption as a function of behavioural intentions. This behaviour is dependent on the adopter's attitude, which includes behavioural beliefs, normative beliefs and the motivation to adopt. If a farmer perceives that adopting technology will add value to their farm, the technology is adopted. By relating this group of theories with the factors identified in this literature review, the individual (farmer's) characteristics was identified as the only set of factors considered by this set of theories. The first type of model is based on the socio-psychological Theory of Reasoned Action (TRA). According to this theory, the attitude determines intention and it is shaped by the expectation and evaluation of an individual. The TRA, which is proposed by Ajzen and Fishbein (1977), suggests that behavioural intention determines actual behaviour and is influenced by both attitude and subjective norms. As TRA has a limited explanatory power for behaviour, which is not under the complete control of an individual's will, Ajzen extended TRA by adding the element of perceived behavioural control, and formally proposed the TPB. According to TPB, an individual's intention determines the individual's behaviour and depends on the individual's attitude, subjective norm, and perceived behavioural control. Thus, following this field of literature and stemming from TPB this paper investigates the factors that influence the probability of intending to adopt new technologies.

2.3. The conceptual framework

TPB assumes that the decision to engage in a certain behaviour is directly influenced by the individual's behavioural intentions (Ajzen, 1991; Fishbein and Ajzen, 2011). More specifically, Intention (I) is determined by two central constructs: Attitude (ATT) and Subjective Norm (SN). According to Beedell and Rehman (2000), I is the intention to perform the behaviour, ATT is the degree to which execution of the behaviour is positively or negatively evaluated, SN refers to people's perceptions of the social pressures upon them to perform or not perform a behaviour and PBC is the perceived own capability to successfully perform a behaviour. ATT, SN and PBC originate from, respectively, behavioural beliefs, normative beliefs and control beliefs (Ajzen, 1991).

Yang et al. (2022) argue that adoption refers to the degree to which farmers perceive experiencing difficulty with adopting the technology. Venkatesh and Davis (2000) determined that agricultural entrepreneurs were more willing to adopt proposed agricultural technology when they believed it would be easy to learn the requirements and high investments were not required. Lalani et al. (2016) concluded that farmers were inclined to adopt conservation agricultural technologies if they believed the technologies were useful and easy to operate.

Ajzen (2015), as one of the founders of this theory, states that new communication components and structures could be considered to improve this theory. The core argument of TPB is that human behaviour results from rational choices rather than from wilful action and is influenced by attitude, subjective norm, and perceived behavioural control through their effect on behavioural intentions. Restated, human behaviour is governed by behavioural intentions, which are in turn influenced by attitude (evaluation of the target behaviour), subjective norms (judgment about others' potential attitude towards the target behaviour), and perceived behavioural control (perceived ability of performing the target behaviour). Many studies agreed that TPB accurately predicted many different behaviours. Hagger et al. (2002) maintained that the three aforementioned factors can be used to predict behavioural intentions and behaviour; however, many other studies (Chen and Hung, 2016) suggested that more predictors should be added to TPB in order to increase its explanatory ability. Thus, many researchers have studied other variables that are not in this framework and believe that introducing other variables can improve the prediction ability of the model (Yadav and Pathak, 2016). Thus, this study attempts to propose additional factors to the original TPB model, in order to examine the farmers' intention to adopt new technologies.

2.3.1. Additional variables to extend the TPB framework

The TPB framework offers the opportunity for empirical identification of further relevant determinants by including new variables in addition to the original model (Ajzen, 1991). Previous research improved the TPB´s explanatory power by extending it with relevant additional constructs (Hou and Hou, 2019; Singh et al., 2021; Tama et al., 2021; Yang et al., 2022). This approach can be used to identify new relevant determinants that enhance the intention to adopt new technologies. Hence, we start to propose and extended model that includes three additional variables, often recurring in previous literature on technology adoption in the agricultural sector but not yet integrated into a single model (Verma and Sinha, 2018).

The first factor is Acquisition of Information and Knowledge, that,

with respect to a certain topic, influences the intention to adopt certain behaviour (Pradhan et al., 2022; Koutsouris and Papadopoulos, 2003). This is a "type of co-operation", that refers to collaborative innovations with other firms from the same group, from the same sector, with public and private customers, with suppliers (Magni et al., 2021). Baumgart-Getz et al. (2012) argue that access to information, financial capacity, and being connected to agency or networks of farmers had the largest impact of technology adoption (Blasch et al., 2022; Chege et al., 2020).

The second factor is External support from Government and Credit Market. Indeed, also External support from government (Sapbamrer and Thammachai, 2021; Donovan et al., 2006; Echeverria and Elliott, 2002) and the credit market (Ruzzante et al., 2021), may represent a resource for producers, agricultural service providers and enterprises (Donovan et al., 2006) that stimulate the adoption of new technologies.

The third factor is Sustainability. Sustainability is a crucial factor in the mindset for technology adoption. Indeed, Pilarova et al. (2018) also pointed out that agricultural entrepreneurs' risk perception significantly influenced the adoption of sustainable practices by smallholders. Yang et al., (2022) highlight that for small farmers is important to consider personal perceptions of the social, economic, and ecological benefits generated by the adoption of new technologies.

Thus, in this paper, we aim to investigate factors influencing the intention to adopt technology in a rural developing local context, through the application of the TPB, that we extended by adding three more factors, suggested by the literature (Fig. 3). Specifically, we explore the possibility to include the three more factors into the original model of TPB: Sustainability; Acquisition of Information and Knowledge and, Access to Resources, Credits and Markets.

2.4. The context: the agricultural sector in Italy during the global crisis of COVID-19

The Covid-19 pandemic is an unexpected and global event, reason why it is defined by some as "Black Swan" (Phan and Wood, 2020). The COVID-19 pandemic has made conditions unstable in all sectors of the economy and for some has meant a business crisis with no return (Larue, 2020; Mussell et al., 2020; Polese et al., 2022), for others an opportunity to 'reinvent' themselves by adopting new technologies, especially in Italy (Cucino et al., 2021; Ferrigno and Cucino, 2021). Thus, the probability of entrepreneurs to adopt new technologies is considered a key factor in overcoming the pandemic crisis. Torry (2020), for example, argues that, in the last year, the adoption curve of new technologies rose faster than in the absence of the pandemic shock (Güsken et al., 2019), as it stimulates the resilience in entrepreneurs.

Agriculture is the human activity consisting in the cultivation of plant species. Agriculture is defined as a complex system that incorporates a number of actors and the relationships between them (Sørensen and Bochtis, 2010). The agricultural sector is an income source for >1 billion of people across the globe. Agriculture production needs labour requirements due to the different stages that provides: from planting, growing, nurturing, harvesting to shipping of goods. Italy is represented as a leader in agricultural production (Pino et al., 2017; Proietti et al., 2016; Rossi et al., 2020). The National Rural Network Report (2014–2020) highlighted how the COVID-19 emergency put the Italian agri-food sector under great stress. Especially during the first lockdown, the sector suffered a slowdown, which was however overcome in the second half of the year, reaching a value of €540 million in 2020 (about 4 % of the global market) and growing by 20 % compared to the previous year, in line with the pre-pandemic trend. The report underlined that the most frequent difficulties encountered by farms during the lockdown period stemmed from the inability to repair equipment, machinery and buildings during this emergency period, the unavailability of adequate financial liquidity, difficult access to advisory and technical assistance services and the procurement of technical means. Data from the Smart Agri-Food Observatory[2] (www.osservatori.net) show that digital and technological innovation are the keys to the future of this sector. Agricultural technologies are entering the agri-food supply chain with solutions that increase the competitiveness of the entire sector and improve the quality and traceability of Made in Italy products. The research shows that about 80 % of the agricultural technologies offered are applicable in the cultivation phase and only 12 % in the planning phase. The majority of solutions (73 %), exploit data and analytics, 41 % the Internet of Things and 57 % software systems for processing and user interface. The majority of solutions (50 %) can be used irrespective of the agricultural sector, while 27 % are specifically aimed at fruit and vegetables, 25 % at cereals and 16 % at wine. In terms of activity, 48 % of solutions enable mapping and monitoring of land and crops, 42 % monitor and control the movement and activities of machinery and equipment in the field, and 35 % targeted irrigation and fertilisation. As far as the ability to obtain funding is concerned, while precision agriculture receives the most funding worldwide (37 %), in Italy this sector is in second place (35 % of funds), preceded by environmental sustainability, which manages to obtain half. Data from the Smart Agri-Food Observatory confirm the interest in digital innovation by companies in the Italian agri-food sector, despite the crisis and the disruptions caused by the pandemic. Investments in R&D have been driven by precision farming solutions – the tools supporting field activities – such as monitoring and control systems for vehicles and equipment (36 % of the market), and related machinery (30 %). The context is truly challenging; indeed, the dependence of market value chains, food, and agricultural sectors are considered to be less resilient due to the occurrence of the pandemic (Sridhar et al., 2022).

From the observation of this phenomenon comes the curiosity to investigate the probability of agricultural entrepreneurs to adopt technologies. This study aims to analyse the phenomenon of technology adoption during the period of the pandemic crisis, by agricultural entrepreneurs operating in Calabria, an Italian rural developing local context. In this context, exploratory empirical analysis is proposed, with the aim of understanding the factors that that influence the probability of farmers to adopt new technologies, during the period of the COVID-19 crises.

3. Methods

3.1. Research design

The empirical study is purely exploratory and is aimed at understanding which factors influence the intention to adopt new technologies on the part of agricultural entrepreneurs.

The questionnaire consisted of multiple-item measures for all the constructs in the model. The measures, taken from previous studies, were adapted slightly to the research context (Table 1). Venkatesh et al. (2003) study was the primary source for the measures. The questionnaire includes two macro sections:

- the first is aimed at collecting general and demographic information on the farmers and on the related company (Sok et al., 2021);

[2] The Smart AgriFood Observatory is a network of research institutions and companies. It has become the reference point in Italy to understand the digital innovations (process, infrastructure and application) that are transforming the agricultural and agri-food chain, unifying the main skills needed: economic management, technological and agronomic

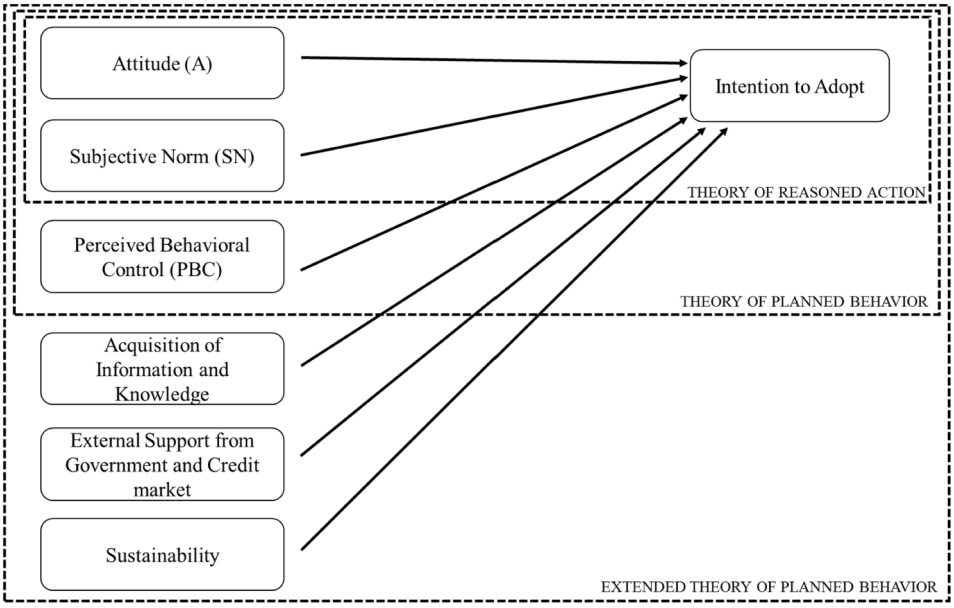

Fig. 3. From Theory of reasoned action to an extended TPB.
Source: our elaboration

- the second section aims to analyse the main factors that may influence the adoption of new technologies. It is divided into sub-sections related to the TPB and other sections related to other factors that are used to improve the power of TPB and that can influence the probability to adopt. Specifically, the first sub-section consists of predefined questions about the intention to adopt new technologies; the second one concerns the Attitude towards technology adoption and the expected results after adoption; the third one refers to the importance of Subjective norms in the process of technology adoption; the fourth detects the so-called Perceived Behavioural Control; the fifth one considers the importance of sustainability for farmers (Yang et al., 2022); the sixth investigates the importance of some "Supportive factors" (Sok et al., 2021; Sapbamrer and Thammachai, 2021), such as: Information acquisition, Access to financial public and private Resources.

The estimates of the variables related to Extended TPB, except for "Intention to Adopt" and control variables, since they were valued with the dichotomous questions (0 = No; 1 = Yes), are measured using a different 7-point Likert scale. All the items included in this work, with respective measures, were described below.

The psychometric properties and reliability of the scales were determined through the use of Cronbach's alpha (Cronbach and Gleser, 1965). In the evaluation of the proposed items, the reliability coefficient for the questionnaire, as a whole, was 0.93. Attitudes towards adoption intention were measured using three items with a composite reliability of 0.9. Subjective norm was assessed with two items with a composite reliability of 0.86. Perceived behavioural control was measured with four items with composite reliability of 0.86. Sustainability was assessed with four items with composite reliability of 0.86. Acquisition of knowledge and Information was assessed with four items with composite reliability of 0.77. Access to external Resources, Credits and Markets was assessed through two items with composite reliability resulting in 0.89.

3.2. Sample description

The questionnaire was first tested by a restricted panel of entrepreneurs who gave us useful suggestions to improve it. Subsequently, the questionnaire was sent to all the members of Confagricoltura, Confederazione Italiana Agricoltori (CIA) and Caa-Copagri.[3] The questionnaire was administered between March 2020 and October 2020, that was the most severe pandemic period. Due to the public health emergency the questionnaire was ran through the Google Forms online.

The reference sample consisted of 130 Italian agricultural enterprises. The sampling used to collect the data is non-probabilistic as it involved some trade Italian associations such as Confagricoltura, CIA and Caa-Copagri.

The statistical software used for the analysis is SPSS version 26.0. With reference to the first section of the questionnaire, the agricultural entrepreneurs belonging to the surveyed sample (130) are mainly male (110) with an average age of about 50, in line with national data of Smart Agrifood Observatory (OSA) (2021). The subjects are characterized by a medium-low level of education and the percentage of graduates is around 30 %. A large proportion of the subjects are direct farmers and many of them have sole proprietorships and/or family businesses. In most instances, the entrepreneurs are also owners of the land where the farm is located. More than half of the entrepreneurs in the sample do not use family workforce. Regarding outlet markets, most of the entrepreneurs' target wholesale traders; products are mainly destined for the local and national market. Referring to the adoption of new technologies, 52 % of the respondents have never adopted new technologies. The sample description is detailed in Table 2.

3.3. Explorative Factor Analysis (EFA)

The second section of the questionnaire returns a series of variables of interest measured through different items. Due to the excessive number of items, it was decided to reduce the complexity through the use of an explorative factor analysis, moving from the analysis of a large set of variables to a smaller one. Exploratory factor analysis is a statistical technique that is used to reduce data to a smaller set of summary variables and to explore the underlying theoretical structure of the phenomena. The aim is to find out how each of the elementary indicators changes in relation to all the others and how much they are associated one another. Factor analysis is developed using the principal

[3] Professional agricultural and representative organization of Italian agricultural enterprises

Table 1
Description of items and questions.

Item	Question	Measures	References
Intention to adopt	In this year or in the next, you intend to adopt or a new technology	0 = No 1 = Yes	Beedell and Rehman (2000); Li et al. (2021).
Attitude (towards adoption)	According to you, adopting a new technology, this year or the next, is a choice	1 = Impossible; 7 = Possible 1 = Negative; 7 = Positive 1 = Very bad 7 = Excellent	Ajzen, 2012, 2015 Sarkar et al. (2022); Hou and Hou (2019).
Subjective norms	1. When you want to adopt new technology, what is the probability that users of the agricultural sector approve it; 2. When you want to adopt new technology, what is the probability that consumers, suppliers and civil society approve;	1 = Totally improbable 7 = Totally probable	Ajzen (2012); Sarkar et al., 2022); Hou and Hou, 2019
Perceived behaviour control	1. You think it is possible that your company will adopt new technologies in this or the next few years; 2. You think that if your company adopts new technologies in this or in the next few years, the decision depends only on you; 3. You think that if your company adopts new technologies in this or the next few years, you have the skills and knowledge to do it; 4. You think that if your company adopts new technologies in this or in the coming years you have the equipment and structures to do it;	1 = Surely not; 7 = Surely	Ajzen (1991); Yang et al., 2022. Lalani et al. (2016); Sarkar et al. (2022); Hou and Hou, 2019
Sustainability	1. Adopting new technology in this year or the next will lead to a reduction in costs; 2. Adopting new technology in this year or the next will lead to increase productivity; 3. Adopting new technology in this year or the next will lead to higher environmental sustainability; 4. Adopting a new technology in this year or the next will lead to an increase in the company's added value;	1 = Strongly disagree, 7 = Strongly agree	Yang et al., 2022 Rogers (1995)
Information and knowledge acquisition	1. In your opinion, it would be interesting if a colleague of your age informs you about the adoption of new technologies; 2. In your opinion, it would be interesting to receive information from agricultural technology experts on the benefits and possible use; 3. In your opinion, it would be interesting to have the opportunity to observe new technologies in agriculture directly in action; 4. In your opinion, it would be interesting to receive support by universities and research centres;	1 = Strongly disagree, 7 = Strongly agree	Rogers (1995); Koutsouris (2003); Tezeswi and MVN (2022).
Access to external resources, credits and markets	1. In your opinion, when you want to adopt a new technology, what is the probability that subsidies or incentives take over; 2. In your opinion, when you want to adopt a new technology, what is the probability that bank loans take over;	1 = Totally improbable; 7 = Totally probable	Ruzzante et al., 2021
Farmer's technological experience	Has the company adopt any innovations in the past 5 years?	0 = No 1 = Yes	Mussell et al. (2020); Sapbamrer and Thammachai (2021)
Internal workforce	The farmer directly cultivates his own land	0 = No 1 = Yes	Paustian and Theuvsen, 2017
Explorative Ownership	The farmer owns the land	0 = No 1 = Yes	Paustian and Theuvsen, 2017
Education	Educational title of the farmer	1 = Degree 0 = Other	Paustian and Theuvsen, 2017
External workforce	The farmer uses workforce outside the family context	0 = No 1 = Yes	Paustian and Theuvsen, 2017
Gender	(0 = Female; 1 = Male)		

Source: our elaboration.

components analytical method: a smaller number of principal components are extracted from the original N variables, that are able to account for a considerable proportion of the variance of the original variables. Pearson's correlation, one of the assumptions of factor theories, is used, with a focus on correlations >0.30. In this case, there is correlation between the variables, and they are significant in almost all cases. Subsequently, it is necessary to evaluate the coefficients assumed by the two indicators: Kaiser-Meyer-Olkin index (KMO) and Bartlett's test of sphericity. KMO is constructed by comparing the correlation coefficients with those of partial correlation, with variation between 0 and 1, suggesting the potential inadequacy of factor analysis, since the correlations between pairs of variables cannot be explained by the variance shared by the set of variables, which means that common factors cannot be identified. In this case, a value of 0.849 is particularly

Table 2
Descriptive statistics of the sample.

Respondents' characteristics	Frequency ($n = 130$)
Age	
<33 years	39
34–45 years	25
46–56 years	18
57–67 years	25
68+ years	23
Gender	
F	20
M	110
Direct farmer	
No	51
Yes	79
Utilized Agricultural Area (UAA)	
<10 ha	102
>10 ha	28
Form of ownership of the land	
Rent	31
Property	99
Educational qualification of the owner	
Primary education	7
Secondary education	19
Tertiary education	63
Graduation	41
Family labor	
No	80
Yes	50
Farmer's technological experience (5 years)	
No	68
Yes	62

Source: Our elaboration.

acceptable (Table 3). Bartlett's test of sphericity is used to verify the hypothesis that the correlation matrix is an identity matrix. In other words, it aims at verifying whether the variables are independent. If it is significant, as in this case, it shows that there are correlations that are sufficiently high not to be comparable to zero.

Subsequently, it is evaluated the analysis of communality, which allows to purify the input variables in order to eliminate from the model those variables that present extracted saturation lower than 0.40. From the analysis on the reference sample, there is a good level of explanation of the variance deriving from the excellent saturation of the chosen variables. As far as extraction is concerned, the criterion used is the one proposed by Guttman and Kaiser, by which it is decided to extract as many factors as there are eigenvalues greater than or equal to 1. Through factor analysis it is appropriate to lose the least amount of information, therefore, the objective is to select those factors that, cumulatively, are able to explain at least half of the variance. In the present case, 5 components are selected, which explain about 72 % of the cumulative variance.

Here, the EFA has be applied to explore the underlying theoretical structure of the Extended TPB proposed in the Conceptual model (Fig. 3). Specifically, this procedure, transforms the observed items into a simpler structure that nevertheless contains the same information as the original. Table 4 below, shows the Matrix of Rotated Components. After performing varimax rotation, that is a type of orthogonal rotation from the EFA, five factors emerge.

Table 3
KMO and Bartlett tests.

Kaiser-Meyer-Olkin measure of sampling adequacy	.849
Bartlett's test of sphericity	
Approx Chi-square	1883.528
gl	210
Sign.	.000***

$0 < KMO < 1$.
*** p-value <0.01.
Source: Our elaboration.

Therefore, after the EFA, the extended TPB model becomes an extended model with the following five factors (instead of six) (Fig. 4), as explained in the following. Specifically, (1) the variable that we originally called Attitude was matched with the variable called Sustainability, generating a new factor called *Attitude to Environment and Economic Sustainability (AEES)*. More concretely, this variable allows to measure the attitude of agricultural entrepreneurs to adoption of new technologies with a positive effect on environment and society (Rogers, 1995; Baessler, 2006); (2) *Subjective Norms (SN)* is a measure of the s the approval that the entrepreneur perceives from all the subjects that belong to the ecosystem in which he/she operates (Ajzen, 2012; Hall and Rhoades, 2010); (3) *Perceived Behavioural Control (PBC)*, is the entrepreneur's perception of controlling external events and corporate resources (Lefcourt, 1991; Abay et al., 2017); (4) *Acquisition of Information and Knowledge (AIK)* refers to what the entrepreneur has available in form of support, experts and direct experience. This variable is linked to the support that universities, institutions, companies and others can give in an environment characterized by open innovation, a mean to seize new opportunities and react to the crisis in a resilient way (Ajzen, 1991); (5) *External Support from Government and Credit Market (ES)* which refers to subsidies, incentives and credit market products for agriculture (Abate et al., 2016; Pannell and Claassen, 2020).

The Extended Theory of Planned Behaviour after EFA will be tested with the Binary logistic model proposed in the next section.

3.4. Binary logistic model

For our purpose, it is necessary to understand in which way the variables included in the Extended Theory of Planned Behaviour model may influence the probability to adopt new technologies and the consequent real adoption. To do so, it is necessary to verify the existence of significant causal relationships between the different independent variables and with the dependent variable "intention to adopt" using the binary logistic model.

More specifically, the dependent variable is "*intention to adopt*", which assumes value zero in the case of no intention to adopt and value 1 in the case of intention to adopt. Thus, in this case, a binary logistic model is the most appropriate econometric tool for the analysis. The logit model based on the logistic distribution is specified as Gujarati and Porter (2008):

$$P_i = E(Y = 1|X_i) = F(Z_i) = F\left(\propto + \sum_{i=1}^{n} \beta_i X_i\right) = \frac{1}{1 + e^{-Z}}$$

that after a few arithmetical steps results in the odds ratio given by:

$$\frac{P_i}{1 - P_i} = e^{Z_i}$$

which by calculating the natural logarithm becomes:

$$Z_i = ln\left(\frac{P_i}{1 - P_i}\right) = \propto + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i = L_i$$

where:

- P_i the probability that Yi = 1, '*if a subject intends to adopt a new technology*'.
- *1-*P_i the probability that Yi = 0, '*if a subject does not intend to adopt a new technology*'.

Table 4
Matrix of rotated components.

Description	Components				
	Attitude to environment and economic Sustainability AEES	Subjective norms SN	Perceived behavioural control PBC	Acquisition of information and knowledge AIK	Access to external financial resources ES
I think the adoption of new technologies is a good thing	0.7				
Adoption means greater environmental sustainability	0.753				
Adoption implies increased added value	0.766				
Adoption means increased productivity	0.798				
Adoption leads to cost reduction	0.734				
It is important for the agricultural sector or supply chain to approve		0.782			
It is important that consumers, suppliers and civil society approve		0.805			
Technology is adopted to preserve all the supply chain		0.622			
I believe that the adoption of new technologies is a realistic action			0.652		
I think it is possible to adopt new technologies			0.775		
The decision to adopt new technologies is entirely up to me			0.673		
The company has equipment to implement new technologies			0.778		
The company has the skills and knowledge to implement new technologies			0.763		
Technology is adopted if one of my peers informs me about opportunities				0.703	
Technology is adopted if you have information from experts				0.898	
Technology is adopted if you directly observe experts in action				0.837	
Technology is adopted if you have the support of external parties				0.478	
Technology is adopted by partnering universities and research centres				0.635	
Technology is adopted if you have public funds					0.715
Technology is adopted if you have bank financing					0.86

Source: Our elaboration.

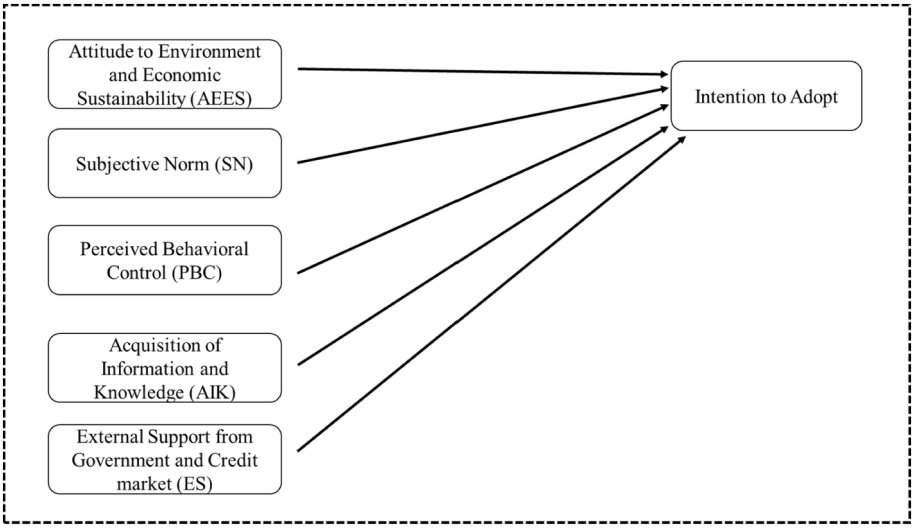

Fig. 4. Extended Theory of Planned Behaviour after EFA.
Source: our elaboration

- β_i coefficients of the explanatory variables to be estimated. The unknown parameters βi estimated with the maximum likelihood procedure.
- X_i variables that include factors that may influence the probability that a subject intends to adopt a new technology.
- e base of the natural logarithm.

- ε_i error term.
- $ln\left(\frac{P_i}{1-P_i}\right) = L_i$ the odds ratio of the probability that a subject intends to adopt a new technology.

Along with the dependent variable, the others include in this model, for the econometric analysis, are: the independent variables and the control variables. The independent variables are continuous variables and are the following: Attitude to Environmental and Economic sustainability (AEES), Subjective Norm (SN), Perceived Behavioural Control (PBC), Acquisition of Information and Knowledge (AIK), External Support from Government and Credit market (ES). Among the control variable, Age is a continues variable, while all the others are categorical. Gender is a variable that specifies if the responder is male or female, Internal workforce measures if the farmer directly cultivates his own land, Ownership considers if the farmer owns the land, Education includes the level of education of the farmer, External Workforce measures if the farmer uses workforce outside the family context and Farmer's technological experience is a measure of the Experience in the adoption of technologies by agricultural entrepreneurs in the last 5 years.

3.5. Preliminary analysis

In order to analyse the factors influencing adoption, multicollinearity was checked between the continuous variables and between the categorical variables before they were added to the logit model.

Regarding the continuous variables, the Tolerance index and the VIF (Variance Inflation Factor) were used (Table 5). The first index measures the amount of variance of the variable, which is not explained by the other independent variables. If $T = 1$, collinearity does not exist; vice versa, if $T = 0$, then there is a perfect collinearity problem. The second index represents the reciprocal of T, so in case of multicollinearity its value increases because the denominator approaches zero. In this case we have values very close to 1, which underlines the non-collinearity between the variables.

On the other hand, with regard to the categorical variables, a Spearman correlation analysis (Table 6) was performed to minimize the effect of collinearity of the independent variables and variables with values above 0.5 were excluded from the model. After collinearity checks, out of the 12 independent variables chosen for the model, just 11 of them are really included, of which 5 are categorical (Gender, Internal workforce, Ownership, Education, Farmer's technological experience) and 6 are continuous (Age, AEES, PBC, AIK, SN, ES).

4. Results and discussion

In order to analyse the logistic model, SPSS software was used to load all the data present in the sample of 130 participants. The Omnibus test of the maximum likelihood ratio with chi-square was evaluated, comparing the model containing only the dependent variable with the model containing all the predictors. The inclusion of the variables is justified if the test is significant as in this case, with p-value <0.05 (Table 7).

Table 8 below illustrates the pseudo R-square (Cox-Snell R-square and Nagelkerke R-square) and classification as a measure of how well the logit model fits the data. The correct classification of cases into different groups concerns the number of correctly and incorrectly assigned cases based on the probability of occurrence of an event. In this case there is a correctness rate of about 91 % of the cases. As far as the R-square is concerned, for regression models with a categorical dependent variable, it is not possible to calculate a single R-square statistic that has all the characteristics of the one contained in the linear regression model, so these approximations are considered by trying to establish the amount of variation explained by the covariates. The Nagelkerke measure adapts the Cox-Snell measure so that it varies from 0 to 1 (Cox and Snell, 2017). In this case, the values obtained are respectively 0.482 and 0.724, which therefore explain a large part of the variance (in general, values above 0.3 show that the model's performance is good for prediction).

Table 5
Collinearity statistics: tolerance and VIF for dependent variable.

Tolerance VIF		
AEES	.976	1.024
PBC	.950	1.052
AIK	.992	1.008
SN	.963	1.038
ES	.994	1.006
Age	.886	1.129

If T and VIF = 1, collinearity does not exist.
Source: our elaboration.

Once the technical characteristics were verified, the logistic regression analysis showed that all coefficients were loaded and that only few of them were significant in explaining the intention to adopt. The Wald test was also performed, which, along with the significance level, determines the statistical significance for each of the independent variables (Table 9).

The elaborations of the logit model return the following results. Firstly, control independent variables such as Age, Gender, Education and Land ownership are not significant. Secondly, the Extended TPB offers good contribution to the probability of technology adoption intention. In fact, the variable AEES is positive and significant. The attitude of agricultural entrepreneurs towards interest in technologies that have these particular characteristics that significantly increase the likelihood of intention to adopt is then described. Agricultural entrepreneurs are always alert to the sustainability in the adoption of new technologies, both from a purely economic point of view (reduction of costs and increase in productivity) and with regard to the environmental perspective. Also, the PBC variable is positive and significant; in fact, the perceived level of control one believes that the individual has over the execution of a behaviour, that is, the perception that one has related to the ease/difficulty of performing a given behaviour. The model underlines some peculiar aspects of the agricultural entrepreneur operating in the Southern part of Italy: he/she has a strong personality, he/she needs to always have everything under control and rarely collaborates with external subjects (companies, research centres), rather he/she tends to act autonomously. Moreover, a model of closed innovation is diffused and this is also confirmed by the Acquisition of Information and Knowledge Information and knowledge acquisition (AIK), which is not significant.

Another significative variable in the model is the experience in the adoption of technologies by agricultural entrepreneurs in the last five years (Farmer's technological experience), but with a negative effect on the dependent variable. That variable reduces the probability on intention to adopt new technologies. This shows that agricultural entrepreneurs who have already adopted new technologies in the last five years are unlikely to be adopting them again in the near future. The variable SN is not significative. This variable is related to perceived behavioural expectations for people/groups important to the individual are found to be not significant and have no effect on the likelihood of adopting new technologies. Also the variable External support from Government and Credit Market, in terms of public funds or private financing, is not significant, highlighting how the financial incentive does not always translate into a real intention to adopt.

5. Conclusions

This paper investigated which are the main factors affecting farmers' intention to adopt new technologies. Indeed, although the phenomenon of new technology adoption in agriculture has been receiving much attention in recent years (Calisti et al., 2020; Rehman and Razzaq, 2017; Wang and Fan, 2021; Zaremohzzabieh et al., 2015) more studies are

Table 6
Spearman correlation.

	Gender	Internal workforce	Ownership	Education	External Workforce	Farmer's technological experience (last 5 years)
Gender	1000	−.156	−0.091	0.056	−0.136	.162*
Internal workforce	−.156*	1000	0.047	−,178*	.296**	−0.125
Ownership	−0.091	0.047	1000	0.048	0.053	−0.057
Education	0.056	−,178	0.048	1000	−0.079	0.124
External Workforce	−0,136	.296**	0.053	−0,079	1.000	−0.142
Farmer's technological experience (last 5 years)	.162	−0,125	−0,057	0,124	−0,142	1000
N	130	130	130	130	130	130

* p-value <0.1.
** *p*-value <0.05.
Source: Our elaboration.

Table 7
Omnibus test of model coefficients.

		Chi-square	gl	Sign.
Phase 1	Phase	85,620	11	.000
	Block	85,620	11	.000
	Model/pattern	85,620	11	.000

Source: Our elaboration.

Table 8
Pseudo R-square and model classification.

	Classification table		
	Intention to adopt		Percentage of correctness
Intention to adopt	0	1	80.6
0	25	6	93.9
1	6	93	90.8
Logarithm of likelihood −2 = 57.198			
Cox and Snell R-square = .482			
Nagelkerke R-square = .724			

Source: our elaboration.

needed to highlight the main factors that that push farmers, operating in rural developing local contexts, to adopt new technologies (Lee and Trimi, 2021; Hackfort, 2021) during strong crises. Specifically, the study has the aim to investigate which are the main factors that determine the probability of farmers to adopt new technologies during the period of global strong crisis.

Thus, to answer our research question, we applied an Extended Theory of Planned Behaviour, by adding to the original model, two more variables, that are: Acquisition of Information and Knowledge and External Support from Government and Credit market. The results offer valid contributions to the literature on technology adoption in agriculture and also corroborate the findings of the extant literature while adding new insights.

Specifically, from the empirical analysis, comes out a very interesting contribution from the positive role of Attitude in technology adoptions. In fact, after the EFA, the variable that we originally called Attitude was matched with the variable called Sustainability, generating a new factor called "Attitude to Environment and Economic Sustainability; thus, we get a new interpretation on the variable Attitude already proposed in the original TPB model. Our study, in fact, highlights how agricultural entrepreneurs perceive technology adoption as an opportunity to face environmental and economic constraints. Therefore, for the agriculture entrepreneurs, operating in a rural developing local context, during a period of strong crisis, the attitude to adopt new technology embeds Sustainability values and they consider not only those technologies that allow a reduction in terms of costs and an increase in productivity, but also technologies that may have a low environmental impact. This result is consistent with several studies (Terano et al., 2015; Adnan et al., 2019; Piñeiro et al., 2020; Serebrennikov et al., 2020). that have shown how the probability to create inclusive agricultural markets attentive to environmental dynamics has increased also due to the push of European regulations (Shi and Lai, 2013).

Further, the importance of the perceived behavioural control to adopt new technologies, as mentioned by Ajzen (1991) is also confirmed by the study. Even if the two added variables include in the extended model (Acquisition of Information and Knowledge and External Support from Government and Credit market), are not significative, we think that these results can also offer important insights. The first comes from the variable related to the Acquisition of Information and Knowledge. This variable is related to the opportunity of farmers to apply an open

Table 9
Model and coefficients: variables within the equation.

Variables	B	S.E.	Wald	gl	Sign.	Exp(B)	95 % C.I. per EXP(B)		
							Lower	Higher	
Age	−.003	.004	.457	1	.499	.997	.989	1.006	
AEES	1.012	.465	4742	1	.029	2.751	1106	6.838	**
PBC	2.352	.598	15.451	1	.000	10,510	3.252	33.962	***
AIK	.528	.376	1.969	1	.161	1.696	.811	3.547	
SN	.176	.398	.195	1	.659	1.192	.547	2.600	
ES	.091	.495	.034	1	.854	1.095	.415	2.891	
Gender	−1.427	1.419	1.011	1	.315	.240	.015	3.876	
Internal workforce	−.273	.878	.097	1	.756	.761	.136	4.251	
Ownership	−1.465	.934	2.459	1	.117	.231	.037	1.442	
Education	.091	.785	.013	1	.908	1.095	.235	5.099	
Farmer's technological experience	−3.011	1.203	6.265	1	.012	.049	.005	.520	**
Constant	6485	2052	9991	1	.002				***

*** *p*-value <0.01.
** p-value <0.05.
Source: Our elaboration.

innovation model. From the analysis it comes out that the variable is not considered a crucial factor fro entrepreneurs. This can be considered a signal of a diffused closed innovation model among the responders. This is probably related to both the entrepreneurial mindset and also to the weak relations with universities and research centres. The other important insight comes from the variable related to the External Support from Government and Credit market. Even if public funding represents a valid and effective measure for rural developing local contexts, the results from our empirical analysis show that this is not considered a key factor. This evidence could be due for example, to the complexity of bureaucratic systems, often complex for the agricultural entrepreneurs' knowledge, but also to the lack of information.

There is also another important contribution of our study to the technology adoption literature. Specifically, entrepreneurs who already adopted new technologies, have a low probability to adopt new technologies in the future. The reasons could be different. Most agricultural entrepreneurs, for example have a low education in the adoption of new technologies, and the agricultural entrepreneurs with greater experience in terms of adopting new technologies are warried about the training commitment that adoption requires (Sapbamrer and Thammachai, 2021). Another motivation could be found in the deficiency of high skilled employees, therefore, becomes very difficult the diffusion technology process within firms.

However, the results are consistent with national data collected by some authoritative reports, including the Osservatorio Smart Agrifood (2021). The OSA report shows, in fact, that Italian farms are not fully ripe for the adoption of new technologies. In particular, a significant data confirmed how the level of education influences the adoption of new technologies. From the same report it also emerges that the entrepreneur is very confident in his abilities and therefore often opts for the purchase of a ready-made solution, suited to his needs, without resorting to co-development with external parties (other companies or research systems). Looking at the needs that lead to the adoption of new technologies, the OSA report points out that controlling production costs and increasing production are the key requirements. Coherently, the empirical analysis points out the significance of the economic sustainability sought by entrepreneurs who intend to adopt new technologies, both in terms of cost reduction and productivity increase.

Together with the theoretical contributions, our study provides important implications for entrepreneurs and policy makers. Firstly, agricultural entrepreneurs, especially in rural developing local contexts, should receive more support from the ecosystem, in terms of services, information, workshops and training courses, in order to enhance the probability to adopt new technology by collaborating with others actors, in a process of open innovation (Bellandi and Caloffi, 2010). In fact, the integration of the main elements of the service ecosystem (actors, integration of resources, technology, institutions) in different sectors encourages the creation of new resources and new uses of technology (Botti and Monda, 2020). Especially in a period of global crisis, awareness of the advantages of open innovation could stimulate farmers' interest in the adoption of technologies and their uses, resulting in models such as the Quintuple Helix Model (Carayannis et al., 2012; Passarelli et al., 2020). The adoption of new technologies could require significative amount of investment. Thus, the simplification of administrative procedures to get access to external funds, along with a more diffused information activity, could be useful to enhance the access to financing instruments by encouraging the adoption of new technologies. Knowing the determinant factors of agricultural technology adoption, it is very crucial points for policy makers and agricultural technology developer to overcome the low adoption rate problems.

5.1. Limitations and future research

This study has certain limitations. Firstly, convenience sampling was used to maximize the survey response rate. Therefore, it can be considered that only farmers interested in the study contacted the researchers, leading to potential selection bias. Secondly, we used narrow criteria to identify participants, which could have influenced the study results. Future research could conduct a survey and compare data from farmers who have adopted new technologies with data from non-adopters. The study was carried out on a limited sample of entrepreneurs operating in Calabria (rural developing Italian local context), that represents a limitation of the research. More concretely, due to limitations of time and financial resources, it was not possible to extend the study any further in geographical terms. Researchers are encouraged to conduct future research on a larger sample of data, with the aim of validating or challenging the present research and increasing literature. The purpose of this work was to understand the phenomenon of technology adoption, particularly during the pandemic period, which was a time of great uncertainty and disorientation. This means that farmers' behavioural intentions formed while COVID-19 was severe. However, the COVID-19 crises are becoming less severe, indeed future research should aim to analyse how the intention to adopt new technologies translates into the context of post crisis. In particular, future research might use the questionnaire submitted to the entrepreneurs themselves in order to make a comparison between the probability to adopt technologies in the first phase of the pandemic, and the same probability in the subsequent phases.

CRediT authorship contribution statement

Mariacarmela Passarelli: Conceptualization, Methodology, Software, Original draft preparation, Writing - Reviewing and Editing, Visualization.

Giuseppe Bongiorno: Conceptualization, Methodology, Software, Original draft preparation, Writing - Reviewing and Editing, Visualization.

Valentina Cucino: Conceptualization, Original draft preparation, Writing - Reviewing and Editing, Visualization.

Alfio Cariola: Supervision.

Data availability

Data will be made available on request.

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