Factors influencing adoption of digital technologies in agrifood sector. A literature review and research agenda

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Abstract

Framing of the research: *The research focuses on the factors influencing the adoption of enabling technologies in the agri-food sector. Through a systematic literature review, in which 58 papers were analyzed, the study proposes a classification of factors by investigating their impact on adoption intent. Furthermore, by emphasizing the framework of technology adoption, the study considers institutional support, managerial skills, financial resources, and regulatory frameworks as key elements shaping decision-making in agribusiness.*

Purpose of the paper: *The purpose of this paper is to explore the factors that affect the spread of enabling technologies in agri-food sector. Factors affecting companies' technologies adoption are individually investigated and clustered by conceptual groups. Then, their positive or negative effects on the adoption tendency of enterprises technologies were investigated.*

Methodology*: This research is based on a systematic literature review, considering a range of online database from 2012 to 2024. Specific filters have been applied, resulting in a final database that consists of 58 articles. After reading the articles, variables were classified according to social, economic, environmental, and technical nature. Finally, their positive or negative effects on technology purchase intention were investigated.*

Findings*: The research showed that "social factors" are more prevalent than "technical", "economic" and "environmental" factors. Moreover, there is arguably a clear need to improve specific technical and managerial competences about advanced technologies, even by stimulating entrepreneurs to train themselves social, not relying on the experience of others.*

Research limits: *The literature review was limited to articles in English, excluding studies in other languages that could offer significant contributions. Additionally, the selection of empirical studies was confined to the fields of "Business, Management and Accounting, " and Engineering, limiting the scope of the analysis. Lastly, our methodology for evaluating the influence of factors was subjective, based on the interpretation of textual content, with a potential risk of bias.*

Practical implications: *In light of the presented framework, we propose theoretical and managerial implications that would be useful for researchers and practitioners; a research agenda has been provided as well.*

Originality of the paper: *This paper aims to provide an increased understanding of the current state of research and what still needs to be investigated about the adoption of technologies in agri-food sector. Our study offers an integrative conceptual framework where factors affecting the adoption of technologies in agri-food sector are* *individually investigated and clustered by conceptual groups, as well as analysed in terms of impact generated.*

Key words: *Agri 4.0, digital transformation, purchase intention, intention to adopt, systematic literature review.*

1. Introduction

The adoption of cutting-edge technologies in industries signals a change in how businesses operate and create value prompting companies to reconsider the processes that contribute to their success. This shift, as seen in the works of Bagnoli *et al.* (2019) and Toniolo *et al.* (2020) and others represents a revolution that leads to competitive environments as highlighted by Mariani and Fosso Wamba (2020) and Sjödin *et al.* (2020). This transition towards advanced technological adoption has encouraged organisations to enhance sustainability, quality, and transparency in their practices, an approach strongly advocated by Quattrociocchi *et al.* (2022a). Specifically, the agricultural and food industry is at the forefront of this transformation, where the implementation of Industry 4.0 technologies addresses issues like product traceability, food safety and prevention of fraud. This is moreover evidenced by the FAO's objectives of enhancing food security, promoting sustainable agricultural practices, and mitigating environmental impacts through innovation (FAO, 2020). Similarly, they support the European Commission's Agenda 2030, which prioritises the digitalization of agriculture and the adoption of sustainable practices aimed at reducing greenhouse gas emissions, in accordance with EU regulations (United Nations, 2015). Given the agricultural sector's substantial contribution to greenhouse gas emissions, the implementation of frameworks such as the EU Effort Sharing Decision (ESD) and Effort Sharing Regulation (ESR) plays a crucial role in addressing these challenges. In this scenario, Agriculture 4.0 (even Agri 4.0) is being developed, also known as "digital agriculture", "smart agriculture", "smart farming", or "digital farming" (Giua *et al.*, 2022; Engås *et al.*, 2023; Dayioglu and Turker, 2021; Fielke *et al.* 2020). This phenomenon consists of a development form based on resource optimization and logics with the aim of increasing the quality of processes (Gong and Ribiere, 2021) and reducing waste (Benyam *et al.*, 2021). Under this umbrella, it was shown that by applying technologies such as artificial intelligence (AI), blockchain, drones, augmented and virtual reality, companies are facilitated in offering digitised value-added services (Scuderi *et al.*, 2020; Abbasi *et al.*, 2022). It is expected that, by 2050, the demand for food will surge by 70%, in line with rapid population growth. Furthermore, the adoption of digital technologies within the agrifood sector is expected to generate significant environmental and operational benefits, as observed by Secinaro *et al.* (2022) and Rana *et al.* (2021), who underscore the sector's increased accountability and responsiveness to consumer demands. This leads to an increasing awareness that the adoption of enabling technologies has become a necessity, both from a sustainable and competitive perspective (Appio *et* *al.*, 2021; Scuderi *et al.*, 2020; Trivelli *et al.*, 2019). Despite this, the agrifood sector still presents a low rate of technological investment compared to other sectors and it is considered as a sector with reduced capacity for self-innovation (Bjerke and Johansson, 2022; Läpple *et al.*, 2015). Contrary to the previous considerations, there are sceptical lines of thought towards the uncontrolled use of digital technologies, as claimed by Rijswijk *et al.* (2021), who literally stated that "Current digital technologies may have several undesirable, unseen and unknown impacts, e. g., emergent effects that only become clear once these technologies are brought into practice". This view is shared by Herrero *et al.* (2021) who argued that "Stand-alone technical solutions are in many instances unlikely to result in exclusively positive effects, and they are unlikely to be implemented quickly because of pushbacks from players wanting to maintain the status quo". At global level, UNEP has similarly underscored the potential risks associated with the deployment of technology, including the unequal distribution of benefits and environmental hazards, should these technologies be implemented without a strong regulatory framework in place (UNEP, 2021). As seen, while existing literature has explored specific aspects of technologies adoption in agri-food sector (Srivetbodee *et al.*, 2021), a comprehensive understanding of the underlying factors influencing this process remains elusive. While certain studies have identified key elements that either promote or hinder the diffusion of enabling technologies (Dal Mas *et al.*, 2023), the overall picture is far from complete. Much of the existing literature conceptualizes technology adoption as a binary decision-either a firm adopts the technology or it does not (Sunding and Zilberman, 2001). However, recent research indicates that this process is more nuanced, representing a dynamic and multifaceted progression shaped by a range of variables that influence different stages of decision-making (Jafarpanah *et al.*, 2020). In particular, factors of a personal, social, and behavioural nature, which have the potential to significantly impact adoption decisions, remain relatively underexplored (Busse *et al.*, 2014; Pathak *et al.*, 2019). Moreover, efforts to classify these influencing factors have thus far yielded inconsistent results. Mazzefoli *et al.* (2022), for example, categorises the factors according to the three pillars of sustainability-environmental, social, and economic-while Bucci *et al.* (2019) employs a broader classification scheme encompassing seven categories, including socioeconomic, agro-ecological, and institutional factors. Similarly, Fadeyi *et al.* (2022) proposes an alternative framework, identifying five principal categories such as farmer characteristics, institutional factors, and financial considerations. Despite these various attempts, no common classification system has been established, nor has there been a comprehensive analysis of how these factors collectively influence the intention to adopt technology. This absence of a unified framework not only limits academic discourse but also complicates the development of effective strategies for fostering technology adoption within the agrifood sector. To close this gap, our paper aims to establish an integrative conceptual framework where factors affecting the adoption of technologies in agri-food sector are individually investigated and clustered by conceptual groups, as well as analysed in terms of impact generated.

In the light of the foregoing, this paper tries to answer the following research questions (RQs):

- RQ1) Which factors are affecting technologies adoption in the agri-food sector and how they can be clustered?
- RQ2) In what terms do these factors influence the technologies intention to adopt?

To answer these RQs, 58 papers published from 2012 to today were considered. From reading the papers, factors influencing technology adoption were investigated and conceptualised by two levels of detail based on a holistic approach. In detail, factors were classified according to the three pillars of sustainability - environmental, social, and economic- as well as the technical factors were considered. Once the factors were clustered, the type of effect - positive or negative - they generate on enterprises' technologies intention to adopt were investigated. This paper addresses the urgent need for a coherent framework that elucidates the factors influencing technology adoption in the agrifood sector, providing a foundation for future research and practical strategies to navigate the complexities of digital transformation in agriculture

2. Theoretical background

2.1 Digitalization in agri-food sector

The Industry 4.0 paradigm introduces innovation processes characterised by an increasing interconnection between physical, digital, and biological dimensions (Culot *et al.*, 2020). In particular, even the agricultural sector, traditionally linked to processes reluctant to adopt new technologies, has expanded its vision by changing the business model of entire supply chains (Bagnoli *et al.*, 2019; Ruzzante *et al.*, 2021). In fact, Industry 4.0 enabling technologies such as cloud, additive manufacturing, simulation, augmented reality, big data and analytics, autonomous robots, IoT, vertical and horizontal integration and cybersecurity (Boston Consulting Group, 2015) have become a highly relevant topic for agricultural sectors. Its potential is increasingly recognized not only by primary producers seeking to enhance efficiency and sustainability within their operations, but also by stakeholders throughout the agro-food supply chain. The benefits of data collection in the field, and more broadly within agricultural enterprises, are becoming more apparent, providing more accurate and detailed information for improving traceability throughout the supply chain, enhancing the quality and use of production inputs, and optimising processes for greater efficiency and precision (Lezoche *et al.*, 2020; Liu *et al.*, 2021; Antolini *et al.*, 2015). Literature has also demonstrated the effects derived from the applications of these technologies in the agricultural sector. For instance, several publications agreed that Internet of Things (IoT) stands out as a key turning point for productivity and sustainability in the agrifood system, due to its ability to connect devices and collect data that enhance operational efficiency (Mazzefoli *et al.*, 2022; Oztemel and Gursev, 2020). Trivelli *et al.* (2019) emphasised that big data and data analytics (Wamba *et al.*, 2020) are crucial for a more efficient and effective evolution of the sector, contributing to the optimal use of resources (Lioutas and Charatsari, 2020). Furthermore, artificial intelligence offers powerful algorithms for performance evaluation and forecasting, promoting a form of smart agriculture aimed at sustainable development (Lezoche *et al.*, 2020). Cloud applications, encompassing both cloud computing and cyber-physical systems (Liu *et al.*, 2020), significantly improve soil condition monitoring and disease detection. Among the most tested technologies are drones, which have demonstrated their ability to sustainably enhance production efficiency through precise soil condition monitoring, early plant disease detection, and real-time weather updates (Quattrociocchi *et al.*, 2022b; Tsouros *et al.*, 2019). Additionally, blockchain applications are emerging (Mercuri *et al.*, 2021), which contribute to improved traceability and transparency of activities within agrifood supply chains. Overall, according to Oztemel and Gursev (2020), control technologies, robotics, and automation are progressively reshaping production processes by automating several operations, thereby allowing human operators to focus on activities that require higher cognitive skills, resulting in reduced labour costs and increased system efficiency

2.2 Adoption of enabling technologies in agri-food businesses

The process of adopting new technologies is often viewed as a journey that begins when an entrepreneur first learns about the innovation and continues until its full integration into their business operations. (Fadeyi *et al.*, 2022). The process of adoption of a new technology is conditioned by organisational and personal factors, such as human behaviour, organisational readiness, and the perceived utility of the technology itself. So far, several models have been developed to understand how and by what the process of technology adoption is influenced. In this scenario, models such as the Technology Acceptance Model (TAM) (Davis, 1989) and the Diffusion of Innovations Theory (Rogers, 2003) have identified key variables, such as perceived ease of use and perceived usefulness of the technology. However, these models demonstrate limitations within the agricultural context, where factors like low risk tolerance and infrastructural barriers, particularly in rural areas, pose significant obstacles (Ugochukwu and Phillips, 2018). Moreover, other models as the Unified Theory of Acceptance Use of Technology (UTAUT) developed by Venkatesh *et al.* (2003), and the Diffusion of Innovations (DOI) (Rogers *et al.*, 2014) have been developed in order to introduce additional variables such as institutional support and facilitating conditions. Despite these advancements, the UTAUT often remains insufficient to address the specific needs of the agri-food sector, which requires a more targeted integration of socio-economic and environmental factors, along with considerations of cooperative dynamics and sustainability (Bayaga and Madimabe, 2024; Blut *et al.*, 2022). Diffusion of Innovations (DOI) emphasises the social and cultural spread of technologies, offering a broader perspective, but it under emphasises individual motivations. In this context, the evolution of models such as TAM2 (Venkatesh and Davis, 2000), TAM3 (Venkatesh and Bala, 2008), and UTAUT2 (Venkatesh *et al.*, 2012) highlights the integration of social, cognitive, and technical factors to better understand technology acceptance. Each model builds on its predecessors by incorporating new determinants, such as social influence and facilitating conditions, thereby enhancing their explanatory power. For instance, UTAUT2 extends these concepts by including elements such as hedonic motivation and price value, which are particularly relevant in broader consumer contexts. In general, these models have been used to investigate the several aspects which affect the adoption of the different technologies, even in the agricultural sector. In coherence, Ugochukwu and Phillips (2018) state that this mindset-shift must be supported by appropriate corporate and government policies as the adoption of new technologies by conservative farmers, especially in developing areas, is particularly demanding and must be managed in an adequate and efficient way. In order to push the adoption process of new technologies by farmers, it is important to set out the effects that derive from (Challa and Tilahun, 2014), even to limit the perception that the entrepreneur has toward the specific technology (Yokamo, 2020). In these terms, several studies highlight that several factors influence the intention to adopt new technologies, such as access to information, financial capacity, adherence to cooperatives and government support also in terms of institutional subsidies (El Fartassi *et al.*, 2023). Obviously, the process of selecting and adopting Industry 4.0 technologies is not without obstacles (Liu *et al.*, 2020) as there is no single technological solution that meets the needs of all business counterparties (Lezoche *et al.*, 2020). Katz (2019) states that lack of digital knowledge and differences in technical skills are the main obstacles to technology adoption. Similarly, low risk appetite, uncertainty, and information asymmetry are limitations to its use (Ugochukwu and Phillips, 2018). In particular, the abovementioned impediments in agriculture are often also due to the size of the farm, the low availability of labour, the difficulties of accessing bank credit and financing, the lack of technological infrastructure and the complexity of the infrastructure itself (Annosi *et al.*, 2020). In contrast, numerous benefits are identified. Among these, it emerges the increase in turnover due to the development of a new product/ service (Kölsch *et al.*, 2017), improve productivity, reduce food safety risks and improve the sustainability of the entire sector (Hassoun *et al.*, 2022; Revathi *et al.*, 2019). Moreover, the implementation of such technologies inevitably influences customer expectations; in fact, the offer of greater customization of services and connected experiences on physical and online channels increases customer discretion, thus increasing the difficulties in defining business strategies. In the context of contemporary scientific research, different methodological approaches have been used to facilitate an in-depth examination of the integration of technological innovations in the digital agricultural sector.

3. Methodology

The analysis was conducted through a systematic literature review (SLR) (Seuring and Gold, 2012) aimed at identifying the determinants influencing the adoption of new technologies in the agri-food sector and assessing their effects on technologies intention to adopt. Through this objective it is expected to fill a gap within the research, as the current literature has not yet identified the nature of the factors influencing farmers' decisions to adopt smart solutions and qualify their effects with respect to technology adoption.

In accordance with the aim of the paper, the search string used for the study consists of three parts; The first includes all the various technology designations and all nine enabling technologies (Boston Consulting Group, 2015), as well as the recognised smart factories technologies (Mazzefoli *et al.*, 2022). The second part of the string includes all the keywords that are generally used in the literature to express adoption intention. The third and final part of the string identifies the different nomenclatures of Agri 4.0.

((“technology”) OR (“technologies”) OR(“innovation technology”) OR (“digital transformation”) OR (“innovation 4.0”) OR (“enabling technology*”) OR (“qualifying technology*”) OR (“advanced manufacturing solutions”) OR (“additive manufacturing”) OR (“augmented reality”) OR (“simulation”) OR (“horizontal integration”) OR (“vertical integration”) OR (“industrial internet”) OR (cloud) OR (“cyber security”) OR (“big data”) OR (“blockchain”) OR (“artificial intelligence”) OR (“internet of things”) OR (“data mining”) OR (“drone”) OR (“robots”))

AND ((“technology adoption”) OR (“technology acceptance”) OR (“technology diffusion”) OR (“value perception”) OR (“purchase intention”) OR (“purchasing intention”) OR (“potential purchase”) OR (“potential choice”) OR (“implementation intention”) OR (“Implementation behaviour”))

AND ((“agri-food”) OR (“agri-food 4.0”) OR (agrifood) OR (agriculture) OR (“digital agriculture”) OR (“smart agriculture”) OR (“smart farming”) OR (“digital farming”).

In a SLR, researchers gather the best instances of previous research to identify, evaluate, and interpret all available studies related to a specific topic (Kitchenham and Charters, 2007). This SLR was conducted according to the PRISMA approach (preferred reporting items for systematic review and meta-analysis) which provides clarity and transparency (Moher *et al.*, 2015) and has been depicted in Fig. 1. To ensure quality and extract all relevant articles, two search engines Scopus and Web on Science (WoS) were used as these are the two bibliographic databases generally accepted as the most comprehensive data sources for various purposes (Zhu and Liu, 2020). However, the usability of data sources may also depend to a large extent on the additional restrictions on content accessibility and the willingness to download and export data, affecting research in accuracy (Pranckutė R., 2021). The string was primarily launched simultaneously in the two databases on 1 November 2022 and re-launched on 21 March 2023, 6 October 2023 and 12 April 2024. The first search without the application of database filters resulted in 1608 articles from Scopus and 2101 articles from WoS. At this stage, following the principles of PRISMA, the goal was to identify relevant publications and apply a practical scheme.

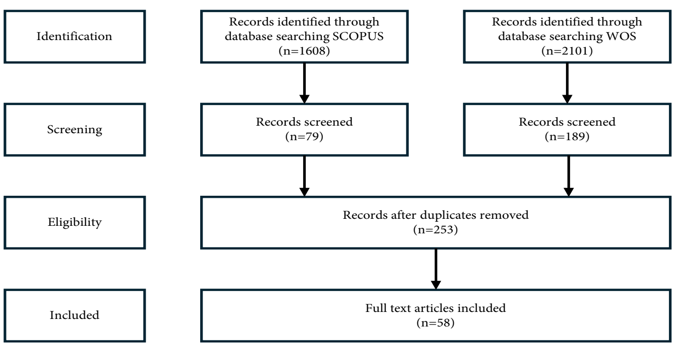
In this SLR, the following filter criteria were used:

- Language: English

- Document type: article
- Research type: journal
- Research area: Business, Management and Accounting, Engineering
- Timespan: 2012-2024

The following filters reduced the number of articles: in WoS only 189 articles while in Scopus 79 articles, including 15 pooled articles, resulting in a final dataset of 253 articles. This is the usual procedure for systematic reviews, as this process acts as a quality control mechanism that confirms the transparency of the result (Light & Pillemer, 1984). The second phase aimed at reading the abstract and selecting papers that analysed a specific technology through empirical analysis. In particular, several studies were discarded because they focused on technical aspects of the technologies, such as protocols or standards specific to each type of culture and therefore outside the focus of the research (Arasti *et al.*, 2022). A screening of the full text of these articles was carried out in the final phase (Tranfield *et al.*, 2003). To proceed with further analysis, including the valuation of quality and originality, were selected for further analysis because they were found to be closely related to the topic of this review, the following assessments were carried out by the researchers independently and in parallel, and, where doubts arose, they were discussed and resolved (Xiao and Watson, 2017). The articles excluded during the eligibility phase were omitted because they only superficially touched upon the key topics of technology adoption and innovation in the agri-food sector. By the end of the systematic review, only the studies directly addressing the research objectives were selected for deeper analysis. In the final stage, a content analysis was employed to answer the research questions. This process involved systematically coding each study's data into broader themes before analysing the prevalence and importance of those themes (Dixon-Woods *et al.*, 2005). Abstracts were initially screened, followed by a comprehensive review of the full texts to extract relevant information. As highlighted by Kraus *et al.* (2022), qualitative researchers often use content or thematic analysis to categorise data, identifying recurring patterns and organising them into coherent themes for further exploration. This method allows for a more nuanced understanding of the research topic and ensures a structured approach to data interpretation.

Fig. 1: Prisma Flow Diagram



Source: our elaboration

As a result, the final database consisted of 58 articles, which are listed and marked in the bibliography with an asterisk at the end of the citations. The entire categorization of the variables was developed on an Excel file shared between the authors, divided into eight columns, respectively divided as follows: authors, year, extrapolated variables, nature of the variable, positive or negative effect of the variable on the farmer's or farm's intention to adopt, state and Research Agenda. In the final session, any uncertainties were discussed to ensure consistency, and the final classification was proposed. All authors collaboratively reviewed the analysis results and jointly contributed to drafting the various sections of this study. The technological adoption process in the agrifood sector is a complex and multifaceted phenomenon, influenced by numerous factors that can either promote or impede the adoption of innovations. For an in-depth understanding of these dynamics, theories on the diffusion of innovation have been extensively applied since the 1970s. These theoretical models provide a framework for analysing how farmers adopt new technologies, which include equipment, genetic materials, cultivation techniques, and productive inputs, as illustrated by Ruzzante *et al.* (2021). Further examination of technological adoption in the sector is presented in studies by Gao *et al.* (2024) and Jeong *et al.* (2021), which highlight the critical role of technological compatibility in shaping farmers' attitudes towards innovations. Yang *et al.* (2023) have pointed out how technological compatibility can directly influence users' intentions and attitudes towards adopting or embracing a specific technology. Hanelt *et al.* (2021) have further enriched this field of study by investigating the factors that hinder or facilitate technological adoption through a detailed content analysis of selected works. In this study, we have employed a methodology that classifies influencing factors based on the three pillars of sustainability: environmental, social, and economic, with an additional category dedicated to technical variables. This approach, inspired by but distinct from Elkington's (1997) model, incorporates specific technical variables pertinent to the agrifood sector. This schema enables the categorization of factors based on their impact on the intention to adopt technologies, promoting a holistic analysis that considers the interdependencies among the different dimensions. The analysis conducted has led to the standardisation of terms used to describe similar variables, unifying the nomenclature to enhance the coherence and precision of the study. This significantly contributes to the evolution of the existing theoretical framework, marking one of the first attempts to categorise and analyse so comprehensively the factors influencing technological adoption in a business context. The content analysis has delineated the impact of the selected factors, assigning a positive or negative impact, and has laid the groundwork for a future research agenda that could explore further dimensions and interactions within the proposed theoretical framework.

4. Results

This section is divided into two subsections. The first one shows the analytical results based on the literature review, while the second subsection presents the different types of factors influencing the adoption of technologies by enterprises operating in the agri-food sector where variables were identified according to their economic, social, technical and environmental nature.

Factors impacting technologies purchase intention

The analysis conducted shows that purchase intentions towards new technologies in the agri-food sector are strongly dependent on various factors, in particular on the confidence one has towards certain variables. It highlights a predominance of social and economic variables, which demonstrates that decisions are influenced by several factors including demographic, socio-economic and institutional factors (Zegeye *et al.*, 2022). It is necessary to point out that these percentages analyse, in absolute terms, the number of variables belonging to each cluster. This paragraph also highlights whether factors have a positive or negative effect on the enterprises' intentions to adopt new technologies. The following subparagraphs highlight the research results.

Social factors - Social factors play a pivotal role in shaping technology adoption, accounting for 43% of the total factors considered. Age emerges as a significant determinant within this group, with numerous studies (Branca *et al.*, 2022; Kramer *et al.*, 2021; Bucci *et al.*, 2019; Antolini *et al.*, 2015) demonstrating that older farmers tend to be less inclined to invest in medium- to long-term initiatives. This reluctance is often attributed to their resistance to external recommendations, particularly when such advice originates from unfamiliar or untrusted sources (Läpple *et al.*, 2016; Manda *et al.,* 2020). Furthermore, despite possessing considerable work experience, older farmers often have lower levels of formal education, which contributes to their hesitation toward new technological investments (Kramer *et al.*, 2021; Adams and Jumpah, 2021). Social networks, including participation in cooperatives or business clusters, also play an essential role in technology adoption by facilitating knowledge dissemination and resource sharing (Blash *et al.*, 2022; Manda *et al.*, 2020). These networks effectively improve farmers' access to critical information and resources, thereby enhancing the likelihood of technology uptake (El Fartassi *et al.*, 2023). Nevertheless, the perceived complexity of managing new technologies, especially concerning data management, can present a significant barrier (Annosi *et al.*, 2020). This is particularly true when farmers lack sufficient information or face technical and financial asymmetries, which further hinder their ability to adopt new technologies (Gerli *et al.*, 2022; Barham *et al.*, 2018). Gender differences add an additional layer of complexity to the adoption landscape. Studies indicate that women, particularly in Australia, are more likely to adopt new technologies compared to men (Hay and Pearce, 2014). However, gender marginalisation and language barriers continue to act as substantial impediments to technology adoption in various regions (Annosi *et al.*, 2020; Fadeyi *et al.*, 2021). Addressing these challenges necessitates fostering collaborative mechanisms, such as cooperative structures, which can mitigate these barriers and support broader technology adoption (El Fartassi *et al.*, 2023; Adams and Jumpah, 2021). Thus, collective effort and structured collaboration are vital to overcoming social constraints and ensuring more equitable and widespread technology adoption in the agricultural sector.

Tab. 1: Social factors

FACTORS	EFFECTS	REFERENCES
High Educational status	Positive	Branca *et al.*, 2022; Khan *et al.*, 2022; Fadeyi *et al.*, 2021;Yokamo *et al.*, 2020; Manda *et al.*, 2020; Skevas and Kalaitzandonakes, 2020; Annosi *et al.*, 2019; Mottaleb *et al.*, 2018; Aubert et al, 2012; Zegeye *et al.*, 2022;Giuia *et al.*, 2022; Swinnen, J and Kuijpers, R, 2019; Blasch *et al.*, 2022; Jellason *et al.*, 2021; Adams and Jumpah, 2021; Bjerke andJohanssen, 2022; Bucci *et al.*, 2019; Eze *et al.*, 2018; Antolini *et al.*, 2015; Pierpaoli *et al.*, 2013
Young age	Positive	Giua *et al.*, 2022; Branca *et al.*, 2022; Annosi *et al.*, 2019; Skevas and Kalaitzandonakes, 2020; Manda *et al.*, 2020; Khan *et al.*, 2022; ;Giuia *et al.*, 2022; Fadeyi *et al.*, 2021 Mottaleb, 2018; Aubert *et al.*, 2012; Kramer *et al.*, 2021; Janssen and Swinnen, 2019; Zegeye, *et al.*, 2022; Barham *et al.*, 2018; Blasch *et al.*, 2022; Jellason *et al.*, 2021; Adams and Jumpah, 2021; Bjerke and Johanssen, 2022; Bucci *et al.*, 2019 Läpple *et al.*, 2016.; Antolini *et al.*, 2015
Membership in cooperatives	Positive	Adams and Jumpah, 2021; Manda *et al.*, 2020; El Fartassi *et al.*, 2023
Large family size	Positive	Manda *et al.*, 2020; Mottaleb *et al.*, 2018; Zegeye *et al.*, 2022; Giuia *et al.*, 2022; Adams and Jumpah, 2021; Fadeyi *et al.*, 2021; Yokamo, 2020
Perception of difficulty	Negative	Giua *et al.*, 2022; Annosi *et al.*, 2020
Experiences	Positive	Annosi *et al.*, 2019; Kramer *et al.*, 2021; Blasch *et al.*, 2022; Adams and Jumpah 2021; Bjerke and Johansson, 2022
Knowledge sharing	Positive	Blash *et al.*, 2022
Ease of use	Positive	Giua *et al.*, 2022; Aubert *et al.*, 2012; Tsai *et al.*, 2021
Access to information	Positive	Branca *et al.*, 2022; Gerli *et al.*, 2022; Yokamo, 2020; Barham *et al.*, 2018; Adams and Jumpah, 2021; Fadeyi *et al.*, 2021; Kathage *et al.*, 2015 Antolini *et al.*, 2015; Pierpaoli *et al.*, 2013
Information asymmetries	Negative	Long *et al.*, 2019; Thomas *et al.*, 2023
Women Gender	Positive	Khan *et al.*, 2022; Zegeye *et al.*, 2022; Skevas and Kalaitzandonakes., 2020; Barham *et al.*, 2018; Hay and Pearce, 2014
Language marginalization	Negative	Annosi *et al.*, 2020
Social influence	Positive	Giua *et al.*, 2022; Manda *et al.*, 2020; Bucci *et al.*, 2019; Srivetbodee and Igel, 2021

Source: our elaboration

Economic factors-The second group relates to economic factors, which include all variables that affect firms' competitiveness, including institutional and infrastructural ones. This category accounts for 35 % of the total amount. Table n. 2 shows that most of the authors identify the cost of investment as one of the main factors that impacts on purchase intention to adopt technologies (Kebebe, 2019; Mottaleb, 2018; Blasch *et al.*, 2022; Bergougui *et al.*, 2024). In this regard, Annosi *et al.* (2019) pointed out that decision makers should focus on the long-term benefits of applying technologies in the agr-ifood sector, especially in relation to cost and investment decisions. Indeed, awareness as well as expectation of economic return play a key role in the digital transformation process and in defining capabilities (Burkitbayeva *et al.*, 2020). In addition to the cost, among the main adoption barriers are the infrastructure improvements (Lele and Goswami, 2017; Pivoto *et al.*, 2018; Iovlev et al, 2019; Zaytsev, 2020), difficulties in acquiring technologies abroad, limited access to credit (Yokamo *et al.*, 2020; Yang *et al.*, 2018) and company size (Adams and Jumpah, 2021). Several papers emphasise a greater propensity of large firms to invest in innovation and R&D as a consequence of their greatest economic resources (Bjerke and Johansson, 2022; Mercuri *et al.*, 2021). On the other hand, a study of Ayenew *et al.* (2020) highlights examples of small-medium companies which, due to their flexibility, demonstrate high market adaptability. Several authors agree that another factor is the uncertainty of economic return involved in the technological investment made (Burkitbayeva *et al.*, 2020; Swinnen and Kuijpers, 2019). The choice of investment should be made based on objective parameters related to technology; for instance, the adoption of systems capable of handling big data enables the detection of optimal quantities for the production line through historical production parameters, thereby reducing the time of production (Cubric, 2020) and the cost of launching new products (Hassoun *et al.*, 2022).

Tab. 2: Economic factors

FACTORS	EFFECTS	REFERENCES
High Cost	Negative	Bergougui *et al.*, 2024; Manda *et al.*, 2020; Cubric, 2020; Kudryavtseva and Skhvediani, 2020;Skevas and Kalaitzandonakes, 2020;Kebebe *et al.*, 2019; Mottaleb, 2018; Blasch *et al.*, 2022;Jellason *et al.*, 2021; Fadeyi *et al.*, 2021; Antolini *et al.*, 2015
Uncertainty economic return	Negative	Burkitbayeva *et al.*, 2020; Skevas and Kalaitzandonakes, 2020¸ Janssen and Swinnen, 2019
Infrastructure improvements	Positive	Lele and Goswami, 2017; Pivoto *et al.*, 2018; Iovlev et al, 2019; Zaytsev *et al.*, 2020; Kudryavtseva and Skhvediani, 2020; Omotilewa *et al.*, 2019
Access to credit	Positive	Branca *et al.*, 2022; Manda *et al.*, 2020; Burkitbayeva *et al.*, 2020; Branca *et al.*, 2022; Kebebe, 2019; Janssen and Swinnen, 2019; Zegeye *et al.*, 2022; Yokamo, 2020; Swinnen and Kuijpers, 2019; Omotilewa *et al.*, 2019
Size area	Positive	Revathi and Sengottuvelan, 2019; Blash J. *et al.*, 2022
Company size	Positive	Khan *et al.*, 2022; Aubert *et al.*, 2012; Janssen and Swinnen, 2019; Bjerke and Johansson, 2022; Mercuri F., 2020; Adams and Jumpah, 2021; Ayenew *et al.*, 2020
Long-term benefits	Negative	Annosi *et al.*, 2019
Expectation of economic return	Positive	Burkitbayeva *et al.,* 2020
Financial availability	Negative	Aubert *et al.*, 2012
High Purchase cost	Negative	Annosi *et al.*, 2020; Young, 2020; Srivetbodee and Igel, 2021
High Installation cost	Negative	Annosi *et al.*, 2020; Omotilewa *et al.*, 2019
High Maintenance cost	Negative	Annosi et al, 2020; Srivetbodee and Igel, 2021
Reducing production time	Positive	Cubric, 2020
High Launch costs	Negative	Hassoun *et al.*, 2023; Srivetbodee and Igel, 2021
Reserach and infrastructure support	Positive	Fadeyi *et al.*, 2021; Bucci *et al.*, 2019
Increased job	Positive	Jellason *et al.*, 2021; Omotilewa *et al.*, 2019

Source: our elaboration

Technical factors - Technical factors account for 17 % of the total variables considered. Table n. 3, Technical factors include the need for managerial skills (Jellason *et al.*, 2021), the technical difficulties in the use (Fadeyi *et al.*, 2021; Bucci *et al.*, 2019; Thomas *et al.*, 2023), the availability of data (Cubric, 2020) and the need for highly qualified personnel who can adapt to new requirements (Kudryavtseva *et al.*, 2020). Micheels and Nolas (2016) state that the outcome resulting from the application of a specific technology, in addition to depending on the functionality of the technology, depends greatly on the skills of the operators who use it. The adoption of innovative technologies, therefore, requires personnel who have adequate technical skills and possess the capabilities to use them (Skevas *et al.*, 2020).

Another determinant factor is the connection to the broadband network or other connections (Eastwood *et al.*, 2017; Pant and Odame, 2017). Moreover, internet connection is often a hindering factor for companies located in rural areas that intend to adopt enabling technologies, as they have an objective starting disadvantage. Quality and Internet Utilization. The quality aspect pertains to farmers' access quality to the Internet. As noted by Abdullah (2015), the broadband connection speed appears to influence the adoption of digital technologies. Additionally, the extent of Internet utilization among farmers serves as an indicator; those who do not engage with the Internet are typically less inclined to adopt Information and Communication Technology (ICT) as well. In addition, proximity to research centres (Kebebe, 2019; Adams and Jumpah, 2021), possession of infrastructure, security (Dutta *et al.*, 2020; Kudryavtseva and Skhvediani, 2020; Thomas *et al.*, 2023), and transparency of movements (Quattrociocchi *et al.*, 2022a) contribute to the adoption of 4.0 technologies. For instance, blockchain technology allows for increased transparency and traceability of information (Ciasullo *et al.*, 2022), as well as contributing to the development and coordination of new sustainable business models (Mercuri *et al.*, 2021).

Endurance time is defined as the duration for which a specific UAV, equipped with its payloads, is able to remain airborne on a single charge. Traditional drones often face restrictions regarding their flight duration, which may prevent farmers from surveying an entire agricultural field in one go (Puppala *et al.*, 2023). Given the scarce presence of versatile Agro-UAVs, it is crucial to promote research and development efforts aimed at creating drones capable of supporting every stage of the harvesting process. Multi-functional drones have the potential to substantially reduce the costs involved in acquiring, operating, and maintaining distinct pieces of equipment. Furthermore, there is a pronounced demand for the development of various tools that can analyze the gathered data and implement automated, timely interventions (Zuo *et al.*, 2021).

Tab. 3: Technical factors

FACTORS	EFFECTS	REFERENCES
Managerial skills	Positive	Jellason *et al.*, 2021
Perceveid usefulness	Positive	Fadeyi *et al.*, 2021; Bucci *et al.*, 2019
Technical competence	Positive	Gerli *et al.*, 2022; Khan *et al.*, 2022; Skevas and Kalaitzandonakes, 2020; Annosi *et al.*, 2019; Micheels and Nolas, 2016
Data availability difficulty	Negative	Cubric, 2020; Thomas *et al.*, 2023
Qualified staff	Positive	Kudryavtseva and Skhvediani, 2020; Annosi *et al.*, 2020
Private agricultural consultant	Positive	Eastwood *et al.*, 2017
Internet access	Positive	Fadeyi *et al.*, 2021; Bucci *et al.*, 2019, Abdullah, 2015; Hay and Pearce, 2014
Research centers	Positive	Kebebe, 2019; Adams *et al.*, 2021
Increased security	Positive	Dutta *et al.*, 2020; Cubric, 2020; Kudryavtseva and Skhvediani, 2020; Ciasullo *et al.*, 2022; Hassoun *et al.*, 2023
Greater trasparency	Positive	Dutta *et al.*, 2020; Dal Mas *et al.*, 2023

Source: our elaboration

Environmental factors - Our results show that environmental factors only account for 4% of the total factors. Smart agriculture uses several advanced technologies, including IoT and others among the top nine, to collect data from multiple sources to be able to make decisions associated with various types of production (Thomas *et al.*, 2023; Medici *et al.*, 2019) with the aim of maximising yields but more importantly preserving the environment. The new technologies of Industry 4.0 show several benefits, including energy savings, better environmental performance, higher level of health and safety, and better conditions for workers (Hassoun *et al.*, 2022). Among other uses, in the agricultural stage IoT can improve chemical control such as pesticides and fertilisers, crop monitoring, disease prevention, irrigation control, and soil management (Navarro *et al.*, 2020; Adams and Jumpah, 2021). Thus, the use of 4.0 technologies in agriculture reduces the use of environmental pollutants, bringing atmospheric benefits, as well as improving soil quality and reducing groundwater pollution (Maffezzoli *et al.*, 2022). The current period is also characterised by the scarcity of raw materials, which is why the difference in competitive advantage between companies is especially given by the degree of environmental management of the company. It is therefore necessary to develop production plans that ensure environmentally sustainable production and food security. Cane and Parra (2020) studied how digital technologies can create benefits from both business and consumer perspectives by trying to leverage food waste reduction. In conclusion, academic studies promote the development of green agricultural entrepreneurial activities that integrate sustainable technologies (Savastano *et al.*, 2022).

Tab. 4: Environmental factors

FACTORS	EFFECTS	REFERENCES
Greater sustainability	Positive	Giua *et al.*, 2022; Cubric, 2020; Jellason *et al.*, 2021
Environmental sustainability	Positive	Skevas and Kalaitzandonakes, 2020; Annosi *et al.*, 2019
Energy conservation	Positive	Hassoun *et al.*, 2023
High level of security	Positive	Hassoun *et al.*, 2023
High level of health	Positive	Hassoun *et al.*, 2023; Thomas *et al.*, 2023
Higher soil quality	Positive	Blasch *et al.*, 2022; Adams and Jumpah, 2021; Maffezzoli *et al.*, 2022
Food waste reduction	Positive	Cane and Parra, 2020
Enviromental benefit	Positive	Medici *et al.*, 2019; Antolini *et al.*, 2015

Source: our elaboration

5. Discussion and conclusion

Our paper aimed to identify factors that can influence companies' propensity to adopt new digital technologies in the agrifood sector, classifying them into conceptual groups belonging to four clusters - economic, technical, social and environmental factors (RQ1) - and evaluating their effects on technologies intention to adopt (RQ2). The research thus defines a new theoretical framework through which a clustering of factors was provided; in addition, the factors were further qualified according to their impact on purchase intention of new digital solutions in agri-food sector. In light of this analysis, we can present some deductions; there is a clear need to provide specific technical and managerial competences about enabling technologies, even by stimulating entrepreneurs to train themselves personally, not relying on the experience of others. In this way, by training personnel and providing them appropriate skills, it is possible to integrate new solutions into the business environment with substantial benefits in terms of human-machine interactions. Moreover, there is a need to invest primarily in business structure in order to make access to credit easier. The socio-economic business environment assumes a key role in order to push enterprises toward a cross-cutting digitization process.

6. Theoretical implications

Our paper contributes to the literature through three insights. First, the research provides an update and a new conceptualization of factors influencing technologies' purchase intention in the agrifood sector (RQ1). Specifically, according to the literature, social, technical, economic and environmental factors were identified. Although there is no common classification of factors that influence the adoption of new technologies in the agri-food sector, this research is useful as it provides an updated framework on the several factors that influence the intention to adopt the enabling technologies in the agri-food sector. In particular, the analysis advances theoretical understanding of technology adoption by integrating the three pillars of sustainability-environmental, social, and economic-while also emphasising the role of technical variables, which are especially pertinent in the agrifood sector. Furthermore, this study expands the traditional sustainability framework by incorporating sector-specific technical considerations. This provides a more comprehensive perspective on how these multiple dimensions interact and shape the intention to adopt new technologies. The study thus contributes to bridging the gap between sustainability and technology adoption, fostering a more nuanced theoretical framework that is better suited to address the complexities of modern agricultural practices. Moreover, this paper should be considered useful for academic and practitioners as the -positive or negative- effects of each factor on technologies purchase intention are investigated (RQ2), thus providing an updated framework that enhances understanding of the key factors to target in order to promote technology adoption within the agrifood sector. This comprehensive analysis enables more effective interventions aimed at facilitating the uptake of innovations in this specific context. Lastly, our contribution provides some future research direction in order to deeply investigate customer needs and perceptions, as individuated through the following paragraph. In this term, it has to be highlighted that just a few papers have set a research agenda so far.

7. Managerial implications

This research offers some important implications for managers and policy-makers. In particular, this research can be useful for policy makers to establish policies to encourage the use of new technologies by directing efforts toward public incentive policies with the allocation of public funds throughout the sustainability dimensions: economic, social and environmental. It is highlighted that it becomes useful to direct funds towards the formation of specific technical skills, in order to reduce reluctance to technological and innovative investment. In our opinion, we believe that public initiatives should be planned in order to encourage the entrepreneurial culture towards sustainable business models based on the implementation and sharing of digital technologies in the agrifood sector. Environmentally, implementation of enabling technologies helps to create sustainable business conditions by reducing the polluting effects of production processes (Long *et al.*, 2019). These considerations lead to reconsider the importance of managerial class knowledge, which enables companies to develop long-term investment strategies by not limiting them to the act of purchasing. Specifically, managerial perceptions need to be acted upon, as they do not have full awareness of the positive externalities that result from technological investment since they do not perceive a need for it either from an environmental or technical perspective. Moreover, managers need to rethink their business strategy, basing value creation process on a long-term perspective and rethinking the labour market by a computerisation and digitisation of employees. In general terms, agrifood companies must change the logic that have characterised their business models so far, adopting digital technologies and improving both personal and technical skills throughout the production chain.

8. Limitations and future research directions

Our investigation into the application of technology in the agrifood sector presents several practical limitations that might influence the generalizability and applicability of our conclusions. The primary constraint of our research lies in the selection of sources; our literature review was exclusively confined to scholarly articles published in English. This linguistic restriction potentially omits pivotal studies published in other languages that could offer valuable insights into the topic, thereby narrowing the diversity and scope of our analytical perspective. Secondly, the selection of empirical studies for our factor analysis was constrained to the domains of "Business, Management and Accounting, " and Engineering. This deliberate choice, influenced by the authors' academic specialisations, may have inadvertently narrowed the scope of our analysis, limiting its ability to capture a broader spectrum of factors relevant to the adoption of technology in agriculture. Furthermore, our methodology for assigning a positive or negative influence to various factors was inherently subjective, relying primarily on our interpretation of the textual content of the selected papers. This approach bears the risk of bias and misinterpretation, which could affect the reliability and validity of our findings. The results of our Systematic Literature Review (SLR) indicate that although there is a growing interest in technological innovations within the agrifood sector, the body of research requires significant improvements both qualitatively and quantitatively. From a qualitative standpoint, our review has identified a lack of comprehensive studies that deeply analyse the levels of adoption and awareness of new digital solutions in agriculture. To date, there has been no exhaustive research that systematically evaluates and assigns specific weights to the factors influencing technology adoption within this sector. Moreover, the geographical focus of most empirical studies has been predominantly on developing countries. This geographic bias highlights the necessity for more inclusive research that conducts comparative analyses across different countries with similar agricultural profiles, such as Spain, Italy, and France.

In terms of future research directions, there is a substantial need to explore how different factors vary in their impact on technology adoption and to understand the underlying reasons for these variations. Questions such as how governmental support can affect the adoption rates of technological solutions in agrifood companies or the extent to which financial support from institutions influences purchasing intentions are crucial. Additionally, investigating whether similar research methodologies can be applied across various branches of the industry, including breeding, distribution, and consumption, would provide valuable insights. On a quantitative level, there is a clear pathway for extending the sample size through the development of cross-country studies and conducting comprehensive surveys on the attitudes of managers and entrepreneurs toward the implementation of Agrifood 4.0 solutions, utilising both surveys and interviews. Such studies should aim to encompass a broader array of countries and companies, thereby uncovering additional factors that could influence the success or failure of technology implementations. Moreover, our findings indicate that certain economic agents may prioritise technologies that support economic viability, yet these choices may not always align with environmental goals (Bergougui *et al.*, 2024). Therefore, a deeper investigation into how the scale and focus of technological investments can impact both economic and environmental sustainability is essential, even by investigating how the different agents across the supply chain perceive the trade-offs between technological investment and sustainability objectives. This approach would help identify strategies that balance the dual aims of fostering innovation and ensuring long-term ecological resilience.

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