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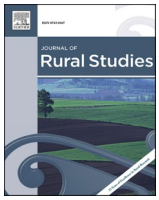

Assessing the digital transformation in agri-food cooperatives and its determinants

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ABSTRACT

The digital transformation (DT) of companies implies the emergence of new business models based on the widespread use of digital technologies. Digital transformation is necessary to improve efficiency, productivity, and market access in a context of increasing competition. In the case of the agri-food sector, DT is also required to address the challenges of food safety, food waste, and sustainability. This research aims to build a theoretical framework and a methodology to assess the global level of DT and its dimensions and factors that influence it in a specific type of agri-food company, namely agri-food cooperatives. These prominent social economy entities follow cooperative principles and play a significant role in rural development, especially in the most backward regions. An empirical analysis has been conducted to validate the methodology and meet the objectives. To this end, a Global Index of DT was built, and data was obtained from a survey of agri-food cooperatives in Andalusia, a southern Spanish region with a long-standing tradition of agri-food cooperatives, which also presents a low per-capita income in the European context. Empirical results effectively reveal that the proposed theoretical framework and methodology expediate the assessment of the global level of DT of agri-food cooperatives and the relevance of certain influential critical factors. In this way, relevant information for cooperatives and policy-makers can be collected to facilitate the implementation of DT.

1. Introduction

The digitalisation process profoundly impacts the efficiency, productivity, and competitiveness of companies (Vial 2019) and territories (UNCTAD 2019). Specifically, the "digital transformation" (DT) stage is the most pervasive of this process (Ancín et al., 2022; Verhoef et al., 2021). This stage implies the emergence of new business models based on the widespread use of digital technologies as opposed to the "digitisation" stage, which means encoding analogue information into digital data, and the "digitalisation" stage, which means applying certain specific digital technologies, such as blockchain, Big Data, Artificial Intelligence, and the Internet of Things, to particular company processes.

Among the diverse economic sectors that need to accelerate their DT, the agri-food sector stands out. This sector is currently facing, on the one hand, significant changes, such as new consumer-purchasing patterns, retail concentration, and new approaches to food delivery (Fritz and Matopoulos, 2008; Routroy and Behera, 2017), and, on the other hand, new challenges, such as food safety and security, food waste management, and sustainability (Yadav et al., 2022). All these circumstances, closely linked to globalisation, exert an impact on rural development, especially in less developed regions (Marsden et al., 1999). In this context, although agri-food companies present a delay in the implementation of DT regarding the manufacturing sector, DT is considered essential to tackle those changes and challenges, as the new concept of *Smart Farming* shows (Klerkx et al., 2019; Giua et al., 2022).

Within the agri-food sector, agri-food cooperatives play a significant role in market share (COGECA, 2020) and, even more importantly, contribute to rural development (Ajates 2020). Specifically, it is pertinent to highlight that, due to the values and principles which lead this company model (ICA 1995), they show a more prominent commitment to the territory, promote greater security in food supply for local communities, provide a good price/quality ratio for such supply, and also protect the environment (Candemir et al., 2021; Grashuis and Su 2019; Zurdo and Dopacio 2022). However, according to the literature, this type of cooperative presents a delay in their digital transformation (DT) compared to that of conventional companies (Cristóbal-Fransi et al., 2020; Jorge-Vázquez et al., 2021). Therefore, agri-food cooperatives must also carry out DT to remain in the market while maintaining the

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provision of their essential functions for rural areas.

In this context, although diverse studies address DT in the agri-food sector (Khanna, 2021) and its conditioning factors (Parra-López et al., 2021), a vital task yet to be carried out by research involves precisely measuring the global level of DT of the agri-food companies in general and that of agri-food cooperatives in particular. Specifically, regarding cooperatives, the literature has focused the analyses thereof on the use of only specific digital technologies, such as websites and e-commerce (Jabbouri et al., 2022) and blockchain for traceability and food safety (Borrero 2019; Giagnocavo et al., 2017). However, measuring the global level of DT of agri-food cooperatives implies measuring the level reached by its various dimensions, such as processes, products and services, infrastructure, organisation, and clients (Ifenthaler and Egloffstein 2020; Mettler 2011; Valdez-de-Leon, 2016). Furthermore, it also requires an analysis of the influence of various key determinants that may incentivise or discourage this DT, such as the specific characteristics of cooperatives and economic barriers they face to implementing the DT (Jorge-Vázquez et al., 2021). In this way, not only do firms know the level of TD achieved and how they can improve it (Ifenthaler and Egloffstein 2020; Lorenzo, 2016) but institutions which support agri-food cooperatives will also have information for policy planning (Parra-López et al., 2021).

In the specific case of Spain, agri-food cooperatives play a significant role within the agri-food sector, with 3,755 companies and 1.15 million members (COGECA, 2020). However, compared with other northern European countries, their size is smaller (MAPA, 2020), which is considered to constitute a negative influence on digital transformation (Giua et al., 2022). More specifically, in the southern region of Andalusia, where there is a long-standing tradition of cooperatives and where the contribution to the regional GDP by the economic activities of the primary sector exceed the national average (INE, 2022), there is a definite lack of information of a more quantitative and comprehensive nature regarding the level of digital transformation (Parra-López et al., 2021). Therefore, these circumstances are less conducive to improving the DT of these companies compared to cooperatives in more advanced European regions.

This research aims to contribute to filling these gaps in the literature with two objectives. On the one hand, it strives to build a theoretical framework and a methodology to assess the level of digital transformation of agri-food cooperatives and its different dimensions. On the other hand, it aims to explore which factors may influence this level of DT. Both objectives are approached herein by taking the Andalusian case as reference.

In this way, a survey on agri-food cooperatives in Andalusia has been carried out. The survey included questions regarding various dimensions of the digital transformation identified, mainly departing from the previous literature review on digital maturity models and the "Digital Maturity Matrix" established by the Andalusian government (Junta de Andalucía, 2023a). Furthermore, other survey information was related to factors that may influence the DT of agri-food cooperatives. From the data collected, the statistical method applied consisted of constructing a Global Index of Digital Transformation (GIDT), which subsequently became the dependent variable in a regression model where the independent variables were the factors that may influence digital transformation.

This research is one of the first studies that globally evaluate the implementation of digital technologies in agri-food cooperatives. Its main contribution to the literature involves proposing a methodology to assess the DT level of these companies by constructing the Global Index of Digital Transformation, with several sub-indices related to the digital transformation dimensions. Furthermore, the research also provides information on the explanatory role of different factors concerning digital transformation in agri-food cooperatives, particularly the characteristics of the cooperatives and economic barriers. The results of the study lead us to reveal several implications for practitioners and for policy planning in the Andalusian case.

2. Theoretical background and framework

2.1. Digital transformation (DT)

In general, digital technologies are widely diverse and complex. They can be classified into four groups: efficiency technologies (e.g., cloud computing), connectivity technologies (e.g., the Internet of Things), trust disintermediation technologies (e.g., blockchain), and automation technologies (e.g., Artificial Intelligence and Big Data) (Ancín et al., 2022). They also fit the acronym SMACIT, which stands for social, mobile, analytics, cloud, and Internet of Things (Vial 2019).

Furthermore, these technologies share the common characteristic that they can be used at all phases of any company's value chain (Bigliardi et al., 2022). The reason for this versatility is related, on the one hand, to their contribution to the agility of companies in their adaptation to the changing conditions of the environment and, on the other hand, to their ambidexterity, which means the bimodal ability to successfully combine digital innovations with the exploitation of existing resources (Vial 2019).

With the implementation of these technologies, DT is progressing worldwide due to the profound improvements it brings about for companies (Vial 2019) and territories (UNCTAD 2019) in terms of efficiency, productivity, and competitiveness. According to the literature, this process consists of three stages (Ancín et al., 2022; Verhoef et al., 2021). Firstly, the "digitisation" stage refers to converting analogue information into digital information, that is, information encoded in data. Information and Communications Technologies (ICTs) and the Internet, combined with new digital technologies, are accelerating such conversion, thereby enabling the storage and exchange of digital information. Secondly, the "digitalisation" stage involves incorporating certain digital technologies into organisations regarding specific business processes, such as production, distribution, and consumer experience. Finally, the third stage is the "digital transformation" (DT), where many organisations and economies are currently immersed. This stage goes beyond the previous "digitalisation" stage. This is the most pervasive since it involves the emergence of new business models based on the widespread use of digital technologies, thereby completely changing the company's logic and value-creation process (Ancín et al., 2022; Verhoef et al., 2021).

Digital transformation has advanced significantly largely due to restrictions on human movement during the COVID-19 pandemic (Reuschl et al., 2022; Rowan and Galanakis 2020), although it did not begin with the pandemic. The expression "digital economy" was coined in the 1990s to refer to an economy that creates digital goods and services using digital technologies (UNCTAD 2019). Moreover, the level of DT that organisations achieve differs depending on a variety of factors. Regarding size, large companies have more resources to implement digital technologies, although it is true that these technologies are also being implemented in SMEs (Müller et al., 2018). Regarding the economic sector, DT has advanced faster in the manufacturing industry than in other activities with low technological content, such as agri-food (Klerkx and Rose, 2020).

2.2. DT in the agri-food sector

The agri-food sector is undergoing significant changes resulting from the rapid increase in the world's population, climate change, and economic globalisation (Arora 2019; Blanc and Reilly, 2017). Several of these changes specifically affect agri-food markets. For example, new purchasing patterns are emerging, an industry concentration is happening at the retailer level, and food delivery patterns have been transformed (Fritz and Matopoulos, 2008). Other changes exert their impact at the aggregate level, such as those related to the sustainability of rural development, especially in less developed regions (Marsden et al., 1999). In this respect, it is necessary for agri-food businesses and local communities that farmers innovate, and, in this context, DT offers

new opportunities. Nowadays, Agriculture 4.0, Precision Agriculture, and Smart farming all refer to different forms of DT (Klerkx et al., 2019; Giua et al., 2022).

Hence, to boost DT in this sector, it is necessary to be aware of the complexity of the "agri-food supply chain" (AFSC), which is primarily derived from the perishable nature and customer orientation of most of its products (Routroy and Behera, 2017). The AFSC also comprises diverse processes involving multiple actors: providers, producers, processors, distributors, retailers, and consumers (Caro et al., 2018). In this regard, the AFSC faces significant challenges that affect the whole chain, such as sustainability issues (high energy and water consumption, land use and soil erosion, poor waste disposal, GHG emissions, etc.), food waste (transportation, inadequate storage facilities, strict export standards, etc.), food safety and security (food fraud, lack of traceability, poor implementation of food security programs, etc.), and other challenges (uncertainty, poor irrigation and drought management, legal and political issues, etc.) (Yadav et al., 2022).

In this context, certain digital technologies have been incorporated into particular business processes, for instance, monitoring machinery operated by smartphone applications, and equipment-monitoring solutions with GNSS (Global Navigation Satellite System) to automate irrigation pumps. These technologies are also utilised to monitor, predict, and make decisions concerning the care of crops and livestock through the Internet of Things (sensors and drones). Furthermore, they can perform basic agricultural tasks, such as planting, harvesting, weed control, and spraying, and even transform, pack, and store processed products through the application of robots.

Blockchain technology also deserves special attention since it helps to solve problems of traceability, food safety, and quality, thereby benefitting the “Farm to Fork” strategy in the context of globalisation and multiple intermediaries (Caro et al., 2018; Kamilaris et al., 2019). Furthermore, the use of social networks and digital platforms to share information expediates contact between actors in the supply chain. In this regard, e-commerce constitutes an important digital service that contributes to cost reduction, market access, and demand stimulation, principally for small farmers (Zeng et al., 2017).

Although these digital technologies positively impact efficiency, productivity, and competitiveness, they can also cause undesirable effects. Among such secondary effects, an increasing digital divide highlights the difference between the most powerful and the weakest players in the development of new digital business models (Klerkx and Rose 2020).

2.3. DT in agri-food cooperatives

Since DT is necessary for the agri-food sector, it is also essential to evaluate how this process is evolving in one of the most important types of companies in this sector: agri-food cooperatives. These companies have a long-standing tradition in Europe. The largest European countries, such as Italy, Spain, Germany, France, and Poland, have thousands of agri-food cooperatives with thousands of members. Still, other smaller countries in terms of population, such as Ireland, Denmark, Hungary, and Bulgaria, also have thousands of members (Monzón and Chaves 2017). According to the European Agri-Food Cooperatives Monitor, the market share held by agri-food cooperatives in last decade regarding the main products stood at 40% (COGECA, 2014, 2020). However, this share can vary depending on the type of agri-food sector and the specific country (Bijman et al., 2012a).

The type of organisational structure of these enterprises is determined by the cooperative principles of voluntary and open membership, democratic control by members, economic participation of members, autonomy and independence, of education, training, and information, of cooperation among cooperatives, and of concern for the community (ICA 1995), thereby providing specific advantages not only to their members but also to rural areas. On the one hand, farmer cooperatives act as market coordinating institutions, in that they maximise the members’ interests instead of seeking profit maximisation by taking advantage of the cost reduction derived from internalising transactions thereby creating a countervailing power (Staatz 1987). Indeed, collective decision-making incurs inherent costs related to greater time needs and information flow that are typical in democratic processes. Nevertheless, farmers face significant disadvantages derived from high uncertainty, high asset specificities, and a disadvantageous position regarding their trading partners, which create powerful incentives to belong to a farmer cooperative (Hansmann 1996; Staatz 1987). Among specific benefits, cooperative farmers usually receive higher prices and higher incomes for their production, and they also increase their productivity due to easier access to crucial production factors, such as seeds, pesticides, knowledge, and machinery (Grashuis and Su 2019).

On the other hand, due to the specific concern of farmer cooperatives for the local community, rural areas benefit from the cooperative’s policy of not maximising profits since they defend members’ interests as well as those of other local stakeholders, thereby contributing to rural development (Candemir et al., 2021). Other advantages for rural areas include an increase in the security of food supply for local communities, good value for money for this supply, and increased environmental protection due to lower greenhouse gas emissions from this local model of production (Candemir et al., 2021; Grashuis and Su 2019).

However, despite this positive role of agri-food cooperatives, certain studies emphasise different institutional disadvantages (Bijman et al., 2012b). Related to incentive problems, neo-institutional economic theories point out the problem of parasitism, the horizon problem, and the monitoring problem (Valentinov 2007). Furthermore, related to competitive pressure and market globalisation, some studies reveal higher levels of corporatisation and professionalisation of farmer cooperatives as a self-defence mechanism against large agri-food companies (Szabó, 2006). This factor strongly influences farmers’ primary motivation to belong to cooperatives and participate in their operations. However, individualism and the need to survive often dominate members’ behaviour (Ajates, 2020). Therefore, the dilution of the cooperative spirit often leads cooperatives to fail to adhere to cooperative values, consequently failing to defend local communities’ interests and sustainability (Ben-Ner, 1984).

Another critical issue for farmer cooperative behaviour is the growing heterogeneity of members related to farm size, product type, and members’ personal characteristics, such as age, risk aversion, and preferences (Cook 1995). This heterogeneity conditions their commitment and participation and, therefore, the adoption of certain strategic decisions, such as implementing new technologies and innovations (Grashuis and Su, 2019; Candemir et al., 2021). It also exerts an impact on the ability of the cooperative to place constraints on the quantity of production supplied by members, which often leads to an oversupply and an increase in low-quality producers benefitting from high-quality producers (Candemir et al., 2021).

In this context, DT provides agri-food cooperatives with solutions similar to those mentioned above for any agri-food company and new ways to solve the institutional disadvantages identified (Ciruela-Lorenzo et al., 2020). Nevertheless, the two issues more habitually analysed in DT are those involving organisation and relations with clients through the implementation of websites, social media content, and cloud computing.

According to the literature, using websites strengthens the links between members and other stakeholders, thereby reinforcing the social capital of these enterprises (Warburton et al., 2013). Moreover, since horizontal and vertical coordination is necessary for agri-food cooperatives (Rolfe et al., 2022), these websites and social media content contribute towards improving communication channels between far-flung members (Ratten 2018), thus facilitating members’ participation in the decision-making process (Meroño and Arcas 2006). Furthermore, if these new technologies can improve trust between members in cooperatives and other stakeholders despite the heterogeneity of said members (Bareille et al., 2017; Rolfe et al., 2022), then they

can also facilitate the adoption of other innovations (Candemir et al., 2021) while preventing the dilution of the cooperative spirit.

In addition, websites and social networks are also necessary to contribute towards being in direct contact with clients and end consumers, especially in the case of smaller cooperatives. Using websites and social content implies a disintermediation process that reduces retailers' bargaining power (Sen and King, 2003). In this respect, e-commerce is crucial for cooperatives to maintain a higher share of added value, since it reduces transaction costs and accesses the market (Bernal-Jurado et al., 2017; Zeng et al., 2017). The literature has shown that websites are used by agri-food cooperatives not only for promotional purposes but also for distribution and sales (Cristóbal-Fransi et al., 2020). E-commerce is also necessary for agri-food cooperatives, especially in less developed regions and developing countries (Jabbouri et al., 2022). However, agri-food cooperatives show low levels of e-commerce implementation on their websites, although this does depend on the characteristics of the cooperative's product, whereby e-commerce is less implemented in those cooperatives that sell seasonal and perishable products, such as fruit and vegetables (Cristóbal-Fransi et al., 2020).

Nevertheless, the literature regarding DT of agri-food cooperatives also focuses on business processes, such as food traceability in the agri-food value chain, and blockchain technology. As suggested in the previous section, blockchain technology can benefit agri-food companies by improving the credibility of agri-food safety information and by combatting counterfeit products (Caro et al., 2018; Kamilaris et al., 2019). In this regard, several studies have analysed how blockchain technology is implemented in cooperatives of fresh fruit and vegetables (Borrero 2019; Giagnocavo et al., 2017). The exchange of these fresh products in markets involves numerous intermediaries, making them suitable for the application of this technology. These studies show that blockchain adds value to the production of the members of agri-food cooperatives, generally regarding small farms (Giagnocavo et al., 2017). However, the small size of most of these cooperatives and the high investment costs constitute major barriers to the application of blockchain in business processes (Borrero 2019).

2.4. Assessing the global level of DT: theoretical framework and hypotheses

The literature review shows a delay in agri-food cooperatives in their adoption of specific digital technologies compared to other agri-food companies (Ciruela-Lorenzo et al., 2020; Jorge- Vázquez et al., 2019; 2021). However, only a few studies have analysed the overall level of DT of the agri-food sector in general and of the agri-food cooperatives in particular (Mendes et al., 2022). Since has been carried out for the manufacturing sector, this scientific task is necessary for the agri-food sector since collecting this information facilitates the adoption of strategies for the implementation of digital technologies and policy planning (Parra-López et al., 2021; Mendes et al., 2022). Furthermore, all the reviewed literature indicates that agri-food cooperatives need to increase their DT not only by improving the deficient digital infrastructures in rural areas, but also by improving the level of training of members in digital technologies, and by overcoming several barriers, such as their small size and the high economic costs involved in implementing these technologies (Ciruela-Lorenzo et al., 2020; Bernal-Jurado et al., 2017).

An essential task in the assessment of the level of DT in agri-food cooperatives entails establishing a specific methodological tool (Mendes et al., 2022). In this regard, one of the few studies carried out is based on only two aspects of the DT: the use of the most important digital technologies and employee training (Ciruela-Lorenzo et al., 2020).

According to the literature on DT in the manufacturing sector, one way to study DT in the agri-food sector in greater depth is to design a Digital Maturity Model (DMM) (Bumann and Peter 2019). This tool offers a model path to reach a higher level of DT (Ifenthaler and Egloffstein 2020; Lorenzo, 2016). In these models, maturity involves an evolutionary progress to an ideal situation, and the objectives of maturity assessment usually involve processes/structures, objects/technology, and people/culture (Mettler 2011). In this respect, DMMs measure the level of DT by defining several dimensions deemed relevant to implementing digital technologies (Ifenthaler and Egloffstein 2020; Valdez-de-Leon 2016). In this way, following the previous literature on DMM, there are five principal dimensions proposed in this research to assess the digital maturity of agri-food cooperatives:

1. Infrastructure: technologies used, such as computers, mobiles, and the Internet.
2. Processes: information traceability, Big Data, and stock management.
3. Products and services: online sales (e-commerce) and digitised catalogues.
4. Organisational culture and employees: innovativeness, training policy, and employee training in new technologies.
5. Clients: use of websites, social networks, and marketing online.

In order to attain a better diagnosis, it is also necessary to study which factors may affect the global level of DT (Bernal-Jurado et al., 2017). Regarding these factors, the literature related to characteristics of conventional companies in general (Ancín et al., 2022; Klerkx and Rose, 2020; Müller et al., 2018) and to specific characteristics of agri-food cooperatives in particular (Bernal-Jurado et al., 2017; Ciruela-Lorenzo et al., 2020; Cristóbal-Fransi et al., 2020; Jabbouri et al., 2022; Jorge-Vázquez et al., 2019, 2021) include the age of the cooperative, size in terms of the number of members, size in terms of the number of employees, the position in the value chain (production, processing, or distribution), and the destination market of products and services (local, regional, national, and international). Age is usually positively related to any business innovation since it implies long-term adaptation to change. Size is also positively associated with any innovation since it indicates more tangible and intangible resources. Finally, the position in the value chain and the market destination of products are characteristics also associated with innovations, and hence more complexity in the market orientation implies more innovation. Therefore, in accordance with the literature, we can establish the following hypotheses regarding these characteristics of cooperatives:

H1. The higher the cooperative age, the higher the level of DT.

H2. The larger the cooperative in terms of the number of members, the higher the level of DT.

H3. The larger the size of the cooperative in terms of the number of employees, the higher the level of DT.

H4. The closer the cooperative is to clients in the value chain, the higher the level of DT.

H5. The further the destination market of the cooperative's production, the higher the level of DT.

Additionally, the impact of the environment must be considered in explaining any company's overall level of DT. Farmers need to overcome various difficulties related to marketing and transportation, their weak bargaining power, severe weather conditions, and the role of numerous intermediaries along the chain (Yadav et al., 2022). However, the literature regarding general barriers to business innovation (Madrid-Guijarro et al., 2009) and digital transformation (Ali, 2012) and barriers specific to DT in agri-food cooperatives (Bernal-Jurado et al., 2017; Ciruela-Lorenzo et al., 2020; Cristóbal-Fransi et al., 2020; Jabbouri et al., 2022) point in particular to economic barriers to investing in DT. These barriers are usually related to the high costs of investing in digital technologies for many cooperatives. However, they are also associated with difficulties in obtaining financial resources to cover these

technological investments, mainly when cooperatives are located in low-income regions (Khanna 2021; Fao 2022). In this respect, economic barriers directly influence the DT of agri-food cooperatives, especially considering that their size is usually minor compared to conventional agri-food companies. Therefore, the last hypothesis can be established:

H6. The greater the economic barriers in implementing digital technologies, the lower the level of DT.

3. Empirical analysis

This section presents an empirical study that explores the global level of DT of agri-food cooperatives, their dimensions, and the various determinants included in the theoretical framework as shown in Fig. 1. The data used for the study comes from a survey developed for agri-food cooperatives from the southern Spanish region of Andalusia.

3.1. Contextualisation of the region of Andalusia

Andalusia is the country's largest and most populated region, with more than 8.5 million inhabitants (18% of the national population) (INE 2022). Nevertheless, this region is one of the most economically underdeveloped in the national panorama, since it has the lowest GDP per capita (18,906 € vs. 25,498€ national average) and the highest unemployment rate (19% vs. 12.87% national average) (INE 2022). Furthermore, rural areas, defined as those with fewer than 5000 inhabitants (Eurostat, 2022), account for 72% of the Andalusian population (Instituto de Estadística y Cartografía de Andalucía, 2022).

Given the importance of the rural sector in this territory, it is not surprising that the primary activity sector has historically played a vital role in the region. Although the tertiary sector is the leading sector of activity in the Andalusian economy at present (tourism deserves special attention), the contribution of the primary sector to the regional GDP remains higher than that of the national average (6% vs 2.6%) (INE, 2022). However, these economic characteristics are usually associated with specific issues, such as the ageing of the population, the lower level of education and training (in this regard, Andalusia has the lowest national score in the PISA reports), the isolation of the population, and the remoteness of the centres of innovation and knowledge development (Barroso and Morente 2011; Caravaca et al., 2007).

With the globalisation process and the technological changes of recent decades, these primary activities have been forced to introduce technological changes and also to evolve towards a broader range of industries (Ciruela-Lorenzo, 2008; Rodriguez-Cohard et al., 2002), such as those related to the transformation of agricultural products and related services. Andalusia has hence become the most important region at the national level in this sector and represents 20% in terms of production and 22% in terms of employment in the national agri-food sector (Observatorio del sector agroalimentario de las regiones españolas, 2021).

This region has a long-standing tradition of cooperatives, particularly in the agri-food sector. The 1147 Andalusian agri-food cooperatives employ more than 20,000 workers along the agri-food supply chain (AFSC) and provide 44% of the total national turnover of the sector (Sistema de Análisis de Balances Ibéricos, 2019). Consequently, agri-food cooperatives represent a crucial economic pillar for Andalusia, and its modernisation through DT would provide a significant boost to the economic development of the region and its rural areas.

3.2. Data collection, methods, and variables

The empirical research is exploratory and focuses on analysing the DT of cooperatives in the agri-food sector in Andalusia and its determinants. To attain the research objectives, these Andalusian companies have been surveyed. As aforementioned, the population universe comprised 1147 Andalusian agri-food cooperatives (Sistema de Análisis de Balances Ibéricos 2019) and the contacts of these firms were provided by both the local Chambers of Commerce and the regional government (Junta de Andalucía). Contacts were established via email, and they were sent a questionnaire designed by the authors together with experts in digital technologies in the agri-food sector to measure their global level of DT. A convenience sampling of 75 cooperatives was obtained, which meant a response rate of 6.5% (Emerson 2015; Etikan et al., 2016).

The first step of the research involved building a "Global Index of

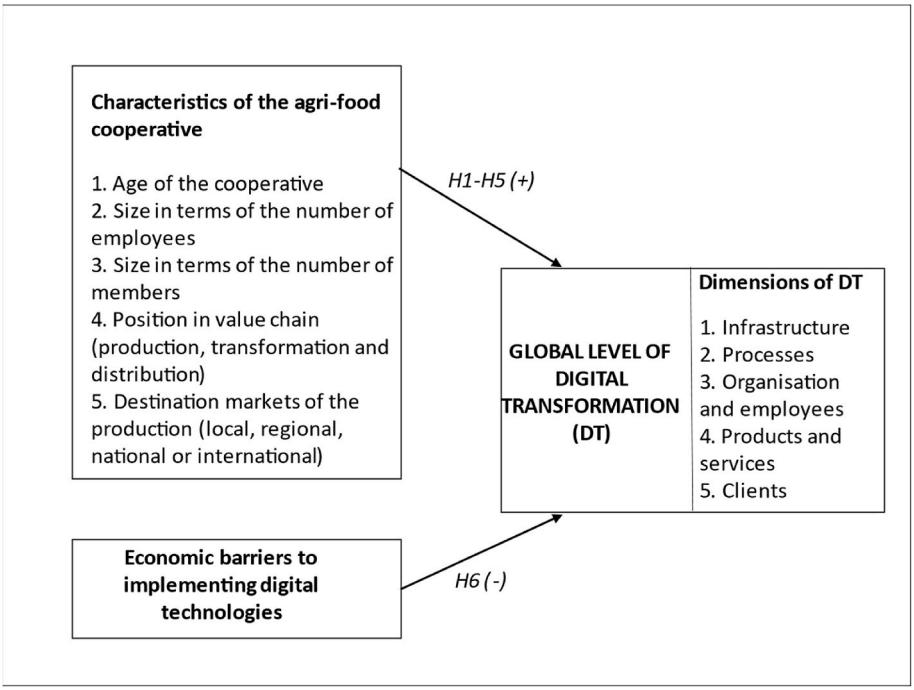

Fig. 1. Theoretical framework to assess DT in agri-food cooperatives and research hypotheses.
Source: Authors' own

Table 1
Weight utilised to construct partial index and Global Index of Digital Transformation.

Index1: Infrastructure (IND1)		Index 2: Processes (IND2)		Index 3: Organisational culture and employees (IND3)		Index 4: Products/services (IND4)		Index 5: Clients (IND5)		GIDT	
Items	Weights	Items	Weights	Items	Weights	Items	Weights	Items	Weights	Items	Weights
TECH	0.28	INF_TRAC	0.36	ICT_EMP	0.42	ONL_SAL	0.41	WEB_SSNN	0.23	IND1	0.20
TECH_INF	0.27	BIG_DATA	0.35	TRAIN_DTC	0.40	CAT	0.32	ADV	0.21	IND2	0.19
APP_COM	0.21	STOCK_WAR	0.29	ORG_INN	0.18	DEL_PRD	0.27	PRS_ONL_ENV	0.28	IND3	0.20
SEC_MEC	0.24							ANAL_EVOL	0.28	IND4	0.18
										IND5	0.23
CFI: 0.877		CFI: 0.999		CFI: 0.999		CFI: 0.999		CFI: 0.983		CFI: 0.904	
GFI: 0.901		GFI: 0.999		GFI: 0.999		GFI: 0.999		GFI:0.975		GFI: 0.900	
RMR: 0.005		RMR: 0.001		RMR: 0.001		RMR: 0.001		RMR: 0.003		RMR: 0.004	

Digital Transformation". To this end, based on previous work on digital maturity models (Bumann and Peter 2019; Ifenthaler and Egloffstein 2020; Lorenzo, 2016; Valdez-de-Leon 2016) and on the Digital Maturity Matrix designed by the Spanish government (Gobierno de España, 2021), the following dimensions of this DMM have been included: Infrastructure, Processes, Organisational culture and employees, Products and services, and Clients. To confirm that the items included in each dimension by the authors and experts were correct, a confirmatory analysis was developed for every dimension. All the variables or items included in every dimension of the DMM are available in APPENDIX A. Furthermore, different indices have been constructed for each of these dimensions (partial indicator or first-level indicator), which have been employed to create the "Global Index of Digital Transformation" as a multidimensional second-level indicator. All the statistical processes are explained in greater detail below.

Having obtained all the data from the questionnaire, we first have to recode all the values from 0 to 1 to create the indicators, which designate the least and the most favourable situations, respectively, regarding DT. In this way, the indicators also take the values from 0 to 1, whereby the highest (lowest) values signify a higher (lower) digital transformation. This standardisation of the items or variables involved the following equation:

$y_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}}$, where x_{ij} is the item i utilised to compose the partial indicator of every dimension or factor j. Assuming that every dimension or factor j is represented by Z_j, and that this factor is composed of c_j items, we define:

$Z_j = \sum_{i=1}^{c_j} w_i \cdot y_{ij}$, where $w_i = \frac{|\beta_{ij}|}{\sum_{j=1}^{c_j} |\beta_{ij}|}$, and where β_{ij} is the slope of the item y_{ij} in its confirmatory analysis over Z_j. Therefore, Z_j is a weighted average indicator of scaled initial elements, or first-level indicator, where $j = 1, \ldots, k$. To carry out the confirmatory analysis and obtain the weights of each item for every factor, the AMOS program version 26 is used, through which the confirmatory analysis is developed for each factor Z_j.

Once the partial indicators are obtained, the global index can be calculated by following the same procedure. If k first-level indicators are considered, then a global index Z or a second-level index is constructed with them, as follows:

$Z = \sum_{j=1}^{k} \omega_j \cdot Z_j$, where $\omega_j = \frac{|\gamma_j|}{\sum_{j=1}^{k} |\gamma_j|}$, and where γ_j is the weight of the index j of the first level in the confirmatory analysis of the second level.

The second step of the research involves assessing certain determining factors of the global level of DT detected by focusing on specific characteristics of the agri-food cooperative (age of the firm, size, its position in the value chain, and the main market in which it operates) and the existence of economic barriers. To this end, a linear regression (Least Squares means) is carried out using SPSS program version 26, where the dependent variable is the global index of digital transformation (GIDT) and the independent variables are the following.

1) Age of the firm (Age): This variable takes the number of years of the cooperative.
2) Members of the Cooperative (Coop): This variable takes the value "1" if the cooperative has fewer than 50 members, "2" if the number of members ranges from 50 to 99 members, "3" from 100 to 199, "4" from 200 to 299, and takes the value "5" if the cooperative has 300 or more members.
3) Position in the value chain (Pos): This variable takes the value "1" if the cooperative only produces, "2" if the cooperative transforms and/or processes, and "3" if the cooperative distributes and/or commercialises.
4) Size (Size): This variable takes the value "1" if the cooperative has fewer than 10 employees, "2" from 10 to 49, and "3" if it has 50 employees or over.
5) Market size (Mark): This variable takes values from "1" to "4", depending on whether the cooperative operates in the local, regional, national, or international market.
6) Economic Barriers (Eco_Bar): This variable takes the value "1" if the cooperative finds economic barriers to implementing a DT and "0" otherwise.

The equation of the econometric model is therefore:

$$GIDT = q_1 Age + q_2 Coop_2 + q_3 Pos_3 + q_4 Size + qMark + q_6 Eco\_Bar$$

3.3. Results

The results of the confirmatory analysis for the weighting of the slopes of every dimension of the GIDT are shown in Table 1. Regarding the goodness of fit of the models, also shown in Table 1, the results obtained confirm the validity of the models; that is, all the items included in the dimensions are valid as is the composition of a global index with the partial indices (dimensions). The goodness-of-fit index (GFI) and comparative fit index (CFI) are, therefore, both over 0.9 for all partial indices and the global index (Joreskog and Sorbom 1981; Bentler 1990). Furthermore, the Root Mean Square Residual (RMSR) is less than 0.05 for all the models, which indicates a good model fit (Joreskog and Sorbom 1981; Brown 2006).

Descriptive statistics of the various indicators (partial and global) are shown in Table 2. As can be observed, except for Index 2 (Processes), all the partial indicators are, on average, under 0.5, which indicates that the situation of digital transformation remains low, especially in the case of the product/service dimension (Index 4: 0.30) and client dimension (Index 5: 0.33). In turn, the processes dimension (Index 2) is the best regarding DT since it presents the highest score despite not being high (0.53), followed by infrastructure (Index 1) (0.42). Globally, it can be observed that the situation is not favourable, since the Global Index mean is 0.38, which leaves significant room for improvement.

With the focus now shifted to the Global Index of Digital Transformation and the explanatory variables, Table 3 shows the descriptive statistics of the variables included in the linear regression. The correlation matrix is also available in APPENDIX B. It should be borne in mind

Table 2
Descriptive statistics of partial indicators and global index of digital transformation.

	Min.	Max.	Mean	SD
IND1	0.05	0.97	0.42	0.22
IND2	0.00	1.00	0.53	0.22
IND3	0.00	1.00	0.36	0.29
IND4	0.00	0.95	0.30	0.27
IND5	0.00	1.00	0.33	0.27
GIDT	0.02	0.93	0.38	0.20

Table 3
Descriptive Statistics of variables in the regression.

	Min.	Max.	Mean	SD
Age	0	74	26.77	21.97
Coop	1	5	2.68	1.79
Pos	1	3	2.40	0.85
Size	1	3	1.57	0.76
Mark	1	4	2.89	1.05
Eco_Bar	0	1	0.60	0.62

Table 4
Linear regression results.

	SD	Standardised Coefficients	t	Sig.
		Beta		
Constant	0.077		0.150	0.882
Age	**0.001**	**−0.201**	**−1.971**	[a]
Coop	0.012	0.122	1.138	0.259
Size	**0.028**	**0.254**	**2.447**	[a]
Pos	**0.022**	**0.282**	**3.023**	[b]
Mark	**0.019**	**0.261**	**2.609**	[a]
Eco_Bar	**0.038**	**−0.201**	**−2.231**	[a]
Goodness of Fit				
Adjusted R squared	0.434			
F statistic	10,459[b]			

[a] Significant at the 95% confidence level.
[b] Significant at the 99% confidence level.

that no problem of multicollinearity exists since the variance inflation factor (VIF) statistics in our variables remain below 10 (Vittinghoff et al., 2012) and the Condition Index is under 30 (Kennedy 2003). Specifically, the highest VIF is 1.505 for the variable "*Coop*" and the highest Condition Index is 12.175 for the variable "*Eco_Bar*".

Table 4 shows the results of the linear regression and the model's goodness of fit, which indicate that the model is statistically significant at the 99% confidence level. As can be observed, all the variables are significant except for the variable "Coop", whereby the number of members of the cooperatives appear to exert no impact on the level of DT. Consequently, H2 is not supported. As for the variable "Age", a negative influence on GIDT is obtained at the 95% confidence level. In this respect, new cooperatives seem to be more aware of the importance of implementing a DT, and hence H1 is rejected. On the other hand, the variables "Size", "Pos", and "Mark" are positive and significant at 95%, 99%, and 95% confidence levels, respectively, which means that the number of employees, the position of the company in the value chain, and the geographical area of activity, positively affect the level of DT of the Andalusian agri-food cooperative sector. Therefore, H3, H4, and H5 are all supported. Lastly, a negative influence of the variable "Eco_Bar" on GIDT is obtained at the 95% confidence level. In this way, economic barriers are confirmed as an unfavourable variable for implementing DT, thereby supporting H6.

Table 5 summarises the main results regarding the GIDT, its dimensions, and the influencing factors through the hypothesis.

Table 5
Main results.

DIGITAL TRANSFORMATION RESULTS (0–1) (AVERAGE VALUES)		
Dimensions	Index1: Infrastructure (IND1)	0.42
	Index 2: Processes (IND2)	0.53
	Index 3: Organisational culture and employees (IND3)	0.36
	Index 4: Products/services (IND4)	0.30
	Index 5: Clients (IND5)	0.33
Global Index of Digital Transformation (GIDT)		0.38
FACTORS INFLUENCING DT		
Age	*H1: The higher the cooperative age, the higher the level of DT.*	Refused
Number of cooperative members (Coop)	*H2: The larger the cooperative in terms of the number of members, the higher the level of DT.*	Not supported
Position in the value chain (Pos)	*H3: The larger the size of the cooperative in terms of the number of employees, the higher the level of DT*	Supported
Size	*H4: The closer the cooperative is to clients in the value chain, the higher the level of DT.*	Supported
Destination of products (Mark)	*H5: The further the destination market of the cooperative's production, the higher the level of DT.*	Supported
Economic Barriers (Eco_Bar)	*H6: The greater the economic barriers in implementing digital technologies, the lower the level of DT.*	Supported

4. Discussion

The results obtained in this research coincide with those of previous research in certain aspects and differ in others. The low level of DT in agri-food cooperatives has also been found in other studies. However, those studies tended to focus on specific variables to measure DT, whereas our study approaches the reality of DT of agri-coop cooperatives from a general perspective, by considering all the areas or dimensions related to this process. Previous studies aimed at examining the DT of agri-food cooperatives therefore mostly referred to the use of e-commerce and websites, which, in our analysis, belong to dimensions 4 and 5, labelled "Product and services" and "Clients". In the present research, these two dimensions present the lowest values, thereby reinforcing the results of the previous literature regarding DT in agrifood cooperatives (Jorge-Vázquez et al., 2019, 2021; Cristóbal-Fransi et al., 2020).

This unfavourable result contrasts with that of dimensions 2 and 1, "Processes" and "Infrastructure", since they present the highest and second highest values of all the dimensions (although still remaining at a medium level). Dimension 2 includes data regarding information traceability, Big Data, and stock management, while dimension 1 refers to the incorporation of technologies, such as computers, mobiles, and the Internet. The results in these two dimensions therefore show how Andalusian agri-food cooperatives face the challenges related to food safety in the agri-food sector, which has also been recognised in the previous literature (Borrero 2019; Giagnocavo et al., 2017). Furthermore, although the margin for improvement remains very high in both dimensions, it is surprising that compared with the aforementioned dimensions (4 and 5, "Processes" and "Infrastructure"), the dimensions related to a more internal aspect of the cooperative ("Processes" and "Infrastructure") are in a better situation than those referring to the external perspective for the Andalusian case ("Clients" and "Products and Services"). This could be related to the fact that these cooperatives often present weak bargaining power and compete with major intermediaries along the value chain (Yadav et al., 2022), and hence they are seldom interested in commercialisation activities. This attitude is also related to the lower entrepreneurial propensity in many rural areas with respect to urban areas (Del Olmo-García et al., 2023).

Lastly, the final dimension, "Organisational culture and employees" (dimension 3), which includes aspects referring to innovativeness and

the training and promotion of the specialisation of employees in DT, also presents a deficient level of DT. In this respect, these results for Andalusian agri-food cooperatives also coincide with those of previous research, in that the lack of digital skills constitutes one of the most critical barriers recognised in the literature to advancing the implementation of DT in the agri-food sector in rural areas (Chaudhary and Suri, 2022; Dibirov and Dibirova 2022).

Regarding the factors determining the level of DT, the findings herein reinforce the literature on DT in the case of certain variables and contradict it concerning other variables. Our result involving the "age" variable is in contrast to that in the previous literature. In general, the literature on DT shows a positive association between this aspect and DT (Isgin et al., 2008; Adamczak et al., 2023), whereas our study suggests a negative relationship may exist for this kind of company in the agri-food sector. A possible explanation for this result in Andalusia, a region with a long-standing tradition in agricultural cooperatives, could be that new agri-food cooperatives entering the market arose in a context of globalisation and are more aware of the need to incorporate new technologies in their business models in order to be competitive. However, older companies, as a consequence of having been set up in a less advanced phase of the globalisation phenomenon and the ICT revolution, together with the fact of being located in rural areas with less well-developed digital and communication infrastructures and suffering from depopulation processes, are often become very isolated and tend to adopt a more passive attitude and carry out their activity on the margins of technological advances, like they did in the past (Zurdo and Dopacio, 2022).

Moreover, our findings on Andalusian cooperatives also reinforce previous research referring to the positive affection on the DT: of the size (measured in terms of the number of employees, not through members) (Jorge-Vázquez et al., 2021; Isgin et al., 2008); of the position in the value chain ("Pos") (Adamczak et al., 2023); and of the destination of the sales ("Mark") (Du et al. (2022). It should be borne in mind that the non-significance of the variable referring to the number of cooperative members ("Coop") suggests that the DT is not related to governance issues, since decision-making depends on the democratic votes of the members. Consequently, this aspect, which has usually been considered a curb for cooperative advances (Hansmann, 1996) such as DT implementation, seems to have been discarded. Lastly, our results on economic barriers also coincide with the previous literature, which concluded that these barriers negatively influence DT (Cichosz et al., 2020; Ali, 2012).

Regarding practical implications related to these results, it is necessary to differentiate between those related to agri-food cooperatives from those related to policy-making. On the one hand, agri-food cooperatives need to be aware of the importance of their size, of their position in the value chain, and of the geographic area of their activity. Therefore, if Andalusian cooperatives want to be more competitive in the global market, they need to create a new business model that focuses on increasing their activity beyond local markets and on approaching final consumers. This new perspective would push cooperatives towards DT since by going ahead in this new competitive model, DT would serve to overcome obstacles of a different nature. Nevertheless, at the same time, we must be aware that this process would imply deepening the professionalisation of cooperatives, losing some of their roots in their rural areas and, consequently, also losing some of their cooperative spirit (Ajates 2020). In this context, Andalusian cooperatives should manage to combine DT while maintaining their values and commitment to rural areas and avoiding the onset of a "degeneration" process (Ben-Ner 1984).

On the other hand, local and regional authorities and other private institutions need to support this process with various programs by giving financial support through investing in digital technologies (and overcoming economic barriers) and promoting collaboration on DT. This political support to agri-food cooperatives is justified since they play a significant role in rural development and, therefore, these policies could counterbalance the higher presence of large companies by reinforcing not only the autonomy of rural areas but also their sustainability (Zurdo and Dopacio 2022). Thus, in the context of Andalusia, for example, a number of these support programs can be found, such as the Agrotech Digital Innovation Hub, which provides the agri-food sector with an ecosystem to support digital transformation, thereby promoting collaboration between a range of agri-food companies and institutions (Junta de Andalucía, 2023b).

5. Conclusions

In this research, the objectives have involved, on the one hand, building a theoretical framework and a methodology to assess the level of digital transformation of agri-food cooperatives and its different dimensions and, on the other hand, identifying which factors may exert influence on this level of DT, specifically diverse characteristics of the agri-food cooperatives and economic barriers to DT. Specifically, a Global Index of Digital Transformation based on the literature on digital maturity models has been built to assess the overall level of DT.

Although the literature on agri-food cooperatives and DT recognises a low level of DT in these social economy entities, few studies have tried to carry out a global assessment of that level (Mendes et al., 2022). In this research, considering the results obtained, the theoretical framework and methodology proposed have proved helpful in the assessment of the DT in agri-food cooperatives.

In this regard, an important conclusion is that DT is a multifaceted phenomenon comprised of different dimensions. The analysis of the use of websites, e-commerce, and social media networks is insufficient to analyse the DT properly since it reflects only a partial view of this issue, in terms of the client and product dimensions. In the case of the fundamental role of agri-food cooperatives in rural development, circumscribing the assessment of their DT exclusively to these dimensions also involves dismissing essential information. The same can be stated regarding the need for information on specific characteristics of the cooperatives and the role of economic barriers they face since they play a fundamental role in explaining the global level of DT. Specifically, it is concluded that agrifood cooperatives present a low level of DT from a general perspective and that the size, position in the supply chain, and destinations of sales positively affect this level, whereas the age of the firm affects it negatively.

In summary, the theoretical framework and the specific methodology of this research make a relevant contribution to the literature on DT and agri-food cooperatives and help not only cooperatives to boost the DT but also policy-makers in planning specific measures which lead cooperatives on their path towards DT (Parra-López et al., 2021). Given that agri-food cooperatives play an essential role in the rural context, the reinforcement of DT will also contribute to rural development in the face of increasing competition from major retailers (Zurdo and Dopacio, 2022).

Finally, this research is not exempt from limitations, and these are mostly linked to the methodology used. First, regarding the indices created, although the confirmatory analysis demonstrates that the items selected are valid, other items could be considered for the construction of the partial and global indices of DT. Second, regarding the regression, a linear regression model does not ensure the causality of the significant relationships detected. In order to verify the causality, it would be necessary to develop a longitudinal study to analyse whether the results obtained are maintained (Scheneider et al., 2010). And third, regarding the data, it comes from agri-food cooperatives in Andalusia, a region whose particularities and culture influence the findings. For this reason, the results obtained should be treated with caution when generalising to other territories, since each region may present its own specific traits that can influence the digital transformation of its cooperatives. Future research can address all these limitations with a replication of the study in Andalusia and other territories, while also taking the cultural values of each region into consideration.

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Declaration of interest

None.

Authors statement

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Data availability

The data that has been used is confidential.

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