Digital transformation of the agrifood system: Quantifying the conditioning factors to inform policy planning in the olive sector

1 Introduction

Digital transformation (DT) can be defined as the use of new digital technologies that enables major business improvements and influences all aspects of customers' life (Reis et al., 2018). The ability of firms to join this so-called fourth industrial revolution, marked by the convergence of digital, physical and biological technologies, may determine their chances of competing and surviving in the global market in the medium term. At the organisational level, the concept of DT focuses on innovation strategies that implement digital technologies and thus improve and boost the operation of the organisation (Vial, 2019). The key areas that the DT can cover are business models, operational processes and customer experience (Morakanyane et al., 2017).

Specifically, in the agricultural sector, DT is seen as a key transformative force, using concepts such as digital agriculture and Agriculture 4.0 (Fielke et al., 2020; Klerkx et al., 2019; Klerkx and Rose, 2020; Rose and Chilvers, 2018). It has been argued that digital technologies can help farmers provide safe, sustainable and quality food; not only do they help farmers 'produce more with less', but they can also help combat climate change (Krishnan et al., 2020; Makate et al., 2019; Shepherd et al., 2018). For example, it has been stated that DT can play a role in creating a better life in Europe's rural areas, as highlighted in the Cork Declaration 2.0. This document states that the use of digital technologies will increasingly be vital for farmers and other rural businesses to provide sustainable solutions to current and future challenges (EC, 2018). Digital technologies related to sensorization, remote sensing, GIS, drones, big data, artificial intelligence, machine learning, robotics, IoT, e-commerce, blockchain, etc., are radically changing the processes of production, marketing and consumption in the agrifood system (Busca and Bertrandias, 2020; Helo and Hao, 2019; Klerkx et al., 2019; Koch and Windsperger, 2017; Snow et al., 2017; Teece and Linden, 2017; Zhu et al., 2020). These technologies can lead to the creation of new products and services (EC, 2018). Smart farming technologies (SFT), i.e. digital technologies applied to the agrifood system, are multiple, including intelligent irrigation, prediction of crops and pests, treatment of pests with robots, intelligent harvesting according to maturity, traceability from field to table, logistics, and e-marketing, among many others (Bernhardt et al., 2018; El Bilali and

Allahyari, 2018; Fleming et al., 2018; Meier et al., 2020; Pappa et al., 2018; Shamshiri et al., 2018; Wolfert et al., 2017). Thus, the DT of the agrifood, forestry and rural sectors represents a new field of opportunities (Beltrán et al., 2017), but also engenders technological and institutional challenges and barriers that can limit their development (EC, 2018; Shepherd et al., 2018). DT can also have risks and disadvantages, which need to be analysed and taken into account, for example in relation to the ethical issues of data ownership rights and their impact on rural employment, and the equitable sharing of the benefits of digital agriculture, among other questions (Bronson, 2018; Bronson and Knezevic, 2016; Carolan, 2017; Eastwood et al., 2017; Lioutas and Charatsari, 2020; Loebbecke and Picot, 2015; Shepherd et al., 2018).

In this context, the role of science should be to evidence and support the design and use of digital technologies to achieve the desired beneficial outcomes and avoid unintended consequences (Shepherd et al., 2018). Comprehensive systematic analysis of DT processes in agriculture (Eastwood et al., 2019; Eastwood et al., 2017; Fielke et al., 2019) can feed into policy planning. Despite the vast literature on DT (Klerkx et al., 2019; Morakanyane et al., 2017; Reis et al., 2018; Vial, 2019), not much is known about regional digital strategies towards proactive responses to rapid technological changes (Alam et al., 2018). To inform policy planning, robust information is needed on what influences DT in agrifood.

In the specific case of Spain, some previous works analysed the barriers and give recommendations for the development of digitisation in the agrifood sector in the country, in general (MAPA, 2018a, b), and in the agrifood cooperative sector, in particular (Vázquez et al., 2019). More particularly, in Andalusia, some studies analysed the needs and barriers for the DT in the agrifood sector, in general (Junta_de_Andalucía, 2019) and agricultural cooperatives, in particular (Ciruela-Lorenzo et al., 2020). However, most of this work, both in Spain and elsewhere, are qualitative and focuses on the analysis of some specific (often negative) factors. There is therefore a lack of quantitative and more extensive information. Also, more consideration needs to be given to the views of different stakeholders. Additionally, there is no specific work for the case of the olive sector in Andalusia.

This manuscript intends to contribute to filling this scientific gap, both on a theoretical and practical level of policy planning. It therefore aims to propose and illustrate the implementation of a integrated quantitative methodological framework, which can be applied to different policy planning problems, with two objectives: 1) to identify, classify, structure, prioritise and compare the factors that are conditioning the DT of the olive sector (olive growing and industry) in the short and medium term in Andalusia; and 2) to design public policy strategies to strengthen the DT of the Andalusian olive sector, taking advantage of the potentialities (strengths and opportunities) and trying to alleviate the deficiencies (weaknesses and threats) found. For the first objective, a SWOT/PESTLE model, in combination with AHP, is developed. For the second objective, a quantitative TOWS analysis is proposed, taking advantage of the previous prioritisation of factors with AHP. AHP is used as a methodology to make SWOT/PESTLE and TOWS analyses quantitative and abandoning the conventional qualitative approach to them. In all the analyses the knowledge of diverse groups of experts, i.e. stakeholders of the sector, is essential, due to the lack of hard data and the complex nature of the issues analysed.

2 Study setting

2.1 The olive sector of Andalusia

Olive growing is an important economic activity in the countries of the Mediterranean Basin, especially in Spain, which represented 22.36% of the world's olive-growing area and 46.10% of world olive oil production in 2017 (FAO, 2017; MAPA, 2019). Spain is also the world's leading exporter of olive oil (IOC/COI, 2019). The Spanish olive sector is mainly made up of a large group of small/medium olive growers organised in cooperatives with an oil mill, representing more than 70% of the olive oil produced, plus a minority of private oil mills belonging to large farmers (Sanz-Cañada et al., 2014).

Andalusia, located in the south of Spain, is the most important olive-growing region in the world. It represented 62.50% of the olive-growing area and 76.83% of the olive production in Spain in 2017 (MAPA, 2019). The olive sector plays an important socio-economic role in the region, as olive oil and olives accounted for 18.1% of the total production of the Andalusian agricultural sector in 2020 (CAGPDS, 2020). Olive growing generates about a third of agricultural employment, half of which is family-based (CAP, 2009), and has a wide territorial presence, covering 28.77% of the Andalusian agricultural area (CAGPDS, 2018). Most of the olive grove is cultivated in a traditional extensive manner, although an increasing growing area, around 17%, is cultivated more intensively with a massive use of inputs (Hinojosa-Rodríguez et al., 2014b).

The Spanish olive sector, in general, and the Andalusian sector, in particular, are currently facing a critical situation, especially in the initial stages of the agrifood chain, due to 1) the atomisation of the sector; 2) the low productivity of a significant number of olive growers, as 32.7% of them (representing 26.8% of the surface) are above the 20% slope (CAPDR, 2015), limit above which an olive grove cannot be mechanised and is managed mainly in a traditional way; 3) the fall in olive oil prices from 2009 (CAP, 2011) and also in CAP subsidies; and 4) the tariffs of USA (currently on standby), one of the main destinations outside the EU for Spanish exports, on Spanish olives and olive oil, among other issues.

2.2 Innovation context in the olive sector

In the olive sector the available digital technologies are varied. Although there is a wide range of SFT as mentioned above, the literature has mainly studied some related to the use of remote images to predict the time of harvest, damage to it, irrigation needs, and disease monitoring (García Torres et al., 2008; Hornero et al., 2020; Jimenez-Jimenez et al., 2013a; Jimenez-Jimenez et al., 2013b; Kurucu et al., 2015; Noori and Panda, 2016; Omara et al., 2004; Ram et al., 2010; Torres-Sanchez et al., 2018), and the use of IoT for precision agriculture (Boursianis et al., 2020).

In the specific case of the olive sector in Andalusia, previous studies have analysed its capacity for innovation linked to the technological packages of organic farming (Parra-López and Calatrava-Requena, 2006; Parra-López et al., 2007), integrated production (Hinojosa-Rodríguez et al., 2014b) and different certified quality systems such as PDO (Hinojosa-Rodríguez et al., 2014a; Parra-López et al., 2015a) and ISO 9001 (Parra-López et al., 2016). Although there are several factors which make farmers hesitant to adopt new technologies and practices, these studies highlight the scarce innovative attitude, in general, of the olive growers in Andalusia, which behaves like a closed system with scarce permeability to external sources of information. This traditional lack of initiative in developing innovative business models may, in the case of DT, lead to the Andalusian olive sector lagging behind and losing competitiveness in a context of increasingly globalised and competitive markets. As a positive aspect, the DT has broad support at the administrative level, from the EU to the regional administration of Andalusia, and a number of policy initiatives are beginning to be implemented.

3 Material and methods

The proposed methodological framework consists of two phases, with different analyses and data sources (Figure 1), which is detailed in the following sections.

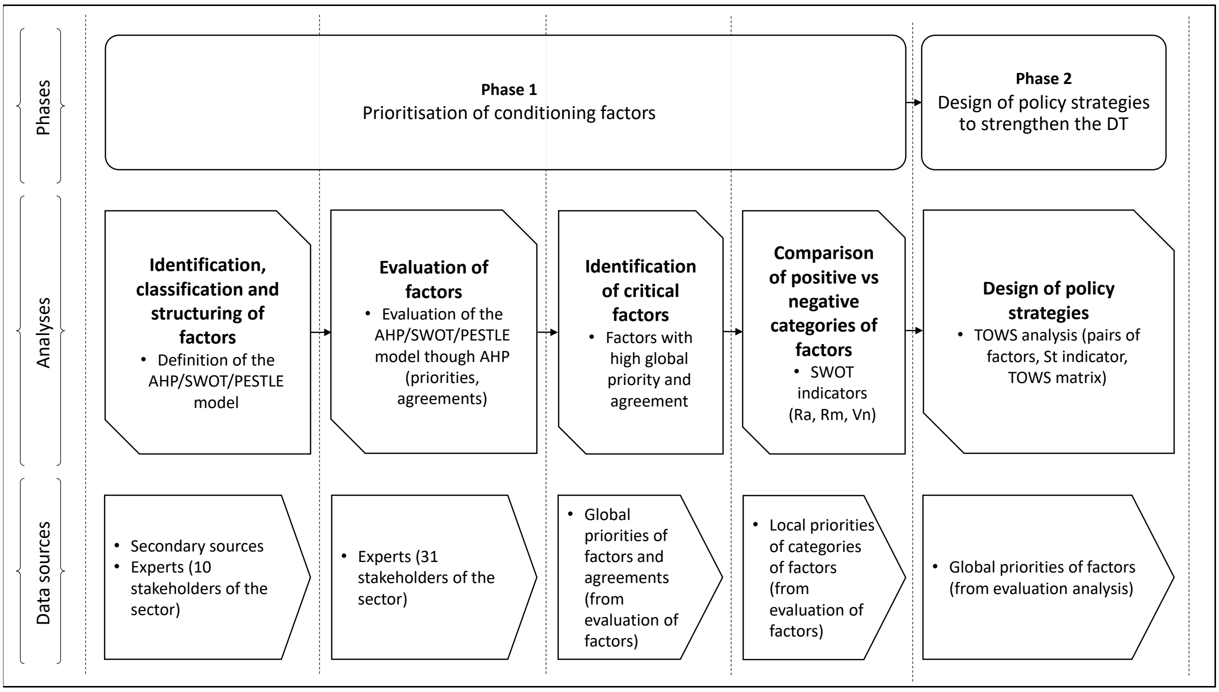


Figure 1. Methodological framework

3.1 Prioritisation of conditioning factors

3.1.1 Identification, classification and structuring of factors

In order to prioritise the importance of the conditioning factors of DT in the Andalusian olive sector, a structured model have been developed combining the AHP, PESTLE and SWOT methodologies. This represents a relatively new methodological approach with respect to traditional PESTLE and SWOT analyses, as AHP allowed these analyses to be more structured and quantitative.

AHP - Analytic Hierarchy Process (Saaty, 1980) is a multicriteria decision-making technique, which represents a decision problem as a hierarchy of components, where the elements of the lower levels of the hierarchy contribute to the elements of the upper level on which they depend. In our field of interest, AHP has been used to evaluate the underlying decision factors of cloud computing adoption, and to identify the factors influencing the adoption of big data among Korean firms (Park and Kim, 2019). The hierarchical decomposition of the factors in the developed AHP model followed the SWOT and PESTLE methodologies. Thus, the factors have been identified and classified theoretically into different categories according to the SWOT methodology. SWOT analysis is the process of exploring the internal and external environments of an organisation and extracting convenient strategies based on its Strengths, Weaknesses, Opportunities and Threats (Ghazinoory et al., 2011). Therefore, the conditioning factors in our case were classified into: Strengths (positive factors within the olive sector), Weaknesses (negative factors within the olive sector), Opportunities (positive factors outside the olive sector), and Threats (negative factors outside the olive sector). The SWOT analysis has been widely applied in diverse fields since the seminal work of Weihrich (1982), especially in the analysis of the strategic position of a company. Ghazinoory et al. (2011) conducted a review of works. In our field of interest here, SWOT has been used to assess regional digital competence in Australia (Alam et al., 2018).

Recently, some proposals have emerged to refine or even replace the categories of SWOT into the more granular categories of PESTLE (Srdjevic et al., 2012; Zalengera et al., 2014). The PESTLE analysis is a methodological framework, similar to SWOT, for strategic planning in which the conditioning factors are grouped into six categories: Political, Economic, Social, Technological, Legal, and Environmental (Kolios and Read, 2013; Parra-López et al., 2017). The objective of PESTLE is to identify the factors that influence a system, their impact, and their positive or negative effects on the system (Parra-López et al., 2015b; Srdjevic et al., 2012). In our model, the classical categories of SWOT factors have been internally divided into six subcategories according to the PESTLE classification.

For a preliminary identification of the specific conditioning factors, first of all, some studies on digitalisation in the agrifood sector in Spain have been extensively reviewed. They stand out 1) those carried out by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2018a, b) which, based on a focus group with experts from the agrifood, forestry and rural sectors, identified barriers and recommendations for the development of digitisation and big data in these sectors; and 2) that of the Regional Government of Andalusia (Junta_de_Andalucía, 2019) which identified needs and barriers in the field of digitisation in the agrifood value chain in Andalusia also through stakeholders and experts from the agrifood sector. It should be noted that no specific information has been found for the DT of the olive sector of Andalusia.

This secondary information was combined and integrated into an initial AHP/SWOT/PESTLE model. Subsequently, a group of 10 experts (stakeholders of the sector) related to the DT of the olive sector in Andalusia reviewed this initial model individually: 2 from the public administration, 2 from digital technologies companies and 6 from universities and innovation centres. The aim was to have as broad a vision as possible. Finally, the information from all the experts was combined and integrated into a final AHP/SWOT/PESTLE model (Figure 2), which consist of 4 levels with the following elements: 1) G - Goal (or overall objective): Prioritisation of the conditioning factors of the DT of the olive sector in Andalusia; 2) CF - Categories of factors: Types of factors grouped into SWOT categories; 3) SF - Subcategories of factors: Internal subdivision of the conditioning factors into PESTLE categories; 4) F - Factors: Specific issues conditioning the DT in the Andalusian olive sector. The detail of the Categories of factors and Subcategories of factors will be provided in Table 1 in the Results and discussion section.

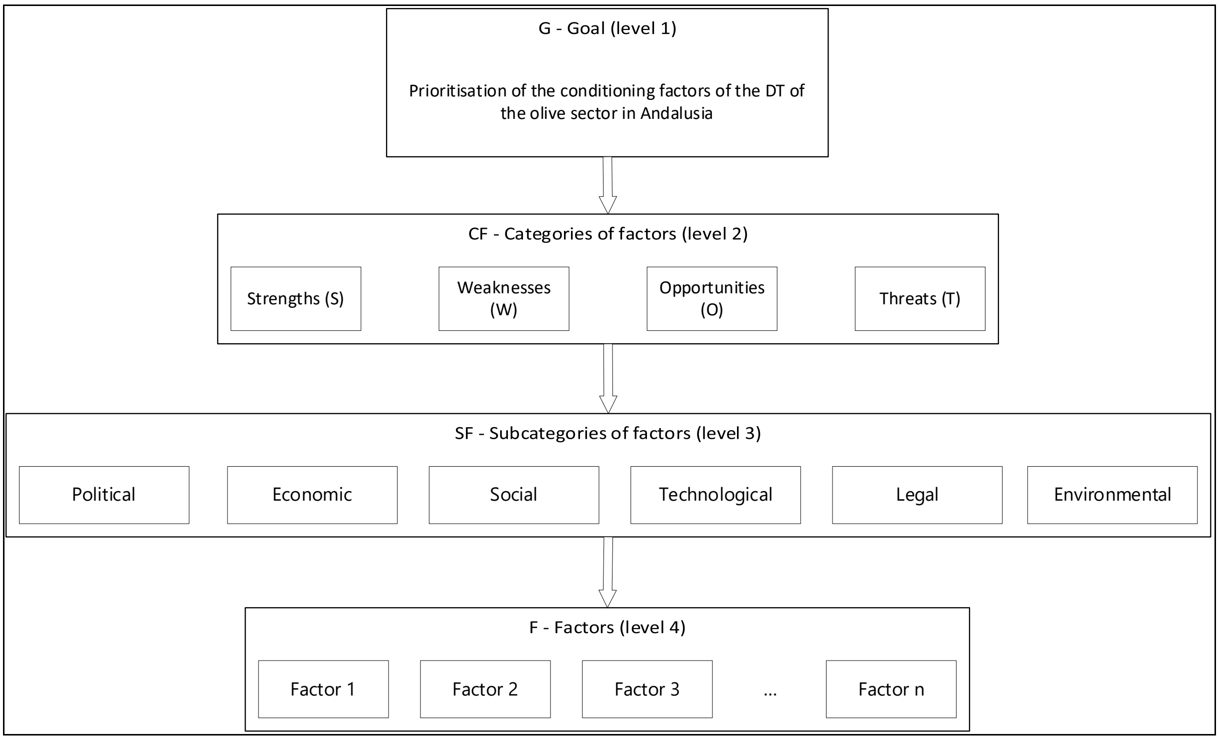


Figure 2. The AHP/SWOT/PESTLE model for the DT in the olive sector of Andalusia

3.1.2 Evaluation of factors

Subsequently, the priority (weight or importance) of each category, subcategory and factor of the model need to be evaluated. Both the SWOT analysis and the PESTLE analysis approaches, and their combination, are qualitative, since valuations normally use categorical scales. This poses the problem of the incommensurability and the impossibility of comparison of the elements (Parra-López et al., 2015b; Vanek et al., 2014). AHP, on the contrary, makes it possible to carry out a quantitative evaluation of the decision-making elements, allowing the different types of elements (in our case categories, subcategories and factors) to be prioritised on a ratio scale and making them commensurable and comparable (Forman and Selly, 2001; Kurttila et al., 2000; Parra-López et al., 2009). Additionally, AHP allows the incorporation of qualitative, subjective and intangible information into the evaluation process, for instance in the form of expert knowledge, as well as quantitative and hard-data information when available (Parra-López et al., 2008a).

For each node of the AHP model, i.e. one element and the sub-elements depending on it, the local priorities of the sub-elements (ω_L) can be evaluated based on hard data, if available, or soft data in the form of expert knowledge and/or stakeholder preferences. To evaluate the proposed model for DT, expert knowledge was used due to the low availability of hard data for Andalusia and the complex nature of the issues investigated (technical, environmental, social, economic, etc.). In particular, 31 experts/stakeholders with diverse profiles and experience in the subject were surveyed from October 2019 to January 2020: 5 from public administration, 7 from R&D organisations, 7 from agrifood companies, 6 from digital technologies companies and 6 from other organisations supporting the olive sector. The aim again was to have as broad a view as possible and to compare the assessments of different groups. The survey was conducted from October to December 2019, following a structured questionnaire presented face-to-face or submitted by email and with telephone support if necessary. The experts were given a choice of format depending on what was most convenient for them. The responses were verified in terms of possible invalid data and responses that differed from those of the other experts in their group. Due to the high number of elements to be compared in some cases (higher than 7±2, as recommended in AHP), the evaluation of the priorities by the experts was based on the 'direct rating' method (Bottomley and Doyle, 2001; Calabrese et al., 2019; Forman and Selly, 2001; Larichev et al., 1995; Oliveira et al., 2018; Parra-López et al., 2008b). The rating scale used ranged from 0, in the categories/factors with null priority, to 9, in those with very high priority (Carmona-Torres et al., 2014; Carmona-Torres et al., 2016; Parra-López et al., 2008b; Rodríguez Sousa et al., 2020). This scale is linear, as indicated to the interviewees, where 9 is 9/1 times greater than 1, 9/2 times greater than 2, and so on. It is therefore to be expected that experts will think on this linear scale. This is a difference with the Likert scale where problems of interpretation of the scale may arise (Carifio and Perla, 2008; Jamieson, 2004; Pell, 2005).

It is necessary to indicate that in multi-criteria decision-making methods based on experts it is not possible to speak of representativeness and confidence level of the results because the population of experts is not known. Moreover, due to the requirement for in-depth technical knowledge and availability to fill in long questionnaires, the number of experts to be consulted is usually small (usually from 6 to 15 in AHP and its generalisation ANP) (Sánchez-Zamora et al., 2017; Villanueva Rodríguez et al., 2014). In our case, it has indeed not been an easy task since the subjects dealt with (the digitalisation of the olive grove) are very new and it is not easy to find people who are familiar with the subject. In any case, 31 experts have been interviewed, as indicated above, over and above the usual 6-15. In addition, at the level of expert groups we have tried to have at least 5 experts of each type, as indicated in the literature (De Luca et al., 2018; Parra-López et al., 2008a). Due to the small number of experts and the fact that on some topics they may not have knowledge, an analysis of intra-group variation would be very weak.

Subsequently, the individual local priorities of experts were aggregated for each group of experts and for all the groups of experts through the Weighted Arithmetic Mean Method (Ramanathan and Ganesh, 1994), i.e. through the arithmetic mean of the priorities for each node:

$$\omega_{L(g)} = \sum_{x=1}^{X} \omega_{L(x)}/X$$

where $\omega_{L(g)}$ are the local priority of a given element for the group of experts *g*; $\omega_{L(x)}$ is the local priority of this element for expert *x* pertaining to group *g*; and *X* is the number of experts of group *g*. The average evaluation of the whole group of experts is considered to be more reliable than individual evaluation, as individual biases and lack of knowledge of some individuals on a particular subject are minimised. Subsequently the local priorities of all the groups is calculated in the same manner as the arithmetic mean of the local priorities for each group of experts.

After that, the priorities of the categories, subcategories and factors (for a group of experts or all groups) must be synthesized according to their satisfaction of the goal (global priorities, ω_G), or any intermediate node of the model (final priorities, ω_F). The global/final priorities of the categories, subcategories and factors in any upper element of an AHP model could be calculated by means of the weighted sum of the sub-elements that depend on it (Saaty, 1980). For example, for an AHP model with 3 levels (goal, elements and sub-elements) one would have:

$$\omega_{G(s)} = \sum_{e=1}^{E} \omega_{L(e/G)} * \omega_{L(s/e)}$$

where $\omega_{G(s)}$ is the global priority of sub-element *s* (for a group of experts or all groups); $\omega_{L(e/G)}$ is the local priority of element *e* over the goal (for a group of experts or all groups); $\omega_{L(s/e)}$ is the local priority of sub-element *s* over element *e* dependent on the goal (for a group of experts or all groups); and *E* is the number of elements within the goal.

Additionally, the heterogeneity of responses was analysed by the Relative Global Agreement Index (RGA) among different groups of experts in a node. This RGA index is defined by Parra-López et al. (2008a) as:

$$\mathbf{RGA} = \mathbf{1} \Big/ \sum_{\forall g} \left(\left(\sum_{i=1}^{n} \left(\left| \omega_{L(i),g} - \omega_{L(i),m} \right| / \omega_{L(i),m} \right) \right) / n \right) / \mathbf{G}$$

where *G* is the number of decision groups, *g* is a particular decision group, $\omega_{L(i),g}$ is the mean local priority of the *i* element with respect to the element for the *g* group, $\omega_{L(i),m}$ is the mean local priority of the *i* element for the *G* groups and *n* is the number of child sub-elements or alternatives of the node. RGA index is a measure of the differences of opinions of individual groups with respect to the mean of all the groups. The greater the RGA Index in a node, the greater the consensus among all groups.

3.1.3 Identification of critical factors

Critical factors are defined as those that have a high global priority and their degree of agreement, both at the category and subcategory from which they depend on, are high or medium.

These critical factors will allow the definition of future lines of action that positively influence DT processes, given their influence on the overall goal.

3.1.4 Comparison of positive vs negative categories of factors

Based on the prioritisation of the categories of factors (Strengths, Weaknesses, Opportunities and Threats), three indicators have been developed that allow an overall comparison of positive versus negative factors faced in the short and medium term by the DT of the olive sector in Andalusia. For this, we have relied on the rationale of the BOCR (Benefits, Opportunities, Costs and Risks) merits used in the cost-benefit analyses based on AHP (and ANP, which is a generalisation of AHP based on networks rather than hierarchies) (Lee et al., 2009; Saaty, 2004). The positive aspects are supposed to be the Strengths and Opportunities, comparable to the Benefits and Opportunities in BOCR, and the negative aspects are the Weaknesses and Threats, similar to the Costs and Risks. The intention is to compare the results of the three indicators for the priorities for the five expert groups. These SWOT indicators are:

$$R_m = \frac{\omega_{L(S)} * \omega_{L(O)}}{\omega_{L(W)} * \omega_{L(T)}}$$

where R_m is the Multiplicative Ratio, very similar to a common indicator in the BOCR merits; and $\omega_{L(S)}$, $\omega_{L(W)}$, $\omega_{L(O)}$, and $\omega_{L(T)}$ are the local priorities for each group of experts of the Strengths, Weaknesses, Opportunities and Threats, respectively.

$$R_a = \frac{\omega_{L(S)} + \omega_{L(O)}}{\omega_{L(W)} + \omega_{L(T)}}$$

where R_a is the Additive Ratio, which adds up rather than multiplying the priorities of the SWOT factors. This alternative form considers that positive (or negative) effects have an additive rather than a multiplicative effect on others.

$$\mathbf{V_n = \omega_{L(S)} + \omega_{L(O)} - \omega_{L(W)} - \omega_{L(T)}}$$

where V_n is the Net Value of the DT status for each expert group; here the priorities of the positive factors are added, $\omega_{G(S)}$ and $\omega_{G(O)}$, and the priorities of the negative factors are deducted from the result, $\omega_{G(W)}$ and $\omega_{G(T)}$.

3.2 Design of policy strategies to strengthen the DT

Finally, the priorities obtained through the AHP/SWOT/PESTLE model have been analysed with TOWS. TOWS is a methodology that combines external and internal factors (SWOT) analysis, and from there develops four types of strategies and actions (Baudino et al., 2017; Weihrich, 1982). The TOWS methodology develops a matrix to provide strategies based on the linkages between Threats, Opportunities, Weaknesses and Strengths indicated by the SWOT (Baudino et al., 2017; Weihrich, 1982). TOWS analysis has been widely used to identify strategies based on previous SWOT/AHP analysis (Gottfried et al., 2018; Haque et al., 2020). In our field of interest, it has been used to assess the implementation of ICTs to boost E-government in Lebanon (Alaaraj and Hassan, 2014) and to analyse strategies for the adoption of blockchain in the marketing sectors in India (Buvaneswari and Swetha, 2019). Although AHP has been previously combined with SWOT analysis (Ghazinoory et al., 2011; Kurttila et al., 2000; Solangi et al., 2019), with SWOT/PESTLE (Mishra, 2019; Srdjevic et al., 2012), and with SWOT/TOWS (Gottfried et al., 2018; Haque et al., 2020), the combination of SWOT, PESTLE, AHP and TOWS is new, at least in the case of the analysis of the agrifood and agricultural sector.

The TOWS analysis can be applied to the development of tactics necessary to implement strategies and to find more specific actions that support these tactics. The analysis examines Threats (T) and Opportunities (O) first, followed by Weaknesses (W) and Strengths (S). TOWS proposes four possible types of strategies (Weihrich, 1982):

- Growth strategies (SO strategies): They are based on the principle of maximising both Strengths and Opportunities (Max–Max), enhancing merits and taking advantage of opportunities.
- Re-orientation strategies (WO strategies): they use the principle of minimising drawbacks and maximising opportunities (Min–Max), decreasing Weaknesses and using Opportunities.

- Defensive strategies (ST strategies): they use the principle of maximising Strengths and minimising Threats (Max–Min), strengthening advantages and averting risks.
- Survival strategies (WT strategies): they are based on the principle of minimising both threats and drawbacks (Min–Min), reducing Threats and overcoming Weaknesses.

Based on this, the policy strategies were developed as follows:

1) For each type of strategy (SO, WO, ST, WT), pairs of factors with common issues were identified. For example, a pair of factors may be related to a very similar issue that is both a Strength and an Opportunity, and therefore a potential SO strategy may be defined to address the issue (an example is shown in Section 4.2).
2) For each pair of factors identified (potential strategy), the multiplication of their global priorities was obtained:

$$\boldsymbol{S_t} = \boldsymbol{\omega}_{\mathbf{G(x)}*}\boldsymbol{\omega}_{\mathbf{G(y)}}$$

where S_t is the multiplicative score between the global priorities of a pair elements, and $\omega_{G(x)}$ and $\omega_{G(y)}$ are the global priorities of each factor, x and y, identified.

3) For each type of strategy, the three strategies with the highest S_t score were selected.
4) Finally, among all the strategies identified, those with the highest S_t score were selected.

4 Results and discussion

4.1 Priorities of conditioning factors

Table 1 summarises the results of the relative local priorities (importance) of the different elements (categories, subcategories and factors) of the model (column “Local priorities”). It shows the average prioritisation of the five groups of experts, not the separate priorities for each group. The variance of opinions among the groups of experts is indicated in the columns ‘Agreement’. These data, as well as their aggregate sums for calculating global and final priorities, will be discussed in the following subsections.

G - Goal (level 1) CF - Categories of factors (level 2) SF - Subcategories of factors (level 3) F - Factors (level 4)	Local priorities+	Agreement	
		RGA index	Agreement degree
G	1.0000	41.4069	***
CF1. STRENGTHS (S)	0.2445	18.5605	**
SF1.1. S - ECONOMIC (Ec)	0.2353	∞	***
F1.1.1 Andalusia is a world leader in the olive sector	1.0000	-	-
SF1.2. S - SOCIAL (S)	0.2258	11.9832	*
F1.2.1 There is a clear trend in the agricultural associations on the importance of the digital transformation	0.4689	-	-
F1.2.2 The olive sector is an important generator of employment in Andalusia	0.5311	-	-
SF1.3. S - TECHNOLOGICAL (T)	0.2674	26.4344	**
F1.3.1 Existence of technologies currently available in the sector	0.4784	-	-
F1.3.2 Digital technologies application is key to a more transparent value chain and improved traceability	0.5216	-	-
SF1.4. S - ENVIRONMENTAL (En)	0.2715	∞	***
F1.4.1 The application of digital technologies leads to greater environmental efficiency in production processes	1.0000	-	-
CF2. WEAKNESSES (W)	0.2647	15.1470	**
SF2.1 W - ECONOMIC (Ec)	0.3268	10.2726	*
F2.1.1 Atomization of the olive growing and industrial sector	0.2617	-	-
F2.1.2 Most of the olive grove is extensive, traditional and not very professional	0.2601	-	-
F2.1.3 Dependence on other actors in the value chain and digital technology providers (loss of autonomy)	0.2060	-	-
F2.1.4 Lack of evidence on the economic viability of digital technologies investment (cost/benefit ratio, etc.), especially in small farms	0.2721	-	-
SF2.2 W - SOCIAL (S)	0.3497	10.9930	*
F2.2.1 Scarce innovative attitude of the olive sector	0.1955	-	-
F2.2.2 Lack of a culture of collaboration among stakeholders	0.1916	-	-
F2.2.3 Lack of digital culture and training in the sector (digital skills and digital technologies personnel)	0.2308	-	-
F2.2.4 Orientation of the sector towards digitisation (incorporation of technologies) rather than digital transformation (cultural change). There is no perception that digital transformation is a profound business change	0.2175	-	-
F2.2.5 Lack of confidence, certainty and/or ethical codes about how and by whom the data will be used	0.1646	-	-
SF2.3 W - TECHNOLOGICAL (T)	0.3234	11.1866	*
F2.3.1 Lack of technological integration in the agrifood chain (connectivity, interoperability and quality standards)	0.2728	-	-
F2.3.2 Different rates of digitization between different stages in the value chain (agriculture and industry)	0.2529	-	-
F2.3.3 Digital divide between large companies and SMEs in the agrifood sector	0.2202	-	-
F2.3.4 Lack of structured data and poor data quality in the sector	0.2541	-	-
CF3. OPPORTUNITIES (O)	0.2708	14.1294	**
SF3.1 O - POLITICAL (P)	0.1635	20.9246	**
F3.1.1 High institutional interest to improve public-private collaboration for digital transformation (e.g. DIH Andalucia Agrotech)	0.2536	-	-
F3.1.2 digital technologies can contribute to the objective of simplification of the CAP by enabling new forms of interoperability and accessibility of data used in the management and control of the CAP	0.2573	-	-
F3.1.3 Political interest in fixing population in rural territories by reducing the digital divide and supporting 'smart territories'	0.2558	-	-
F3.1.4 Policy interest in encouraging the generation and use of open and public data	0.2333	-	-
SF3.2 O - ECONOMIC (Ec)	0.1704	17.8951	**
F3.2.1 Potential for the development of new businesses and services	0.2353	-	-
F3.2.2 Potential of digital transformation for value creation along the food chain	0.2478	-	-
F3.2.3 Potential of digital technologies for improving economic efficiency (cost reduction, productivity increase, etc.), competitiveness and coordination of the value chain	0.2732	-	-
F3.2.4 Existence of an important innovation ecosystem to support agriculture in Andalusia (companies and public institutions)	0.2437	-	-

G - Goal (level 1) CF - Categories of factors (level 2) SF - Subcategories of factors (level 3) F - Factors (level 4)	Local priorities+	Agreement	
		RGA index	Agreement degree
SF3.3 O - SOCIAL (S)	0.1628	14.5396	**
F3.3.1 Growing consumer demand for the use of digital technologies in agrifood (trade, traceability, etc.)	0.3253	-	-
F3.3.2 Growing use of ICTs by the general population	0.3382	-	-
F3.3.3 Potential for job creation related to the digital transformation of the olive sector	0.3364	-	-
SF3.4 O - TECHNOLOGICAL (T)	0.1838	24.1877	**
F3.4.1 Potential of digital technologies for the control of pests and diseases in olive groves (Xylella fastidiosa, etc.)	0.3523	-	-
F3.4.2 Some development of digital ecosystems in other sectors that may favour digital transformation in the olive sector	0.3111	-	-
F3.4.3 Implementation of new forms of interoperability and accessibility of data used in CAP management	0.3366	-	-
SF3.5 O - LEGAL (L)	0.1393	∞	***
F3.5.1 Interest in developing a common interoperability strategy	1.0000	-	-
SF3.6 O - ENVIRONMENTAL (En)	0.1803	∞	***
F3.6.1 Growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the fight against climate change	1.0000	-	-
CF4. THREATS (T)	0.2200	9.4069	*
SF4.1 T - POLITICAL (P)	0.1587	11.1827	*
F4.1.1 Little or no correlation of the current CAP with digitisation or ICTs	0.2637	-	-
F4.1.2 Scarce global vision of the chain in the planning of public policies. Need for integration of funds and strategies in digital transformation	0.2416	-	-
F4.1.3 Existence of public incentives for innovation, but low priority for digital transformation	0.2523	-	-
F4.1.4 Lack of training plans promoted by local and regional governments for the digitization of the sector	0.2424	-	-
SF4.2 T - ECONOMIC (Ec)	0.1908	47.4140	***
F4.2.1 High costs of digital transformation for the sector	0.4409	-	-
F4.2.2 Insufficient coordination between actors of the innovation system (agrifood companies, research centres, public administration, digital technologies companies, support entities)	0.5591	-	-
SF4.3 T - SOCIAL (S)	0.1833	9.3201	*
F4.3.1 Migratory flows towards urban centres. Shortage of labour and young farmers	0.6347	-	-
F4.3.2 Potential negative effects of digital transformation on agricultural employment	0.3653	-	-
SF4.4 T - TECHNOLOGICAL (T)	0.1879	14.1998	**
F4.4.1 Lack of technological resources in rural areas (low connectivity, broadband, infrastructure)	0.1773	-	-
F4.4.2 Lack of integral services and adapted to the olive companies in digitalization issues	0.1702	-	-
F4.4.3 Difficulty of farmers in transferring their needs to technology agents	0.1473	-	-
F4.4.4 Shortage of support professionals with a multidisciplinary vision in agriculture and ICTs	0.1726	-	-
F4.4.5 Need to improve public and open data to enable the development of digital business models	0.1674	-	-
F4.4.6 Digital divide between urban and rural areas	0.1652	-	-
SF4.5 T - LEGAL (L)	0.1646	22.4517	**
F4.5.1 Legal confusion over ownership and exploitation of data	0.3228	-	-
F4.5.2 Lack of definition of a clear legal framework allowing public collaboration with the private sector in digitisation	0.3361	-	-
F4.5.3 Little legislation and dispersion of regulations on the use of digital technologies and open access to data in the agrifood sector	0.3410	-	-
SF4.6 T - ENVIRONMENTAL (En)	0.1148	∞	***
F4.6.1 Potential unintended and unanticipated effects of the use of digital technologies (change of varieties, effect on the landscape, effects on wildlife, etc.)	1.0000	-	-

+: According to the mean opinion of the five types of experts
*Agreement degree: *** = High; ** = Medium; *= Low*
-: Not applicable because there are not sub-nodes depending of the node

Table 1. Local priorities and agreements in the AHP/SWOT/PESTLE model

4.1.1 Category priorities

The four categories of factors (CF) have different priorities (importance) with respect to the goal, on which they depend, according to the average of all expert groups. The local priorities (ω_L) of opportunities, weaknesses, strengths and threats are 0.2728, 0.2647, 0.2445, 0.2200, respectively, and in descending order of importance (Table 1, level 2). It is remarkable that opportunities have the greatest priority, being a category of factors external to the olive sector, although weaknesses, which are internal to the sector, follow at a short distance. In addition, there is a high degree of agreement among experts on these local priorities of the four categories with respect to the goal (RGA index = 41.4069, Agreement degree = High) (Table 1, level 1).

The prioritisation by expert groups (Table 2) shows that the experts in R&D organisations and agrifood companies keep up the tendency of the average of all expert groups, i.e. opportunities, weaknesses, strengths and threats. In the case of public administration experts, the opportunities are also highlighted first, but followed by the strengths, thus being more optimistic. However, for experts from digital technologies companies and other support organisations, the first category that stands out are the weaknesses, thus being more pessimistic. In all groups, threats are considered the least important category.

	Public administration	**R&D organisations**	**Agrifood companies**	**Digital technologies companies**	**Other organisations**
CF1. Strengths (S)	0.2491 (2)	0.2346 (3)	0.2531 (3)	0.2290 (3)	0.2566 (2)
CF2. Weaknesses (W)	0.2410 (3)	0.2724 (2)	0.2615 (2)	0.2746 (1)	0.2739 (1)
CF3. Opportunities (O)	0.2830 (1)	0.2765 (1)	0.2660 (1)	0.2726 (2)	0.2562 (3)
CF4. Threats (T)	0.2270 (4)	0.2165 (4)	0.2194 (4)	0.2238 (4)	0.2134 (4)

Table 2. Priorities (and ranking) of the categories of factors by expert groups

4.1.2 Strengths priorities

The final priorities of the subcategories of factors (SF) and factors (F) within the Strengths category, i.e. the most important strengths for the DT in the olive sector, average for all expert groups, are shown in Figure 3. The environmental subcategory SF1.4 stands out by its priority/importance (0.2715), followed by the technological SF1.3 (0.2674), economic SF1.1 (0.2353), and social SF1.2

(0.2258). There is a medium degree of agreement among the experts on the local importance of these subcategories (RGA index = 18.5605) (Table 1, level 2). Among the factors, the most prioritised as Strengths is F1.4.1 ‘The application of digital technologies leads to greater environmental efficiency in production processes’ (0.2715) (Figure 3). In this line, other studies from Germany and Ireland in the fruit and vegetable sectors highlighted that the use of smart farming technologies (SFT), i.e. digital technologies applied to agriculture, would enable more efficient farming practices, leading to more sustainability (Barnes et al., 2019; Knierim et al., 2019). Other important strengths identified are F1.1.1 ‘Andalusia is a world leader in the olive sector’ (0.2353) and F1.3.2 digital technologies application is key to a more transparent value chain and improved traceability (0.1395) (Figure 3). With regard to the latter factor, Regan (2019) found that in Ireland consumers can specifically benefit from digital technologies as a result of improved information flows and transparency introduced into food value chains.

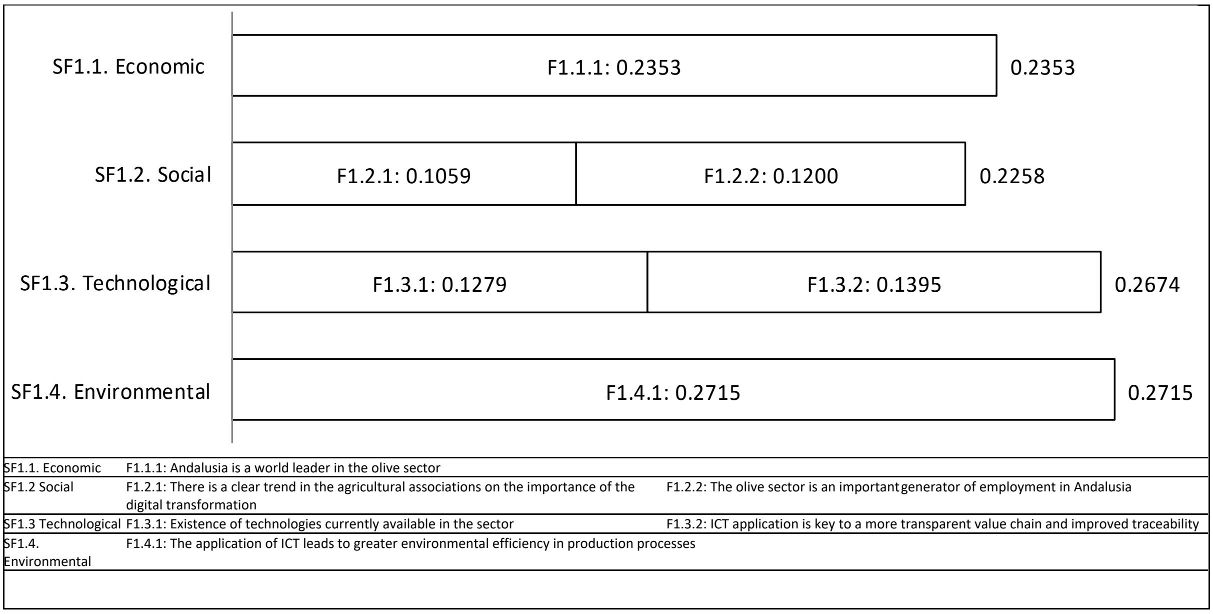
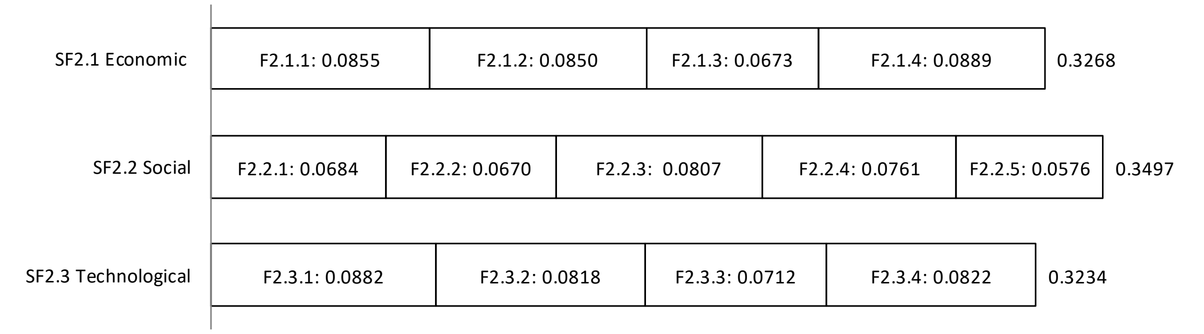


Figure 3. Priorities within Strengths

4.1.3 Weaknesses priorities

Within the Weaknesses, the social subcategory stands out, SF2.2 (0.3497), followed by the economic SF2.1 (0.3268) and, finally, the technological SF1.3 (0.3234) (Figure 4). The degree of agreement among the experts on this prioritisation is medium (RGA index = 15.1470) (Table 1, level 2).

Among the factors F2.1.4 ‘Lack of evidence on the economic viability of digital technologies investment (cost/benefit ratio, etc.), especially in small farms’ stands out (0.0889). In relation to this issue, some studies highlight the perception of European farmers that the cost-benefit ration and added value are not clear when adopting SFT (Kernecker et al., 2020; Knierim et al., 2019; Regan, 2019). Likewise, Knierim et al. (2019) emphasises that economic farm size does matter because of the farms’ capacity to invest and the resulting economy of scales. Thus, the farm size is an indicator of the innovation adoption, and an increase in the surface area of an olive grove implies an increase in the likelihood of adoption, as reported in Greece (Chatzimichael et al., 2014), in Iran (Allahyari et al., 2016), and in Andalusia (Spain) (Calatrava and Franco, 2011; Rodríguez-Entrena and Arriaza, 2013). Other important weaknesses identified are F2.3.1 ‘Lack of technological integration in the agrifood chain (connectivity, interoperability and quality standards)’ (0.0882), and F2.1.1 ‘Atomisation of the olive growing and industrial sector’ (0.0855) (Figure 4). In relation to lack of technological integration in the agrifood chain, previous research has also identified these as issues of concern for the development of SFT in other countries: low compatibility (Kernecker et al., 2020; Knierim et al., 2019), missing standards (Erdle, 2018; Knierim et al., 2019) and the lack of interoperability (Kernecker et al., 2020). Finally, F2.2.5 Lack of confidence, certainty and/or ethical codes about how and by whom the data will be used, has a low importance (0.0576). This finding is consistent with other studies, which conclude that data security has an unexpectedly low importance in farmers' perception of SFT for farming systems across Europe (Kernecker et al., 2020).

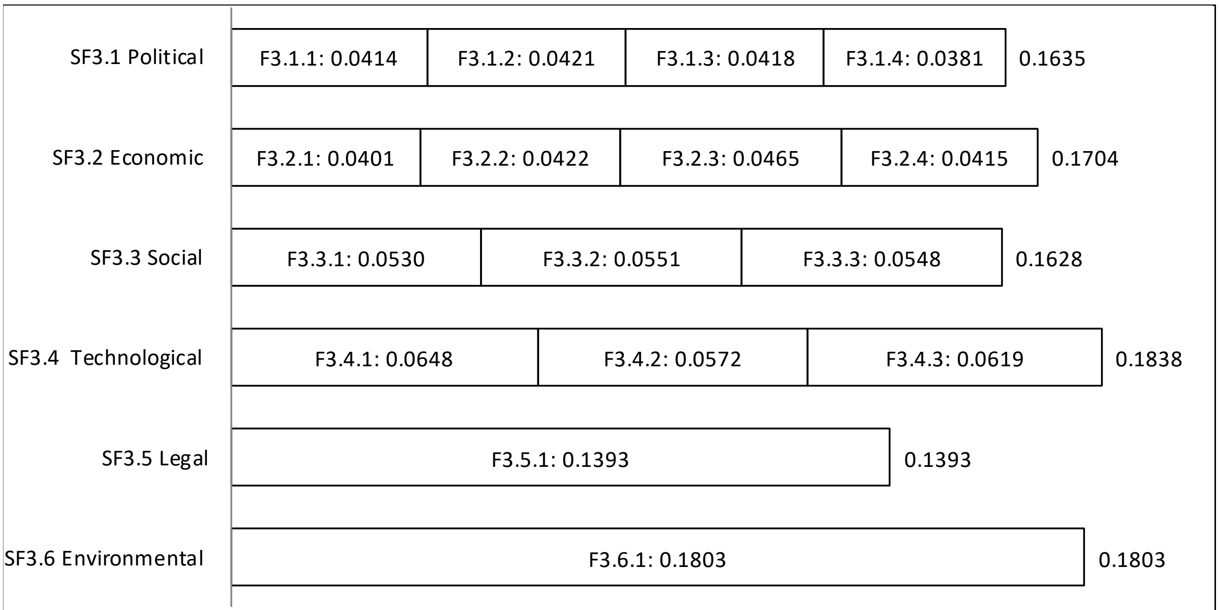


SF2.1. Economic	F2.1.1: Atomization of the olive growing and industrial sector	F2.1.2: Most of the olive grove is extensive, traditional and notvery professional
	F2.1.3: Dependence on other actors in the value chain and digital technology providers (loss of autonomy)	F2.1.4: Lack of evidence on the economic viability of ICT investment (cost/benefit ratio, etc.), especially in small farms
SF2.2 Social	F2.2.1: Scarce innovative attitude of the olive sector	F2.2.2: Lack of a culture of collaboration among stakeholders
	F.2.2.3: Lack of digital culture and training in the sector (digital skills and ICT personnel)	F2.2.4: Orientation of the sector towards digitisation (incorporation of technologies) rather than digital transformation (cultural change). There is no perception that digital transformation is a profound business change
	F2.2.5: Lack of confidence, certainty and/or ethical codes about how and by whom the data will be used	
SF1.3 Technological	F2.3.1: Lack of technological integration in the agrifood chain (connectivity, interoperability and quality standards)	F2.3.2: Different rates of digitizationbetween different stages in the value chain (agriculture and industry)
	F2.3.3: Digital divide between large companies and SMEs in the agrifood sector	F2.3.4: Lack of structured data and poor data quality in the sector

Figure 4. Priorities within Weaknesses

4.1.4 Opportunities priorities

Figure 5 shows that, within the Opportunities, the technological subcategory SF3.4 stands out (0.1838), followed by the environmental SF3.6 (0.1803), economic SF3.2 (0.1704), political SF3.1 (0.1635), social SF3.3 (0.1628), and legal SF3.5 (0.1393). The degree of agreement among experts on these priorities is medium (RGA index = 14.1294) (Table 1, level 2). At the factor level, the most important opportunities are F3.6.1 'Growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the fight against climate change' (0.1803) and F3.5.1 'Interest in developing a common interoperability strategy' (0.1393) (Figure 5). In line with the first factor, society's expectations and growing demand for quality products are seen as favouring the adoption of SFT, especially in northern Europe (Knierim et al., 2019).

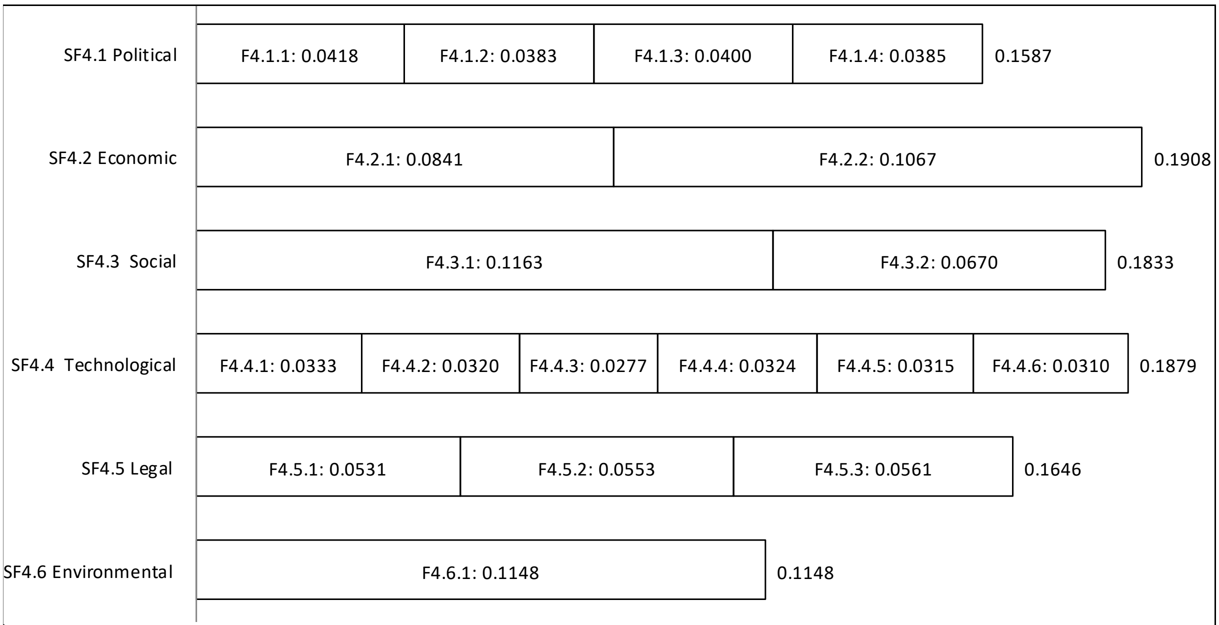


SF3.1. Political	F3.1.1: High institutional interest to improve public-private collaboration for digital transformation (e.g. DIH Andalucia Agrotech)	F3.1.2: ICT can contribute to the objective of simplification of the CAP by enabling new forms of interoperability and accessibility of data used in the management and control of the CAP
	F3.1.3: Political interest in fixing population in rural territories by reducing the digital divide and supporting 'smart territories'	F3.1.4: Policy interest in encouraging the generation and use of open and public data
SF3.2 Economic	F3.2.1: Potential for the development of new businesses and services	F3.2.2: Potential of digital transformation for value creation along the food chain
	F3.2.3: Potential of ICT for improving economic efficiency (cost reduction, productivity increase, etc.), competitiveness and coordination of the value chain	F3.2.4: Existence of an important innovation ecosystem to support agriculture in Andalusia (companies and public institutions)
SF3.3 Social	F3.3.1: Growing consumer demand for the use of ICTs in agrifood (trade, traceability, etc.)	F3.3.2: Growing use of ICTs by the general population
	F3.3.3: Potential for job creation related to the digital transformation of the olive sector	
SF3.4 Technological	F3.4.1: Potential of ICT for the control of pests and diseases in olive groves (Xylella fastidiosa, etc.)	F3.4.2: Some development of digital ecosystems in other sectors that may favour digital transformation in the olive sector
	F3.4.3: Implementation of new forms of interoperability and accessibility of data used in CAP management	
SF3.5 Legal	F3.5.1: Interest in developing a common interoperability strategy	
SF3.6 Environmental	F3.6.1: Growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the fight against climate change	

Figure 5. Priorities within Opportunities

4.1.5 Threats priorities

Within the Threats, the economic subcategory SF4.2 is highlighted (0.1908), followed by the technological SF4.4 (0.1879), social SF4.3 (0.1833), legal SF4.5 (0.1646), political SF4.1 (0.1587) and environmental SF2.6 (0.1148) (Figure 6). The degree of agreement among experts is low (RGA index = 9.4069) (Table 1, level 2), unlike the other categories, where it was medium. At the factor level, the most important threat that need to be countered is F4.3.1 'Migratory flows towards urban centres. Shortage of labour and young farmers' (0.1163) (Figure 6). This has been also highlighted by Knierim et al. (2019), who noted that the limited availability of labour force may increasingly become a constraint on farm management. Also, in Spain, evidence has been found that the adoption of innovation increases if the olive grove is passed on to younger people (Parra-López and Calatrava-Requena, 2005; Rodríguez-Entrena and Arriaza, 2013). Other important factors assessed as having high priority are F4.6.1 'Potential unintended and unanticipated effects of the use of digital technologies (change of varieties, effect on the landscape, effects on wildlife, etc.)' (0.1148), F4.2.2 'Insufficient coordination between actors of the innovation system (agrifood companies, research centres, public administration, digital technologies companies, support entities)' (0.1067), and F4.2.1 'High costs of digital transformation for the sector' (0.0841) (Figure 6). In relation to insufficient coordination between actors, this has also been highlighted in previous research. For example, Knierim et al. (2019) found evidence of a lack of effective interaction and knowledge flows, in particular between farmers and technology providers. Weak links between actors in the agricultural knowledge and innovation system (AKIS) have been recognised as an obstacle to the effective implementation of agricultural technology systems. Finally, in line with the high costs of DT, Kernecker et al. (2020) found that the main obstacles to the adoption of SFT on European farms are related to high costs. Similarly, Knierim et al. (2019) highlighted that the factors driving the generation and adoption of SFT innovation were limited due to economic challenges in the phase of prototype development. In the olive sector in Andalusia, it has been shown the main obstacle is that the cost of adopting the innovation usually exceeds the short-term benefits, even though they produce long-term benefits (Rodríguez-Entrena and Arriaza, 2013).



SF4.1. Political	F4.1.1: Little or no correlation of the current CAP with digitisation or ICTs	F4.1.2: Scarce global vision of the chain in the planning of public policies. Need for integration of funds and strategies in digital transformation
	F4.1.3: Existence of public incentives for innovation, but low priority for digital transformation	F4.1.4: Lack of training plans promoted by local and regional governments for the digitization of the sector
SF4.2 Economic	F4.2.1: High costs of digital transformation for the sector	F4.2.2: Insufficient coordination between actors of the innovation system (agrifood companies, research centres, public administration, ICT companies, support entities)
SF4.3 Social	F4.3.1: Migratory flows towards urban centres. Shortage of labour and young farmers	F4.3.2: Potential negative effects of digital transformation on agricultural employment
SF4.4 Technological	F4.4.1: Lack of technological resources in rural areas (low connectivity, broadband, infrastructure)	F4.4.2: Lack of integral services and adapted to the olive companies in digitalization issues
	F4.4.3: Difficulty of farmers in transferring their needs to technology agents	F4.4.4: Shortage of support professionals with a multidisciplinary vision in agriculture and ICTs
	F4.4.5: Need to improve public and open data to enable the development of digital business models	F4.4.6: Digital divide between urban and rural areas
SF4.5 Legal	F4.5.1: Legal confusion over ownership and exploitation of data	F4.5.2: Lack of definition of a clear legal framework allowing public collaboration with the private sector in digitisation
	F4.5.3: Little legislation and dispersion of regulations on the use of ICT and open access to data in the agrifood sector	
SF4.6 Environmental	F4.6.1: Potential unintended and unanticipated effects of the use of digital technologies (change of varieties, effect on the landscape, effects on wildlife, etc.)	

Figure 6. Priorities within Threats

4.1.6 Critical factors

The critical factors are shown in Table 3. F1.4.1 ‘The application of digital technologies leads to greater environmental efficiency in production processes’ (global priority of 0.0664) and F1.1.1 ‘Andalusia is a world leader in the olive sector’ (0.0575), which are strengths (positive factors within the olive sector), stand out. They are followed by F3.6.1 ‘Growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the fight against climate change’ (0.0488) and F3.5.1 ‘Interest in developing a common interoperability strategy’ (0.0377), which are opportunities (positive factors outside the olive sector). Finally, they are F1.3.2 ‘digital technologies application is key to a more transparent value chain and improved traceability’ (0.0341), and F1.3.1 ‘Existence of technologies currently available in the sector’ (0.0313), which are also strengths. Therefore, the most critical factors that condition the DT of the olive sector of Andalusia in the short and medium term are positive.

Factor	Category	Agreement degree		Global priority of the factor
		Category	Subcategory	
F1.4.1 The application of digital technologies leads to greater environmental efficiency in production processes	CF.1 Strengths	Medium	High	0.0664
F1.1.1 Andalusia is a world leader in the olive sector	CF.1 Strengths	Medium	High	0.0575
F3.6.1 Growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the fight against climate change	CF.3 Opportunities	Medium	High	0.0488
F3.5.1 Interest in developing a common interoperability strategy	CF.3 Opportunities	Medium	High	0.0377
F1.3.2 Digital technologies application is key to a more transparent value chain and improved traceability	CF.1 Strengths	Medium	Medium	0.0341
F1.3.1 Existence of technologies currently available in the sector	CF.1 Strengths	Medium	Medium	0.0313

Table 3. Characterisation of critical factors

4.1.7 Positive vs negative categories of factors

Regarding the three indicators used to compare the priorities of positive and negative categories of factors (Strengths, Weaknesses, Opportunities and Threats) by expert groups and the average of all groups (Table 4), public administration has the highest ratios, while digital technologies companies have the lowest. This indicates that for public administration, opportunities and strengths (positive factors) are relatively more important than weaknesses and threats (negative factors) compared to digital technologies companies. In other words, public administration is the most optimistic stakeholder group whereas digital technologies companies are the most pessimistic. The group of other organisations can be classified as neutral since their ratios are quite close to the average. Agrifood companies are slightly optimistic and R&D organisations slightly negative. In any case, for all groups the positive factors faced in the short and medium term by the DT of the olive sector in Andalusia are greater than the negative ones (Multiplicative and Additive Ratios, R_m and R_a, are always greater than 1).

Indicator	Formula	Public administration	R&D organisations	Agrifood companies	Digital technologies companies	Other organisations	Average
R_m	SO/WT	1.2886	1.1000	1.1732	1.0162	1.1245	1.1371
R_a	(S+O)/(W+T)	1.1370	1.0454	1.0793	1.0066	1.0522	1.0632
V_n	S+O-W-T	0.0641	0.0222	0.0382	0.0033	0.0255	0.0306

Table 4. Indicators of positive vs negative categories of factors by expert groups

4.2 Policy strategies to strengthen the DT

This section outlines some policy strategies to promote the DT of the olive agrifood sector in Andalusia, using TOWS analysis, grouping pairs of factors with a common issue to define strategies, and prioritising these strategies according to the global priorities of their factors. An example of the definition of a policy strategy based on a pair of factors with a common issue is shown in

Figure 7.

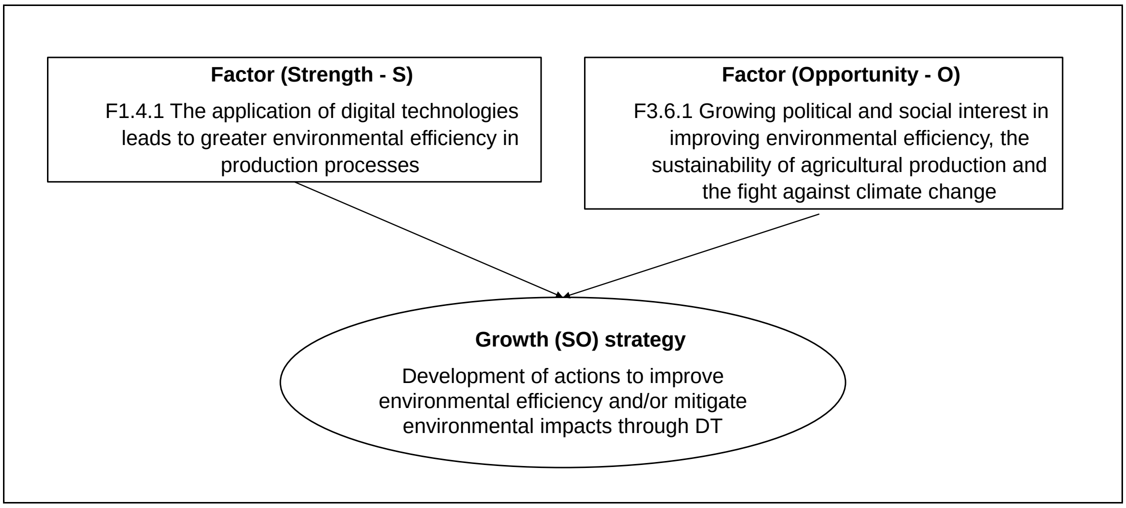


Figure 7. Example of strategy design from a pair of factors

Table 5 shows the scores (S_t) of the potential strategies that can be followed, including the 3 strategies with the highest values for each type of strategy. By types of strategies, defensive strategies are highlighted by their overall scores (0.00450), followed by growth strategies (0.00416). Defensive strategies (ST strategies) try to maximise strengths and minimise threats. Growth strategies (SO strategies) try to maximise strengths and opportunities. Next in importance, but far behind, are reorientation strategies (0.00151) and, finally, survival strategies (0.00126).

	F1. STRENGTHS (S)		F2. WEAKNESSES (W)	
	Growth strategies		**Reorientation strategies**	
F3. OPORTUNITIES (O)	SO1 (F1.4.1*F3.6.1) Development of actions to improve environmental efficiency and/or mitigate environmental impacts through DT	0.00324 (1)	WO1 (F2.3.4*F3.5.1) Development of a common interoperability strategy for the sector (specific conditions on data structure and quality)	0.00082 (5)
	SO2 (F1.3.2*F3.3.1) Improved product traceability and customer communication	0.00049 (7)	WO2 (F2.3.1*F3.4.3) Encouraging technological integration based on the information managed by the CAP	0.00039 (10)
	SO3 (F1.2.2*F3.3.3) Job creation in the olive sector linked to DT	0.00043 (9)	WO3 (F2.1.4*F3.2.3) Studies that evidence the economic viability of digital technologies projects and the real impacts on the economic performance of organizations	0.00030 (11)
	Σ	*0.00416*	*Σ*	*0.00151*
	Defensive Strategies		**Survival strategies**	
F4. THREATS (T)	ST1 (F1.4.1*F4.6.1) Impact studies on the environmental efficiency of the use of technologies, including possible undesirable effects on the territories	0.00168 (2)	WT1 (F2.3.1*F4.2.2) Fostering technological integration through coordination of innovation system actors	0.00055 (6)
	ST2 (F1.1.1*F4.3.1) Fostering employment of young people in the olive sector, generational relay and keeping the population in rural territories	0.00147 (3)	WT2 (F2.1.4*F4.2.1) Economic viability studies for DT, especially for small farmers. Financing lines for the implementation of DT projects for small farmers	0.00044 (8)
	ST3 (F1.1.1*F4.2.2) Facilitate the coordination of actors in the innovation system in Andalusia, especially those linked to the olive sector	0.00135 (4)	WT3 (F2.3.4*F4.5.3) Legislation regulating the use of digital technologies data, access, structure and quality	0.00027 (12)
	Σ	*0.00450*	*Σ*	*0.00126*

Table 5. Strategies to improve DT in the olive sector (S_t indicators and ranking)

Individually, the main strategies identified are SO1 'Development of actions to improve environmental efficiency and/or mitigate environmental impacts through DT' (0.00324), a growth strategy, and ST1 'Impact studies on the environmental efficiency of the use of technologies, including possible undesirable effects on the territories' (0.00168), a defensive strategy. These two strategies are linked to environmental issues. They are followed by ST2 'Fostering employment of young people in the olive sector, generational relay and keeping the population in rural territories' (0.00147). In fourth place is ST3 'Facilitate the coordination of actors in the innovation system in Andalusia, especially those linked to the olive sector' (0.0135). The latter two are also defensive strategies. The following strategies by importance are WO1 'Development of a common interoperability strategy for the sector (specific conditions on data structure and quality)' (0.00082), which is a reorientation strategy, and WT1 'Fostering technological integration through coordination of innovation system actors' (0.00055), which is a survival strategy. Many of the strategies identified are consistent with the needs for the digitisation of the agrifood sector in Andalusia identified by Junta_de_Andalucía (2019), such as clarifying the benefit and return on investment that agrifood actors obtain by incorporating new technologies into their processes and organisations (similar to WO3), standardise and regulate Big Data and the Organic Law on Data Protection to generate trust (WT3), access to funding and financial support for investment in equipment and technologies (WT2), and structure regional stakeholders around a cluster-type organisation (ST3 and WT1). Similarly, evidence has been found that networks which represent social capital (such as agricultural associations, irrigation communities or Protected Designation of Origin) play a key role in the innovation adoption process in the olive sector in Andalucia (Parra-López and Calatrava-Requena, 2005; Rodríguez-Entrena and Arriaza, 2013), and therefore should be considered to encourage these processes (similar to ST3 and WT1).

4.3 Methodological considerations

As seen in the previous sections, the results have been compared with those of other works in the literature based on very different methodologies and approaches, both quantitative and qualitative. These previous works are often partial, in the sense that they analyse only some parts of the problem, i.e. the prioritisation of the factors that condition the digital transformation. In general, these results tend to coincide with the integrated methodology proposed in this manuscript, as specifically discussed above. Hence, one of the added values of the work carried out is the holistic vision of this evaluation by applying a multi-criteria assessment approach, which allows for the integration of many partial aspects that are usually analysed.

Particularly, the proposed integrated methodological framework combining AHP, SWOT, PESTLE and TOWS methodologies, involves multi-criteria, multi-stakeholder problems with different and conflicting interests, and the inclusion of quantitative and qualitative, objective and subjective information, which makes it ideal for complex problems characterised by high uncertainty (lack of information) and risk (what is at stake). The results achieved, however, cannot be understood as a definitive and permanent prioritisation of digital transformation in the olive sector. The proposed methodology captures the opinions and assessments of a specific moment of the reality of the study (as if it were a snapshot). This indicates that the results obtained depend on the features of the experts interviewed, on their number, and on the current reality of the subject matter. Therefore, changes in some of these attributes could lead to changes in the obtained results. Thus, if the study is repeated in the future, even with the same experts interviewed the first time, the results may be different, because the reality of the olive sector and the digital transformation (in constant change) will be different. However, this can be understood as a shortcoming, as the proposed methodology is useful for monitoring, control and evaluation of the same subject of study over time. Finally, the crucial point for the results obtained with this framework to be a true reflection of the reality studied lies in the selection of the experts to be interviewed. Here, participants are chosen according to criteria of comprehensiveness (in-depth knowledge of the subject matter) and diversity (stakeholders), not representativeness (CEO or high position in the organisations) or quantity.

According to Klerkx et al. (2019), five thematic clusters of the social science literature on DT in agriculture can be identified: 1) Adoption, use, and adaptation of digital technologies on farms; 2) Effects of digitisation on farmer identity, farmer skills, and farm labour; 3) Power, ownership, privacy, and ethics in digitising agricultural production systems and value chains; 4) Digitisation and agricultural knowledge and innovation systems (AKIS); and 5) Economics and management of digitised agricultural production systems and value chains. This research is mainly framed in the thematic cluster 4, since it focuses on the diagnosis of the DT in the innovation system of the olive sector. Despite, as SWOT/PESTLE/TOWS are tools from the management sciences, it also considers methodological elements of cluster 5.

In the field of DT and innovation systems, the use of qualitative methods and quantitative methods based on indicators and global statistics stands out. For this reason, the use of a multi-criteria methodology, such as AHP, constitutes an innovation and an advance in the field of study. To start off, AHP is known for obtaining quantitative results, but not from general statistics, but from the answers of a group of experts with in-depth knowledge in the field of study. For this purpose, structured questionnaires are answered by the experts. This phase of the process could be comparable to methods used by other studies in the field of innovation in agriculture such as Busse et al. (2015) or Rijswijk et al. (2019), where expert interviews with semi-structured questionnaires have been used. In the case of AHP the processing and analysis of the information has been carried out as described in the Material and methods section, in contrast to the procedures carried out with semi-structured questionnaires in which specialised software for discourse analysis is used, such as MAXQDA software in Busse et al. (2015) or ATLAS.ti in Rijswijk et al. (2019).

The combination of different methods to obtain primary information has been widely used in the academic literature, and specifically in agricultural innovation. For example, Schut et al. (2015) propose the use of the RAAIS methodology, as a set of methods that allow to verify and debug the information obtained between each method used. This aspect is important to be highlighted in order to represent accurately the reality of a research project. However, methodologies such as AHP have been designed and structured to reflect reliable information on their own, so in the first instance it would not be necessary to triangulate information with other research methods if it is the same subject matter (as is the case in this manuscript). However, if different aspects are explored in more depth, the use of different methods may be appropriate. For example, Busse et al. (2015) made use of expert interviews for analysis of technologies used in animal monitoring, and expert workshops and the Delphy survey for animal production. However, it could be appropriate to implement a complementary method in a subsequent research phase. This would allow to receive feedback on the results from the experts consulted and expand elements for the interpretation of the results. Hence, for future research it would be interesting to compare the results obtained with the proposed model with those obtained with other more qualitative approaches, brainstorming, Delphi, vis-a-vis, traditional SWOT, PESTLE and TOWS, etc. However, it is important to take into account the low response rate that this type of method achieves, which can be around 20% (Busse et al., 2015). Thus, the scope of the research, time, economic resources and response rate should be assessed in order to select the research methods.

5 Conclusions

The digital transformation (DT) is considered a key issue to boost competitiveness and meet the current and future challenges in the agrifood sector. Despite the growing importance of DT on the political agenda and its consequences for the economy, traditional policies implemented are not enough to provide proactive responses to rapid technological changes and new approaches for policy planning are necessary especially at regional level. In the specific case of the olive sector in the world's leading region, Andalusia (Spain), taken as a case study, a number of public and private policy strategies have been launched to accelerate DT. However, there are no studies in the scientific literature to rationally design these strategies, and these new approaches for policy planning may help. In this context, this study proposed a new integrated quantitative methodological framework to support and inform policy planning for stimulating DT that innovatively combines AHP, SWOT, PESTLE and TOWS methodologies. AHP made it possible to make the SWOT/PESTLE analysis to prioritise the conditioning factors of DT, and the TOWS analysis to define strategies, more rational and quantitative than in conventional approaches. The proposed theoretical framework may also be valid for other policy planning in other regions and sectors. In the case study of DT in the Andalusian olive sector, the use of expert judgement is justified by the low availability of hard data and the scientific and technical nature of the issues analysed. AHP allowed to transform expert knowledge and perception into quantitative information. Methods based on expert knowledge are a good option if a decision has to be made in a reasonable period of time with a relatively low consumption of research resources.

The results obtained show that the DT in the olive sector of Andalusia is currently in a situation with optimistic perspectives, in which the positive aspects, i.e. opportunities and strengths, are in general more prominent than the negative ones, i.e. weaknesses and threats. Representatives of the public administration and agrifood companies acknowledged the DT situation more optimistically. On the other hand, representatives of R&D organisations and digital technologies companies considered the situation to be less optimistic.

In line with this optimistic vision, the most critical factors that condition the DT of the olive sector of Andalusia in the short and medium term are positive. Environmental issues stand out as an opportunity to boost a strength of DT in the olive sector, given the growing political and social interest in improving environmental efficiency, the sustainability of agricultural production and the efforts to tackle climate change. The olive sector in Andalusia should also take advantage of its strength as a world leader to promote DT. There is also a growing interest in the administrative and private sector to develop an interoperability strategy which is an opportunity to overcome the low technological integration of the value chain. Furthermore, DT can enable a more transparent value chain and improved traceability, which is a growing consumer demand for the use of ICTs in agrifood.

However, although the positive factors are very important, there are some negative ones, apart from the aforementioned low technological integration of the value chain. Thus, the lack of evidence on the economic viability of investment in digital technologies, especially for an atomised sector such as olive growing and associated industries, is a major weakness. In addition, shortage of labour and young farmers, as well as potential unintended and unanticipated effects of DT, are major threats for its development.

Taking into account all these factors, the most important policy strategies that may be defined to foster DT in the Andalusian olive sector are: 1) Development of actions to improve environmental efficiency and/or mitigate environmental impacts through DT, in which measures against possible undesired effects in territories are included; 2) Fostering employment of young people in the olive sector through DT to counteract rural depopulation and keep people in rural areas; 3) Enhancing the coordination of actors in the innovation system in Andalusia, which promotes digital culture in the region; 4) Development of a common interoperability strategy for the sector; and 5) Fostering technological integration through coordination of innovation system actors. The viability of the above-mentioned strategies can be supported by actions at the level of public policies, such as agricultural policy, environmental policy, rural policy and labour policy. However, the commitment of the sector to overcome the intrinsic deficiencies is key to a true digital transformation.

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