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Sustainability evaluation of olive oil mills in Andalusia (Spain): a study based on composite indicators

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Abstract

In recent times, the need for food systems that, in addition to being economically viable and socially equitable, use environmentally friendly production processes has made sustainable production one of the olive oil sector's main concerns and priorities. In this context, evaluation of the economic, social and environmental performance of olive oil companies and the design of sustainable management alternatives have become fundamental activities for companies. Thus, this article's main objective is to measure the sustainability of a representative sample of olive mills located in Andalusia (Spain), the leading olive oil-producing region internationally, and to identify its determinants. First, based on data envelopment analysis, synthetic sustainability indices are constructed. Second, truncated regression analysis and bootstrapping techniques are used to identify the determinants of the sustainability of olive oil mills. The results show that factors such as company size, commitment to quality, and manager training and professionalisation are crucial elements for the sustainable development of olive oil mills. These results can be useful for company managers in the design of strategies aimed at improving company sustainability.

Keywords Sustainability · Olive oil mills · Olive oil · Indicators · Andalusia

1 Introduction

Industry represents one of the most critical sectors of the world economy, is a source of employment and plays an essential role in the development of territories and the creation of wealth. However, the activities conducted in the context of this sector consume a large amount of energy and natural resources, deteriorate and limit the carrying capacity of the planet, and produce considerable greenhouse gas (GHG) emissions (Egilmez et al., 2013). According to the 5th Assessment Report of the Intergovernmental Panel on Climate Change, industry generated almost 21% of total global emissions, which has significant

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implications not only for the environment but also for the economy and society overall (IPCC, 2014).

There is a long tradition of academic debate on the role of industry in society (Waddock, 2004), offering evidence to complement the growing awareness of companies' commitment to improving their economic and social performance while also confronting problems such as global warming or depletion of natural resources (Bellantuono et al., 2018). These issues have led industry and its supply chains to enter the sustainability debate and implement management strategies in response to sustainable development challenges (Salvado et al., 2015; Singh et al., 2012). The need for more environmentally friendly production systems based on a generative, restorative and purely positive economy has led to the emergence of industrial sustainability as a flourishing field of interdisciplinary research (Elms et al., 2010).

In this context, the analysis of the food industry is fundamental not only because of its important social role and its contribution to food security and the eradication of hunger and poverty (UN, 2015) but also because its activity has a notorious impact on the functioning of the planet. Expansion of the food industry due to rapid global population growth and changing lifestyles means that global resources are being consumed at a faster rate than ever (Sellahewa & Martindale, 2010). The food sector contributes more than 25% of GHG emissions and is responsible for a significant share of total water withdrawals and generation of solid waste and wastewater (Liguori et al., 2013; Tilman & Clarck, 2014).

These reasons justify, in part, the gradual growth in recent years in the international community's interest in moving towards sustainable food systems characterised by providing food security and nutrition for today's society in a way that does not compromise the economic, social and environmental foundations of future generations (Bellantuono et al., 2018; One Planet network SFS Programme, 2020). To this end, assessing the environmental, social and economic performance of food systems and designing sustainable management alternatives is probably the key challenge of the coming decades (Notarnicola et al., 2017; Peano et al., 2015).

In the Mediterranean Basin, one of the central food systems revolves around olive cultivation and olive oil production (Türkekul et al., 2010). Spain is the world's leading producer of olive oil, and Andalusia is the most important olive oil region, accounting for more than 80% of national olive oil production, approximately 45% of European production and more than 30% of world production (Junta de Andalucía, 2020). As a result, this sector corresponds to economic activities of great importance, with deep cultural, gastronomic, topographic, social and environmental roots. Nevertheless, this sector is also evolving, with essential transformations having occurred in recent decades.

In general, the changes that have been occurring in the agricultural phase (increases in surface area, incorporation of new varieties, the trend towards more competitive systems and more intensive practices, etc.) have had significant repercussions on the olive oil processing and manufacturing phases. In the olive oil industry, these changes have been aimed mainly at increasing supply chain efficiency, organisational effectiveness and business profitability. These developments have had significant economic, social and environmental implications (Roig et al., 2006). Intensified production and processing can lead to environmental problems arising from olive mill operation, such as an increase in the use of resources (water and energy) or the generation of the following externalities: (i) noise pollution and emissions of GHGs, mainly CO_2 and SO_2; (ii) discharge (such as olive oil mill wastewater) from the processes of transforming olives into oil, which is difficult to degrade and whose effects on nature can be disastrous; and (iii) waste, such as "hojín" (a mixture of olive leaves and fine twigs), olive pits, pulp, or olive pomace.

In response to this situation, sustainable production of olive oil has become one of the sector's primary concerns and priorities. In this sense, in addition to adjustments to the agricultural production phase through practices such as sustainable intensification and organic or integrated agriculture, there have also been notable responses in the industrial phase with innovations such as the implementation of a two-phase system for olive oil extraction (Cinar & Alma, 2008) or, in the bioeconomic context, reuse of by-products generated during the oil production process and generation of new value chains through the design of concentric diversification strategies (Gallardo-Cobos & Sánchez-Zamora, 2017).

Some innovations incorporated by olive mills allow them to move towards sustainable development. However, to identify and apply the most sustainable options in any area of the agro-industrial sector, it is necessary to assess how food processing occurs (Ahmad et al., 2019). In this regard, sustainable assessment is defined as "any process that directs decision-making towards sustainability" (Bond & Morrison-Saunders, 2011; Bond et al., 2012; Hacking & Guthrie, 2008). For this purpose, sustainable development indicators are recognised as useful tools for assessing and anticipating production performance and trends, providing early warning information and aiding decision-making in any management system (Salvado et al., 2015).

Many definitions, schemes and calculation methods have been used to assess the sustainability of agri-food companies (FAO, 2013; GRI, 2016; Peano et al., 2014; Sala et al., 2015; Schader et al., 2014). From a conceptual point of view, despite the diversity of approaches, there is a broad consensus on the relevance of the economic, social and environmental dimensions emphasised in the so-called triple bottom line (TBL) approach (Elkington, 1997, 1998). However, there is a clear trend in the scientific literature towards empirical studies that place greater emphasis on the environmental dimension (Ahmad & Wong, 2019; Diaz-Chavez, 2014), focusing mainly on life cycle assessment or energy analysis in food manufacturing (Cerutti et al., 2014; de Vries & de Boer, 2010). As Schaeder et al. (2014) state, there is no single approach to either task that can be applied globally and used for all levels of assessment. As each case study has its own specificities, the specific sustainability assessment approach must be chosen according to the task for which the evaluation is to be applied.

In the agri-food industry, some studies have analysed and evaluated the sustainability of the entire sector at the national level, for example, in Canada (Pelletier, 2015), Malaysia (Ahmad & Wong, 2019; Ahmad et al., 2019), India (Garg, 2017), Turkey (Erol et al., 2009) and Spain (Blancas et al., 2013), or the regional level, for example, in the Middle East and North Africa (MENA) region (Harik et al., 2015) or Europe (Engida et al., 2018). On a more specific level, there are studies that focus on sustainability analyses of particular industries, such as pineapple canning (Leeben et al., 2013), the sugar beet (Krajnc et al., 2007) and sugar cane industries (Aguilar-Rivera, 2019), the chicken and potato value chain (Yakovleva et al., 2012), and the cheese (Arfini et al., 2019) and brewing industries (Tokos et al., 2012; Zhou et al., 2012).

In the specific case of the olive oil sector, numerous studies have analysed the sector's sustainability, mainly from an environmental point of view, using different types of life cycle assessments (e.g. Espadas-Aldana et al., 2019; Salomone & Ioppolo, 2012, among others) or environmental footprint indicators (e.g. Russo et al., 2016). However, few studies have jointly analysed the three dimensions of sustainability in this sector's industrial phase within a TBL framework. These few studies include Cappelletti et al. (2017), who analyse how the innovations introduced in the sector impact the sustainability of different olive cultivation systems and the olive oil extraction process in Italy, and Polenzani et al. (2020), who focus on the attitudes, habits and behaviour of Italian olive oil consumers and their impacts on the sustainability of olive oil production. In the Spanish context, some studies analyse different aspects of the sustainability of the sector in the agricultural phase (e.g. Alonso & Guzmán, 2006; Cabrera et al., 2013; Carmona-Torres et al., 2014; Parra-López et al., 2008, among others) but not in the processing industry, one of the most important in the national agri-food sector, and the world leader in the context of this sector. To our knowledge, no existing study specifically analyses the sustainability of olive oil mills through the construction and use of sustainability composite performance indicators while building upon the TBL framework.

In this context, a fundamental research question is formulated: What is the overall level of sustainability of olive oil mills and of each of its dimensions (social, economic and environmental), and what are the factors that determine these results? To answer this question, the main objective of this article is to measure the sustainability of a representative sample of olive mills located in Andalusia (Spain), the central olive oil-producing region at the international level, and to identify the determinants that influence it, both overall and along each of its dimensions. The results obtained may be useful for business and policy decision-making and olive oil mills' progress towards sustainable development.

To this end, this research follows the line of works that use data envelopment analysis (DEA) to measure sustainability (Zhou et al., 2018) by applying a two-stage approach. In the first phase, principal component analysis (PCA) is combined with DEA to construct partial synthetic sustainability indices. In the second phase, following Simar and Wilson (2007), truncated regression analysis and bootstrapping techniques are used to identify the determinants of olive mill sustainability. This is an innovative and original methodology in the framework of sustainability research.

The remainder of the manuscript is organised as follows. Section 2 explains the research methodology. Section 3 presents and discusses the results obtained. Finally, Sect. 4 presents the main conclusions of this research.

2 Data and methods

The geographical region selected to conduct this study was Andalusia, the world's leading olive oil-producing region (see Fig. 1). This territory has approximately 1.6 million hectares dedicated to olive cultivation. Andalusian olive oil production accounts for 80% of Spanish output and 45% of the total produced in the European Union (Junta de Andalucía, 2020). Furthermore, olive groves and their products constitute a strategic sector in Andalusia, as they generate employment, foster social cohesion and drive territorial planning, representing approximately 40% of the workforce in the entire agricultural industry and the main economic activity in more than 350 Andalusian municipalities (Junta de Andalucía, 2015). The predominant production form is cooperative societies, to which 48.2% of Andalusia's mills belong, milling approximately 65% of Andalusia's olive oil production (Junta de Andalucía, 2015). Therefore, this region is an appropriate setting in which to analyse the sustainability of olive oil mills. For this purpose, we selected a representative sample of 81 first-grade cooperative mills distributed throughout almost the entire Andalusian territory, specifically in the traditionally olive-growing provinces of Jaén, Córdoba, Seville, Cádiz, Málaga and Granada. These mills account for 20.88% of the 388 cooperative mills in Andalusia (approximate sampling error 8.15%, $p=q=0.5$, CI 90%) (Table 1).

The four phases of the methodology used to achieve the main objective and the statistical methods involved in each stage are shown in Fig. 2.

Fig. 1 Location of the study area (Andalusia)

Table 1 Technical description of the empirical study

Population	
Sampling units	Olive oil cooperative companies
Total population	388 companies
Scope	Southern olive oil cooperative companies (Andalusia, Spain)
Timescale	April–November 2019
Sample	
Type	Simple random
Sample size	81 interviews
Approximate sampling error	8.15%, $p=q=0.5$, CI 90%

Source: Own compilation

2.1 Selection and calculation of indicators to measure sustainability

One of the main steps in constructing a synthetic index is the selection of fundamental indicators based on a conceptual framework (Nardo et al., 2008). In this regard, the indicators used in this research have been selected and calculated based on the guidelines and schemes described in the specialised literature and the sustainability frameworks of the Global Reporting Initiative (GRI) (2016) and the Sustainability Assessment of Food and Agricultural Systems (SAFA) (FAO, 2013). All three TBL dimensions have been considered. Based on the criteria and subcriteria established in these frameworks, specific indicators reflecting the specificities of olive oil companies were selected. The types of industrial sustainability indicators observed in the literature vary from qualitative to quantitative or mixed, and from metric to ordinal and/or nominal. Among the latter, the proxy type is widely used for complex indicators (Hsu et al., 2013). Similarly, the number of indicators used in empirical analyses varies from a minimum of 9 (Yakovleva et al., 2012) to a

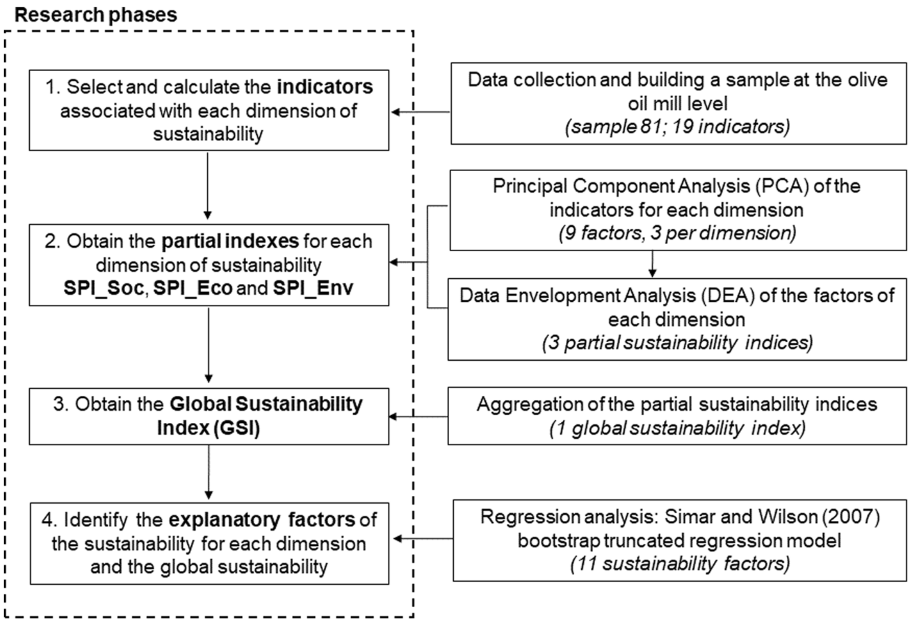

Fig. 2 Research methodology

maximum of 104 (Cagno et al., 2019), with more of these indicators associated with the environmental dimension than with the social or economic dimension. While there seems to be no consensus on the ideal number of indicators for sustainability analysis (Feil et al., 2019), some authors recommend the use of 10–20 indicators (Krajnc and Galvič, 2003) articulated in a balanced way around the three pillars of sustainability (Nordheim & Barrasso, 2007).

Based on these guidelines, 19 indicators were selected in this research: 7 associated with the social dimension, 6 associated with the economic dimension and another 6 associated with the environmental dimension. It should be noted that at all times, special attention has been given to minimising arbitrariness in the selection of indicators. To this end, numerous experts in the field, both stakeholders (i.e. technicians and managers from the mills involved in the analysis) and scientists from different disciplines, have been consulted. In addition to providing the primary data, the stakeholders also participated throughout the analysis process, mainly in the discussion and evaluation of the results obtained. It is also important to highlight that even when certain theoretical indicators are relevant, they sometimes cannot be incorporated into a practical case study if data with the required spatial and temporal resolution are not available. The indicators finally selected for each dimension, the criteria and variables that they are intended to measure, and the definition, notation and bibliography or conceptual framework on which they are based are given in Tables 2, 3 and 4.

For the data collection, primary and secondary sources of information were used. A questionnaire was designed to collect information on the company's general characteristics and its staff and on the indicators developed for the sustainability analysis. Thus, in addition to interviewing the managers of the mills and complementing the information obtained with that available in the SABI (Iberian Balance Sheet Analysis System)

Table 2 Social sustainability indicators

Theme	Criteria	Indicator	Definition	Literature review
Employment	Total workforce by employment type	Permanent staff (PERM_STAFF)	Percentage of permanent employees in relation to total employees (%)	Erol et al. (2009); Tokos et al. (2012); Ahmad et al. (2019); Cagno et al. (2019); Feil et al. (2019)
		Specialised staff (SPEC_STAFF)	Percentage of specialised personnel in relation to the total number of workers (%)	Erol et al. (2009); Tokos et al. (2012); Ahmad et al. (2019); Cagno et al. (2019); Feil et al. (2019)
	Nondiscrimination and equal opportunities. Labour rights	Gender equality (FEM_STAFF)	Percentage of employed women in relation to the total number of employees (%)	Erol et al. (2009); Tokos et al. (2012); Yakovleva et al. (2012); FAO (2013); Leeben et al. (2013); Harik et al. (2015); Ahmad et al. (2019); Cagno et al. (2019); Nikolaou et al. (2019)
	Integration, diversity and equal opportunities. Support for vulnerable people	Employees with disabilities (DISAB_STAFF)	Percentage of employees with disabilities in relation to the total number of employees (%)	FAO (2013); Ahmad et al. (2019)
Professional network	Professional community investment	Association expenditures (ASSOC)	Percentage of expenditures on professional associations in relation to total expenditures (%)	Cagno et al. (2019)
Societal commitment	Philanthropy. Community involvement. Donations and other community investments	Donation and philanthropic expenditures (DONATE)	Percentage of expenditures on donations in relation to total expenditures (%)	Erol et al. (2009); Tokos et al. (2012); Leeben et al. (2013); Harik et al. (2015); Long et al. (2016); Ahmad et al. (2019); Cagno et al. (2019); Feil et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019)
Internal professionalisation	Training	Training expenditures (TRAINING)	Percentage of expenditure on training in relation to total expenditures (%)	Erol et al. (2009); Leeben et al. (2013); Feil et al. (2015); Harik et al. (2015); Ahmad et al. (2019); Feil et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019)

Table 3 Economic sustainability indicators

Theme	Criteria	Indicator	Definition	Literature review
Production	Productive capacity	Production value (PROD_VALUE)	Average olive oil production based on the price of olive oil (1000 €)	Erol et al. (2009); Ahmad et al. (2019); Cagno et al. (2019)
	Productivity	Labour productivity (WORK_PROD-VITY)	Total company income over number of employees (1000 €/employee)	Yakovleva et al. (2012); Long et al. (2016); Manning and Soon (2016)
Costs	Financial structure. Liquidity. External sources	Financial independence (INDEPEND)	Inverse of indebtedness, understood as the financial expenses of the company with respect to its total expenses (dimensionless)	FAO (2013); Long et al. (2016)
	Financial structure. Liquidity. Self-financing	Depreciation rate (DEPREC)	Percentage of depreciation in total fixed assets (%)	Ahmad et al. (2019)
Sales	Market penetration: Competitiveness	Market share (MARKET_SH)	Percentage of the company's sales in relation to total sales of the olive oil sector (%)	Harik et al. (2015); Cagno et al. (2019); Feil et al. (2019)
	Production strategy: Value creation	Circular economy (CIRCULAR_E)	Percentage of olive oil by-product sales in relation to total sales (%)	FAO (2013); Garrido-Azevedo et al. (2017), Saidani et al. (2019); Chiappetta-Jabbour et al. (2020)

Table 4 Environmental sustainability indicators

Theme	Criteria	Indicator	Definition	Literature review
Water	Water pollution prevention	Water quality control (WATER_QUALITY)	Water quality control (1 = yes and 0 = no)	Erol et al. (2009); Tokos et al. (2012); FAO (2013); Leeben et al. (2013); Feil et al. (2015); Harik et al. (2015); Long et al. (2016); GRI Standards (2018); Ahmad et al. (2019); Cagno et al. (2019); Feil et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019)
	Water discharge by quality and destination	Water produced by destination (WATER_DESTINATION)	Destination of washing water (1 = water discharge, 2 = water pond and 3 = water treatment plant)	FAO (2013); Leeben et al. (2013); Tokos et al. (2012); GRI Standards (2018); Cagno et al. (2019); Feil et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019)
Atmosphere	Air pollution control	Air quality (AIR_QUALITY)	Control of gas emissions (1 = yes and 0 = no)	FAO (2013); Harik et al. (2015); Feil et al. (2015); GRI Standards (2016); Long et al. (2016); Ahmad et al. (2019); Cagno et al. (2019); Feil et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019)
Noise	Noise level control	Noise control (NOISE_CONTROL)	Noise level control through factory location in relation to the population (1 = within the municipality, 2 = less than 2 km from the municipality and 3 = more than 2 km from the municipality)	Erol et al. (2009); Long et al. (2016); Cagno et al. (2019); Feil et al. (2019)

Table 4 (continued)

Theme	Criteria	Indicator	Definition	Literature review
Materials and energy	Energy: renewable energies	Renewable energy and biomass (BIOMASS)	Recycling and use of own-source biomass (1 = yes and 0 = no)	Erol et al. (2009); FAO (2013); Leeben et al. (2013); Feil et al. (2015); Harik et al. (2015); Cagno et al. (2019); Nikolaou et al. (2019); Trianni et al. (2019); GRI Standards (2020)
	Materials: recycled	Recycling and use of by-products (BYPROD)	Revenues from sales of by-products (1000 €)	Tokos et al. (2012); FAO (2013); Feil et al. (2015); Harik et al. (2015); Cagno et al. (2019); Feil et al. (2019)

database, the accounts and annual reports of each of the companies for the 2015–2016 and 2016–2017 seasons were made available. Data analysis was conducted by combining the information from these two seasons to avoid the following: (i) effects of alternate bearings, which characterise production in this sector, and (ii) disparities in the temporal frequency (annual or per agricultural season) at which some of the data were available. The names of the 81 olive oil mills were anonymised for reasons of confidentiality.

2.2 Obtaining the partial sustainability indices

To obtain the three partial sustainability indices (one for each dimension), two fundamental steps were followed. First, factor analysis was conducted (principal component analysis (PCA) and orthogonal varimax rotation) with the indicators corresponding to each of the three dimensions, and then the resulting factors in each of them were grouped to form the three synthetic indices. Aggregation of these factors was conducted using the data envelopment analysis (DEA) technique. The suitability of this technique lies mainly in the fact that it allows the weights of the factors to be obtained through an objective and endogenous calculation, which is neither arbitrary nor based on opinion. The complementarity of the PCA and DEA techniques and their usefulness for calculating synthetic indices has been previously demonstrated in studies related to the measurement of different aspects of sustainability (Dong et al., 2015, 2016; Engida et al., 2018).

DEA was developed by Charnes et al. (1978) following the seminal paper of Farrell (Farrell, 1957) to measure the relative efficiency of decision-making units (DMUs) via mathematical programming. DEA benchmarks the performance of DMUs against a frontier composed of the best practices observed in the set of DMUs (Cooper et al., 2007). As a result, DEA identifies efficient DMUs (that form the so-called frontier) and inefficient DMUs (whose inefficiency value is derived from the distance to the frontier). Although the DEA technique is widely used to analyse efficiency and productivity, other applications of the technique have been developed in recent decades, including for the development of synthetic indices in the field of sustainability (Callens & Tyteca, 1999; Reig et al., 2011; Zhou et al., 2018). The use of DEA to construct composite indicators was popularised by Cherchye et al. (2007) with the "benefit of the doubt" approach. In this context, instead of transforming inputs into outputs to calculate efficiency, DEA for sustainability assessment focuses only on the achievements, that is, the output indicators, without explicitly considering the resources (inputs) used.

This literature is the basis of the model proposed below. In the specific case of this research, the objective is to construct a composite index associated with each olive oil mill based on a set of factors corresponding to the different dimensions of industrial sustainability. To this end, and under the multicriteria decision analysis approach, DEA analysis can be assimilated to a function that aggregates outputs and inputs into a single measure of value (Cooper et al., 2007; Lovell et al., 1995; Stewart, 1996). Assuming a single input for each olive mill analysed and making it equal to unity, we propose the following model:

$$\mathrm{Max}_{\mu_{ro}} \quad h_0 = \sum_{r=1}^{R} \mu_{ro} I_{ro} \tag{1}$$

subject to

$$\sum_{r=1}^{R} \mu_{ro} I_{rk} \leq 1 \quad k = 1, \ldots, K \tag{2}$$

$$\mu_{ro} \geq 0 \quad r = 1, \ldots, R \tag{3}$$

where h_0 is the sustainability (in the corresponding dimension) of the olive oil mill under analysis, μ_{ro} is the weighting of factor r, and I_{rk} represents the value of factor r.

The aim is to maximise the weighted sum of certain characteristics or attributes favouring sustainability (maximisation of a set of factors, I). We operate with a virtual input equal to unity for all mills (the first set of constraints). The weights are those that are most favourable for the attributes of the olive oil mill being analysed.

This DEA model was applied three times in this phase, once for each dimension of sustainability, to obtain the three partial indices (SPI_Soc, SPI_Eco and SPI_Env). In this way, the olive oil mills are ranked according to their relative performance level on each of the dimensions. Specifically, the model applied was an output-oriented CCR[1] with a virtual input equal to the unit, and the software used for the calculations was Banxia Frontier Analyst.

2.3 Obtaining the global sustainability index

The next stage of the research consisted of creating the global sustainability index (GSI) from the three partial indices obtained in the previous stage (SPI_Soc, SPI_Eco and SPI_Env). The TBL concept (Elkington, 1997, 1998) distinguishes and proposes a balanced approach towards economic, environmental and social aspects of business performance (Gimenez et al., 2012). All three sustainability pillars (environmental, economic and social) must be equally addressed (Corsi et al., 2020; Zhou et al., 2012, among others). Thus, the partial sustainability indices were aggregated by their arithmetic mean, as is by far the most widespread additive method (Gan et al., 2017). Then, the olive oil mills were ranked according to their sustainability level, determined by their relative performance on each of the dimensions considered.

2.4 Identification of the explanatory factors of sustainability

Once the partial and global sustainability indices were estimated, the next step was to identify which factors characterising the olive oil mills were decisive for their sustainable development. To this end, a truncated bootstrap regression analysis was conducted based on the following model proposed by Simar and Wilson (2007):

$$I = G(\beta, f) + \varepsilon \tag{4}$$

$$\text{with } \varepsilon \in N\left(0, \sigma^2\right) \tag{5}$$

[1] Named for Charnes, Cooper and Rhodes initially proposed the model in 1978. This model can have input or output orientation and operates under constant returns to scale.

where the calculated index I (in this case sustainability) is explained based on a set of factors f (in this case structural elements characterising the olive oil mills) through a function G, with the particularity that the condition $(0<I<1)$ must be fulfilled (see Simar & Wilson, 2007, for further details). As a result of the bootstrap estimation, we can obtain a number of estimates N of the unknown parameters β and σ, allowing us to establish their sampling distribution and therefore confidence intervals.

The bootstrap method is a statistical sampling procedure that is applied to draw inferences in complex problems. The basic idea of this method is to approximate the sampling distribution of the estimators based on the empirical distribution of the estimators obtained in a resampling conducted using the Monte Carlo simulation method. The procedure consists of extracting many samples generated from a first estimation and using the empirical distribution of the estimates obtained for the parameters under investigation (Staat, 2002).

Thus, four bootstrap truncated regression models (1000 replications) were estimated using the "simarwilson" package (Badunenko & Tauchmann, 2018) in Stata (StataCorp., 2019), one for each partial index (SPI_Soc, SPI_Eco and SPI_Env) and for the global sustainability index (GSI). For this purpose, each of the indices mentioned above was taken as a dependent variable, whose values ranged from 0 to 1, and the independent variables were those collected in previous works developed in contexts similar to that of this research (Dios-Palomares & Martínez-Paz, 2011; Özden et al., 2019; Özden & Dios-Palomares, 2015, 2016; Özden et al., 2015). These variables, about which the industry stakeholders were subsequently consulted, are as follows:

- Olive oil mill dimension variables
    - Size (proxied by the quantity of olives milled measured in 1000 t)
    - Work conducted by olive mill personnel (measured in 1000 h)
- Variables related to the infrastructure of the olive oil mills
    - Total number of lines in the olive oil mill (number of lines)
    - Availability of own packaging machine (1 = yes and 0 = no)
    - Availability of quality certification (1 = yes and 0 = no)
- Variables related to the staff performing management functions
    - Personal variables: gender (1 = male and 0 = female) and age (number of years)
    - Professional dedication (1 = total and 0 = partial)
    - Level of staff training: education (2 = university, 1 = intermediate and 0 = basic), management training (1 = yes and 0 = no) and olive oil training (1 = yes and 0 = no)

3 Results and discussion

Independent application of factor analysis for each of the sustainability dimensions allowed the original 19 indicators to be reduced to 9 factors, 3 for each of the three dimensions: social, economic and environmental (Table 5). The results of the factor analyses are summarised in Appendix.

The aggregation of these factors with DEA made it possible to obtain a partial sustainability index associated with each dimension. By aggregating the resulting indices in equally weighted terms, we obtained the overall sustainability index. Table 6 summarises the results obtained in each of the analyses for each of the olive oil mills. The values

Table 5 Factors linked to the different dimensions of industrial sustainability

Dimension	Factor
Social	F1: Social expenditures (professional associations and donations)
	F2: Labour market insertion and employment stability
	F3: Vocational training and specialisation (women)
Economic	F4: Productive potential
	F5: Solvency and financial independence
	F6: Circular economy
Environmental	F7: Water and washing control
	F8: Emissions and noise control
	F9: Biomass, recycling and reuse of by-products

for each of the indicators range from 0 to 1, where 1 reflects the highest relative level of sustainability.

These results show that the most favourable performance (with indices equal to 1) is exhibited by four olive oil mills on the social sustainability dimension (olive mills 06, 31, 39 and 47), five mills on the economic dimension (olive mills 03, 11, 28, 54 and 77), and six mills on the environmental dimension (olive mills 11, 46, 52, 70, 71 and 81). Olive oil mill 11 has the highest level of overall sustainability (GSI = 0.89).

The main descriptive statistics of these results are shown in Table 7. The table shows how the partial index of social sustainability (SPI_Soc) and the partial index of economic sustainability (SPI_Eco) follow a similar distribution, both with an average of approximately 0.60 and minimum values of approximately 0.19–0.28. The average values of the partial environmental sustainability index (SPI_Env) are higher than those of the other two indices and are approximately 0.76. The average global sustainability index (GSI) is 0.65 with a minimum of 0.40, which is significantly higher than the minimums of the partial indices, and a maximum of 0.89.

Table 7 also identifies which olive oil mills are "global leaders" on each dimension according to Oral and Yolalan (1990), i.e. model good practices for nonsustainable olive oil mills, and how often they do so. In this regard, on the social dimension, olive oil mill 31 stands out; on the economic dimension, olive oil mill 54 stands out; and on the environmental dimension, olive oil mill 11 stands out. These olive oil mills most often constitute the reference group for olive oil mills that present an unfavourable situation or that can still improve their sustainability. Determining the set of olive oil mills that can serve as benchmarks for those not performing at their optimum level can be useful for identifying in each case the factors and dimensions on which adjustments must be made to advance towards a sustainable development model.

To identify the explanatory factors of sustainability, the relationships between the previously calculated indices and a set of structural variables characterising the olive oil mills under study were analysed (see Tables 8 and 9). The results obtained after application of the four bootstrap truncated regression models are presented in Tables 10, 11, 12, 13.

The results show how the social dimension of sustainability (SPI_Soc) is influenced by positive or negative changes in six variables (Table 10):

- *Olive oil mill size*. Social sustainability decreases as the size of the olive oil mill increases. In general, a larger size is associated with the introduction of the latest pro-

Table 6 Partial and global industrial sustainability indices

Code	SPI_Soc	SPI_Eco	SPI_Env	GSI	Code	SPI_Soc	SPI_Eco	SPI_Env	GSI
01	0.42	0.88	0.86	0.72	42	0.46	0.71	0.54	0.57
02	0.73	0.64	0.92	0.76	43	0.66	0.20	0.98	0.61
03	0.57	1.00	0.60	0.72	44	0.76	0.40	0.74	0.63
04	0.30	0.51	0.88	0.56	45	0.87	0.70	0.62	0.73
05	0.92	0.40	0.74	0.69	46	0.49	0.55	1.00	0.68
06	1.00	0.53	0.62	0.72	47	1.00	0.75	0.73	0.83
07	0.89	0.63	0.81	0.77	48	0.51	0.19	0.74	0.48
08	0.47	0.55	0.88	0.64	49	0.61	0.38	0.69	0.56
09	0.75	0.41	0.74	0.63	50	0.53	0.57	0.76	0.62
10	0.64	0.19	0.74	0.52	51	0.28	0.55	0.74	0.52
11	0.67	1.00	1.00	0.89	52	0.34	0.35	1.00	0.56
12	0.54	0.65	0.60	0.60	53	0.43	0.57	0.88	0.62
13	0.57	0.61	0.88	0.69	54	0.41	1.00	0.77	0.73
14	0.99	0.76	0.67	0.81	55	0.29	0.69	0.99	0.66
15	0.77	0.56	0.22	0.52	56	0.34	0.76	0.58	0.56
16	0.82	0.44	0.74	0.67	57	0.36	0.71	0.59	0.55
17	0.48	0.78	0.74	0.67	58	0.56	0.59	0.64	0.60
18	0.49	0.38	0.74	0.53	59	0.58	0.27	0.74	0.53
19	0.43	0.76	0.63	0.61	60	0.53	0.56	0.77	0.62
20	0.31	0.55	0.99	0.62	61	0.70	0.71	0.64	0.69
21	0.75	0.60	0.46	0.60	62	0.97	0.72	0.93	0.87
22	0.59	0.63	0.92	0.71	63	0.56	0.69	0.58	0.61
23	0.41	0.56	0.74	0.57	64	0.30	0.36	0.55	0.40
24	0.75	0.52	0.57	0.61	65	0.51	0.79	0.82	0.71
25	0.64	0.81	0.80	0.75	66	0.41	0.51	0.91	0.61
26	0.81	0.70	0.78	0.76	67	0.77	0.56	0.46	0.60
27	0.86	0.48	0.74	0.69	68	0.45	0.35	0.90	0.57
28	0.57	1.00	0.70	0.76	69	0.62	0.24	0.98	0.61
29	0.66	0.68	0.62	0.65	70	0.58	0.21	1.00	0.60
30	0.56	0.37	0.91	0.61	71	0.67	0.94	1.00	0.87
31	1.00	0.35	0.74	0.70	72	0.29	0.68	0.60	0.52
32	0.74	0.53	0.75	0.68	73	0.48	0.69	0.83	0.67
33	0.89	0.39	0.75	0.67	74	0.52	0.74	0.77	0.68
34	0.61	0.44	0.70	0.58	75	0.29	0.45	0.74	0.49
35	0.77	0.65	0.77	0.73	76	0.54	0.46	0.95	0.65
36	0.32	0.58	0.74	0.54	77	0.50	1.00	0.87	0.79
37	0.55	0.74	0.68	0.66	78	0.69	0.76	0.74	0.73
38	0.39	0.25	0.69	0.44	79	0.63	0.69	0.74	0.69
39	1.00	0.69	0.74	0.81	80	0.61	0.75	0.78	0.72
40	0.63	0.79	0.78	0.73	81	0.63	0.78	1.00	0.80
41	0.40	0.41	0.75	0.52					

Table 7 Descriptive statistics of the partial and global sustainability indices

Statistics	Sustainability indices			
	SPI_Soc	SPI_Eco	SPI_Env	GSI
N	81	81	81	81
Number of benchmark olive oil mills	4	5	6	–
DMU benchmarks (frequency in the reference set)	31 (76), 06 (62), 39 (37), 47 (11)	54 (55), 03 (46), 28 (40), 77 (33), 11 (21)	11 (59), 46 (54), 71 (45), 81 (11), 70 (10), 52 (9)	–
Mean	0.60	0.59	0.76	0.65
Std. deviation	0.20	0.20	0.15	0.10
Minimum	0.28	0.19	0.22	0.40
Maximum	1.00	1.00	1.00	0.89

Table 8 Summary statistics of the sustainability factors of olive oil mills (continuous variables)

Variables	*N*	Statistics			
		Mean	Std. deviation	Minimum	Maximum
Olive oil mill size: olives milled (1000 t)	81	18.11	17.61	1.55	90.51
Labour (1000 h)	81	29	39	2	315
Number of lines in the olive oil mill	81	3	2	1	16
Management age	81	51	10	28	68

Table 9 Summary statistics of the sustainability factors of olive oil mills (categorical variables)

Frequency (%)	
Variables	Olive oil mills
Availability of own packaging machine	24.7
Quality certifications	14.8
Management gender	
Male	87.7
Management dedication	
Total dedication	86.4
Management level of education	
Basic	23.5
Intermediate	13.5
University	63.0
Management training	80.2
Olive oil training	6.2
N	81

Table 10 Truncated bootstrap regression for the social sustainability index

Explanatory variables	Observed coefficient	Bootstrap std. err	[95% conf. interval]	
			Lower	Upper
Constant	0.6669	0.1297	0.4035	0.9305
Olive oil mill size	−0.0085***	0.0024	−0.0133	−0.0041
Labour	0.0026***	0.0007	0.0013	0.0042
Number of lines	0.0305**	0.0144	0.0025	0.0605
Availability of own packaging machine	0.0860*	0.0477	−0.0055	0.1784
Quality certifications	0.1050*	0.0554	0.0011	0.2202
Management gender	−0.1891**	0.0565	−0.3011	−0.0850
Sigma	0.1470	0.0127	0.1096	0.1589
Number of DMUs	81			
Number of obs	77			
Number of efficient DMUs	4			
Number of bootstr. reps	1000			
Wald χ^2 (12)	37.86			
Prob > χ^2 (12)	0.0002			

Only significant variables are shown. *$p<0.1$, **$p<0.05$, and ***$p<0.001$. The omitted category is intermediate education

Table 11 Truncated bootstrap regression for the economic sustainability index

Explanatory variables	Observed coefficient	Bootstrap std. err	[95% conf. interval]	
			Lower	Upper
Constant	0.4545	0.1108	0.2397	0.6882
Olive oil mill size	0.0082***	0.0022	0.0040	0.0125
Labour	−0.0022**	0.0010	−0.0042	−0.0002
Basic education	−0.1091*	0.0570	−0.2196	0.0015
Management training	0.0953**	0.0432	0.0114	0.1826
Sigma	0.1341	0.0112	0.0998	0.1441
Number of DMUs	81			
Number of obs	76			
Number of efficient DMUs	5			
Number of bootstr. reps	1000			
Wald χ^2 (12)	52.85			
Prob > χ^2 (12)	0.0000			

Only significant variables are shown. *$p<0.1$, **$p<0.05$, and ***$p<0.001$. The omitted category is intermediate education

duction innovations and mechanisation of olive oil extraction. Consequently, tasks in the industry become more professionalised, while the number of people required for olive oil production is reduced.

Table 12 Truncated bootstrap regression for the environmental sustainability index

Explanatory variables	Observed coefficient	Bootstrap std. err	[95% conf. interval]	
			Lower	Upper
Constant	0.6748	0.1121	0.4581	0.8837
Olive oil mill size	0.0039*	0.0021	−0.0002	0.0082
Management gender	0.0926**	0.0456	0.0050	0.1828
University education	0.0976**	0.0461	0.0007	0.1840
Management training	−0.0700*	0.0419	−0.1506	0.0147
Sigma	0.1208	0.0113	0.0863	0.1309
Number of DMUs	81			
Number of obs	75			
Number of efficient DMUs	6			
Number of bootstr. reps	1000			
Wald χ^2 (12)	22.30			
Prob > χ^2 (12)	0.0343			

Only significant variables are shown. *$p<0.1$, **$p<0.05$, and ***$p<0.001$. The omitted category is intermediate education

Table 13 Truncated bootstrap regression for the global sustainability index

Explanatory variables	Observed coefficient	Bootstrap std. err	[95% conf. interval]	
			Lower	Upper
Constant	0.5890	0.0669	0.4507	0.7124
Quality certifications	0.0610**	0.0283	0.0085	0.1179
Sigma	0.0833	0.0069	0.0630	0.0898
Number of DMUs	81			
Number of obs	81			
Number of efficient DMUs	0			
Number of bootstr. reps	1000			
Wald χ^2 (12)	32.17			
Prob > χ^2 (12)	0.0013			

Only significant variables are shown. *$p<0.1$, **$p<0.05$, and ***$p<0.001$. The omitted category is intermediate education

- *Labour*. The recruitment of personnel has a positive influence on social sustainability. Olive oil mill cooperatives operate in Andalusian municipalities, where the agri-food sector plays a vital role as a driver of rural employment, helps root the population in these territories and promotes social innovation processes (Sánchez-Martínez et al., 2020).
- *Number of lines*. The greater the number of production lines, the higher is a mill's social sustainability. Olive oil mills with several lines to produce different types and varieties of olive oil require specialised labour adapted to each of these lines' specific needs. For this reason, in these mills, the relative budget for employee training and participation in professional associations is usually higher. All of this leads to an improvement in the social performance of the company.

- *Availability of own packaging machine*. Olive oil mills that have their own packaging machines show greater social sustainability. First, this circumstance is related to the fact that this activity generally requires more labour, which must be specialised to complete the tasks required in this area; second, more women are usually employed in the packaging section. Thus, the generation of a greater volume of specialised and equitable work derived from the mill's access to its own packaging machine has a positive impact on these companies' social results.
- *Quality certifications*. Olive oil mills with quality certifications, such as certification under the ISO 9000, ISO 14000 or ISO 22000 standards, are more socially sustainable. This is mainly because these mills fulfil the social function of ensuring the quality of production increasingly demanded by consumers. According to Erraach et al. (2011), the quality characteristics most demanded by consumers are organoleptic (olive oil acidity, flavour, colour, etc.), sociocultural (job creation in rural areas, rural population rootedness, etc.) and environmental (organic production, etc.) in nature. In this regard, we can speak of conscious and responsible consumers (Torres-Ruiz et al., 2020).
- *Management gender*. Olive oil mills with women in management show high levels of social sustainability. The incorporation of women in management and decision-making positions in the olive oil sector demonstrates a process of empowerment, integration and equal opportunities in the workplace and has a positive impact on the development and sustainability of the rural territories in which the mills conduct their activity (García-Sanz, 2004).

The results of the second regression analysis model reveal how the economic dimension of sustainability (SPI_Eco) is influenced by changes in four explanatory variables (Table 11):

- *Olive oil mill size*. Larger olive oil mills are more economically sustainable. As their size grows, olive oil mills benefit from economies of scale that allow them to perform better economically and introduce more eco-compatible technologies. These results are consistent with those obtained by Leeben et al. (2013), who also found a positive relationship between the economic sustainability of the agri-food industry and firm size, and with those of Medina-Viruel et al. (2014), who showed the fundamental role of the size of Andalusian olive oil cooperatives in improving their financial resource endowment.
- *Labour*. The smaller the number of workers is, the greater the economic sustainability of the olive oil mill. This may be explained by the low productivity of the labour factor in olive oil mills, which leads to a negative correlation between the labour factor and profitability. Moreover, due to the automation of processes, less labour is required, as pointed out by Kumar (2016) for Portuguese olive oil mills. These results are in line with those obtained in other studies on Andalusia (Dios-Palomares & Martínez-Paz, 2011). Likewise, they are similar to those obtained in comparisons of Andalusian and Turkish olive oil mills (Özden & Dios-Palomares, 2015, 2016; Özden et al., 2015) and of Turkish and Italian mills (Özden et al., 2019).
- *Basic education*. The academic level of the top management of an olive oil mill influences the mill's economic sustainability. When this level is basic, sustainability is lower. As Medina-Viruel et al. (2014) stated, a high level of education improves managers' skills so that they can effectively face the economic and financial challenges faced by Andalusian olive oil cooperative enterprises.

- *Management training*. Managerial training has a positive influence on the economic sustainability of an olive oil mill. These results are consistent with those observed in Parras et al. (2013), who showed the importance of factors such as training and professionalisation for the success of Andalusian olive oil cooperatives. These results are also similar to those found by Özden et al. (2019) for a sample of Turkish and Italian olive oil mills.

The results of the third regression analysis model show a relationship between the environmental dimension of sustainability (SPI_Env) and four explanatory variables (Table 12):

- *Olive oil mill size*. Larger mills are more environmentally sustainable. The operation of these large mills and their significant production volume, with strong economies of scale and scope, make certain environmental innovations feasible, and a large size is required to make them profitable. Among the outstanding innovations aimed at more ecologically responsible production that minimises environmental impacts are the incorporation of the two-stage system (Cinar & Alma, 2008), innovations that allow the use of by-products as an alternative to raw materials of fossil origin (e.g. Christoforou et al., 2016; Karaca & Ozturk, 2018) and innovations in buildings (Barreca et al., 2017).
- *Management gender*. Olive oil mills managed by men are more environmentally sustainable. This could be related to women's low representation among STEM degree holders due to the STEM gender gap (see Kanny et al., 2014; Buse, 2018; Berra & Cavaletto, 2020, among others). These degrees provide the technical training needed to undertake the technological innovations required to move towards more environmentally sustainable production processes.
- *University education*. Olive oil mills with university-educated managers are significantly more environmentally sustainable. Managers with higher education levels are better able to learn and adapt to change and tend to have a greater awareness of the ecological issues related to olive oil production (Gómez-Limón & Arriaza-Balmón, 2011). In this respect, Özden and Dios-Palomares (2015) showed a positive influence of worker qualifications on the environmental efficiency of the Andalusian and Turkish olive oil mills analysed.
- *Management training*. Managerial training has a negative influence on the environmental dimension of sustainability. This could be related to the fact that this type of training, which is more focused on the company's administrative and management aspects, orients the decisions of olive oil mill managers towards economic and social rather than environmental issues.

Finally, the results of the fourth regression analysis model (Table 13) reveal a direct and positive relationship between the global sustainability index (GSI) and the explanatory variable *Quality certifications*. As previously mentioned, this type of certification reflects different aspects of quality in the olive oil production process (organoleptic-productive but also socio-cultural and environmental). In a scenario of growing globalisation in which competition in the olive oil sector is increasing, a commitment to quality—not only of the product but also of the production process—has become a strategic determinant of the economic, social and environmental sustainability of olive oil companies. Quality conceptualised in this way, with reference to both the characteristics of the olive oil itself and the manner in which it has been produced, is currently one of the most highly valued aspects among consumers of this product (Del Giudice et al., 2015; Gázquez-Abad & Sánchez-Pérez, 2009; Polenzani et al., 2020).

4 Conclusions

Despite the growing interest in the analysis of sustainable development and the multitude of studies that address it, few studies—and practically no empirical studies related to the agri-food industry—focus on the industrial phase of the olive oil sector. This research has made progress in designing a methodology to both measure the sustainability of olive oil mills and identify the determinants that affect it. However, the lack of previous studies that provide a reference for analysing the sustainability of olive oil mills and the need to adapt the multiple schemes, approaches and methods used in other fields to this sector have posed a significant challenge in developing the research.

Despite these difficulties, the proposed methodology has several characteristics that make it practically useful and applicable in this and other geographical areas: (i) it is based on an extensive literature review and features the participation of the main stakeholders involved in the management of olive oil mills; (ii) it presents an integrated and holistic view of the concept of industrial sustainability and its different dimensions; (iii) it represents a step forwards in the operationalisation of this concept and makes it measurable; (iv) the measurement is based on a careful selection of indicators and is conducted in stages through aggregation of the elements, thus facilitating understanding of the analysis; (v) it provides individualised information for each company, its relative sustainability situation and identification of potential elements for improvement; and (vi) it can be considered a potentially useful tool for managers and decision-makers to design strategies to improve companies' sustainability.

From the application of this methodology, the results reveal that in general, smaller olive oil mills are more socially sustainable and larger mills more economically and environmentally sustainable. Regarding the characteristics related to infrastructure, the mills that have the largest number of milling lines, that have their own packaging machine and that incorporate quality management systems are the most sustainable from a social point of view. The variables related to management staff, in regard to both gender and levels of education and training, also prove to be, from different points of view, determinant for the sustainable development processes of olive oil mills.

Based on these results, the following conclusions regarding the determinants of the sustainability of olive oil mills can be drawn.

- Olive oil mill size and increases in company size are fundamental factors in moving towards more sustainable processes. The main challenge in this context is identifying how a company can grow, thus improving its market access, achieving economies of scale and improving its environmental sustainability. This entails reducing the main elements of social sustainability (employment, territorial identity, population rootedness, etc.). The formulas that can be followed to achieve this optimum are highly varied and of very different types (mergers, horizontal integrations, vertical integrations, etc.), as are the results and impacts derived from such actions. Integration through real and effective cooperation between olive oil mills stands out (Luo et al., 2020). Such cooperation would allow sharing not only of costs but also of broader strategies, thus increasing the size of mills while maintaining their "smallholder" ownership structure and sharing the benefits among a larger number of partners. This would contribute to a better distribution of wealth and encourage the population to settle in rural areas. This cooperation would also have the potential to improve olive growers' and mills' contractual power in the sale of their products, thereby balancing the traditional mismatch in the Spanish olive oil market.

- In a context such as that in which the olive oil sector operates, characterised by robust internationalisation of production and consumers who are increasingly informed and aware of foodstuffs' nutritional and health values, a commitment to quality is not simply an opportunity but a necessity. In this sense, it is essential to increase the implementation of quality management and certification systems, both public and private (ISO but also BRC Food, GlobalG.A.P., etc.), which foster differentiation strategies and access to certain markets that require this type of system for product entry. It is also advisable to make progress in the production of extra virgin olive oils with differentiated quality, both in terms of their origin (PDO, PGI) and the way that they are produced (integrated, organic, biodynamic production, etc.) and to link these processes to the social externalities that olive growing generates in the territories (the vitality of the territory, maintenance of the landscape and heritage, etc.). A question of interest in this respect is the necessity and benefit of understanding quality in an integral way. That is, quality is not only about the organoleptic characteristics of olive oil but also about the sustainability of the whole production process.
- The training and professionalisation of those responsible for managing olive oil mills is a fundamental element for business sustainability. Olive oil companies need to incorporate management professionals with different specialisation profiles, ranging from those with expertise in purely economic, commercial and financial matters to profiles covering more technical and agri-environmental aspects. In this sense, it is necessary to improve the organisation of this type of company by creating efficient decision-making structures and processes in the different areas of management. In such a context, which is tending towards digitalisation of processes within so-called Industry 4.0, training managers in digital tools is vital for the improvement of management, marketing, competitiveness and business sustainability.

Finally, it is essential to state that despite the contributions made in this research framework, there are still lines of action and improvements to be pursued. In this sense, from a methodological point of view, the debate on the convenience of integrating indices with and without weights in each of the stages is still open. Furthermore, although this research has been conducted with the collaboration of stakeholders and qualified informants, the criteria and indicators used should continue to be validated through sensitivity analyses in case any adjustments need to be made or any other appropriate factors need to be included (e.g. sustainability of buildings (Barreca et al., 2017) by means of building information modelling (BIM) and building energy model (BEM) environmental assessments). In this vein, based on the main determinants of sustainability, it would be advisable to analyse the suitability of incorporating these elements in strategies that contribute to the sustainable development of olive oil mills. Finally, it is essential to accept the challenge of giving continuity to the approach developed here and building a model that would allow the sustainability indices to be updated permanently and semiautomatically. This action would allow managers to obtain real-time information, reduce their uncertainty levels and thus facilitate adoption of the best decisions.

Appendix

See Table 14.

Table 14 Results of the principal component analysis by sustainability dimension

Indicators	Dimensions of sustainability								
	Social			Economic			Environmental		
	Factors obtained								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
PERM_STAFF		0.779							
SPEC_STAFF			0.518						
FEM_STAFF		0.604	0.520						
DISAB_STAFF		0.425							
ASSOC	0.798								
DONATE	0.756								
TRAINING			0.782						
PROD_VALUE				0.956					
CIRCULAR_E						0.966			
WORK_PRODVITY				0.568					
MARKET_SH				0.967					
INDEPEND					0.852				
DEPREC					0.854				
WATER_QUALITY							0.757		
WATER_DESTINATION							0.627		
AIR_QUALITY								0.731	
NOISE_CONTROL								0.751	
BIOMASS							0.536		0.478
BYPROD									0.875
% variance	18.968	18.427	16.980	36.540	24.359	17.189	22.718	19.268	17.945
% cumulative variance	18.968	37.395	54.375	36.540	60.899	78.088	22.718	41.986	59.931

Table 14 (continued)

Indicators	Dimensions of sustainability								
	Social			Economic			Environmental		
	Factors obtained								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
Statistics	KMO: 0.447			KMO: 0.534			KMO: 0.517		
	Bartlett: 21.510			Bartlett: 234.827			Bartlett: 13.350		
	gl: 21			gl: 15			gl: 15		
	Sig.: 0.428			Sig.: 0.000			Sig.: 0.575		

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Declarations

Conflict of interest We have no known conflict of interest to disclose.

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