

MULTI-OUTPUT EFFICIENCY IN THE ANDALUSIAN OLIVE OIL INDUSTRY

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ABSTRACT

This paper studies the level of technical efficiency in the olive oil industry from a multi-output perspective, and examines olive oil production in quantitative and qualitative terms. The study also covers the environmental impact of the production process. These are key issues due to the current environmental, organoleptic and food traceability requirements of the EU Common Agricultural Policy (CAP). Furthermore, product differentiation is sought after in today's ever more demanding markets. The production of olive oil in Andalusia (Spain) is the most important agricultural food industry in the whole region and it represents 30% of world olive oil production. Three data sources have been used: a comprehensive survey to a sample of olive oil producers, their financial reports, and the opinion of a group of experts in olive oil production techniques interviewed by means of the Delphi survey. With this data and after the construction of indicators, a production frontier is elaborated by applying an extension of the Data Envelopment Analysis (DEA) technique. This will allow for the measuring of the relative technical efficiency indices and set specific efficiency indices for both the quality of the oil produced and the environmental impact of the production process. Those factors impacting on efficiency are determined by a truncated regression model with bootstrap. The results show a medium-high level of relative technical efficiency and highlight the importance of efficiency factors involving production and marketing associations.

Keywords: Efficiency; DEA; olive oil industry; quality index; environmental index; bootstrap; Andalusia.

JEL: C14,C61,D24,L66

1. - INTRODUCTION

Olive oil is a product of particular importance within the Mediterranean agricultural food system, and more specifically in Spain, owing to two main reasons: first, because olive oil is an essential component of the so-called “Mediterranean diet” (Díaz-Méndez and Gómez-Benito, 2010); and second, because Spain, and Andalusia in particular, is the world’s main production area. Thus, over the last five years (2005-2009), more than 40% of the olive oil produced worldwide is Spanish in origin (IOC, 2010), and over 80% of this comes from Andalusia (MAPA, 2009). The olive oil production industry, which is the object of this study, is the central part of a production chain that starts in the olive groves and ends at the olive oil packaging and marketing sector. This production area is highly regulated by the EU Common Agricultural Policy (CAP) through the Common Organization of the Market in Olive Oil, pursuant to Commission Regulation (EC) 136/66, and its successive reforms in 1998 (Commission Regulation (EC) 1638/98), 2004 (Commission Regulation (EC) 865/2004) and 2007 (Commission Regulation (EC) 1234/2007). It has been precisely the aids from the CAP that have changed the olive sector scene. There has been a significant increase in the production, mainly because of management intensification by implementing modern fertirrigation technologies, which have meant not only the economic improvement of the areas related to this sector (Viladomiu and Rosell, 2004), but also the onset of environmental problems (Scheidel and Krausmann, 2011). The CAP tends towards the gradual reduction of direct support to production (Anania, 2009), which is now being discussed for the 2013 CAP reform (EU, 2010). This is why the oil industry will necessarily have to increase its level of direct profitability. Thus, efficiency and productivity levels have to increase, and trade policies devoted to open new competitive markets (Wiesman, 2009) have to be put into practice in order to compensate for the continuing decrease in support for production (Mili, 2009). To this effect, a recent study (Graaff et al., 2011) shows that, without subsidies, only intensive olive farms are financially viable, and that traditional farms, even with the present subsidies, have to deal with returns to labour below local wage rates.

The olive oil sector has a special vertical structure and some features that make it different from other agro-industrial sectors (Fischer and Hartmann, 2010). This sector comprises three links in the value chain (MAPA, 2010): (1) olive producers (olive grove management); (2) industrialization, including

oil extraction machinery (mills) and processing/refining plants; and (3) distribution. For the last campaign for which there is official data (2007-2008), the total costs of the production line in Spain reached 90% of the selling price of virgin olive oil to the public. The sharing of these costs was as follows: 68% to producers, 8% to oil mills, 20% to processing plants, and 4% to distribution. The processing and distribution sector is concentrated in few companies, and the large-scale distribution is taking most of olive oil sales to household consumers, meaning that the remaining distribution channels are being pushed into the background (Langreo, 2010).

Consequently, the primary olive sector operates in a generic strategic frame in quasi-perfect competitiveness, whereas the refiner-processor and the distributor work in an ever more concentrated environment, which grants them a significant market power. The pressure posed by the reduction of trade margins in large-scale distribution is getting to the lowest links of the chain, and making it difficult for the extraction industry and olive producers.

The olive oil extraction industry, object of this study, is the intermediate link of the chain and is in a critical situation at the present time. On the one hand, olive oil supply is micronized seeing that there are many small-scale producers. However, demand is reduced to two or three main groups that take advantage of their controlling the price in commercial transactions. This has caused a clear downward trend in olive oil selling prices in real terms over the last years (MAPA, 2010).

As for the relationship between producers and extraction plants, there is a special horizontal integration in the sector because of the important presence of cooperative associations formed by producers. These associations fulfill the functions of primary industrialization of their members' olives (Parras and Senise, 2003).

Then, in summary, the olive oil extraction industry is suffering pressure from both fronts given its intermediate position in the value chain. This forces this sector to consider the need to work in the most efficient way by taking into account the three aspects which this paper focuses on: production, quality and environmental compliance. The enhancement of these aspects is an essential goal for the extraction industry to achieve the increase in competitiveness it needs to survive in this challenging commercial scene.

The social, financial and environmental importance of the olive sector in Spain and especially in Andalusia is a widely known and researched reality (EU, 2007). Nearly 90% of all olive production in this region (MAPA, 2010) is used to produce oil, which means that the future of the olive sector is closely related to and conditioned by the future of the extraction industry.

In addition, around 70% of the extraction plants in this region are cooperative associations of olive producers, which clearly highlights the above-mentioned horizontal integration and dependence (Bruque and Moyano, 2006).

The analysis of production efficiency is very often applied within the scope of both technical efficiency using the frontier production function, and allocative and economic efficiency based on the cost or the profit frontier. Nowadays mathematical programming using Data Envelopment Analysis (DEA) and the so-called econometric frontier are the most widely used methodologies in efficiency estimation in frontier function (Cooper et al , 2006). These methods allow for both the estimation of the average efficiency level of the sample and the efficiency score of each firm.

The study of efficiency in the agricultural sector has a great tradition which is shown by the meta-analysis performed by Bravo-Ureta et al. (2007), who examined 167 technical efficiency studies at the firm level. Regarding the field of olive production in Spain, some studies recently carried out by Amores and Contreras (2009) analyzed the efficiency of olive groves in Andalusia in terms of farming typologies. Lambarra et al. (2007) studied the technical efficiency and the increase in productivity of the Spanish olive groves. The latest and most significant studies at international level are those by Giannakas et al. (2000), Tzouvelekas et al. (2001), Karagiannis et al. (2003), and Karagiannis and Tzouvelekas (2009), all of them dealing with the technical efficiency of olive groves in Greece. As regards the analysis of the efficiency of the olive oil mill industry, there are only two relevant studies: Millán (1986) and Damas and Romero (1997), both analyzing the technical efficiency of olive oil mills in the province of Jaén (Spain). Research on the efficiency of this industry outside Spain has not been found.

The interest of this paper lies in the lack of recent studies dealing with the efficiency level of this industry, its socioeconomic relevance and the need to upgrade the direct competitiveness of the primary links of the sector's value chain. The main objective is the measurement of technical

efficiency and the assessment of the possibilities for improvement in the resources management. This is a key aspect to explain the survival of agro-industrial companies in the market, as Dimara et al. (2008) corroborate in the case of Greece.

Quality and environmental managements are business practices that affect firm performance (Molina et al., 2009). Furthermore, in order to meet this goal, indicators of the levels of environmental impact and quality control in the production process have been designed and constructed. These indices are another important contribution of this study. The conjunction of both gives rise to a third contribution, namely the construction and estimation of indicators of technical efficiency of quality and environmental managements. These are two key issues for the future of this sector and the manufacture of a high-quality product that will allow for the implementation of strategies for market differentiation and segmentation (Gázquez and Sánchez, 2009). Moreover, they are also essential to meet the current administrative regulations requiring environmentally sustainable processes and to obtain competitive advantages involving image, since the consumer is becoming ever more demanding with regard to these issues (Martínez-Carrasco et al., 2009).

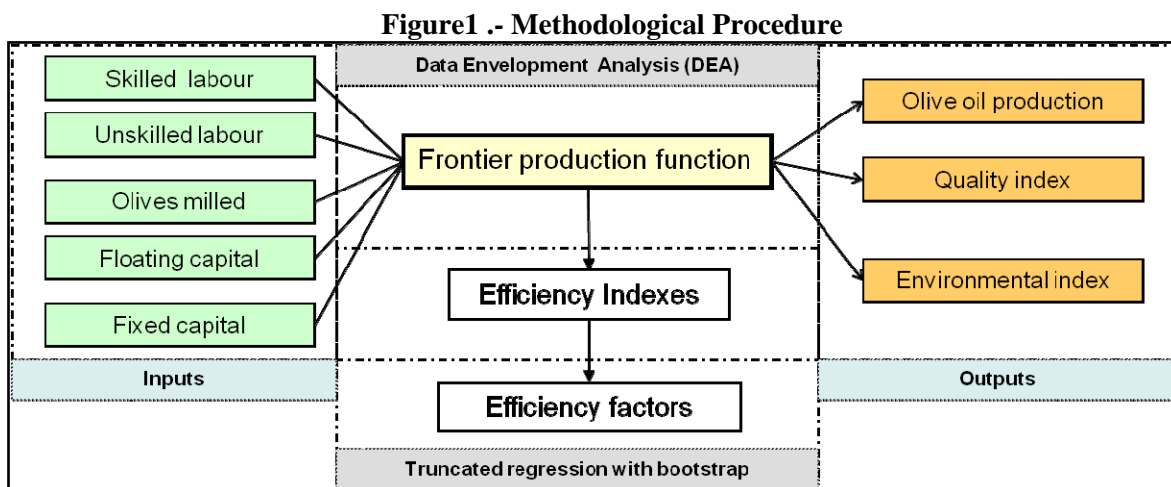
To sum up, a high quality level, adjusted prices and environmental conditions that meet the demands of ever more concerned consumers will allow olive oil to reach a good position in the market. Furthermore, regardless of the CAP requirements, this would safeguard the sector's subsistence. Therefore, in the first place, it is necessary to know the current efficiency level of the sector, which is the starting point of this research. Afterwards, firms' management of resources for olive oil production, their quality level and environmental compliance are studied in greater depth.

The rest of the paper is structured in the following way: Section 2 describes the methodology and data used for the efficiency analysis, the results of which are exposed in Section 3. Then, the main conclusions of the study are presented in Section 4. Finally, the bibliographic references are included in Section 5.

2.-MATERIALS AND METHODS

The main methodology used is the estimation of a production frontier function with 5 inputs and 3 outputs in order to measure the technical efficiency in this sector. Olive oil extracting companies

(mills) located in Andalusia are the unit of analysis, that is, the DMU or decision making unit. The outputs considered are the quantity of olive oil produced, its quality and the environmental impact of the production process. On the other hand, skilled and unskilled labour, olives milled, floating capital and fixed capital are the five inputs used. Once the frontier is estimated and three efficiency indices (total, environmental and quality efficiency) are derived from it, those factors affecting the efficiency are studied by means of a truncated regression model with bootstrap. Figure 1 shows a sketch of this methodology.



2.1 Data and output index

The data used come from a comprehensive sample of 88 olive oil mill companies for the 2005-2006 campaign in Andalusia, which constitutes over 10% of all the firms in this area. Three main data sources have been used: the financial reports of each firm, a direct survey to the managers and/or staff in charge, and a Delphy interview to some experts in the field. The variables used in the efficiency analysis are the following:

- Skilled labour (hours/campaign)
- Unskilled labour (hours/campaign)
- Floating capital: operating expenses and other maintenance expenses (€/campaign)
- Fixed capital: (€/campaign)
- Olives milled (Ton/campaign)

- Olive oil production (Ton/campaign)
- Quality index
- Environmental management index

The labour variable has been divided into two types: skilled labour, which involves technical and management jobs, and unskilled labour, which includes unqualified ones. Given the high percentage of temporary contracts, this variable has been aggregated by taking into account the total number of hours worked, rather than the amount of jobs. The floating capital has been measured through the total amount of operating and maintenance expenses, which square the operative concept of flow capital (OECD, 2001). The consumption of fixed capital has been obtained by subtracting the accumulated capital consumption from the gross capital stock, using standard service lives of assets for manufacturing food industry (OECD, 2001).

The variables of quality and environmental impact have been measured for each DMU by using complex indices (elaborated by the authors) that show technical aspects of the production process. The elaboration of these two indices for each firm includes the following four phases (OECD, 2008):

- I. Determination of the index attributes (k).
- II. Determination of the weights (preferences) of each of the attributes (w_k).
- III. Determination and measurement of the m variables of each i DMU, related to the evaluated attributes (x_{mi}).
- IV. Aggregation of the variables, according to the given weight of each attribute, in order to construct the index. Assuming an additive formulation that is separable in its attributes, the index will have the expression [1].

$$I_i = 100 * \sum_{k=1}^k w_k * f_k(x_{mi}) \quad [1]$$

This formulation can always be interpreted as an index function of the utility gradient, which, in terms of assessment of alternatives, has the same implications as working with a multiattribute utility function (Schoemaker and Waid, 1982).

A two-round Delphi survey (Dalkey and Helmer, 1963; Mili and Rodríguez-Zuñiga, 2001) to a group of 16 experts in the olive oil technological production process has been carried out for phases I) and

II). They evaluated a wide set of attributes referring to the quality and the environmental impact of the production process (Rikkonen, 2005), by means of a regular ranking on a Likert scale (0 null importance – 5 maximum importance). This ranking has allowed for the determination of the relevant attributes for the index (phase I) and the weight of each of the attributes in the index (phase II). The addition of the judgment of the experts was carried out through a geometric mean, which is stronger than the conventional arithmetic mean when it comes to considering the extreme values for some of the individual weights (Aull-Hyde et al., 2006). The data for phase III were taken from the direct surveys to olive oil mills managers, being binary variables in all cases. Finally, the environment and quality indices, which are presented together with the attributes and weights obtained through the Delphi analysis in the results section, were constructed according to formulation [1].

2.2 Technical efficiency analysis

The technical efficiency index (TEI) of the olive oil mills is calculated by means of the resolution of a multi-output mathematical programming model developed as an extension of DEA (Data Envelopment Analysis). This non-parametric efficiency estimate method applying frontier functions was introduced by Charnes et al. (1981) and has been modified and extended after further research (Faré et al., 1994; Cooper et al., 2006). The DEA allows for the evaluation of each DMU by producing one or several outputs from a common set of inputs. The efficiency of each unit is defined as the ratio of the weighted sum of outputs in relation to the weighted sum of inputs. They are not evaluated in relation to an ideal production frontier but by comparison to the most efficient units in the sample. Thus, the concept used throughout the analysis is a measure of relative efficiency. The orientation of the relative efficiency model can be performed either by contrasting the production observed and the maximum reachable given a level of factors (output orientation), or by considering the minimum factors required and the factors actually observed for the level of the product obtained (input orientation). The object of this analysis is to achieve the shortest measure possible between the parameters of the DMU in study and the best results of the group analyzed, within a space containing as many dimensions as inputs (outputs) are in the model. The efficiency of each DMU, which is defined as the percentage of the existing distance between the value observed and the optimum value,

can be measured by way of this distance. The optimum value is achieved from the most efficient operations in the group.

Framework

Following Färe et al. (1995), we extend the classic DEA by incorporating attributes into the technology. We consider that the Quality Index (QI) and the Environmental Index (EI) are attributes in the model.

Let us suppose that we analyze the activities of J producers, each of them using N inputs to produce M outputs and L attributes. y_{jm} and a_{jl} measure the quantity of the M^{th} output and the L^{th} attribute respectively produced by the J^{th} producer, while x_{jn} measures the N^{th} input by the J^{th} producer.

As for production technology in the olive oil industry, despite two indices are included as attributes in the model, we can assume that strong disposability of inputs and outputs is satisfied. An output-orientation approach is performed because the improvement of olive oil production is the main objective.

The output reference (S) is constructed from the observations as follows:

$$\begin{aligned}
 S = \{ & (y, a, x) : y_{jm} \leq \sum_{j=1}^J z_j y_{jm}, m = 1, 2, \dots, M, \\
 & a_{jl} \leq \sum_{j=1}^J z_j a_{jl}, l = 1, 2, \dots, L, \\
 & \sum_{j=1}^J z_j x_{jn} \leq x_{jn}, n = 1, 2, \dots, N \\
 & z_j \geq 0, j = 1, 2, \dots, J \\
 & \sum_{j=1}^J z_j \leq 1
 \end{aligned} \tag{2}$$

A particular modelization was designed because of the introduction of attributes that possess upper bounds. The imposition of constant returns to scale is incompatible in this case. Data were compared to the benchmarks with superior attributes and the imposition of non-increasing returns to scale was established. They were formulated with the restriction that the addition of the intensity variables (z) was not superior to one.

Computation of technical efficiency

The output measure of technical efficiency can be calculated for J^{th} DMU by using the output reference set as the solution to the following linear programming problem:

$$\begin{aligned}
1/D(y_{j'}, a_{j'}, x_{j'}) &= \max_{z, \lambda} \lambda \\
\text{st} \\
\lambda y_{j'm} &\leq \sum_{j=1}^J z_j y_{jm}, m = 1, 2, \dots, M, \\
\lambda a_{j'l} &\leq \sum_{j=1}^J z_j a_{jl}, l = 1, 2, \dots, L, \\
\sum_{j=1}^J z_j x_{jn} &\leq x_{j'n}, n = 1, 2, \dots, N \\
z_j &\geq 0, j = 1, 2, \dots, J \\
\sum_{j=1}^J z_j &\leq 1
\end{aligned} \tag{3}$$

This measure assesses the following property: $0 < D(y_{j'}, a_{j'}, x_{j'}) \leq 1$ [4]

In this particular case, only one output, olive oil, is considered. The QI and the EI are attributes in the model.

The efficiency score of attributes.

The efficiency levels of the attributes can be gauged assuming that the distance functions are multiplicatively separable in attributes and inputs/outputs (Färe et al., 1995), i.e.:

$$D(y, a, x) = A(a)D(y, x) \tag{5}$$

And it is also possible to perform the decomposition by considering only one attribute a_l

$$D(y, a, x) = A(a_l)D(y, \bar{a}, x) \tag{6}$$

\bar{a} represents the set of attributes in the model once attribute a_l has been removed.

This measure is calculated for each a_l attribute by the following expression for J^{th} DMU:

$$A(a_l)_{j'} = \frac{D(y_{j'}, a_{j'}, x_{j'})}{D(y_{j'}, \bar{a}_{j'}, x_{j'})} \tag{7}$$

Therefore, the attribute efficiency level is defined as follows:

$$AEf = 1/A(a_l) \tag{8}$$

This assesses the following condition: $0 < AEf \leq 1$

2.3. - Efficiency factors

After the efficiency estimation, the next phase comprises a study of the potential impacts from factors that might be associated with the management of resources. The object of this analysis, which is called second phase analysis (Fried et al., 1999), is to find patterns of behavior among the most efficient firms. From these patterns it is possible to establish lines of action so as to improve the efficiency level of all firms in the sector. Recent revisions and ways of dealing with this issue can be found in Ruggiero (2004) and Simar and Wilson (2007).

The application of classic regression methods to detect the impact of other variables on efficiency levels in this second stage has been widely criticized (Kumbhakar and Lovell, 2000). In the case of the DEA and its extensions, efficiency factors are very likely to be correlated to outputs and inputs; hence, the following methodological aspects should be borne in mind when approaching the second stage (Sigmar and Wilson, 2007): 1) the regression to be estimated must be truncated according to the nature of the endogenous variable, and 2) the bootstrap technique must be applied in order to avoid biased estimators.

The bootstrap method is a procedure of statistical resampling that is applied with the aim of drawing inferences in complex problems. The basic idea of this method is to approximate the sample distribution of the estimators by means of the empirical distribution of the estimators obtained in a resampling made by Monte Carlo simulation methods. The procedure consists in extracting a great number of samples generated from a first estimation and using the empirical distribution of the estimates obtained for the parameters which are the object of research (Staat, 2002)

Thus, following Simar and Wilson (2007), the second stage model shown in [9] has been established; in which there is an attempt to explain the calculated efficiency index I according to a set of F efficiency factors, through a G function, with the special feature that the condition of truncation has to be accomplished in 0 and 1.

$$I = G(\beta, f) + \varepsilon \quad \text{with} \quad \varepsilon \in N(0, \sigma^2) \quad (0 < I < 1) \quad [9]$$

And its estimation is carried out in the following phases:

- 1) The truncated regression model (Green, 1997) is estimated with the indices resulted from the multi-output mathematical programming DEA-model and the values of the efficiency factors of the sample. Thus the first estimate of the β^* and σ^* parameters is obtained.
- 2) Based on these estimates, a ε^* value is randomly generated for each sample point so that they follow the distribution proposed in [9] and condition [10] is fulfilled:

$$(0 < \hat{I}^* < 1), \text{ being } \hat{I}^* = \hat{G}(\beta^*, f) + \varepsilon^* \quad [10]$$

- 3) The endogenous variable in step 1) is replaced by the one obtained in step 2) and both steps are repeated a high number of times that has been fixed in 1000.

As a result of the bootstrap estimate, we obtain an N number of estimates of the unknown parameters, β and σ . This allows for establishing the sample distribution and thus reliable intervals that are useful to study the significance of the variables and to contrast hypotheses involving these parameters (Myungsup et al., 2007).

3.-RESULTS

3.1. – Variables of the efficiency analysis

First Table 1 shows the attributes of both complex indices calculated (quality and environmental compliance) and the weights given by the experts during the Delphi analysis, based on the process proposed in the methodology section.

An initial group of 15 attributes for the QI and of 16 for the EI was included in the first-round survey. These were extracted from the reviewed literature on the issue (Civantos, 1999). Experts could add new attributes and/or reject any of them explaining why. This led to a reduction of 7 and 6 in the number of attributes in each index, respectively.

A high level of agreement on the attributes of each index and their weights was reached in the second round. It was not necessary to perform the analysis for a third time because of the low variability in the panelists' answers (Adler and Ziglio, 1996).

Table 1.- Components of the quality and environmental impact indices

Quality index	Weights
Classifying the olives according to variety and type of harvest and transport	0.166
Checking the production process in terms of cleanliness, timing and temperature	0.156
Checking the critical points	0.145
Checking traceability	0.132
Having an experienced production expert	0.144
Checking characteristics by means of laboratory analysis	0.137
ISO 9000 Norm Certification	0.120
Environmental management index	Weights
Managing waste disposal in a environmentally friendly way	0.192
Applying the two-phase extraction system	0.181
Waterproof rafts for polluting sewage	0.168
Using low polluting fuel	0.153
Being located outside urban areas	0.167
ISO 14000 Norm Certification	0.139

Source: Authors' own calculations based on survey results.

The QI has been defined by seven attributes, and the consulted experts considered the olive classification and the overall control of the production process by an expert as the most important aspects (Ranalli et al., 2000), whereas the ISO 9000 Norm Certification was the least valued attribute. Likewise, the ISO 14000 Norm Certification was also the least valued attribute in the EI (Arvanitoyannis, 2008). On the other hand, the attributes related to waste management (Roig et al., 2006; Evagelia et al., 2006) and noise control were the most valued ones¹.

At this stage, it is worth mentioning that all industries have to meet legal requirements related to quality and environmental impact. For instance, all olive oil mills carry out the olive quality control and refuse the product that get fermented or rotten that could cause organoleptic problems (Mraicha et al., 2010; Inarejos-Garcia et al., 2010). As regards environmental impact, all industries have been assessed by the EIE (regulated by the R.D. 1/2008 of 11th January, in the case of Spain) and have applied the corresponding programmes of mitigation measures and Environmental Surveillance Plan (Arvanitoyannis et al., 2008).

¹ Many industries are making a great effort to reassess the management of waste materials, as they can be used as both organic amendments to improve soil structure (López-Pineiro et al., 2008) and biofuel (Pattara et al., 2010).

Table 2 shows descriptive statistics of the variables intervening in the frontier for the sample of the 88 olive oil mills studied, including the quality and environmental compliance indices calculated through the procedure presented above. It is worth noting the great variability in the size of all the variables, which indicates the representativity of all types of olive oil mills in the sample.

Table 2.- Descriptive statistics of inputs and outputs

By campaign	Skilled Labour hours	Unskilled Labour hours	Floating capital 10 ³ €	Fixed capital 10 ³ €	Olives milled (Tons)	Oil Production (Tons)	Quality index	Environmental index
Mean	2,898.1	7,982.1	2,239.2	157.2	5,530.3	1,645.4	49.7	61.7
SD	1,637.4	5,837.2	2,011.7	132.5	5,149.3	1,305.3	6.7	8.1
Minimum	1,500.0	1,500.0	22.7	16.1	362.2	185.6	31.6	38.8
Maximum	10,500.0	33,000.0	8,186.1	715.2	21,481.5	5,228.7	68.0	82.8

The quality and environmental indices show average values (note that these indices are limited to the interval 0 to 100 by construction). This means that all the studied companies have a moderate level in both quality and environmental compliance. None of the olive oil mills considered reaches the maximum and minimum values for those indices. All the companies have at least two of the attributes marked for each index among their characteristics, but at the same time none of the companies has all those attributes mentioned by the experts.

The average quality index is located within the average values and process controls (critical points, traceability and complete analysis) are the least developed aspects. The environmental compliance index value is generally higher than the quality one. The main handicap is the use of polluting fossil fuels and the location of mills (in or near urban areas), with the subsequent acoustic and bad odour problems (Kapellakis et al., 2006)

3.2.-Efficiency Scores

Technical efficiency is estimated by applying the formulated model [3]. A global score is achieved by a radial measure considering the maximization of output production and the quality and environment attributes.

Then, two particular models, removing each of both attributes, are solved in order to estimate quality and environmental efficiency scores by the expression [8]. Table 3 shows the descriptive statistics of all three efficiency indices.

Table 3. - Description of the efficiency indices

	Minimum	Maximum	Mean	SD	% Efficient companies
Technical Efficiency	64.82	100	84.38	6.48	55.7
Quality efficiency	58.10	100	86.05	5.81	56.8
Environmental efficiency	54.75	100	80.97	5.48	63.6

After an efficiency estimate is obtained, it is interesting to analyze the magnitude of the slacks for each output in order to find out the increase percentage they could achieve if we eliminated inefficiency. Table 4 shows the descriptive statistics of the total slacks, as well as those corresponding to the decrease in inputs given the output orientation. It is worth noting that in spite of the output orientation, when total slacks (not only radial ones) are calculated, options for input improvement can also be found. Moreover, output slacks differ from radial ones, which would be the same for all three indices.

Table 4. - Total improvement in technical efficiency (%)

By campaign	Skilled Labour	Unskilled Labour	Floating capital	Fixed capital	Olives milled	Oil Production	Quality index	Environmental index
Mean	5.8	11.1	4.8	5.6	4.5	4.4	4.6	6.5
SD	14.1	21.4	12.9	16.3	11.9	8.7	8.5	11.93
Minimum	0	0	0	0	0	0	0	0
Maximum	69.2	74.6	59.5	84.1	62.5	60.50	63.3	66.7

In view of the slacks in technically inefficient companies, an increase of up to 4.4% on average in oil production should be possible; the potential improvement in quality has the same range (4.6%) and the potential improvement in environmental performance rises to 6.5% on average.

As to inputs, it is relevant to highlight the mean slack of unskilled labour (11.1%). Despite the flexible seasonal recruitment, mill companies should regulate their procedures according the time they last, so as to avoid idle workers during some periods of the day. The reason why this happens is the lack of specificity in most tasks, and the subsequent great extent of substitution in carrying them out. A noticeable variability in the slacks of variables is shown all over the sampling. While there are some completely efficient companies that make an optimum use of resources, there are some other companies with a very low level of efficiency. The inputs of the latest may be reduced to up to 74.6% and 84.1% in unskilled labour and fixed capital respectively, due to the own structure of the extraction industry, which is prone to fluctuate in the amount of raw material to be transformed given the physiological development of olive production. To conclude this section, correlations among the

different indices constructed throughout this study are to be analyzed. Table 5 shows Pearson's correlation coefficient and its relevance.

Table 5.- Correlations among indices

Index	Environment	Quality Eff.	Environmental Eff.	Technical Eff.
Quality	0.002	0.494 ***	0.489***	0.126
Environment		0.510 ***	0.284 ***	0.138
Quality Eff			0.305**	0.196*
Environmental Eff				0.191*

Signification: (*) 10% - (**) 5% - (***) 1%

The study of the correlations draws attention to the lack of connection between the QI and EI. This indicates that companies may present a high level of quality and any level of environmental compliance, and vice versa. The fact that all three efficiency indices are positively correlated means that the most technically efficient mill is also efficient in quality and environmental management. In addition, the significant correlation between quality and environmental compliance levels and their corresponding efficiency measures deserves great attention as well.

These relations are of practical interest, as they show the existence of some model mills in the sector, which facilitates an actual benchmarking process to industries that need to enhance their efficiency levels in any of the three aspects. For instance, it would be appropriate to launch campaigns on business management for trainee managers at the most efficient mills. It would be positive to consider the leadership of these companies in both future mergers and horizontal integration in the sector (Malmberg and Maskell, 2002) .

On the other hand, the positive correlation between quality and environmental compliance levels and their corresponding efficiency index shows that those companies concerned about quality are also concerned about environmental management. The slacks in both indices suggest that the industry still has a positive margin of action to improve both aspects. Investments in environmental and quality policies make technical efficiency increase and improve economic results, since competitive advantages in medium-term costs and product differentiation are achieved (Fraj-Andrés et al., 2009b).

3.3.- Efficiency factors

In order to determinate the most efficient companies' profiles, a study of censored regressions with bootstrap has been carried out by using the formulation [9]. Efficiency factors considered a priori as well as their basic statistics are presented in Table 6.

Table 6.- Descriptive statistics of efficiency factors

Continuous variables	Minimum	Maximum	Mean	SD
Number of associates (ASC)	1	1,802	289	415.11
Number of permanent unskilled employees (PEM)	0	10	2.50	2.08
Production experts' years of experience (YEX)	2	40	15	10.97
Binary variables (% yes)				
Specific studies (SPS)				60.20
Farmers association (FAS)				74.10
Marketing association (MAS)				36.00
Internet promotion (IPR)				32.60
E-sales (ESA)				16.30

Three quarters of the olive oil mills in the sample (74.1%) are farmers associations (cooperatives in essence) and only a little more than a third (36%) belong to marketing associations. A third of them (36%) do direct promotion of their products on the Internet (via their own website) but only 16.3% allow direct on-line shopping. The sample shows great variability in the number of associates, reaching a maximum of 1,802 and averaging 289. They usually have an experienced production expert, with an average of 15 years of experience, and most of them have appropriately trained technicians (60.2%). The unskilled labour structure shows that each mill has an average of 2.5 permanent workers.

The truncated regressions estimated with bootstrap for all three technical efficiency indices are shown in Table 7. In view of the results, we can conclude that only the variables of PEM and FAS have a direct impact on technical efficiency. As to membership of farmers' associations, the data in the table show that associative companies (basically cooperatives) are 4.75% on average less efficient than those which are not. With regard to employment, considering the average values, we can assume that one new permanent unskilled job presupposes a 1% decrease in the technical efficiency index. With regard to quality efficiency, there are two relevant efficiency factors. First, mills with technicians specifically trained in oil production (SPS) are 4% on average more efficient. Second, membership of marketing associations increases the efficiency level an average of 8%. On the other hand,

environmental efficiency is directly affected only by the two efficiency factors involving associative relationships.

Table 7.- Bootstrapped truncated regressions

Technical efficiency					
Variable	Observed Coef.	Bootstrap Std Err.	2.5 Percentile	97.5 Percentile	P>z
Constant	91.5673	2.5371	86.5946	96.5401	0.000
ASC	0.0041	0.0042	-0.0041	0.0124	0.326
PEM	-1.0174	0.5657	-2.1263	0.0914	0.072
YEX	0.0102	0.1190	-0.2231	0.2435	0.932
SPS	1.2934	2.5039	-3.6141	6.2010	0.605
FAS	-4.7575	2.0734	-8.8214	-0.6937	0.022
MAS	-2.0448	3.1588	-8.2360	4.1464	0.517
IPR	0.7239	3.2546	-5.6549	7.1029	0.824
ESA	-2.5902	3.7549	-9.9497	4.7693	0.490
Quality efficiency					
Variable	Observed Coef.	Bootstrap Std Err.	2.5 Percentile	97.5 Percentile	P>z
Constant	90.8344	2.7124	85.5180	96.1508	0.000
ASC	0.0035	0.0052	-0.0066	0.0138	0.495
PEM	-0.8589	0.5714	-1.9789	0.2610	0.133
YEX	-0.0047	0.1655	-0.3291	0.3197	0.977
SPS	4.0134	2.2532	-0.4027	8.4296	0.075
FAS	2.9022	5.9004	-8.6624	14.4669	0.623
MAS	8.8273	5.1039	1.1761	18.8308	0.084
IPR	1.3689	4.7116	-7.8656	10.6035	0.771
ESA	-8.3379	5.4720	-19.0629	2.3871	0.128
Environmental efficiency					
Variable	Observed Coef.	Bootstrap Std Err.	2.5 Percentile	97.5 Percentile	P>z
Constant	85.8339	4.3018	77.4023	94.2654	0.000
ASC	0.0026	0.0074	-0.0118	0.0172	0.719
PEM	0.6458	0.9309	-1.1786	2.4704	0.488
YEX	0.1116	0.2643	-0.4064	0.6297	0.673
SPS	0.8587	3.4437	-5.8909	7.6084	0.803
FAS	-10.6264	4.3334	-19.1198	-2.1330	0.014
MAS	10.4669	5.2420	0.1926	20.7412	0.046
IPR	-3.6419	4.5535	-12.5667	5.2828	0.424
ESA	4.7004	5.6672	-6.4071	15.8080	0.407

Observations number=88; replications number=1000

4. – CONCLUSIONS

This paper studies the level of technical efficiency in accordance with production and quality and environmental management in the olive oil industry. The technique used is a non-parametric frontier method. It was necessary to design and evaluate two indicators in order to examine two indices: specific quality and good environmental management. To this end, a group of experts were interviewed by means of the Delphi technique. The following phases are to be considered when studying the quality of the production process and the subsequent final product: (1) classifying olives according to variety and type of harvest and transport; (2) checking the production process in terms of

cleanliness, timing and temperature; (3) checking the critical points; (4) checking traceability; (5) the presence of an experienced production expert; (6) checking characteristics through laboratory analysis; and (6) the ISO 9000 Norm certification. As to good environmental management in this agricultural food industry, the next aspects should be borne in mind: (1) waste disposal, (2) two-phase extracting system, (3) raft waterproofing, (4) use of environmentally friendly fuels, (5) location outside urban areas, and (6) ISO 14000 Norm certification. This set of attributes of dichotomic formulation and their relative importance, also explained in this paper, enable the easy elaboration of similar indices for any company in the olive oil sector. Leaving aside the technical efficiency considerations, the quality and environment levels measured by these indices are of medium magnitude and there is an important improvement margin at minimum cost in many cases.

The analysed firms have a medium-high technical efficiency level (84.8%). The efficiency indices of quality and environmental management have both the same range as the technical one. In addition, it is deduced that the most technically efficient firms are those that also present the best management of resources to achieve the quality and environmental compliance levels.

The second-phase analysis performed by means of the truncated regression and bootstrap methodology has shown that firms belonging to farmers' associations (cooperatives) and those having permanent unskilled employees are less efficient. The first assertion matches the relations proposed by Barnes (2006), who also underlines the connection between low efficiency and cooperative membership. Likewise, Ferrier and Porter (1991) and Barreiro-Hurle et al. (2009) show the same negative connection between cooperativism and technical efficiency in their studies on dairy cooperatives in the United States and cereal farms in Andalusia, respectively. Therefore, the particular nature of cooperative entities, where the employer is the supplier and vice versa, do determine their processes of resources management (Mozas et al., 2005).

The second assertion differs from others established in the past. For instance, Díaz-Mayans and Sánchez (2004) discerned a positive connection between the number of jobs and technical efficiency in a study on the Spanish industry sector for the 1990-2001 period. This relation is due to the differential features of the industrial activity studied here, which has an important seasonal component

in work intensity. This is an issue that Arulampalam and Booth (1998) pointed out when examining British industrial sectors.

The positive relation between efficiency and the factors involving production, labour and fixed capital suggests that the least efficient companies should apply planning procedures and optimum designing with the aim of minimizing the problem of raw material alternation described in the Introduction.

Another conclusion has been drawn: more efficient firms are those with higher training levels. This connection has also been underlined in the analyses carried out by Barnes (2006) and Barreiro-Hurle et al. (2009), among others. Moreover, a less environmentally sustainable management was detected in cooperative business structures in a study on cooperative mill companies by Senise et al. (2008). Given the associative nature of a large amount of cooperative mergers, management methods similar to those of private companies should be considered as an interesting option. This larger volume would allow in turn for a rationalization of the use of resources, fixed employment and seasonal activity, above all. Membership of selling associations is related to an improvement in the efficiency of both quality and environmental management. Second- and higher-order associations and cooperatives have hoarded the supply, developed olive oil bottling facilities, and directly placed their products on the market through their own distribution channels (Langreo, 2010). These associations need to create a differentiated product for the current consumer in the large-scale distribution; this is why they have undertaken intensive campaigns to enhance their quality and environmental management levels. Besides, the implementation of processes of stricter quality and environmental management control should be prioritized in order to obtain a product of higher quality and better market differentiation and also to project an environmentally friendly corporate image. Although this is always advisable for any firm, it is a matter of crucial relevance for the agrifood industry.

As the sector cannot currently promote its competitive strategy by means of price leadership, which is developed by large-scale distribution and based on the price attribute, it should increase its competitiveness by adding value to consumers (Kennedy et al., 1997), and emphasizing the attributes involving quality, environmental commitment and local development (Wilkinson, 2002). This strategy is particularly interesting for those mill firms that do not belong to second-order associations whose target market is the high-level consumption. Protected Designations of Origin institutions dedicated to

Spanish olive oil should play a deciding role in this process, as they are responsible for certifying quality, geographical origin and environmental attributes of the products they give their distinctive label (Sanz and Macias, 2005).

The creation of the Olive Oil Futures Market (MFAO) in 2005 is an additional component that favours the sector's revitalization and the elimination of the market power of the distribution channel's upper links. MFAO provides a new marketing channel and works as a risk minimization agent as well as contributing transparency to the sector and to price formation (Pérez-Godoy et al, 2010).

Finally, as cooperatives have proved less efficient than other business structures, there is room for another conclusion: extra services (insurance management, credit facility, etc.) that cooperative entities offer their members could be included in their outputs or, at least, be considered as a positive externality of the production process, since these services are also a result of these cooperatives. Future research on this issue should be developed in order to corroborate this relation.

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