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A new multicriteria approach for the analysis of efficiency in the Spanish olive oil sector by modelling decision maker preferences

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ABSTRACT

The efficiency in production is often analysed as technical efficiency using the production frontier function. Efficiency scores are usually based on distance computations to the frontier in an $m + s$-dimensional space, where m inputs produce s outputs. In addition, efficiency improvements consider the total consumption of each input. However, in many cases, the "consumption" of each input can be divided into input-consumption sections (*ICSs*), and trade-off among the ICSs is possible. This share framework can be used for computing efficiency. This analysis provides information about both the total optimal consumption of each input, as does data envelopment analysis, and the most efficient allocation of the "consumption" among the ICSs. This paper studies technical efficiency using this approach and applies it to the olive oil sector in Andalusia (Spain). A non-parametrical methodology is presented, and an input-oriented Multi-Criteria Linear Programming model (MLP) is proposed. The analysis is developed at global, input and ICSs levels, defining the extent of satisfaction achieved at all these levels for each company, in accordance with their own preferences. The companies' preferences are modelled with their utility function and their set of weights. MLP offers more detailed information to assist decision makers than other models previously proposed in the literature. In addition to this application, it is concluded that there is room for improvement in the olive oil sector, particularly in the management of the skilled labour. Additionally, the solutions with two opposite scenarios indicate that the model is suitable for the intended decision making process.

1. Introduction

The efficiency in production has often been analysed in the field of technical efficiency using the production frontier function, as well as in the allocative and economic efficiency framework, with the frontier of costs or profits as the basis. Currently, the most used methodologies for efficiency estimation using the frontier function include mathematical programming by Data Envelopment Analysis (DEA) (Cooper, Seiford, & Tone, 2007) and the so-called econometric frontier (Kumbhakar & Knox Lovell, 2000). The average efficiency level of the sample and the efficiency index of every company can be estimated using both methods.

This paper is motivated by the current situation of the Spanish olive oil industry. Olive oil is a product of particular importance within the Mediterranean agricultural food system, and more specifically in Spain, for two main reasons: first, because olive oil is an essential component of the so-called Mediterranean diet and, second, because Spain, and Andalusia in particular, is the world's main production area. Over the last 10 years (2001–2010) approximately 39% of the olive oil produced worldwide is Spanish in origin, and over 79% of this oil comes from Andalusia (Rallo, 2010).

The olive oil production industry is the core of a production chain that starts in the olive sector, the producer of olives, and ends at the olive oil packaging and marketing sector. Efficiency and productivity in the olive oil industry need to increase, and trade policies devoted to opening new competitive markets have to be put into practice to make up for the continuing decrease in support that will take place in the near future (Mili, 2009). The social, financial, and environmental importance of the olive sector in Spain, and especially in Andalusia, is a widely known and researched issue (Sánchez, Gallego, & Araque, 2011). Olive oil factories are often interested in optimising their input consumptions as to guarantee the desired levels of output production.

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This paper belongs to a research line started by the authors and devoted to the efficiency estimation in the olive oil factories in Andalusia. The problem has already been tackled from different viewpoints. Dios-Palomares and Martınez-Paz (2010) work with econometrical distance function methods, taking into account not only the olive oil production but also the quality of the company and the level of environmental respect. Dios-Palomares and Martınez-Paz (2011) proposed a new efficiency estimation model with quality and environmental respect as attributes, where specific efficiency index scores are computed. Recently, Dios-Palomares, Martínez-Paz, and Prieto (2013, chap. 12) introduced a new environmental DEA model with "programs", considering the environmental impact as an undesirable output. In addition, the analysis includes non-discretionary variables from two points of view. On the one hand, the business structure (cooperative or corporation) is considered to affect the frontier (technology). This variable is included using a three-stage method. On the other hand, the relation between efficiency and other non-discretionary variables is analysed by a Tobit model estimation.

All these previous approaches examine the efficiency of each company and advise on possible improvements in the consumption of every input. However, it is also interesting to study the efficiency at a more detailed level, linking the following features of the companies to their consumption of inputs.

This industry produces olive oil and table olives simultaneously. This production process uses some resources that can be modelled by means of the following four inputs: unskilled labour, skilled labour, floating capital and fixed capital. All the four inputs are used in the production of the two outputs. However, for unskilled labour and floating capital, some special considerations should be taken into account. First, unskilled workers can develop many nonspecific tasks, e.g., they can receive the olives in the production process, assist in the oil extraction phase, take part in the packaging and sale of the products, or perform other nonspecific work. This is a common scenario in most production processes where inputs are shared, but unskilled labour has a very important seasonal component in this industry, and the proportion of temporary employees is very high in the olive reception stage. For this reason, managers are very interested in determining the minimum amount of unskilled labour needed for this stage. In other words, managers want to know the best allocation of the unskilled labour input among the four above-mentioned stages according to the performance of the rest of companies in the sector. On the other hand, the total consumed capital can be allocated either to production or other services. In this case, management may also consider that the amount spent on production is essential and therefore, they may want to determine the best allocation among these two sections of capital consumption.

In the olive oil extraction industry, just as with other production processes that occur in real life, some subprocesses are frequently established so that one input can be used in any of them. Let us think of a production process that is split up into K subprocesses in the whole industry, and the total consumption of the input i can be distributed among the K subprocesses. The quantities consumed of input i in the subprocess k with $k = 1,\ldots,K$ are called input-consumption sections (ICSs). Moreover, in most cases, it is important for management to control the consumption of every input in each of the subprocesses and to assign the input consumption in each subprocess in the most appropriate manner for the company. If there was information about the ICS of the input for all the companies in the sample, then it would be very interesting to conduct an efficiency analysis to determine the optimal allocation of resources at this level according to the preferences of management. In this context, given a production process where several inputs are consumed, the following may happen:

1. The decision maker is interested in dividing the consumption of each input differently, or
2. There is no information available for the division of all inputs in the same subprocesses.

For this reason, in this paper, we present a model that reflects this scenario and allows for a different division for each input i.

One of the aims of this paper is to provide the olive oil companies (the decision-making units, DMUs) with detailed efficiency scores about their performance at global, input and ICS levels. In fact, the present paper proposes a new model for application to the Spanish olive oil industry. Unlike other papers, an input-oriented Multi-criteria Linear Programming (MLP) model is suggested for computing the detailed efficiency scores. When all the companies (DMUs) of the sample under consideration have the same inputs and outputs and the same division into ICS for each input, this fact is to be considered as the basis of the efficiency analysis. Like the DEA, the analysis provides information on the total optimal consumption of each input, as well as on the most efficient allocation of every input i and each ICS. This paper studies technical efficiency using this approach.

Multi-Criteria Decision-Making theory is mostly based on Linear Programming and the associated algorithms. Multi-Criteria Decision theory has its own and explicit theoretical framework, which includes well-specified conceptual definitions and a systematic casual logic to assist in decision-making processes. Its goal is to generate a constrained optimisation problem (model) in which the solution would lead to the best choice for the decision maker. The model assumes the existence of the decision maker as an abstraction, enabling operational thinking (see, for example, Barba-Romero & Pomerol, 1997), and seeks to recreate (formalising and modelling) real-life situations. Multi-Criteria Linear Programming (MLP) plays an important role in the Multi-Criteria Decision theory. Important references in Multi-Criteria Decision theory include Charnes and Cooper (1961) and Romero (1983). The dominance concepts and the ideas of dominated or non-dominated points are key aspects in MLP models in the so-called objective space (see, for example, Koopmans, 1951). The non-dominated points are reference points for those that are dominated. Therefore, the control of resources in companies can be conducted using technical efficiency scores as a standard procedure. In this line, the present paper conducts a more detailed analysis (according to each DMU, input and ICS levels) than the existing ones in many DEA models. This detailed analysis is one of the main goals of this work.

It is important to remark that the methodology developed in this paper is different from DEA. Like DEA, we are interested in defining and measuring efficiency scores for the DMUs. Efficiency scores in DEA are usually in the objective function of the associated Mathematical Programming problems, but in the proposed MLP model, the efficiency scores are computed after solving the corresponding Mathematical Programming problems. In addition, unlike DEA, the MLP model enables computation of efficiency scores in further detail, at global, input and ICS levels. Of course, there are some works that propose DEA models working with the internal structure of the DMUs, but they study the cases in which DMUs are divided into several decision-making subunits (DMSUs) and compute the efficiency scores related to such subunits.

A classification of DEA models is given, for example, by Castelli, Pesenti, and Ukovich (2010). However, the methodology proposed here also differs from the ones classified by Castelli et al. (2010). The classification of Castelli et al. is mainly based on three assumptions related to the internal structure of the DMUs, i.e., related to the decision-making subunits (DMSUs). They categorise the models into elementary models, shared flow models, multilevel models and network models by ascertaining which of these three