An analysis of innovation in textile companies: an efficiency approach

ABSTRACT

The elimination of trade contingency measures in 2005 triggered a process of renewal in the textile sector, requiring major investments. The divide between efficiency and innovation has become an issue of major importance for decision-making in the Spanish textile sector. This study provides quantitative data on the efficiency levels of innovative Spanish textile companies. The aim is to identify their distinguishing features and establish a possible pattern to follow. In addition, truncated regression is used to estimate the determinants of efficiency, in order to check the significance of innovation processes for firms.

KEYWORDS: Efficiency, DEA, Textile, Process Innovation, Product Innovation

INTRODUCTION

Over the past two decades, the textile sector has undergone major changes in an attempt to respond to growing external competition, intensified by the elimination of trade restrictions. In 1995, the Multi-Fibre Arrangement was replaced by the World Trade Organization Agreement on Textiles and Clothing. The overall purpose of this agreement was to gradually bring the sector under the provisions of the General Agreement on Tariffs and Trade, leading to the total elimination of contingencies for both importers and exporters of textiles and clothing by 2005. These developments led to the incorporation of new participating countries such as China, which flooded the market with low-priced products of dubious quality.

This research focuses on the Spanish textile sector, which is undergoing a process of transformation in an attempt to orient itself towards a segment of more competitive products of greater added-value. Thus, the concept of product and/or process innovation is becoming increasingly relevant. Spanish companies need to incorporate diversification strategies in order to find an outlet for their products in today's globalized markets. In this context, and unlike other articles published to date, the objective of this article is twofold: First, Data Envelopment Analysis (DEA) is used to estimate the efficiency of Spanish textile firms that have introduced some type of innovation in their manufacturing and/or distribution processes in recent years. The aim of this analysis is to identify their characteristic features and to provide evidence as to the model companies should follow in order to best position themselves in an increasingly adverse business environment. Second, truncated regression is used to analyse the determinants of efficiency in order to assess the possible relationship between efficiency and innovation. The innovation-efficiency nexus is *a priori* key to ensuring companies' optimal adaptation to the new international context. The sample used in the empirical study has been divided according to the size of the firms analysed, thereby ensuring that the groups are sufficiently homogeneous to allow the correct application of the DEA methodology. The data correspond to 2010 as this was the latest year with available information at the time of the empirical analysis.

In the new scenario described above, studies on efficiency and innovation in the textile sector have sparked notable interest given the close relationship between efficiency, profitability and competitiveness (Sellers et al., 2002; Roca and Salas, 2005; Duch, 2006). For example, Bhandari and Maiti (2007) estimate the technical efficiency of Indian textile companies using stochastic frontier analysis (SFA). They report that technical efficiency levels range from 68% to 84%, depending on firm-specific characteristics such as size and age. They also show that public/private ownership is a determinant of efficiency levels. Using a similar sample, Bhandari and Ray (2012) again find evidence that location, ownership and organizational characteristics are significant determinants of efficiency results. In addition, Chaffai et al. (2012) carry out a comparative analysis of the efficiency of the textile industry in eight developing countries, finding that, in addition to size, access to certain technological services greatly limits efficiency levels. Focusing on Spain, Coll-Serrano and Blasco-Blasco (2009) analyse the evolution of the technical efficiency of the Spanish textile industry in the period 1995-2005, concluding that the elimination of tariffs has done significant damage to this sector. Similarly, Jorge-Moreno and Rojas (2015) provide evidence on technical efficiency and its determinants during the period 2002-2009, confirming the negative effects of trade liberalization.

Furthermore, in light of this process of industrial globalization, innovation should be regarded a key factor for companies' survival; with innovation understood as the creation or improvement of products and/or management and organizational processes. The elimination of regulatory barriers, financial constraints and macroeconomic uncertainty are some of the obstacles to the introduction of new technologies (Bastos and Nasir, 2004; Eifert et al., 2005). Since the pioneering work of Aghion and Howitt (1998), an extensive literature has been produced on the close relationship between business growth and innovation (Fagerberg et al., 2007; Raffo et al., 2008; Goedhuys and Veugelers, 2012); industry needs to undergo a continuous process of transformation, introducing improvements into production and/or distribution chains as a way of gaining market share. Becker and Egger (2013) carry out an empirical analysis of process *versus* product innovation, in terms of their effects on export propensity. In the same vein, Cassiman et al. (2010), using a panel of Spanish manufacturing firms, find evidence that it is product rather than process innovation that affects productivity and prompts small non-exporting firms to enter the international market. Other studies, such as those by Costa et al. (2001) and Morantes (2012), focus on analysing the determinants of innovation in the textile sector.

All this highlights the importance of research centred on this industrial sector, where globalization is forcing firms to adopt strategic changes in order to survive. The results of the empirical analysis will enable a characterization of the Spanish textile sector, focusing on the possible nexus between efficiency and innovation.

The rest of the article is structured as follows. Section 2 presents an analysis of the current situation in the Spanish textile sector in order to contextualize the study carried out. Section 3 explains the DEA methodology used to calculate firm efficiency levels. Section 4 describes the sample and the variables used for the empirical study. Section 5 details the results of the analysis. Lastly, the main conclusions are set out in Section 6.

CONCEPTUAL FRAMEWORK: THE SPANISH TEXTILE SECTOR

The Spanish textile industry encompasses a wide range of activities, from the preparation and spinning of textile fibres, to the manufacture of garments to meet the demand of the end consumer. Firms in this industry have to bring a wide variety of products to market to meet an increasingly exacting demand, at a time when domestic supply is threatened by potent international competitors breaking into the market.

This sector is strongly affected by its economic environment, and liberalization has forced it to deal with weakening domestic demand in a context of increasing competitiveness. The situation has been further exacerbated by the international economic crisis and the inroads made by Asian markets, which lead the way in low-cost production (Coll-Serrano and Blasco-Blasco, 2009). However, the Spanish textile industry plays a major role in the secondary sector. At the end of the 1990s, the textile industry represented around 6.7% of total industry, according to information from the Spanish National Statistics Institute. In 2004 and 2006, its share of total industry had fallen to 5.01% and 4.22%, respectively. In the period 2003-2006, 15% of firms in the textile industry disappeared, 20% of the jobs were lost, along with almost 14% of its production and value-added. In 2006, a gradual recovery got underway and, according to the latest available data corresponding to 2014, the textile industry now accounts for 7.6% of total industry in Spain, with revenues of nearly €10 billion, and an employment level equivalent to 4.28% of total employment in Spain. Moreover, there has been a strong take-up of foreign products in the domestic market; as a result, the existing trade deficit exceeds €3.6 billion, with a comparative advantage index of -0.13.

Firms in the sector are characterized as being small and labour-intensive. According to information provided by the Ministry of Industry, Energy and Tourism (MINETUR), less than 0.1% of Spanish textile firms have more than 250 employees; the rest are small and medium-sized enterprises (SMEs) that differ widely in terms of their production and organizational profile (Table 1).

TABLE 1. *Characterization of the Spanish textile sector by firm size (2014)*

This sector is one of the lowest ranking in terms of productivity: it registers an average of just over €32,000 in value-added per employee, compared to sectors such as the pharmaceutical industry, which exceeds €127,000. On the other hand, it is one of the top ranked industries in terms of unit labour cost, with an average of almost 84%, whereas the pharmaceutical industry only registers 44.2%. The overhaul of the sector is thus a pressing need; the data alone call for the introduction of technological and organizational advances that will enable firms to improve their levels of competitiveness.

In addition, there are notable differences between exporting companies and those that only trade domestically. Spanish textile SMEs that sell their products abroad represent 62.4% of the total number of Spanish textile SMEs, with revenues representing nearly 70% of the total and a value-added of more than 71.5%. This brings with it higher productivity (€34,100 in value-added per employee) and lower unit labour costs (79.3%) due to the need to position their products in the international market (Table 2). However, it is imperative that they change their investment policy; the liberalization of the markets means that price competitiveness must be complemented by quality products.

TABLE 2. *Characterization of Spanish textile SMEs (2014)*

Despite this situation—which may not be bad but certainly leaves much room for improvement—it should be noted that the knock-on effect'[1] of the textile sector is among the highest at national level: 2.066 compared with 0.035 for the total economy. At the technological level, however, few companies carry out innovative activities; only 16.8% of textile companies introduce innovation processes into their production chains. In other sectors, such as pharmaceuticals and electronics, this figure is over 64% and 54%, respectively. Moreover, innovative textile companies should rethink their investment levels, as their R&D spending as a percentage of revenue barely reaches 1.6%, compared to 6.27% and 5.48% in the electronics and pharmaceutical sectors, respectively.

METHODOLOGY

In the first stage of the empirical study, the efficiency scores of companies in the Spanish textile sector are obtained using DEA. This procedure is a non-parametric technique that allows the relative efficiency of homogeneous units to be measured. This method is one of the most widely used when dealing with multiple inputs and outputs. It is used to identify the best performing units by comparing each observation with all the possible linear combinations of the variables for the rest of the sample, which in turn allows an empirical production frontier to be defined. Thus, the efficiency of each analysed unit is measured as the distance to the frontier.

Following the pioneering work of Farrell (1957), the DEA model was developed by Charnes, Cooper and Rhodes (1978), who proposed the original input-oriented linear programming model with constant returns to scale:

$$\text{Max}_{u,v} h_0 = \frac{\sum_{r=1}^{s} u_r * y_{r0}}{\sum_{i=1}^{m} v_i * x_{i0}} \qquad (1)$$

$$\text{s.a.} \ \frac{\sum_{r=1}^{s} u_r * y_{rj}}{\sum_{i=1}^{m} v_i * x_{ij}} \leq 1$$

$$u_r \, , v_i \geq 0$$

where:

x_{ij}: quantities of input i (i = 1,2,....., m) used by the jth company

x_{i0}: quantities of input i used by the analysed company

y_{rj}: quantities of output r (r= 1,2,...,s) produced by the jth company

y_{r0}: quantities of output r produced by the analysed company

u_r: output weights

v_i: input weights

The objective of model (1) is to find the optimal set of weights that maximizes the relative efficiency (h_0) of the analysed company, defined as the ratio between the weighted sum of outputs and the weighted sum of inputs. From an economics perspective, the constraints mean that no other firm can have an efficiency score higher than one when using the same weights. These weights take a positive value throughout.

[1] The knock-on effect is understood as the percentage increase in sectoral production in response to a 1% increase in demand.

The original model of Charnes et al. (1978) is not linear but can be transformed to a linear model by modifying the restrictions. Taking into account that there are more constraints than variables, the corresponding dual problem is solved. This article follows the proposal of Banker, Charnes and Cooper (1984), who presented a linear programming model with variable returns to scale and a convexity constraint.

The choice of whether to use an output- or input-oriented application of the DEA technique depends on the extent to which each observation (firm) can control the amount of outputs or inputs. Since private firms can modify the inputs needed to achieve a certain output, this study applies an input-oriented model. Other studies have also used this approach (Diaz-Balteiro et al., 2006).

Efficiency scores range between 0 and 1, and can be interpreted as follows:

- If $h_0=1$, the company is efficient in relation to the others and will thus be located at the production frontier.
- If $h_0<1$, another company is more efficient than the analysed company.

After calculating the efficiency scores, the Kruskal-Wallis test is applied to determine whether there is a significant difference between the mean input use of the most efficient firms and that of the least efficient observations.

In the last stage of the research, a truncated regression model is used to evaluate the determinants of the efficiency of textile companies. The results of the DEA are taken as the dependent variable, while the explanatory variables are those not included in the calculation of the DEA that represent firm characteristics in terms of performance and innovation. This estimation procedure is the most appropriate since the dependent variable takes values between 0 and 1. The estimation of the coefficients in the truncated regression will reveal which indicators should be improved in order to achieve better efficiency; that is, in order to ensure optimal management of firm resources.

VARIABLES AND SAMPLE

The sample used in the empirical study comprises Spanish textile companies whose economic profiles have been collected in the Business Strategies Survey (ESEE by its initials in Spanish)[2], carried out by the SEPI Foundation and financed by MINETUR. This database includes companies from 20 manufacturing sectors, chosen by means of a selective sampling method. Given the close relationship between the two sectors, it was considered appropriate to analyse not only 'Textiles and Clothing' but also the companies included in 'Leather and Footwear'.

The ESEE provides information on 675 companies in these sectors, however, a major data cleansing exercise was carried out due to a lack of information and the contextualization of the study. The analysis focuses on companies that have implemented some type of product and/or process innovation in the five years prior to 2010, which could be reflected in their 2010 results and therefore reported in the corresponding accounting data. The sample was thus reduced to 85 companies, the distribution of which is shown in Table 3.

TABLE 3. *Distribution of Spanish companies by size*

[2] An extensive description of the survey can be found in the article by Fariñas and Jaumandreu (2004)

Given the large divergence in size of the companies in the Spanish textile sector, which is characterized by having few companies with more than 250 employees, this study applies an *ad hoc* division of the sample, classifying firms with fewer than 50 employees as small and all the others as large. As can be seen in Table 4, more large companies than small companies (9 and 7, respectively) have carried out both product and process innovation. The situation is similar regarding process innovation only, supporting the theoretical claim made by some previous studies in the literature (Crépon et al., 1998; Huergo and Jaumandreu, 2004). Large firms are able to benefit from certain elements that are inaccessible to small firms: economies of scale, more skilled labour, better access to external financing, greater capacity to exploit innovation and ease of distribution of new products (Sanchez and Diaz, 2013). However, in terms of firms that engage only in product innovation, small firms outnumber large ones (12 and 4, respectively). This is due to their ability, when introducing a new product, to simultaneously modify their manufacturing and/or distribution process in order to ensure a more successful roll-out.

TABLE *4. Distribution of firms by type of innovation*

The analysis of efficiency requires researchers to construct a production function. In the field of business, several studies have identified the most suitable outputs and inputs for the construction of this production function (Coll and Blasco 2007; Alarcon, 2008; Sellers and Mas, 2009). Following these authors, this study takes sales figures to represent output, while inputs are represented by variables related to capital (productive capital and use of inputs) and labour (staff costs). Table 5 presents the main statistics of these variables.

TABLE *5. Main statistics of the production function variables* (in euros)

The statistics reveal significant differences between the groups under study, thereby supporting the decision of how to split the sample in order to ensure the homogeneity of the analysed groups. Thus, in terms of average sales, for example, the value is approximately 8 times higher for large firms than for small firms, with similar orders of magnitude for the differences in the rest of the variables. Figures 1 and 2 show the inputs of each firm in order to determine whether their manufacturing process is capital-intensive and/or labour-intensive.

FIGURE *1. Comparison of capital and labour inputs in small companies*

FIGURE *2. Comparison of capital and labour inputs in large companies*

As can be seen in Figures 1 and 2, regardless of size, Spanish textile firms tend to be clearly capital-intensive rather than labour-intensive. As a result of the liberalization process, the share of spending on purchasing inputs and productive capital far exceeds spending on labour. In most of the firms, capital accounts for more than 80% of production costs, with the remainder attributed to meeting the staff needs required by the production process. The need to adapt to the new environment has forced companies to introduce technology, changing the production profile from a labour-intensive to a more mechanized one, in order to reduce production costs.

RESULTS

Recent contributions to the literature include studies of efficiency in the textile industry using various methodologies. For example, Coll and Blasco (2007) applied the non-parametric DEA technique to a set of textile firms, under an economic-financial approach. Sánchez and Díaz (2013), on the other hand, applied SFA to estimate the efficiency of a panel of manufacturing companies. Equally, a number of studies can be cited that focus on similar areas and use DEA and SFA interchangeably (Zheng et al., 2000; Zhang et al., 2000; Bhandari and Ray, 2012; Mokhtarul, 2004 and 2007; Bhandari and Maiti, 2007; Kouliavtsev et al., 2007).

As indicated above, in this study DEA is used to calculate efficiency scores. One of the main aims of the article is to subsequently examine the relationship between those efficiency scores, and innovation and firm size.

TABLE *6. Efficiency of innovative textile firms*

The results shown in Table 6 reveal the greater efficiency of large firms: 38.88% of them achieve a score of one, compared to 22.44% of small firms. However, the average efficiency value of small firms is still relatively high (0.873), indicating in any case an excellent performance. Also noteworthy is the efficiency of the large firms in the "Leather and Footwear" sector: 4 out of the 5 firms analysed are shown to be totally efficient, with the fifth registering a score of 0.948. It can thus be classified as an industrial activity that appropriately combines its inputs to obtain the best possible output.

Figure 3 enables a comparison of efficiency levels in the analysed sample, revealing that larger firms score between 0.75 and 1, with lower scores observed for small firms (between 0.47 and 1).

FIGURE *3. Comparison of efficiency levels by company*

In line with the aims initially set out, having determined the levels of efficiency, the study now attempts to identify whether the average input use of the most efficient firms is statistically different from those that register the worst performance. To do so, the Kruskal-Wallis test is applied. Therefore, the hypotheses to be tested are as follows:

H0: mean inputs in sample 1 = mean inputs in sample 2

H1: mean inputs in sample 1 ≠ mean inputs in sample 2

Given the efficiency results obtained, efficiency scores of 0.8 for small firms and 1 for large firms[3] have been taken as cut-off values for dividing the samples. For small firms,

[3] 0.8 and 1 have been established as thresholds in order to have samples of approximately similar size in terms of the number of observations. It has been found that any other efficiency value would result in samples of very different sizes.

the division of the sample yields 13 observations with an efficiency score of less than 0.8, with the rest of the observations registering efficiency levels very close to 1 (Table 7).

TABLE *7. Kruskal-Wallis Test for firms with fewer than 50 employees*

As can be seen in Table 7, the Kruskal-Wallis Test yields similar results for all three variables: the chi-square statistic is significant (p-value<0.05) in all three cases, indicating differences between the mean inputs used by the two groups of firms divided according to their level of efficiency. On average, those with the worst efficiency results use more inputs than the most efficient firms; the latter make better use of available resources.

For large firms, the sample is divided into 22 companies with efficiency scores below 1, and 14 with a score of 1 (Table 8). However, for this group of firms, the Kruskal-Wallis test yields very different results.

TABLE *8. Kruskal-Wallis Test for firms with more than 50 employees*

As shown in Table 8, no variables are found to be significant, which implies that there are no differences between the inputs of the two groups analysed. On average, the most efficient firms use more inputs (€17.5 million and €19.3 million for use of inputs and productive capital, respectively, compared to the least efficient firms, which register €10.3 million and €14.9 million, respectively). It can thus be concluded that firms above a certain size need to use a greater volume of inputs to be efficient, but that this is not the case for small firms.

The next research aim is to analyse the relationship between efficiency and innovation. To that end, Table 9 compares efficiency levels according to the type of innovation. For small firms, the average efficiency in the three analysed cases (process innovation, product innovation and both) is very similar, with no observable differences in their performance. Regarding fully-efficient firms, a higher percentage engage in product innovation (25%) than in the other types; this sector is closely linked to fashion and the need to adapt to new market trends, meaning that the introduction of new products is vital for firms' survival.

TABLE *9. Comparison of efficiency levels by type of innovation*

Large firms also report similar average efficiency levels for the three groups analysed (firms engaging in product innovation, process innovation, and both). However, compared to small firms, large firms that are fully efficient register higher percentages, the most relevant being those that introduce product innovation (50%), followed by product and process innovation (44.4%). These are large firms that need to compete with imported products and are therefore forced to make significant changes to their production chains in order to be able to adapt to new demands.

Lastly, the determinants of efficiency have been estimated using a truncated regression model for the two groups of firms analysed above. The statistical base used has limited the number of independent variables that could be included. It has been considered that factors such as the number of R&D-related employees, R&D marketing activity, the resulting patents, profit and automated technology could explain the efficiency levels achieved (Table 10).

TABLE *10. Estimation of efficiency*

In firms with fewer than 50 employees, profit is the only variable found to be significant and positive; that is, with greater profits come higher efficiency levels. The variables relating to the efforts made to introduce innovations in production processes (R&D-related jobs, automated technology, patents and R&D marketing activities) are not determinants of efficiency. Conversely, in large firms, in addition to profit, the number of R&D-related jobs and the automation used in the manufacturing processes also contribute positively to the level of efficiency achieved by the company. Other variables such as R&D marketing activities and patents are not found to be significant in any sample. It can therefore be concluded that they do not influence the dependent variable.

The estimation of efficiency reveals differences in the economic functioning of the firms according to their size. Efforts to improve the management of inputs in small firms should be aimed at boosting profits, while in large firms, additional concerns relate to jobs and automation.

CONCLUSIONS

The research carried out focuses on the Spanish textile sector and differentiates between large and small firms, so that firms can be characterized by comparing them to similar ones. In the first stage, a DEA analysis has been carried out in order to identify any patterns in performance relating to firms' intrinsic features and their positioning in terms of innovation. Subsequently, truncated regression models have been estimated in order to determine the aspects that may influence the efficiency levels of the companies analysed.

The information provided by the ESEE shows that the larger firms are more focused on introducing new technologies and forms of production that allow them to regain the market share that they may have lost due to liberalization and the elimination of trade contingencies, and even gain new market share. Firms with fewer than 50 employees face barriers that hinder their process of adaptation to the new conditions imposed by the market. These may include difficulty in accessing financing, an inability to take advantage of economies of scale, or a lack of resources to devote to R&D.

Nevertheless, the textile sector has undergone a major transformation in order to adapt to the new scenario marked by increasing competitiveness and highly-diversified demand. This sector has traditionally been a labour-intensive industry, but inroads made by new competitors have forced it to adopt automated processes in its manufacturing chains, in order to lower the costs of its products without sacrificing anything in the way of quality. The ultimate aim is for firms to become more competitive and retain their place in the market. Only 20% of their spending goes on staff costs.

This research has led to the conclusion that innovative companies—regardless of their size—are making good use of their resources, with small firms achieving efficiency scores of almost 0.9, and large firms reaching 0.95. Therefore, relatively little effort is required of such firms to achieve the maximum level of efficiency. Small firms could achieve the same level of output while reducing their input use by just over 10%; for large firms, the equivalent reduction is less than 5%. In addition, in the group of small companies, those that are efficient and engage in product innovation outnumber those that engage in process innovation, or both. However, in the group of large companies, the most numerous efficient firms are those that engage in process innovation only. It could therefore be concluded that, as far as efficiency is concerned, the size of the company does have a slight influence on the results achieved.

Furthermore, the results show that the resources large firms allocate to research have more influence on efficiency levels than their profits do, whereas profit is a key variable for small firms. These results underline the pressing need to increase the size of companies. This is a sector composed primarily of SMEs, which need to adapt their products and manufacturing processes to a changing and increasingly exacting demand. Firms' chances of survival in this environment are extremely limited if they are unable to make improvements to their production chains that enable them to better position themselves against the competition. Larger firms have a greater capacity to allocate funds to research, which will facilitate the incorporation of new processes that raise the quality of their production.

In short, the sector should promote mergers and/or takeovers of small businesses because, although their current results are adequate, in the near future they are likely to face an adverse operating environment, with substantial investments required to maintain their market share. Public authorities should aim to create the conditions that benefit this sector. It can be seen that the guidelines for investments in technological and non-technological innovations represent a major commitment to improving firms' profits and encouraging them to insource their products.

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