ECONOMIC EFFICIENCY DETERMINANTS IN STEVEDORING INDUSTRY

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ABSTRACT

The non-parametric Data Envelopment Analysis (DEA-Cost) method is used to calculate the technical, allocative and cost efficiency indices for the Spanish stevedoring industry during the most significant period of legislative reforms for these activities in Spain. A multioutput approach is used, applied specifically to cargo handling services provided by the stevedoring industry as an activity that is different from other port services that are supplied by different agents. The results obtained from a sampling of 19 ports from 1990-1998 show that the technical inefficiency led to an average cost increase of 7%, and that there is also an allocative inefficiency that resulted in an overuse of the labor factor, inducing an average cost increase of 8%, adding up to an estimated average cost inefficiency of 15%. The results show that large ports, with specialized terminals and a majority of privately-owned cranes, exhibit the largest efficiency indices, while the specific cargo mix handled does not help to explain the differences observed between ports. Finally, the reforms applicable to the industry contributed to the improvement of the three types of efficiency, although certain inefficiencies remain that require new reform initiatives.

JEL Classification: D21, L91.

1. INTRODUCTION

The gradual internationalization of the economy has shown the importance of having an infrastructure that is capable of transporting goods and passengers in the shortest time possible and doing so at a competitive cost. In this sense, transport policy has become a vital instrument to ensuring the competitiveness of the economy while encouraging the economic growth that underpins social welfare.

Moreover, European transport policy has emphasized the importance of promoting the use of maritime transport and intermodality as a possible alternative to the road transport of goods. Thus, it is hoped that this policy will alleviate the congestion and environmental problems associated with road transport and that it will increase competition between transport modes. On this point, the economic analysis of ports is a very relevant issue given their role as an intermodal node and logistical platform in the global transportation chain. Any obstacle to the optimal operation of ports is passed on to other economic agents that rely on their services, with the ensuing additional cost affecting the competitiveness of the economy.

Ports provide a wide variety of services that involve different economic agents. UNCTAD (1995) classified these port services as those involving the ships (navigational aids, pilotage, towing and berthing/unberthing services, repairs, supplies, etc.) and those involving the cargo that usually are provided by the stevedoring industry. Among the latter, of particular importance are those that encompass all the activities involving the movement of cargo within the port facilities, which include, among others, loading-unloading services and cargo delivery and reception. As Cullinane, Song, Ji and Wang (2004) point out, it is possible for a port to provide services to ships efficiently while handling cargo inefficiently, or vice versa.

The economic literature has usually studied port services production following an aggregate approach. In these cases, researchers usually add the stevedoring costs and other kinds of costs as such as for towing, docking and storage services, even though they are offered by different agents. This aggregated approach obstructs the correct identification of the real factors responsible for any possible inefficiencies. This paper does not use an aggregate approach, focusing instead on analyzing the efficiency of the cargo handling operations provided by the stevedoring industry. Therefore, other services offered in ports are not analyzed in this study, especially those related to ships. This paper evaluates the performance of the stevedoring industry in Spanish ports, and excludes those services offered by the Port Authority and by other public or private companies that produce the remaining port services. While technical efficiency in ports has been the subject of many studies, allocative efficiency has received less attention. Cullinane et al. (2004) point out that the ratio between labor and the number of cranes employed in handling containers is not static in time, and note that technological changes affecting these tasks could modify the relationship between production factors. Our research proposes, along with this possibility, the hypothesis that ports, over a given period of time and given a certain technology, employ labor and capital ratios that are allocatively inefficient in terms of factors such as port size, the variety of cargo traffic handled and the ownership of the mechanical means used to accomplish these tasks.

The aim of this paper is threefold. The first is to obtain the technical, allocative and cost efficiency indices for 19 ports in the Spanish port system for the period from 1990 to 1998. The second is to analyze the relationship between these three efficiency indices and relevant port aspects such as size, type of cargo handled, the existence of specialized container terminals and ownership type (public or private) of the equipment. Our intention is to identify some of those port characteristics that are most closely associated with the three efficiency indices. The third objective is to study the change over time of the three efficiency indices so as to assess the extent to which the reform in the stevedoring industry has contributed to solving any potential inefficiency.

We can highlight some aspects in this paper, Firstly, the object of the analysis is the stevedoring operations at the port level; that is, the cost of the stevedores and of the machinery used at each Spanish port. Thus, the efficiency of this activity that is so central to port operations, can be assessed separately from that of those services provided by other agents. This keeps the resulting efficiency measures from being biased by aspects that do not pertain to stevedoring.

Secondly, services provided by production factors must be measured as flow variables. In this sense, we must note that much of the research on port efficiency makes reference to the stock of available inputs, such as the number of workers, cranes, tugs, surface area used, and so on. In contrast, in our research, information on the use of resources makes reference to the number of service hours provided by production factors for each year in the period analyzed. This allows us to obtain a more precise measure for each efficiency type, since the costs analyzed are based on the real use of resources and not on their availability. Thirdly, we highlight the use of the DEA method as applied to the study of cost efficiency in port operations. To the best of our knowledge, only Barros (2003) has conducted a study of port cost efficiency in which the object of the analysis was the Port Authorities. A final, significant contribution of our research is an analysis of the effect that variables such as size, the specialization model, the ownership of mechanical means and the existence of specialized terminals have on efficiency.

The paper is divided into six sections. In the next one we describe the status of the Spanish stevedoring industry during the period analyzed and we review the specialized literature on port efficiency. Section 3 shows the methodology employed in this paper. Section 4 discusses the variables and data utilized. In 5 we show and analyze the results, and finally, in Section 6, we draw the most relevant conclusions of our study.

2. THE CARGO HANDLING INDUSTRY

In recent decades, the stevedoring industry has undergone profound changes, spurred by both the important legislative reforms to which it has been subjected and by the intense technological change affecting cargo handling operations. In particular, the increasing use of the container has revolutionized these types of services since unitizing loads has promoted the standardization of handling services (Talley, 2000). This has increased the speed with which ships are loaded and unloaded, thus reducing the costs for these services. This increasing use of containers has induced important investments in the mechanical resources required for their handling, which has affected the proportion of capital and labor employed in these activities. In the short term, it is easier to adjust the amount of labor used, especially as the required investments in mechanical resources become more expensive. This fact suggests that while a relative overuse of labor versus capital can be maintained in the short term, over broader time periods such an allocative inefficiency should be corrected. In our case, the use of panel data will enable us to analyze the trend in any potential inefficiencies and thus to check said hypothesis. In addition, the cargo handling industry has traditionally been characterized by the existence of unions with considerable negotiating power. This led to the consolidation of very restrictive labor practices with respect to the makeup of crews and to the flexibility of schedules, which had a significant influence on the amount of labor contracted. Both the technological change experienced within cargo handling activities and these restrictive labor practices hint at the possible existence of an overuse of the labor factor along with the underuse of equipment with respect to their optimal levels.

In the Spanish case, the management of crews was entrusted to the Organización de Trabajadores Portuarios (Port Workers Organization), which was an independent administrative agency that reported to the Ministry of Labor. Under the aegis of this legislative protection, the number of stevedores increased disproportionately and salary demands were met regardless of the actual productivity of the labor force. In addition, highly restrictive practices and abuses were tolerated in the performance of job duties (oversized work crews, restricted schedules, etc.). This situation triggered high inactivity rates and the excessive pricing of port services, which led to an alarming reduction in the competitiveness of Spanish ports.

Faced with this situation, starting in the mid 1980s, a reform of the organization of port workers responsible for handling cargo was enacted. Royal Decree-Law 2/1986 of May 23rd and Royal Decree 371/1987 of March 13th, both on the public stevedoring service, was the beginning of the legislative reform of the stevedoring industry in Spain, which would later be complemented by means of a series of Frame Agreements signed by the Administration, stevedoring companies and unions in 1993 and 1997. This new legal framework dictated that a Sociedad Estatal de Estiba y Desestiba (State Stevedoring Company, hereinafter SEED) had to be established at each port considered to be of general interest. These became private companies with the State holding over 50% of the capital, so as to guarantee its hegemony in the decision-making process of an activity that was declared an essential public service. Private companies wishing to provide public stevedoring services have to supply the rest of the SEED capital. The participation of each stevedoring company in the SEED depends on objective criteria, such as the size of the permanent work force, the investment in equipment, the annual cargo volume handled and the tariffs imposed for the use of the port infrastructure. Port workers involved in duties related to cargo handling must enroll in a special register maintained by the SEED, which attends to the daily requests by stevedoring companies for personnel following a rotation system for the distribution and assignments of duties.

The legislative reform focused its efforts on introducing greater flexibility when deciding on the configuration of work crews and the service schedule. The size and configuration of the stevedore crew stopped being dictated by a statewide regulation, and each company was free to decide on the composition of the crews within certain minimum safety limits. Work schedules were also extended, which allowed for requests for stevedoring services to be handled with greater flexibility, including the possibility of working night shifts or holidays. The pay system, negotiated specifically for each port, was stipulated in a collective bargaining agreement which detailed both the minimum salary and the incentive system.

As in most countries, the situation of stevedoring operations in the mid 80s was unsustainable in Spain. The work force figures were vastly disproportionate and the technical organization of the work was completely obsolete. This resulted in unjustifiably inflated port costs. The effects of the reforms can be summarized in the following points: a reduction of the workforce, the deregulation of the composition of work crews and a certain opening up of the activity to other firms which, in the end, proved unsuccessful. The reform, initiated in 1986, began with 12,500 port workers and ended with 4,100 in 1998. The period studied, 1990-1998, can be considered the most significant period of legislative reforms in Spain, regarding stevedoring industry.

3. METHODOLOGY

An evaluation of productive efficiency requires *a priori* identification of the technological frontier that represents the optimal decisions of the economic agents. Once the reference frontier is obtained, the efficiency is calculated by measuring the distance between observed values and those that constitute the frontier, keeping in mind that the greater the distance, the lower the efficiency level of the Decision Making Unit (DMU). Data Envelopment Analysis (DEA) is a non-parametric method based on linear programming techniques to construct a piecewise frontier over the data. Instead of choosing to specify a given functional form to adjust the frontier and estimate the parameters that characterize it, DEA method calculates the frontier ensuring compliance with certain properties of technology, along with the convexity and monotony of the set of production possibilities.

The number of port efficiency studies based on non-parametric frontier models has grown significantly in recent years. Panayides et al. (2009) offers an exhaustive review of the DEA method as it applies to port operations and arranges the literature according to various criteria, such as the theoretical model proposed, the outputs and inputs considered, the type of data used (cross-sectional, time series or panel) and the sample studied (ports in the same or different countries, specialized terminals, etc.).

One of the questions that has been most controversial in the use of DEA is the definition of the inputs and outputs. As shown in Jara-Díaz et al. (2006, 2008), it is important to bear in mind the multiproduct nature of port activities so as to correctly characterize their production structure. This vision of ports where a set of inputs is combined to offer a set of outputs has consolidated in the economic analysis of port activity.

We can differentiate between those papers that use this method to evaluate solely the technical efficiency (DEA-technical efficiency) and those that measure cost efficiency (DEA-cost) by decomposing it into its technical and allocative aspects. In general, the literature on port efficiency has focused on the analysis of production and, therefore, of technical efficiency. This is because an analysis of productive performance only requires data on input and output quantities that tend to be more readily available to researchers. It is usually more difficult to compile data on costs and input prices and, consequently, the effects caused by allocative inefficiency resulting from the disproportionate use of inputs given their prices have generally been ignored in empirical studies on port efficiency. While both types of inefficiency cause higher costs, the underlying reasons for each and the corrective action measures required in each case are different, which justifies measuring these inefficiencies separately. To the best of our knowledge, only Barros (2003) uses the DEA method as applied to cost efficiency analysis for a sample of five Portuguese port authorities in 1999 and 2000. That paper provides measures of technical and allocative efficiency for the purpose of evaluating whether the incentives introduced by regulatory changes served to improve each cost efficiency component.

Building on the pioneering work of Debreu (1951) and Koopams (1951), Farrell (1957) defined the cost efficiency index (CE) as the ratio of the minimum to the observed costs. He also specified two components of cost efficiency, the technical and allocative efficiencies, and showed that the cost efficiency index can be calculated as the product of a technical efficiency (TE) index and an allocative efficiency (AE) index. The former measures the ability to obtain the maximum output possible from a given combination of inputs (output oriented), or to minimize the consumption of inputs to yield a given output level (input oriented). The allocative efficiency index, on the other hand, measures the ability of a DMU to use the inputs in optimal proportions given their prices and the production technology.

The input-oriented measure of technical efficiency (TE) proposed by Farrell (1957) is defined as one minus the maximum equiproportionate reduction in all inputs that allows for the continued production of the given outputs. This input oriented technical efficiency index is usually expressed as the minimum percentage of all inputs that guaranties the production of the output vector. Given that the stevedoring industry at any port is limited to handling cargo traffic transiting through the port, one can only hope to produce the services demanded using as few factors as possible. Therefore, it seems reasonable to adopt an input-oriented approach in our analysis of the technical efficiency of this sector.

Depending on the goal of the study and on the information available, the researcher can calculate different frontiers, such as for production or costs, for example. Since our objective is to measure the cost efficiency and decompose it into its technical and allocative factors, we shall use the DEA methodology to calculate both a production frontier against which to measure technical efficiency, as well as a cost frontier that will allow us to measure the cost and allocative efficiency, in keeping with the indices proposed by Farrell (1957).

Empirical applications of the DEA methodology various models can be found depending on, among other aspects, the input or output approach taken, the assumptions regarding the type of returns to scale shown by the technology and on the method selected for identifying the frontier with respect to which distance - and therefore the degree of efficiency - is measured. To this end, the most widely used methods are the DEA model based on the pioneering work by Charnes, Cooper and Rhodes (1978), which assumes the existence of constant returns to scale (CRS) (hereinafter the CCR DEA model), the extension proposed by Banker, Charnes and Cooper (1984), which proposes the alternative assumption of variable returns to scale (hereinafter BCC DEA model), and the Additive Model. In our paper, we have opted for the BCC DEA model, since we believe the variable returns to scale assumption to be more realistic by not supposing, as in the CCR DEA, that all of the DMUs are operating at their optimum scale. Imperfect competition, financial constraints or other market characteristics may result in a DMU not operating at its optimal scale. This way, if there are DMUs not operating at their optimum scale, the technical efficiency can be measured without the possible bias induced by a potentially incorrect use of scale.

Using the BCC DEA model to calculate the input-oriented technical efficiency, allocative efficiency and cost indices requires solving two types of mathematical programming problems. First, for each of the N ports and years, the input-oriented BCC model evaluates the technical efficiency by solving the following linear programming problem noted in (1):

$$
\begin{aligned}
& Min_{\theta,\lambda}\theta \\
& \text{subject to} : -y_i + Y\lambda \geq 0, \\
& \qquad \theta x_i - X\lambda \geq 0, \\
& \qquad \lambda \geq 0, \\
& \qquad N1'\lambda = 1
\end{aligned}
\tag{1}
$$

In (1), x_i and y_i are the inputs and outputs of port i, X is the matrix of the nxN inputs, Y is the matrix of the mxN outputs, n and m are, respectively, the number of inputs and outputs at each of the N ports analyzed. The variable θ is a scalar whose calculated value (θ ≤1) is the measure of technical efficiency (TE) for each port and year. A value of θ equal to unity indicates the existence of technical efficiency, while a value below unity represents technical inefficiency, such that the same output vector could be maintained while saving (measured as a decimal) on the use of all the inputs, and therefore on costs, an amount equivalent to (1- θ). A column vector of N constants is represented by λ. These constants are the weights used to obtain the port reference for comparing port i and calculating its technical efficiency index. This model includes a convexity constraint to the optimization problem (1), namely

$$N1'\lambda=1 \tag{2}$$

where N1 is an all-ones vector. This way, the assumption of variable returns to scale (VRS) is included, without imposing that the ports operate at the optimal scale of production.

Once the technical efficiency index is calculated, a second type of problem involving linear programming must be solved to obtain the cost efficiency measures and their allocative component. Specifically, for each port and year, we will solve

$$
\begin{aligned}
& Min_{\lambda,x_i^*}\, w_i' x_i^* \\
& \text{subject to: } -y_i + Y\lambda \geq 0, \\
& \qquad x_i^* - X\lambda \geq 0, \\
& \qquad \lambda \geq 0, \\
& \qquad N1'\lambda = 1
\end{aligned}
\tag{3}
$$

where w_i' is the input price vector for the *i* port, and x_i^* (which is calculated by the model) represents the input quantity vector that minimizes the costs at that port, given the price for these factors (w_i) and the production levels (y_i). Once problem (3) is solved, the minimum cost

($C_i^* = \sum_{i=1}^{n} w_i x_i^*$) of producing those output levels (y_i) given the prices of the inputs (w_i) is calculated for each port *i*. This requires using the optimum quantities of inputs (x_i^*).

In keeping with Farrell's proposal (1957), and from the results obtained after solving (3), the cost efficiency index is calculated as the ratio of the minimum cost to the observed cost for each port, that is, as $CE_i = C_i^* / C_i = \sum_{i=1}^{n} w_i x_i^* \Big/ \sum_{i=1}^{n} w_i x_i$ where C_i is the cost level observed for port *i*. Once the cost efficiency index is calculated for port *i*, the allocative efficiency index is calculated as the ratio of the cost efficiency and technical efficiency indices obtained before, that is, $AE_i = CE_i / TE_i$.

4. THE DATA

A database was built using the information provided by a survey directed at two types of companies: the Sociedades Españolas de Estiba y Desestiba (Spanish State Stevedoring Companies, SEEDs) that manage the services of cargo handling labor; and, the companies that own the cranes, which may be private companies and/or Port Authorities.

The SEEDs provided information on the number of service hours worked by stevedores each year and on the annual cost of those hours. The same information was requested from crane owners, who provided data on the number of crane operating hours and their annual operating costs. Compiling these data is extremely complicated, due firstly to the fact that there are several private crane operators in any given port, in addition to the Port Authority. If a single operator fails to provide the required information, that port cannot be included in the database. To this difficulty involving the number of companies we must add the use of the information related to the costs and prices of inputs, which companies regard as strategic and which they are reluctant to supply in the itemized format used herein. These obstacles to gathering the information could explain the lack of research on the cost efficiency of an activity as central to port operations as stevedoring. It also provides an insight into why more recent information was not available for our research, though we were nevertheless able to analyze a key period in the reforms of the stevedoring industry that coincided with similar efforts carried out around the world at the same time.

The database used in our research involves stevedoring industries in 19 ports in the Spanish port system over the period from 1990 to 1998. The ports included in this unbalanced panel data as DMU are: Algeciras, Alicante, Bilbao, Cádiz, Cartagena, Castellón, Gijón, Huelva, La Coruña, Málaga, Palma de Mallorca, Alcudia, Motril, Pontevedra, Santa Cruz de Tenerife, Santander, Sevilla, Valencia and Vigo.

As shown in Jara-Díaz et al. (2006, 2008), it is important to bear in mind the multiproduct nature of port activities so as to correctly characterize their production structure. To do this, we distinguish between three types of cargo handling services defined mostly by their packing, which determines the type of operations required and, ultimately, their cost. A distinction is thus made between general cargo in containers (CGC), non-containerized general cargo (NCGC) - which includes, among others, pallets - and solid bulk cargo handled without special facilities (SB). The data corresponding to these three cargo types were obtained from the annual reports issued by the public agency Puertos del Estado (State Ports) and by the Port Authorities of each of the ports analyzed.

In this study we also distinguish between two production factors in the provision of stevedoring services: labor and cranes. The information on labor was obtained through a survey devised by the authors and sent to the SEEDs, which allowed us to gather information on the usage costs for this input, including salaries, Social Security payments and intermediate expenses associated with the administrative oversight of the work force. Information was also obtained on the number of hours assigned to these tasks. As for the use of cranes, the annual reports published by each port authority and the information received from the proprietary companies of these mechanical resources allowed us to calculate the number of crane hours assigned to stevedoring tasks along with their associated costs. The prices of both inputs were calculated by dividing total expenses on each input by the total number of hours used. As we noted earlier, the services provided by production factors are regarded as flow variables. As a result, both inputs are measured in terms of the number of actual hours of operation, and not of the amount of resources available. Likewise, the costs analyzed correspond to the actual resources used. Thus, the cargo handling cost analyzed includes labor costs and the costs associated with using the cranes to handle the CGC, the NCGC and the SB. The labor and crane operating costs are expressed in 1998 pesetas. The deflator used was the consumer price index as calculated by the Spanish National Statistics Institute. Table 1 shows a description of the variables used.

Table 1 about here

The specialized literature that relies on the DEA methodology has yielded evidence showing how the definition and the number of inputs and outputs has important consequences on the efficiency analysis. Thus, as the number of outputs is increased in order to take into account the complexity of the production process in ports, the number of agents that must be included in the sample to obtain statistically meaningfull results also increasesNorman and Stoker (1991) provide some useful guidance on variable definition and justification when applying DEA. They suggest that a general guideline for the minimum number of units (ports in our case) that comprise the sample to be evaluated be at least twice the sum of the inputs and outputs. Our research complies with this recommendation.

5. ANALYSIS OF RESULTS

As noted in Section 3, the technical efficiency indices were calculated for each port and year, yielding the results shown in Table 2. There are several points to highlight. First, notice that the average technical efficiency index is 0.93, which means that the cost of handling the goods that transited through Spanish ports could have been an average of 7% lower than what was noted. Second, there are differences across port-specific technical efficiency indices, which oscillate between a value of 0.861 for the port of Santander and a value of unity at the port of Algeciras, the single port technically efficient every year of the period.

Table 2 about here

In order to explain the differences observed between the technical efficiency indices at each port, we will consider the size of the port, the type of cargo handled, the existence of specialized container terminals and the mode of ownership of the cranes as potential explanatory variables. To this end, we propose the six hypotheses shown in column 1 of Table 3, which we will contrast using the Rank-Sum Test developed by Wilcoxon, Mann and Whitney (see Cooper et al., 2000). This non-parametric test is used to contrast whether the differences in the efficiency indices between the groups proposed by the researcher are statistically significant. The hypotheses contrasted and the results are shown in column (2) of Table 3. Moreover, Tables A1 and A2 in the Appendix provide information on the construction and results, respectively, of the rank-sum tests applied in this study.

Table 3 about here

The null hypotheses regarding technical efficiency were accepted at a 5% confidence level in every case except for hypothesis 1. These results indicate that neither the cargo type, nor the existence of a specialized container terminal nor the mode of ownership of the cranes explain the differences noted in the the technical efficiency indices. Hypothesis 1 was rejected at a 5% confidence level, which confirms that significant differences exist among the technical efficiency levels depending on the size of the port, measured as the total volume of cargo traffic. In this sense, it should be pointed out that ports with above-average cargo traffic exhibit an average technical efficiency index of 0.979, versus an average index for the average ports of 0.865. The results indicate that as the total cargo increases, the usage of both labor and equipment approaches the optimal value, which explains why the large ports of the Spanish port system included in this sample (Algeciras, Valencia and Bilbao) possess the highest technical efficiency indices. Note that, along with the aforementioned ports where container traffic is the predominant activity, there is a second goup of ports (Sevilla, Alcudia, Cartagena and Huelva) with equally high technical efficiency levels and where the main activity involves SB. This result justifies the rejection of those hypotheses that consider the type of merchandise traffic to account for differences in technical efficiency. It should be noted that these results confirm those obtained by Díaz-Hernández et al. (2008a) for a sample of 21 Spanish ports over a smaller time frame.

Based on the results obtained in the solution to problem (3), we calculated the allocative efficiency indices for each port and year; results are shown in Table 4. First, note the average allocative efficiency index of 0.92, which indicates that the improper choice of the labor-crane ratio led to an average cost increase of 8%. The results obtained in terms of optimal labor and crane hours show, for nearly all ports and years, that the Spanish stevedoring industry overused labor while employing a lower than optimal amount of crane hours. These results also confirm those shown in Díaz-Hernández et al. (2008b), namely the existence of oversized work crews, which was one of the initial justifications for the reform process undertaken in the industry.

Table 4 about here

A detailed analysis of the allocative efficiency indices clearly reveals that, as happened in the case of technical efficiency, there are important differences between ports. We note, for example, that there are allocationally efficient ports over the entire period, such as Algeciras, and others that became efficient in the last years, like Valencia, Bilbao and Palma de Mallorca. Remaining ports were inefficient throughout the entire period.

As was the case with technical efficiency, the same six hypotheses were contrasted, this time with the intention of analyzing the relationship between allocative efficiency and port size, traffic type, the existence of specialized container terminals and the mode of ownership of the cranes. The results obtained are shown in column (3) of Table 3 and in Tables A1 and A2 in the Appendix. Following the application of the rank-sum test show that hypotheses 2, 3 and 4 are accepted at the 5% confidence level. This allows us to state that there are no significant differences between the allocative efficiency indices as a function of the predominant traffic type at each port.

Hypotheses 1, 5 and 6 were rejected at the 5% confidence level, which is indicative of how larger ports, with specialized container terminals and mostly privately-owned cranes, exhibit allocative efficiency indices significantly different from those of the other ports. Specifically, the larger ports exhibit an average allocative efficiency index of 0.969 versus an average value of 0.858 for the remaining ports. Those ports with specialized container terminals have an average allocative efficiency index of 0.954 versus a value of 0.866 for the rest. Finally, ports with a majority of privately-owned cranes show an average efficiency of 0.935 versus an average allocative efficiency of 0.864 for ports where publicly-owned cranes prevail. This all explains why the large ports, with specialized container terminals and with a predominance of private cranes, such as Algeciras, Bilbao and Valencia, attain the highest allocative efficiency indices. This result shows that large ports with a significant presence of private enterprises in specialized container terminals using their own cranes are better capable of adjusting the proportion of labor and crane hours, thus avoiding the overuse of the former and the infrautilization of the latter.

The cost efficiency indices were calculated based on the technical and allocative efficiency indices. The results are shown in Table 5. The average cost efficiency index is 0.856, meaning that cargo transiting through Spanish ports could have been handled with an average cost reduction of 14%. These results confirm the cost efficiency ranking presented in Díaz-Hernández et al. (2008b) and illustrate how, by lowering cost inefficiency in the stevedoring industry, it is possible to reduce transport costs and improve the competitiveness of the Spanish economy.

Table 5 about here

An analysis of the important differences noted in the cost efficiency indices among the ports once again leads to a contrasting of the six hypotheses proposed earlier (see column (4) in Table 3 and Tables A1 and A2 in the Appendix). As happened with the allocative efficiency, hypotheses 2, 3 and 4 were accepted, while hypotheses 1, 5 and 6 were rejected with a 5% confidence level. This means that port size, the existence of specialized container terminals and the predominance of private cranes give rise to differences in the cost efficiency indices, contrary to what happens in relationship to the type of cargo handled. In this sense, large ports present an elevated cost efficiency value of 0.978 versus a value of 0.843 for the remaining ports. Those ports with specialized container terminals show a cost efficiency index of 0.901 versus a value of 0.767 for the rest, while ports with a majority of private cranes present an average cost efficiency index of 0.874 versus 0.760 for the rest. These results seem to indicate that opening this activity to private enterprises that are willing to invest in their own mechanical resources and which are actively engaged in managing specialized terminals is a possible means for improving cost efficiency in the Spanish stevedoring industry.

The time evolution of the technical, allocative and cost efficiency was analyzed for the period from 1990 to 1998. It is interesting to note that a constant trend of improvement is detected for the three efficiency types for the Spanish cargo handling industry. This allows us to conclude that the legislative reform contributed to the reduction of the inefficiency stemming from the inadequate use of labor and equipment and from the improper selection of combinations between both factors, given their prices. In particular, the average improvement in technical efficiency was 8.9% over the analyzed period, while the allocative efficiency showed a 6.5% average improvement. These results indicate that while the impact of the changes that affected the Spanish cargo handling industry corrected both inefficiencies, the impact on technical efficiency was 40% greater than that recorded for the allocative efficiency. If the allocative inefficiency noted was caused by a shortage of mechanical resources, it is possible that as investment in cranes increased, the proportion of inputs was able to be adjusted. Likewise, the increase in traffic at all levels seen in Spanish ports during this period facilitated the correction of the technical inefficiency.

A more detailed analysis of the changes over time for each port shows that all the ports, except La Coruña, Tenerife and Sevilla, improved their technical and allocative efficiency levels, and therefore reduced the excess costs they exhibited with respect to optimal levels. In these three cases - where some of the efficiency indices decreased -, no common traits are apparent. While the reason for the reduction in cost efficiency in Tenerife was a reduction in technical efficiency, the reason in the case of Sevilla was a drop in allocative efficiency. In the case of La Coruña, on the other hand, although the allocative efficiency worsened, the significant improvement in technical efficiency resulted in increased cost efficiency. The analysis of the time variance of efficiency serves to highlight how the ports that started with higher levels of inefficiency are those that experienced the most significant improvements. Particularly noteworthy are the cases of Palma de Mallorca, Alcudia, Cartagena and Castellón, which experienced cost efficiency improvements above 20% over the time frame analyzed.

6. CONCLUSIONS

The stevedoring industry in Spanish ports underwent, as it did in almost every port around the world, a profound process of reform starting in the mid 1980s. The main milestones in this reform culminated in 1992 with the Law on Ports and the Merchant Marine. The process was driven by the technological advance represented by the widespread use of containers. That is why an analysis of this time period is of such interest both for identifying efficiency levels and for evaluating the impact of the aforementioned changes. This paper analyzes the efficiency in the stevedoring sector at 19 Spanish ports from 1990 to 1998, the most significant period of legislative reforms in Spain, regarding stevedoring industry.

First, the analysis of the results shows that technical inefficiency has caused an average increase in costs of 7%. The allocative inefficiency related to the overuse of labor resulted in an average cost increase of 8%. These translated into an average annual extra cost of 14% .

An analysis of the differences observed in the efficiency indices among ports helps identifying the likely causes. We used the rank-sum test to contrast whether the size, cargo type, the presence of specialized container terminals or the crane ownership regime can explain the differences between the efficiency indices obtained for the ports.

The results show that the large ports with specialized terminals for handling containers and where the majority of cranes are privately owned, present higher efficiency indices than other ports. It is also evident that the type of cargo handled at a port does not contribute to explain the differences in efficiency between ports.

The study of the variation over time of the efficiency indices shows that most ports experienced significant advances in both technical and allocative efficiency. The average improvement in technical efficiency was 8.9% over the analyzed period, while the allocative efficiency showed a 6.5% average improvement, and cost efficiency increased a 15.9%.

Finally, we should note that, despite the observed efficiency improvements, most ports still exhibited technical and/or allocative inefficiencies at the end of the study period. This underscores the fact that despite the improvements brought about by industry changes, certain inefficiencies still persist that require a new reformative effort. To this end, we believe that a gradual process of opening the sector to other stevedoring companies that allows for the creation of more competitive conditions could significantly contribute to solving these continuing inefficiencies.

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Table 1 Descriptive statistical measures of the sample

Variable	Units	Mean	Std. Dev.	Minimum	Maximum
Output	Tons (thousands)	3.035	3.545	0.264	20.742
CGC	Tons (thousands)	1.271	2.959	0	18.635
NCGC	Tons (thousands)	0.488	0.604	0.006	3.218
SB	Tons (thousands)	1.275	1.134	0.009	5.326
PL	Pesetas (thousands)	5.1	1.236	2.746	8.958
PK	Pesetas (thousands)	37.1	10.886	19.828	61.101
Cost	Pesetas (millions)	1711.7	2051.011	141.886	9644.180
HL	Hours (thousands)	205.5	236.391	17.501	1282.471
HK	Hours (thousands)	14.2	14.346	1.223	65.060
SL	Share	0.649	0.151	0.249	0.90
SK	Share	0.351	0.151	0.100	0.751

Table 3 Hypotheses contrasted

Hiphotesis (1)	Technical efficiency (2)	Allocative efficiency (3)	Economic efficiency (4)
1. Ports with above-average total traffic exhibit efficiency indices equal to those of other ports.	Rejected	Rejected	Rejected
2. Ports where GCC represents the leading source of total cargo volume exhibit efficiency indices equal to the rest.	Accepted	Accepted	Accepted
3. Same as hypothesis 2 but for NCGC instead.	Accepted	Accepted	Accepted
4. Same as hypothesis 2 but for SB instead.	Accepted	Accepted	Accepted
5. Ports with specialized container facilities have efficiency indices equal to the rest.	Accepted	Rejected	Rejected
6. Ports with a majority of privately-owned cranes have efficiency indices equal to the rest.	Accepted	Rejected	Rejected

Table 2 Farrell's technical efficiency indices by port and year

Port	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Mean**
Algeciras	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Alicante	0.885	0.901	0.923	0.946	0.978	0.965	0.951	0.934	0.945	0.936
Bilbao	0.923	0.935	0.941	0.952	0.968	0.981	**1.000**	**1.000**	**1.000**	0.967
Cádiz	-	-	-	-	0.846	0.951	0.934	0.921	0.934	0.917
Cartagena	0.904	0.936	0.948	0.956	0.923	0.931	0.945	0.991	**1.000**	0.948
Castellón	0.879	0.924	0.911	0.886	0.913	0.934	0.951	0.959	0.973	0.926
Gijón	0.811	0.843	0.866	0.872	0.859	0.923	0.888	0.903	0.926	0.877
Huelva	0.863	0.921	0.948	0.951	0.921	0.932	0.944	0.956	0.972	0.934
La Coruña	0.801	0.823	0.846	0.889	0.915	0.923	0.934	0.946	0.968	0.894
Málaga	-	-	0.881	0.845	0.867	0.873	0.898	0.924	0.934	0.889
P. Mallorca	0.871	0.886	0.852	0.837	0.867	0.889	0.934	0.968	**1.000**	0.900
Alcudia	0.889	0.916	0.935	0.942	0.955	0.968	0.973	**1.000**	**1.000**	0.953
Motril	-	-	-	-	0.938	0.911	0.894	0.911	0.931	0.917
Pontevedra	-	-	-	-	0.928	0.936	0.956	0.903	0.938	0.932
Tenerife	-	-	-	**1.000**	0.921	0.927	0.934	0.911	0.935	0.938
Santander	-	0.823	0.845	0.836	0.875	0.846	0.861	0.889	0.913	0.861
Sevilla	-	0.943	0.925	0.966	0.965	0.968	0.984	**1.000**	**1.000**	0.969
Valencia	0.903	0.975	1.000	0.936	0.964	0.987	**1.000**	**1.000**	**1.000**	0.974
Vigo	-	-	-	-	0.931	0.946	0.953	0.919	0.928	0.935
Mean	0.884	0.910	0.916	0.921	0.923	0.936	0.944	0.949	0.963	0.930

Table 4 Farrell's allocative efficiency indices by port and year

Port	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Mean**
Algeciras	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Alicante	0.864	0.853	0.854	0.874	0.894	0.901	0.923	0.938	0.946	0.894
Bilbao	0.925	0.946	0.957	0.961	0.973	0.981	**1.000**	**1.000**	**1.000**	0.971
Cádiz	-	-	-	-	0.834	0.826	0.841	0.863	0.901	0.853
Cartagena	0.803	0.815	0.843	0.861	0.896	0.913	0.926	0.935	0.968	0.884
Castellón	0.886	0.901	0.923	0.931	0.965	0.926	0.943	0.952	0.968	0.933
Gijón	0.874	0.899	0.914	0.921	0.926	0.898	0.899	0.891	0.916	0.904
Huelva	0.901	0.892	0.832	0.869	0.921	0.923	0.935	0.946	0.956	0.908
La Coruña	0.961	0.886	0.874	0.995	0.920	0.949	0.901	0.930	0.903	0.924
Málaga	-	-	0.843	0.856	0.879	0.897	0.901	0.924	0.938	0.891
P.Mallorca	0.898	0.912	0.914	0.937	0.998	0.978	**1.000**	**1.000**	**1.000**	0.960
Alcudia	0.863	0.879	0.889	0.913	0.923	0.931	0.936	0.959	0.964	0.917
Motril	-	-	-	-	0.801	0.832	0.868	0.899	0.923	0.865
Pontevedra	-	-	-	-	0.883	0.894	0.931	0.941	0.978	0.925
Tenerife	-	-	-	0.906	0.923	0.934	0.945	0.956	0.946	0.935
Santander	-	0.889	0.905	0.916	0.924	0.936	0.909	0.913	0.928	0.915
Sevilla	-	0.934	0.966	0.941	0.932	0.867	0.813	0.914	0.847	0.902
Valencia	0.847	0.887	0.918	0.923	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.953
Vigo	-	-	-	-	0.911	0.931	0.945	0.968	0.981	0.947
Mean	0.893	0.899	0.902	0.920	0.921	0.922	0.927	0.944	0.951	0.920

Table 5 Farrell's cost efficiency indices by port and year

Port	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Mean**
Algeciras	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Alicante	0.765	0.769	0.788	0.827	0.874	0.869	0.878	0.876	0.894	0.837
Bilbao	0.854	0.885	0.901	0.915	0.942	0.962	**1.000**	**1.000**	**1.000**	0.939
Cádiz	-	-	-	-	0.706	0.786	0.785	0.795	0.842	0.782
Cartagena	0.726	0.763	0.799	0.823	0.827	0.850	0.875	0.927	0.968	0.839
Castellón	0.779	0.833	0.841	0.825	0.881	0.865	0.897	0.913	0.942	0.863
Gijón	0.709	0.758	0.792	0.803	0.795	0.829	0.798	0.805	0.848	0.793
Huelva	0.778	0.822	0.789	0.826	0.848	0.860	0.883	0.904	0.929	0.849
La Coruña	0.770	0.729	0.739	0.885	0.842	0.876	0.842	0.880	0.874	0.826
Málaga	-	-	0.743	0.723	0.762	0.783	0.809	0.854	0.876	0.792
P.Mallorca	0.782	0.808	0.779	0.784	0.865	0.869	0.934	0.968	**1.000**	0.864
Alcudia	0.767	0.805	0.831	0.860	0.881	0.901	0.911	0.959	0.964	0.874
Motril	-	-	-	-	0.751	0.758	0.776	0.819	0.859	0.793
Pontevedra	-	-	-	-	0.819	0.837	0.890	0.850	0.917	0.863
Tenerife	-	-	-	0.906	0.850	0.866	0.883	0.871	0.885	0.877
Santander	-	0.732	0.765	0.766	0.809	0.792	0.783	0.812	0.847	0.788
Sevilla		0.881	0.894	0.909	0.899	0.839	0.800	0.914	0.847	0.874
Valencia	0.765	0.865	0.918	0.864	0.964	0.987	**1.000**	**1.000**	**1.000**	0.928
Vigo	-	-	-	-	0.848	0.881	0.901	0.890	0.910	0.886
Mean	0.790	0.819	0.827	0.848	0.851	0.864	0.876	0.897	0.916	0.856

APPENDIX
Table A1 Test of hypotheses

	Hyp 1	**Hyp 2**	**Hyp 3**	**Hyp 4**	**Hyp 5**	**Hyp 6**
m=number of observations under null hypothesis	38	49	12	96	33	53
n= number of observations under alternative hypothesis	120	109	146	62	125	105
$\bar{S} = \text{Mean of Ranking Sum}\,(S) = m\times(m+n+1)/2$	3021.0	3895.5	954.0	7632.0	2623.5	4213.5
$Std.Dvt.S = \text{Standard Deviation of } S = \sqrt{\mathrm{m}\times\mathrm{n}\times(\mathrm{m}+\mathrm{n}+1)/12}$	245.8	266.0	152.4	280.8	233.8	271.5
CONTRAST OF HYPOTHESES RELATIVE TO TECHNICAL EFFICIENCY						
***S*= Ranking Sum**	2035.5	3597.5	939.5	7971.0	1906.0	3461.0
$T - Statistic = \left(S - \bar{S} \big/ Std.Dvt.S \right) \sim N(0,1)$	-4.009 (*)	-1.120	-0.095	1.207	-3.069 (*)	-2.771 (*)
CONTRAST OF HYPOTHESES RELATIVE TO ALLOCATIVE EFFICIENCY						
***S*= Ranking Sum**	1909.0	3624.5	892.0	7891.0	1842.5	3324.5
$T - Statistic = \left(S - \bar{S} \big/ Std.Dvt.S \right) \sim N(0,1)$	-4.524 (*)	-1.019	-0.407	0.922	-3.341 (*)	-3.274 (*)
CONTRAST OF HYPOTHESES RELATIVE TO COST EFFICIENCY						
S=Ranking Sum	2111.5	3626.5	893.5	7888.0	1844.0	3326.5
$T - Statistic = \left(S - \bar{S} \big/ Std.Dvt.S \right) \sim N(0,1)$	-3.700 (*)	-1.011	-0.397	0.912	-3.334 (*)	-3.267 (*)

Table A2 shows the results for the technical, allocative and economic efficiency indices calculated both under the null hypothesis (H0) and under the alternative hypothesis (HA) for each of the six hypotheses contrasted. The percentage difference among the efficiency indices obtained for each case was also calculated. In those cases where the null hypothesis was rejected (indicated in the tables with an asterisk), the conclusion may be drawn that there is a statistically significant difference between the efficiency indices calculated under both hypotheses, in which case the average efficiency in each case is of particular interest.

Table A2 Average efficiency index values for the hypotheses contrasted

		Hypothesis 1	**Hypothesis 2**	**Hypothesis 3**	**Hypothesis 4**	**Hypothesis 5**	**Hypothesis 6**
TE	**H0**	0.979	0.929	0.929	0.88	0.943	0.936
	HA	0.865	0.893	0.884	0.913	0.897	0.894
	Dif %	**13.2 (*)**	**4.0**	**5.1**	**-3.6**	**5.1**	**4.7**
AE	**H0**	0.969	0.916	0.921	0.873	0.954	0.935
	HA	0.858	0.887	0.875	0.902	0.836	0.834
	Dif %	**12.9 (*)**	**3.3**	**5.3**	**-3.2**	**14.1 (*)**	**12.1 (*)**
CE	**H0**	0.978	0.829	0.843	0.782	0.901	0.864
	HA	0.842	0.795	0.797	0.815	0.767	0.76
	Dif %	**16.2 (*)**	**4.3**	**5.8**	**-4.0**	**17.5 (*)**	**13.7 (*)**