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# DECOMPOSING COST EFFICIENCY IN CARGO HANDLING IN SPANISH PORTS USING A NON-PARAMETRIC APPROACH

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## ABSTRACT

The measurement and decomposition of cost efficiency in the provision of cargo handling services at ports can help with the identification of certain production inefficiencies that are transferred to the rest of the economy. In this paper the non-parametric Data Envelopment Analysis (DEA) method is used to calculate the technical, allocative and cost efficiency indices for the Spanish cargo handling industry following a period of significant legislative reforms. The results obtained from a sampling of 19 ports from 1990-1998 shows that the technical inefficiency led to an average cost increase of 7%. There is also an allocative inefficiency that resulted in an overuse of the labor factor above its optimal levels, inducing an average cost increase of 8%. As a consequence, it is estimated that the average cost inefficiency in the Spanish cargo handling industry was 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 improving the three types of efficiency, although certain inefficiencies remain that require new reform initiatives.

**KEY WORDS:** Cost efficiency, Ports, Data Envelopment Analysis.

## 1. INTRODUCTION

The increasingly globalized economy has renewed the interest in the economics of transportation, specifically in the analysis of the determinants of transportation costs. Among other issues, we wish to understand how to reduce the transportation time and cost of goods in order to stimulate commercial trade, and thus encourage a process of economic growth and improved prosperity.

Along these lines, an economic analysis of ports is of vital importance given their role as an intermodal node and logistical platform in the transportation chain. Any obstacle to the optimal operation of ports is passed on to the other economic agents that rely on their services, with the ensuing additional cost affecting the competitiveness of the economy. That is why it is of considerable interest to measure and decompose any potential production inefficiencies in the provision of port services.

Ports provide a group of services that involve different economic agents using multiple resources. This variety of services may be classified as those involving the ship (towing and docking services, repairs, supplies, etc.) and those involving the merchandise. Among the latter, of particular importance are those that encompass all the activities involving the movement of goods within the port facilities, which include, among others, loading-unloading services and cargo reception and dispatch. These cargo handling services requires the use of production services provided by stevedores and mechanical resources, mainly cranes.

In UNCTAD (1975) it was shown that for an average transoceanic route and a medium-size freighter, ports accounted for 67% of the transportation costs including both monetary and time expenses. The remaining costs were incurred en route. Considering only the monetary fees of the various services provided in port, it was estimated that the cargo handling costs at ports represented 66% of port costs. Two more recent studies, though much smaller in geographical scope and sample size, partially confirmed the results of UNCTAD (1975). De Rus et al. (1994) determined that 78% of all port fees for a container from mainland Spain to Gran Canaria result from handling cargo. Eyre (1989) calculated the following percentages for a container en route from Genoa to New York: the port accounted for 76.4% of the monetary costs, and the maritime transportation for 23.6%, while the time spent in port was 41.8% versus 58.2% in maritime transportation. Moreover, in Spain, some 70% of foreign trade involves maritime transportation, and therefore relies on ports. Ports costs in general and cargo handling in particular are quite relevant in the intermodal transportation chains and in the final cost of the process.

The economic literature has analyzed the aggregate production efficiency of port terminals including cargo handling services (see Cullinane et al., 2006, for a general survey of the literature on port efficiency). When no differentiation is made between services provided to the ship and those which specifically make reference to cargo handling, or when cargo handling and storage services are jointly analyzed, port efficiency analysis could lead to confusion when attempting to identify the real origin of certain production inefficiencies, which might be used to justify some economic policy measures and/or business management decisions involving services that are not the real causes for these inefficiencies. To the best of our knowledge, an analysis of the efficiency of cargo handling operations separate from other port services has been addressed only by Díaz-Hernández et al (2008a,b) who analyzed the Spanish cargo handling industry. The first is an analysis of the production function that measures separately the contribution to productivity of both technological change and variations in the technical efficiency indices. The latter analyzes the cost function by evaluating the effects of technical and allocative inefficiency.

In general, the literature on port efficiency has focused on an analysis of production and, therefore, of technical efficiency and technical change. An analysis of production 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 prices of factors, hence the almost total lack of studies on costs. Consequently, the effects caused by allocative inefficiency resulting from the disproportionate use of resources due to cost constraints, have generally been ignored. While both inefficiency types translate into higher costs, the underlying reasons for each and the corrective measures required in each case are different, which justifies the need to measure each inefficiency type separately. In this paper, like in Díaz-Hernández et al. (2008b), we aim at addressing both types of inefficiencies but using a completely different methodological approach: first, we use the non-parametric Data Envelopment Analysis (DEA) method, while Díaz-Hernández et al. (2008b) employed the parametric shadow cost function technique; and second, this study uses a series of non-parametric tests that allow for a more detailed explanatory analysis of the determinants of efficiency.

In recent decades, the cargo handling 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 growing use of the container has revolutionized these type 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 growing use of containers has induced important investments in the mechanical resources required for their handling, which has affected the proportion of capital and labor used in these activities. 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.

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 the 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 industry has contributed to solving any potential inefficiencies. The paper is divided into six sections. In the second we describe the status of the Spanish stevedoring industry during the period in question. In Section 3 we review the methodology employed. Section 4 discusses the variables and data utilized. In 5 we show and analyze the results, and finally, in 6, we draw the most relevant conclusions of our study.

## 2. THE CARGO HANDLING INDUSTRY IN SPAIN

As occurred in the rest of the world, the need to ensure the availability of a professional work force that could quickly and safely perform cargo handling tasks in ports has traditionally resulted in these being regulated activities. As such, the handling of cargo was exclusively reserved for a class of dock workers that progressively consolidated its monopolistic position in all stevedoring operations. 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 80s, 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 levies 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.

Cargo handling in ports underwent, starting in the 70s, a notable technological transformation driven by the unitization of merchandise into pallets and containers, which facilitated and expedited its handling. In particular, containerization facilitates the displacements, transfers (between land and sea) and storage of cargo in a faster and safer way. Pallets also result in more compact units though smaller in size and weight than containers, which implies more handling time than containerized merchandise. Closely linked with these changes in the packing of cargo was the addition of equipment capable of quickly transferring and moving merchandise. In this sense, the increase in port traffic justifies the investment in cranes with great lifting power and cranes specific to containers, which has allowed for an increase in the amount of merchandise handled per unit time. The installation of rail-mounted cranes, transtainers and long-reach stacking cranes, speeded up horizontal transportation on the ground. These technological changes were the driving force behind the reforms of stevedoring organizations worldwide.

The situation of stevedoring operations in the mid 80s was unsustainable in most countries. In Spain the work force figures were vastly disproportionate (12,500 port workers in 1986 versus 4,100 in 1998) and the technical organization of the work was completely obsolete. This resulted in unjustifiably inflated port costs. A reform was thus initiated whose ultimate goal was to make ports more competitive. The result can be described 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.

## 3. METHODOLOGY

An evaluation of production efficiency requires *a priori* identification of the technological frontier that represents the optimal decisions of the economic agents. Then inefficiency is obtained by measuring the distance between observed values and those that constitute the frontier. Data Envelopment Analysis (DEA) is a non-parametric method based on mathematical programming techniques and proposed by Charnes et al. (1978) and extended by Banker et al. (1984). This method will allow us to calculate the frontier as well as to measure and decompose the cost efficiency into its technical and allocative components. Instead of opting to specify a given functional form to adjust the frontier and estimate the parameters that characterize it by imposing certain constraints on the distribution of the inefficiency,[1] the DEA method calculates the frontier ensuring compliance with certain properties of technology, along with the convexity and monotony of the set of production possibilities. In this way we avoid potential specification mistakes in the model that could influence the resulting measurements of efficiency. See Cooper et al. (2000) for a more detailed review of this method.

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 deviation of the observed inputs ratios with respect to the ratio of inputs that minimizes the firm's production costs, given input prices.

Given that the stevedoring industry at any port is limited to handling cargo traffic transiting through the port and is incapable of increasing the production of its services, but rather can only hope to offer the services demanded of it while consuming as few factors as possible, it seems reasonable to adopt an input-oriented approach in our analysis of the technical efficiency of this sector. Using the DEA method 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 following problem will be solved, thus allowing us to calculate the technical efficiency index for each observation:

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

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[1] Research into estimating the technological frontier has basically employed two methods: parametric and non-parametric. The first case includes that research in which a specific functional form is chosen for estimating the technological frontier, and where certain statistical distributions are assumed for the model's error components which include the effects of the inefficiency. The drawback to this approach to stochastic frontiers is the introduction of potential bias that the choice of an inadequate functional form and distribution of the error term can have on the measure of efficiency. In light of these complications, and despite other disadvantages involved in the non-parametric DEA method, we opted to use the DEA in our work, given our interest in obtaining efficiency measures that are not affected by the specification used. See Fried, Lovell and Schmidt (1993) for a more exhaustive review and comparison of the different methods available for analyzing production efficiency.

In (1), $x_i$ and $y_i$ are the inputs and outputs of company 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 ($\theta \leq 1$) 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.

The mathematical programming problem noted in (1) is relevant to the model under the assumption of constant returns to scale, which is only applicable when all the ports are operating at the optimal scale of production. Should this condition not apply, the use of the model specification under constant returns to scale could result in an incorrect measure of the calculated technical efficiency due to the inclusion of effects related to the improper use of scale. In this paper the model is calculated asssuming variable returns to scale since this is a more flexible specification in that it does not assume that the ports operate at the optimal scale of production[2]. Such model requires the addition of a convexity constraint to the optimization problem (1), namely

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

where N1 is an all-ones vector.

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

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

where $w_i'$ is the input price vector for the i-th port, and $x_i^*$ (which is calculated by the model) represents the quantity vector for the production factors that minimize the costs at that port, given the price for these factors ($w_i$) and the production levels ($y_i$).

In keeping with Farrell's proposal (1957), and from the results obtained after solving (2), the cost efficiency index is calculated as the ratio of the minimum cost to the observed cost for each port, that is, as $CE_i = w_i' x_i^* / w_i' x_i$ . The allocative efficiency index, on the other hand, is calculated as the ratio of the cost efficiency and technical efficiency indices, that is, AE=CE/TE.

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[2] Based on a comparison of the technical efficiency indices obtained under the assumption of constant and variable returns to scale, we can determine whether ports are operating at their optimal scale. This aspect, however, is beyond the scope of this paper. See Coelli et al. (1999) for a more detailed explanation of this topic.

## 4. THE DATA

The database used in our research involves 19 ports in the Spanish port system over the period from 1990 to 1998 and which comprise an unbalanced panel data. The ports included in this study 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 (GCC), 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 equipment. 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 factor, 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 equipment, the annual reports published by each port and the information received from the proprietary companies allowed us to calculate the number of operating 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 work hours.

The cargo handling cost analyzed in our research includes labor costs and the costs associated with using the cranes to handle the GCC, the NCGC and the SB. The personnel 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.

## 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 1. 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 large 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. 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 following six hypotheses, 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 significant. The hypotheses contrasted are:

1. Ports with above-average total traffic exhibit efficiency indices equal to other ports.

2. Ports where GCC represents the leading source of total cargo volume exhibit efficiency indices equal to the rest.

3. Same as hypothesis 2 but for NCGC instead.

4. Same as hypothesis 2 but for SB instead.

5. Ports with specialized container facilities have efficiency indices equal to the rest.

6. Ports with a majority of privately-owned cranes have efficiency indices equal to the rest.

The null hypotheses 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 .979, versus an average index for the average ports of 0.866. The results indicate that as the total merchandise traffic 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 2. First and foremost, 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 work hours and crane usage[3] show, for 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.

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

[3] The effects of allocative inefficiency on labor hours and the use of cranes for each port and year were not included in this paper due to the excessive amount of data that would entail and because the fundamental results are already included in the allocative efficiency indices shown in Table 2. Readers interested in these effects can approach the authors directly.

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 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 values.

The cost efficiency indices were calculated based on the technical and allocative efficiency indices. The results are shown in Table 3. 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).

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. 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.

Lastly, the time evolution of the technical, allocative and cost efficiencies, were 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 period in question, 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 deficiencies, the impact on technical efficiency was 40% greater than that recorded for the allocative efficiency.

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 by over 20% over the time frame analyzed.

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.

## 6. CONCLUSIONS

The cargo handling industry in Spanish ports underwent important changes as a result of both a legislative reform process and technological advances related primarily to the growing use of containers. Given this changing scenario, an analysis of the technical, allocative and cost efficiency at 19 Spanish ports between 1990-1998 shows that technical inefficiency has caused an average increase in costs of 7%, while the overuse of labor resulted in an average cost increase of 8%.

An analysis of the differences observed in the efficiency indices among ports helps identifying the likely causes; in particular, large ports with specialized terminals for handling containers and where the majority of cranes are privately owned, present efficiency indices higher 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.

Finally, a study of the variation over time of the efficiency indices shows that most ports experienced significant advances in both technical and allocative efficiency. However, a certain level of inefficiency persisted at the end of the period studied. This situation calls for a new reform process to encourage participation by a larger number of companies, thus increasing the competitive environment in the Spanish stevedoring industry.

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**Table 1. 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 2. 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 3. 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 |