Eur. Transp. Res. Rev. (2016) 8: 1
DOI 10.1007/s12544-015-0187-z

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ORIGINAL PAPER

Evaluating Iberian seaport competitiveness using an alternative DEA approach

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Received: 26 June 2014 / Accepted: 16 November 2015 / Published online: 2 December 2015

Abstract
Purpose This paper aims to evaluate the competitiveness of Iberian seaports through efficiency using an alternative DEA approach (Data Envelopment Analysis) and identifies explicit causes of inefficiency.
Methods This paper applying an alternative DEA approach (three stage DEA model) to provide a more useful insight about the cause of efficiency or inefficiency of the seaports.
Results and conclusions The average efficiency score under CCR equal to 83.74 meaning that, on average, the seaports analysed could operate at 83.74 % of their current levels while still returning the same output value. Unlike the ranking in terms of cargo throughput, the most efficient Portuguese seaports are Leixões and Setubal and their Spanish peers are Algeciras, Barcelona and Tarragona. This has proven what has been reported in other studies: that seaport efficiency is not necessary influenced by its cargo throughput.

Keywords Competitiveness · Efficiency · DEA · Iberian seaports

1 Introduction

The globalization of the world economy has led to an increasingly important role for the transportation industry [14]. The seaport industry that carried 80 % of world international trade has been affected by this global change. In order to support trade oriented economic development, seaport authorities have increasingly been under pressure to improve seaport efficiency by ensuring that seaport services are provided on an internationally competitive basis [39]. Seaports form a vital link in the overall trading chain and consequently, seaport efficiency is an important contributor to a nation's international competitiveness.

The importance of seaports to national economies attracts broad consensus in the literature as does the rise in competition between seaports. Iberian seaports are no exception to this struggle for global market share. In this context, it becomes important to assess the Iberian seaport competitiveness by focusing on efficiency outputs. The Iberian seaports represent an important role in the world and maritime transportation acts as gateway for Europa and Asia. In terms of global rankings of containerized cargo consideration, Spain ranked 22nd in 2007, whilst Portugal came in 53rd amongst 60 countries [16]. The Iberian seaports are also important to the national economies of both Portugal and Spain as in 2009, 32 % of the goods in Portugal and 20 % of goods in Spain were carried through seaports [27, 28].

In order to evaluate the seaport competitiveness, efficiency is used as a proxy for understanding output [12, 14, 35, 37]. Evaluating the efficiency score is important because it could influence the decision-making strategies of seaport authorities to help them identify areas requiring improvement and training. Plus, it can help them to determine, whether a particular seaport is under-utilized or can be used in another capacity [37]. This means that important insights into setting the direction or the scope of the seaport's activities can be better understood.

The present study aims to evaluate the competitiveness of Iberian seaports by examining efficiency applied in an alternative DEA model, which will identify the reasons of

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efficiency or inefficiency of the seaports and consequently how they can improve it. The DEA analysis is a mathematical programming based method that converts multiple input and output measures into a single summary measure of production efficiency. According to Song et al. [38], DEA is a method for benchmarking production units' productivity, profitability or any other criteria that could be assessed based on the available input and output variables. This methodology has been applied in many seaports but few compare the efficiency of Iberian seaports. In a previous study, Dias et al. [17] applied DEA to Iberian seaports but focused on container terminals. There are also some other studies [4, 5, 7, 9, 17, 23, 32] dealing with Portuguese and Spanish seaports efficiency issues but separately or in conjunction with other European seaports. Furthermore, none of these studies identify the cause of efficiency or inefficiency of seaports that can help inefficient seaports to improve their efficiency. Iberian seaports play an important role in the development of their economies and this has implications on the way seaports can improve their performance. Thus, it is crucial to found out the how the seaports can improve their efficiency and how could be implemented. A modern, efficient seaport system has benefit for all sectors of the economy. The proposed alternative DEA approach will provide information about the efficiency in three stages: productivity, profitability and overall output in order to support management decisions of seaports operators, their competitive strategy and to better understand the real source of efficiency/inefficiency. The most popular Iberian seaports of each country were selected for this study.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review on seaport efficiency analysis. Section 3 explains the methodology namely the method and the variables used. Section 4 reports the results of the alternative DEA approach used and identify the cause of efficiency or inefficiency of the seaports. Finally, Section 5 sets out the article's conclusions.

2 Literature review

Managers of seaports are often under great pressure to improve their competitiveness due to time and cost reasons [15, 22]. Traditionally, the indicators to measure seaport competitiveness are based on cost and technical efficiency in handling ships and cargo [15]. This has meant that the scope of a seaport to increase its level of competitiveness is enhanced when it can offer technical efficiency and lower costs, and capitalize on its strategic advantages and core competencies in delivering efficient, cost-competitive services to its users. Thus, it is important to measure efficiency to help seaport management planning and control activities and this has received considerable attention by both management practitioners and theorists.

Lovell [31] suggests that there are two fundamental reasons why it is important to measure efficiency. Firstly, they are indicators of the success achieved by production units and thus provide a basis for their evaluation. Secondly, they enable us to explore hypotheses concerning the sources of efficiency and productivity differentials. Identifying these sources is essential to instituting both public policy and private business strategies that are designed to enhance overall performance. Seaport efficiency is not only a powerful management tool for seaport operators, but also constitutes a most important input for informing regional and national seaport planning and operations [14, 35]. This means that an efficient seaport raises the productivity of prime factors of production (labour and capital) and profitability of the producing units thereby permitting higher levels of output, income, and employment [18].

In Europe, seaport efficiency is a major issue in economics debates due to the intense pressure that competition exerts on prices and thereby economic standards of living for citizens [8]. Competition between European seaports focuses mainly upon their capacities to attract maximum cargo volumes [19]. This competitive pressure derives from two evolutionary processes. The first one being the deregulation of former national markets fostering competition between domestic seaports. The second is the adoption of the European Union's Single Market Program and developments in overland infrastructures boosts competition between domestic and international seaports [25].

Most recently, a growing body of literature deploying a variety of approaches has emerged dealing with efficiency issues in seaports [4, 9, 12, 13, 17, 23, 32, 35, 36]. The basic premise underlying the concept of efficiency is that no output can be produced without resources (inputs) and that these resources are scarce. Consequently, there is a limit to the volume of output (commodities) susceptible to production.

The traditional methodology for measuring efficiency in economics has been the production frontier approach based on principles from statistics and econometrics [11]. These functions, which are estimated to determine efficiency, are also known as stochastic frontier approach (SFA). During the last few decades, however, an alternative methodology to the SFA knows as the DEA has been developed with its application growing rapidly in popularity in recent times [12, 17, 23, 40]. Both the DEA and the SFA approaches have been applied to study seaport productive efficiency due to the sheer importance of improving their productivity levels. Cullinane et al. [15] put forward a detailed synthesis on the application of these techniques in seaports and applied them to the world's largest container seaports. Cullinane et al. found that the technical efficiency indexed rankings obtained using DEA and SFA have similar functionality. The two categories of methodologies display specific strengths and weakness. The strength of SFA is the fact that adapts econometric techniques for the efficiency estimation. However, econometric approaches come up with strong prior assumptions about the production technology of seaports, since the true production technology is unknown [33]. The strengths of DEA are the possibility to accommodate multiple inputs and multiple outputs within a single measurement of efficiency and it does not impose a specified functional form to modelling and calculating the efficiency of a decision making unit (DMU). On the other hand, since DEA is a non-parametric technique, statistical hypothesis testing is difficult to obtain.

According to Sharma and Yu [37], DEA models are classifiable according to the type of envelopment surface and the orientation. There are two basic types of envelopment surfaces in DEA known as constant returns-to-scale and variable returns- to-scale surfaces. The first DEA model, DEA-CCR (Charnes, Cooper and Rhodes) was introduced by Charnes et al. [10] and assumes constant returns to scale so that a change in the input level leads to an equi-proportionate change in the output level. On the other hand, the DEA-BCC (Banker, Charnes and Cooper) model introduced by Banker et al. [3] assumes variable returns to scale where performance is bounded by a piecewise linear frontier. According to Gollani and Roll [24], the CCR model identifies overall technical efficiency (pure technical efficiency and scale efficiencies), while the BCC, pure technical efficiency only. The concept of scale efficiency was first introduced by Farrell [21], which can be simply defined as the relationship between a seaport's per unit average production cost and volume. This differentiation is based on the definition of technical efficiency by Fare et al. [20] who stated that it has been decomposed into the product of measures of scale efficiency and pure technical efficiency. Another researcher Barros [6] interpreted pure technical efficiency as managerial skills, thereby assuming overall technical efficiency is due to managerial skills and scale effects. This leads to a ratio of the overall technical efficiency scores to pure technical efficiency scores provides a scale efficiency measurement. Therefore, when a DMU is inefficient in CCR models and turns out to be efficient in BCC models, signifying that the dominant source of inefficiency is due to scale efficiency.

In regards to orientation, DEA models are also classified as input oriented, output oriented, or additive (both inputs and outputs are optimized) based upon the direction of inefficient unit projections into the frontier [37]. The input-oriented model focuses on how much inputs can be reduced while maintaining the same level of output, whilst the output-oriented model focuses on how much can output(s) increase but also keeping the level of inputs constant. The input-oriented models used to measure seaport efficiency were used by Barros [4], Barros and Athanassiou [7], Park and De [35] and Cullinane et al. [14], while Cullinane et al. [13] whilst Dias et al. [17] used the output-oriented model. According to Cullinane et al. [13], the input-oriented model is closely related to operational and managerial issues, whilst the output-oriented model is more related to planning and strategies.

Since its beginning in 1978, DEA approach has been widely utilised to analyse relative efficiency and has covered a wide area of applications and theoretical extensions. One of these theoretical extensions of general DEA was proposed by Park and De [35]. Park and De [35] developed an alternative approach to efficiency measurement of seaports using DEA, which they refer to as a "Four-Stage DEA Method": i) productivity; ii) profitability; iii) marketability, and iv) overall efficiency. This involves the disaggregation of the overall efficiency model into its constituent components thereby generating better insights into the real sources of efficiency. Tongzon [39] adopted the super-efficiency DEA models to allow the ranking of the efficient seaports. Another researcher Lee et al. [30] employed the recursive DEA model, which constitutes a multi stage DEA model. Many researchers have implemented contemporaneous and windows analysis to examine the efficiency in intervals of time [1, 17, 20, 29, 36]. Hung et al. [26] used the bootstrapped DEA in order to reduce the statistical noise of the basic DEA models.

3 Methodology

The most representative Iberian seaports of each country were selected for this study. In Portugal the five biggest seaports were selected for analysis in this study (Sines, Lisboa, Leixões, Setubal, and Aveiro). Overall, in 2009 these seaports represent 97.39 % of total traffic. In Spain, the top five seaports, Algeciras, Valencia, Barcelona, Bilbau, and Tarragona were selected, which in 2009 accounted for 59.61 % of total traffic. Figure 1 displays the locations of the main Iberian (Portugal and Spanish) seaports.

For assessing the differences in the efficiency of Iberian seaports, DEA was the statistical technique adopted. The choice of DEA is primarily based on the strengths of this method and on the fact that the econometric models with a small number of seaports (the case of our sample) may turn out to be inefficient and instable. The alternative DEA approach suggested by Park and De [35] is applied in order to achieve the proposed objective. This methodology represents as an extension of general DEA. There are, however, certain basic differences between general DEA and this proposed alternative DEA that make it more useful to achieve our goals. Firstly, conventional DEA methods usually measure the overall efficiency by using specific input and output variables but the proposed alternative DEA divides the overall efficiency into several stages by transforming the inputs and outputs in each stages. Secondly, the four-stage DEA method also shows the role of the inputs and outputs according to the stages

Source: APA [2]

Fig. 1 Iberian seaports location. Source: APA [2]

differently. Thirdly, policy planners can analyse a situation correctly, and suggest solutions for enhancing the efficiency of each individual DMU, because this methodology allow understanding the real source of efficiency/inefficiency.

Without precise information on the return-to-scale of the seaport production function and for greater scope of comparison, the CCR and BCC models are applied to analyse seaport efficiency. The input oriented-based approach is adopted because the seaports have better control over inputs than outputs. Given that productive output is fairly predictable in the short and medium term, an input-oriented model is most appropriate to the analysis of seaport production.

The mathematic formulation of DEA is: Consider n DMUs, when each DMU j ($j = 1,...,n$) uses m inputs $X_j = (X_{1j}, X_{2j}, ...X_{mj}) > 0$ for producing s outputs $Yj = (Y_{1j}, Y_{2j}, ...Y_{sj}) > 0$. The DEA efficiency score h_{jo} in CCR model can be obtained by solving the following fractional program:

$$\text{Maximize } h_{jo} = \sum_{r=1}^{s} u_r y_{rjo} \Big/ \sum_{i=1}^{m} v_i x_{ijo}$$
$$\text{Subject to } \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \leq 1, \text{ j} = 1...., \text{n}, \tag{1}$$
$$u_r, v_i \geq 0 \quad \text{for r} = 1, ..., \text{s and i} = 1, ..., \text{m}.$$

Where y_{rj} = amount of output r from unit j, x_{ij} = amount of input i from unit j, u_r = weight given to output r, v_i = weight given to input i, n = total number of units, s = total number of outputs, m = total number of inputs.

The weights are all positive and the ratios are bounded by 100 %. If a DMU reaches the max possible value of 100 % it is considered efficient, otherwise it is inefficient. The formulation of (1) can be translated into a linear program, which can be solving relatively easily, and a DEA solves n linear program, one for each unit:

$$\text{Maximize } h_{jo} = \sum_{r=1}^{s} u_r y_{rjo}$$
$$\text{Subject to}: \sum_{i=1}^{m} v_i x_{ijo} = 1, \tag{2}$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \text{ j} = 1...., \text{n},$$
$$u_r, v_i \geq \varepsilon \quad \text{for r} = 1, ..., \text{s and i} = 1, ..., \text{m}.$$

Where is defined as an infinitesimal constant (a non-Archimedean quantity).

The BCC model can be defined by adding the constraint $z_{j_0} = 1 - \sum_{r=1}^{m} v_i x_{ij_0}$ as show in model 3.

$$\text{Maximize } h_{jo} = \sum_{r=1}^{s} u_r y_{rjo} + z_{j_0}$$
$$\text{Subject to}: \sum_{i=1}^{m} v_i x_{ijo} + z_{j_0} \tag{3}$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + z_{j_0} \leq 0, \text{ j} = 1...., \text{n},$$
$$u_r, v_i \geq \varepsilon \quad \text{for r} = 1, ..., \text{s and i} = 1, ..., \text{m}.$$

The first step in conducting relative efficiency analysis is to define the characteristics that best describe seaport performance [36]. Second, we have to take into account the unit number to define the variables or the number of variables for a determined sample. Norman and Stoker [34] suggest that the minimum number of firms that should be considered is 20 or, alternatively, that a general guideline for the minimum number of units making up the sample for evaluation is at least twice the sum of the inputs and outputs. In general, the number of test units should be considerably greater than the total number of variables [37]. As we chose the ten biggest Iberian seaports, to ensure we meet the conditions above we need five variables [10 ≥ 2(5)] for each analytical process.

The chosen variables derived from our review of the DEA literature on seaports. In relation to inputs, all seaport studies use capital and labour as inputs. The labour input is usually either the number of employees [4, 5, 7, 17] or the total of wages paid [32]. The most common measures of capital are: the net value of fixed capital [7]; the book value of assets [4, 5]; depreciation expenditure [32]. Others authors include factors such as 'other expenditure' to represent intermediate inputs [32].

Two variables were selected as inputs in this study: i) labour (number of employees) and ii) capital (fixed assets), with the following five variables as outputs: i) cargo throughput, ii) net income, iii) turnover, iv) ships handled, and v) market share. With the exception of i) and ii), the role of each variable is changed from input to output and vice versa in each stage. Instead of the four stages (productivity, profitability, marketability and overall efficiency) proposed by Park and De [35], we used three stages (productivity, profitability, and overall efficiency) due to the difficulties in obtaining data measuring the marketability stage, namely customer satisfaction. In order to measure the marketability stage Park and De [35] suggest using as input "revenue" and output "customer satisfaction". Although there are other proxies to measure marketability in business service, as perceived value by the customer and customer expectations, these have not been applied to seaports, yet. The reason for this lack lies in the nature of the complex activity of this sector which difficult the measurement of those proxies. Indeed, we do not use marketability stage but it does not bring inconvenience to attain our goal because the stages adopted will allow analysing the efficiency in terms of productivity, profitability and overall efficiency.

The three-stage is measured as follows:

Stage 1 - Productivity: input (number of employees, fixed assets) and output (cargo throughput, number of ships handled),

Stage 2 - Profitability: input (cargo throughput, number of ships handled) and output (turnover, net income, market share),

Stage 3 - Overall efficiency: input (number of employees, fixed assets) and output (cargo throughput, number of ships handled, turnover).

All the data in this study is obtained either from official seaport websites, namely from the annual financial reports, or following email contact from the seaport authorities themselves. The software Frontier Analyst 4 is employed to derive a solution for the (2) and (3) DEA model. Table 1 shows the input and output values of the ten Iberian seaports.

4 Results

To validate the variables chosen, we calculate the correlation coefficients and estimate multiple regression. Table 2 shows the Pearson correlations calculated by the two inputs and the three outputs adopted for overall efficiency.

Multiple regressions are deployed to determine the kind of relationship between inputs and outputs. Table 3 details the coefficient of determination (R^2) values showing how the proportion of variation in the dependent variables turnover, ships handled and cargo throughput explained by the regression model are 0.943, 0.880, and 0.740 respectively. As the significance value is less than 0.05, the variables labour (No) and

Table 1 Inputs and outputs values of Iberian seaports research, 2009

Seaports	Variables					
	Labour (No.)	Fixed asset (1000 euro)	Turnover (1000 euro)	Ships handled (No.)	Cargo throughput (1000 t)	Market share (%)
Sines	210	381,989	30,293	1479	24,378	8
Leixões	218	260,393	40,886	2610	14,143	5
Lisboa	339	370,341	49,727	3219	11,712	4
Setúbal	181	91,753	17,139	1321	5860	2
Aveiro	113	299,810	10,679	848	3007	1
Algeciras	347	749,348	83,882	24,852	69,911	23
Valencia	386	1,320,478	104,882	6806	62,222	20
Barcelona	161	1,746,508	162,197	8418	50,884	17
Bilbau	264	776,222	59,500	3042	32,390	11
Tarragona	183	464,965	53,412	3012	31,703	10

Table 2 Correlation coefficients with inputs and outputs

	Labour (No.)	Fixed asset	Turnover	Ships handled (No.)	Cargo throughput
No. labour	1.000*				
Fixed asset	0.182	1.000*			
Turnover	0.281	**0.965***	1.000*		
No. ships handled	0.295	**0.930***	**0.958***	1.000*	
Cargo throughput	**0.565***	**0.740***	**0.779***	**0.672***	1.000*

*Correlation is significant at 0.05 levels

fixed asset generate a significant and unique contribution towards predicting the dependent variables (turnover, ships handled, and cargo throughput).

Table 4 provides the results from the DEA-CCR and DEA-BCC models across the three stages adopted.

The most important findings in Table 4 are as follows. Firstly, all seaports in the two models return a 100 % profitability score. Hence, when comparing cargo throughput, the number of ships handled with turnover, net income and market share, all seaports are efficient.

Secondly, in terms of overall efficiency, the seaports of Leixões, Setúbal, Algeciras, Barcelona and Tarragona attain a 100 % efficiency score in the two models, meaning they performed the best amongst this group and represent benchmark reference seaports on the Iberian Peninsula. Bonilla et al. [9] based on 23 Spanish seaports conclude that when we compare the traffics with the available equipment of the different seaports of the Spanish system, the efficiency measure presents high contrasts. The seaports of Algeciras and Tarragona also were considered in their studies as efficient seaports against seaports with a low efficiency level as Bilbau seaport.

Thirdly, beyond these seaports, Aveiro seaport turns out efficient when BCC model is applied, indicating that its dominant source of inefficiency is due to scale efficiency. In other words, when analysed the pure technical efficiency, this seaport is efficient but in terms of overall technical efficiency (pure technical efficiency and scale efficiency) this seaport is inefficient. As previous research by Barros and Athanassiou [7], Barros [6] and Cullinane et al. [14] suggest, the dominant source of inefficiency in this seaport could be due to scale economies. This means that the Aveiro seaport has been inefficient in exploiting the economies of scale given the scale of operations and seaports achieve economies of scale when an increase in output is accompanied by a lower unit cost of production. In analysing all the ten seaports, Aveiro is the smaller and without deepwater, the number of ship calls is lower, so it's more difficult to taking advantage of scale economies. About this aspect, Barros [4] concludes that an organisational governance environment, with accountability, transparency and efficiency incentives, is needed to overcome the deficits in technical and allocative efficiencies observed in the Portuguese seaports analysed.

Fourthly, the seaports of Setubal and Tarragona made good use of their inputs to produce outputs, even though they are small seaports in their respective countries when compared with the biggest five. This complements what has been reported in other studies [1, 13, 39], seaport efficiency is not necessary influenced by its cargo throughput. In addition, Al-Eraqui et al. [1] studied 22 seaports in the Middle East and East African region and concluded that the small seaports (Mukalla Yemen, Bander Abbas Iran) are efficient while large seaports (Jeddah Saudi, Dammam Saudi) are inefficient. Another study by Cullinan et al. [13] applied to 25 world container seaports concluded that the efficiency of a seaport is not significantly influenced by its size. Tongzon [39] have analysed 16 world seaports and found an indistinct relationship between size and efficiency level. Garcia-Alonso e Martin-Bofarull [23] concludes that seaport authorities should not base their success in competing with other seaports for maritime traffic on the volume of their expenditure on infrastructure. Although the resulting gains in efficiency are essential, these do not necessarily derive from the size of the investment because they do not always depend on the increase in the size of the seaport's installations.

Fifthly, despite the Park and De [35] results about 11 Korean seaports that found overall efficiency stage is low compared to productivity, we found overall efficiency stage is high compared to productivity for all the seaports under study. Since overall and productivity efficiency differ in the output "turnover", this may mean that this is a critical output to the Iberian seaport efficiency score.

Finally, the average efficiency score under CCR and BCC is equal to 83.74 and 94.64 % respectively, meaning that, on average, the seaports analysed could operate at 83.74 % and

Table 3 Regression results on inputs and outputs

Inputs	Outputs		
	Turnover	Ships handled (No.)	Cargo throughput
Labour (No.)	54.723	3.467	116.064
Fixed asset	0.087	0.004	0.031
Constant	−6283.21	−215.529	−16,895.3
R^2	0.943	0.880	0.740
P value	0.000	0.001	0.009

Table 4 Efficiency results of CCR and BCC models in 2009

Seaports	Country	CCR			BCC		
		Productivity (Stage 1) (%)	Profitability (Stage 2) (%)	Overall efficiency (Stage 3) (%)	Productivity (Stage 1) (%)	Profitability (Stage 2) (%)	Overall efficiency (Stage 3) (%)
Sines	Portugal	68.4	100.00	69.19	90.6	100.00	90.6
Leixões	Portugal	58.2	100.00	100.00	84.00	100.00	100.00
Lisboa	Portugal	33.9	100.00	84.41	53.8	100.00	97.5
Setúbal	Portugal	68.5	100.00	100.00	100.00	100.00	100.00
Aveiro	Portugal	12.8	100.00	30.66	100.00	100.00	100.00
Algeciras	Spain	100.0	100.00	100.00	100.00	100.00	100.00
Valencia	Spain	76.3	100.00	84.75	77.2	100.00	89.7
Barcelona	Spain	100.0	100.00	100.00	100.00	100.00	100.00
Bilbau	Spain	57.8	100.00	68.34	68.4	100.00	68.6
Tarragona	Spain	83.9	100.00	100.00	100.00	100.00	100.00
Mean		65.98	100.00	83.74	87.40	100.00	94.64

94.64 % of their current levels while still returning the same output value. Dias et al. [17] have found that the majority of container terminals studied (10 container terminals of Iberian Peninsula) are efficient with different levels of performance. For more information, we need to analyse the input/output contributions across the three stages (Table 5) and the input reductions and or output increases needed to render the individually inefficient seaports efficient (Table 6). Table 5 shows that apart from the seaports of Sines and Algeciras, the variable "turnover" is the output which contributes most to the efficiency score of the seaports under study. Table 6 sets out the percentage by which inefficient seaports need to either decrease their inputs or increase their outputs in order to become 100 % efficient, when compared with the others seaports. This information might help inefficient seaports improve their efficiency. As can be seen in Table 6, Aveiro seaport needs not only to reduce fixed assets and the amount of labour by 69.34 % but also increase cargo throughput by 33.30 %, while maintaining the same level of turnover and ships handled, in order to become efficient. Sines seaport needs to reduce fixed assets by 60.81 %, the amount of labour by 34.91 % and increase ship handled by 480.61 %, while maintaining the same level of turnover and cargo throughput. Lisboa seaport needs to reduce fixed assets and the amount of labour by 15.59 % and increase cargo throughput by 46.73 and ship handled by 0.27 %. Valencia and Bilbau seaports needs to reduce fixed assets and the amount of labour by 15.25 % and 31.66 % respectively, and increase ships handled by 69.86 % and 8.94 %, while maintaining the same level of turnover and cargo throughput. These results corroborate with Park and De [35] study that found all seaports should decrease their input amount and increase output amount to become more efficient.

5 Conclusions

In order to support trade oriented economic development, seaport authorities have increasingly been put under pressure to improve efficiency by ensuring that seaport services are

Table 5 Input/output contributions

	Fixed asset	Labor (No.)	Turnover	Ships handled (No.)	Cargo throughput
Sines	100.00	0.00	32.82	0.00	67.18
Leixões	54.09	45.91	100.00	0.00	0.00
Lisboa	84.91	15.09	100.00	0.00	0.00
Setúbal	72.30	27.70	100.00	0.00	0.00
Aveiro	72.04	27.96	96.19	3.81	0.00
Algeciras	0.00	100.00	0.00	67.81	32.19
Valencia	66.74	33.26	77.12	0.00	22.88
Barcelona	91.45	8.55	100.00	0.00	0.00
Bilbau	74.40	25.60	93.07	0.00	6.93
Tarragona	63.65	36.35	77.22	0.00	22.78

Table 6 Input reductions and/or output increases needed to render the individual inefficient seaports efficient

	Fixed asset	Labor (No.)	Turnover	Ships handled (No.)	Cargo throughput
Sines	−30.81	−34.91	0.00	480.61	0.00
Lisboa	−15.59	−15.59	0.00	0.27	46.73
Aveiro	−69.34	−69.34	0.00	0.00	33.30
Valencia	−15.25	−15.25	0.00	69.86	0.00
Bilbau	−31.66	−31.66	0.00	8.94	0.00

provided on an internationally competitive basis. Thus, monitoring and comparing one's seaport with other seaports in terms of overall efficiency has become an essential part of macroeconomic reform programs in many countries. In an internationalized and competitive market, the positioning of seaports, although constrained by some external factors - location, economic development of the region they serve, amongst others - are increasingly dependent on their ability to adapt and meet the operational conditions arising from the physical and technological means and the strategic choices made by the main players in the market.

Within this perspective, this paper presents the efficiency analysis of the top-ten Iberian seaports using a DEA approach. This paper has explored the alternative "Four-stage" DEA methods develop by Park and De (35). Using a cross sectional data of 2009 was possible to conclude that the average efficiency score under CCR is equal to 83.74 meaning that, on average, the seaports analysed could operate at 83.74 % of their current levels while still returning the same output value. All seaports in the two models return a 100 % profitability score. In terms of overall efficiency, the seaports of Leixões, Setúbal, Algeciras, Barcelona and Tarragona attain a 100 % efficiency score, meaning they performed the best amongst this group and represent benchmark reference seaports on the Iberian Peninsula.

Unlike the ranking in terms of cargo throughput, the most efficient Portuguese seaports are Leixões and Setubal and their Spanish peers are Algeciras, Barcelona and Tarragona. This has proven what has been reported in other studiesthat seaport efficiency is not necessary influenced by its cargo throughput. Setubal seaport, despite being fourth in terms of total cargo throughput, makes good use of its inputs to produce outputs, probably due to being located near both an industrial park and some important companies such as Autoeuropa (automotive industry) and Portucel (paper industry) and the seaport's operators probably adjust their inputs to make better use of cargo carried by these companies. Tarragona seaport, despite being fifth in the Top 5, has benefited from being located near Barcelona seaport and absorbs all the overspill cargo that Barcelona seaport has difficulty in operationally handling. When looking at the input/output contributions to the efficiency level we find that the variable "turnover" is the output which contributes most to the efficiency score of the seaports under study.

The findings of this research are important to seaports authorities because this study allows them to know its efficiency during a long time period, the input and output that contribute to it and how they can improve it.

The main limitation of this study derives from not considering all Iberian seaports in the analysis and hence preventing any conclusions onsmaller seaports. Therefore, the conclusions presented here are limited to the selected sample of the most representative Iberian seaports. As DEA analysis calculates the efficiency based on the selected DMU's, the results probably would be different if the sample was different. In this sense, we would suggest the study be applied to all Iberian seaports. We would also recommend that the study be applied to the same seaports for the period since 2009 to analyse and compare i) the effects of the global financial crisisand the recovery, or otherwise, of seaports, ii) the effect of the latest restructurings, for example, Aveiro seaport's link to the national railway network, operational in 2010, provides for the movement of around 600,000 t, and iii) the effects of the enlargement of the Panama Canal from 2013 that will impact on the world's shipping routes and the positioning of Iberian seaports.

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