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Analysis of Operating Efficiency of the Iberian Peninsula Container Ports. A Multiple Regression Analysis and DEA in a Second Stage

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ABSTRACT

The aim of this paper is to obtain the most consistent values of efficiency of Iberian Peninsula container ports from 2008 to 2014. This study applies DEA methodology to a sample of the 16 Iberian Peninsula container ports they account for more than 85 per cent of the total container traffic, during the five-year period of 2008-2014. Firstly, multiple linear regression models have been applied for all possible combinations of explanatory variables and using the number of manipulated TEUs as an independent variable which has been considered as the most relevant of the outputs chosen in the efficiency analysis. The aim has been to represent a variable response (TEUs) according to different possible explanatory variables. The explanatory variables used are: Number of Cranes (NG), Area of the Terminal (ST) and Docks with draft of more than 14 meters (M14). The indices that allow us to measure the quality of the results obtained are the corrected multiple determination coefficients (R2) and the Fisher-Snedecor (F) statistic. It can be observed that the best results for both coefficients are obtained in those hypotheses where the explanatory variable corresponding to the Number of Cranes (NG) is included. In a second Stage Data Envelopment Analysis (DEA) with variable return to scale (BCC) has been used to obtain the standard efficiency, using output-oriented option in order to determine efficiency rankings of Iberian Peninsula container ports. The results show that the ports with significant import/export traffic seem to exhibit lower levels of technical efficiency than those ports specialized in transhipment operations. On the other hand, in those cases in which the transhipment traffic has increased, the technical efficiency has diminished.

1. Introduction.

Presently, world trade is determined by the growing role of emerging economies and by technological advances related to telecommunications and transport.

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Trade transactions between the countries of the north and the south have been balanced in recent decades and the participation of developing countries in world trade is increasing (Cerbán and Piniella, 2016). Simultaneously, globalization, mainly understood from the opening of economies and borders to trade, has led to a progressive process of deregulation in the main maritime transport structures (Alderton et al., 2002). Technological innovations applied to modes of transport and communications have allowed the movement of large volumes of goods at ever lower cost and with increasing reliability. globalization, mainly understood from the opening of economies and borders to trade, has led to a progressive process of deregulation in the main maritime transport structures (Alderton et al., 2002). Technological innovations applied to modes of transport and communications have allowed the movement of large volumes of goods at ever lower cost and with increasing reliability.

In the last 30 years the weight of non-containerized general merchandise has been decreasing to the benefit of the containerized goods. From 2000 to the present, global container traffic has tripled, surpassing 679 million TEUs in 2014. Table 1 shows the evolution of global container traffic and in the EU, and in terms of European Union data, container traffic has gone from 90 million TEUs in 2007 to almost 105.9 million TEUs in 2014, an increase of 17.8% (World Bank, 2016).

According to data held by the holding company Spanish port System, national port traffic in 2005 was over 11 million TEUs and in 2014 exceeded 14 million TEUs. Therefore, it has increased by 27% in seven years.

As evidence in Table 2 (Spanish Port System and Instituto da Mobilidade e dos Transportes, I.P., 2015), container traffic in Portugal has tripled in the last ten years, exceeding 2.5 million TEUs in 2014. In the context of the EU, Portugal ranks tenth with 2.7% of total container traffic in 2014, while Spain ranks second with about 5 million TEUs less than Germany, which leads the European ranking. It is significant that during the period between 2010 and 2014, in the midst the world economic and financial crisis, Portuguese container traffic increased by more than one million TEUs. In this sense, the growth of the port of Sines plays a very important role, whose traffics were just over 376,000 TEUs in 2010, reaching over 1,227,000 TEUs in 2014.

As can be seen in Figure 1.1, all ports that have be analyzed in this study have a good road connection with Madrid, although the ports of Valencia and Barcelona are approximately half the distance and, consequently of time, of the center of the country than the Algeciras Bay port, which makes them even more, if possible, real competitors of that port.

Figure 1: Main road connections of the ports analyzed with Madrid.

Source: Authors, 2015.

The economic crisis has resulted in very substantial cargo shifts between ports. More attention to such shifts is needed, for one thing to better understand the risks involved in port development projects. The period between 2008 and 2011 was characterized by the financial and economic crisis, that deeply impacted the Spanish economy and the import/export activity, and then the port activity and efficiency (Gil-Ropero et al., 2015).

Therefore, the main contribution of this study is to analyze and compare the efficiency of the 16 Iberian Peninsula ports they account for more than 85 per cent of the total container traffic, during the five-year period of 2008-2014, taking into consideration that the conditions has significantly changed in recent years, especially in a period characterized by the global financial and economic crisis. To our best knowledge, it is the first paper that compares the efficiency in the Spanish ports in the current situation.

2. Port efficiency of container terminals.

In recent years many authors have investigated efficiency in the port industry. They have used two main methods to measure efficiency: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). Artificial Neural Networks (ANNs) and Principal Components Analysis (PCA) had also been used, but with less frequency (Gil-Ropero et al., 2015).

However, there are few references in the literature related to the efficiency and productivity of container terminals in the Iberian Peninsula during the last years.

The objective of most of the studies and publications that have been consulted for the elaboration of this work is to analyze the efficiency and the port competitiveness from several points of view. Establish a relationship between the efficiency and the type of property or administration and management of the ports, as well as their container terminals, until a ranking of ports more or less efficient. Even analyze the efficiency of these terminals in their integration within the supply chain.

Zhen et al. (2013) affirmed that with globalization companies organize their production and source their raw materials more and more internationally, and so a global trade and transport chain has gradually been formed. In every part of the world, coastal ports especially have become integral parts of the international logistics network. Ports logistics plays an important role in most national economies and in international trade, which has become a primary indicator of the level of development reached by a national economy.

The correct planning and execution of operations on a container - carrier vessel is a decisive element in the strategy of a Terminal. Numerous factors come into play and some of these, but only some, can be controlled. Experience and knowledge of the problems that can arise is fundamental when attempting to deal with these operations (Cañero et al, 2011).

A rigorous and comprehensive discussion on the definition of the variables to use in port efficiency studies is provided by Cullinane et al. (2004). Container port production depends crucially on the efficient use of labour, land and equipment. Another consideration is that container throughput is the most appropriate and analytically tractable indicator of the effectiveness of the production of a port (Cullinane et al. 2006).

In much of the analyzing literature issued on efficiency and productivity, the total quay length, the terminal area, the number of quayside cranes, the number of yard gantry cranes and the number of straddle carriers are the most suitable elements

Table 1: World and EU container evolution traffic.

Year	World (TEUs)	Variation (%)	EU (TEUs)	Variation (%)
2007	489,818,309		89,924,957	
2008	516,152,333	11.20	90,222,728	0.33
2009	472,175,125	-16.69	78,192,773	-13.33
2010	542,248,030	23.59	86,839,541	11.06
2011	587,483,461	13.37	94,572,776	8.91
2012	622,313,936	9.26	98,930,636	4.61
2013	649,453,845	6.51	102,182,409	3.29
2014	679,264,658	6.09	105,895,724	3.63

Source: World Bank, 2016.

Table 2: Spanish and Portuguese container evolution traffic.

Year	Spain (TEUs)	Variation (%)	Portugal (TEUs)	Variation (%)
2005	11,049,250		940,181	
2006	12,044,417	9.01	1,038,889	10.50
2007	13,188,879	9.50	1,161,416	11.79
2008	13,334,924	1.11	1,270,423	9.39
2009	11,749,295	-11.89	1,242,103	-2.23
2010	12,500,043	6.39	1,440,093	15.94
2011	13,892,044	11.14	1,598,426	10.99
2012	14,035,525	1.03	1,741,266	8.94
2013	13,892,231	-1.02	2,193,459	25.97
2014	14,204,121	2.25	2,519,563	14.87

Source: Spanish Port System and Instituto da Mobilidade e dos Transportes, I.P., 2015.

to be incorporated into the models as input variables. On the other hand, container throughput and ships calls are unquestionably the most important and widely accepted indicators of port or terminal outputs. For example, Notteboom et al. (2000) studied the efficiency of 36 European and 4 Asian container terminals in 1994; Cullinane et al. (2002) compared the efficiency of 15 Asian container ports over the 10 year period between 1989 and 1999; Barros (2005) obtained the efficiency of 10 ports of Portugal, during the period 1999-2000; Martinez-Budría et al., (1999) analyzed the efficiency of Spanish ports during the period 1993-1997; and Cullinane and Wang (2006) used DEA-CCR and DEA-BCC models for studying 57 container terminals in 30 major ports worldwide.

There has been considerable interest in the measurement of efficiency as organizations have focused strongly on improving productivity (Cook and Seiford, 2009). As stated by Farrell (1957) many researchers have studied the problem of measuring the productive efficiency of a particular industry since the topic is important to both the economic theorist and the economic policy maker.

Farrell (1957) empirically determined a reference standard, the frontier, with which to compare firms to determine whether they are efficient or not. The efficiency measures calculated in this way define what is known as relative efficiency, that is, they measure the efficiency of a company by comparing its performance with that of the "best" observed firms, which are those that define the efficient frontier. This work can be considered as the origin of all the studies in this field, although, the study of Farrell has like antecedents Debreu (1951) and Koopmans (1951) papers.

Envelopment Data Analysis (DEA) uses linear programming algorithms to calculate the frontier. This idea was originally proposed by Hausman (1978) in his discussion of Farrell's article (1957). The first application of linear programming to the calculation of efficiency is due to Boles (1966). Subsequently, Charnes, Cooper and Rhodes (1978) gave this technique the name Data Envelopment Analysis, the use of which has become more frequent and today surpasses applications based on stochastic frontiers (Førsund and Sarafoglou, 1999).

It is interesting to note that the fundamental difference between the DEA and Farrell (1957) methods for the calculation of the frontier. Farrell does not use mathematical programming, but calculates the boundary algebraically. However, the results of both approaches are equivalent.

Among the advantages of the non-parametric approach is that it is not necessary to assume a concrete functional form for the frontier. Some studies have found that efficiency indices are sensitive to the specification of the functional form. On the other hand, the non-parametric approach allows the simple treatment of multioutput technologies.

In order to better understand all the theoretical-practical concepts, as well as the methodology of the different models that study efficiency and/or productivity, two books of great importance that represent the first source of information and knowledge they deserve to be highlighted in this report. Coelli et al. in 1997 published An introduction to efficiency and productivity analysis. This book provides an accessible introduction to the main methods of efficiency analysis, focusing primarily on DEA and SFA models. Subsequently, in the year 2000, Cooper et al. published Comprehensive Text with Models, Applications, References and DEA-Solver Software. This other reference book constitutes a solid base of mathematical programming for the development through linear algebra, including matrices and vectors, of the different DEA models.

3. Methodology.

Firstly, Linear Regression Multiple models have been applied for all possible combinations of explanatory variables (inputs), and using as an independent variable the TEUs handled, which have been considered the most relevant of the outputs chosen in the analyzes of efficiency.

Once the robustness of the input data to explain the output data was verified as being valid, the DEA methodology has been applied to obtain the port efficiency of the chosen ports.

Traditionally, efficiency has been a subject studied and worked by many researchers from the economic point of view. The use of ratios between magnitudes has been, and still is, a standard procedure for measuring the efficiency of different units. This ratio between an output variable and another input variable gives rise to a usual and proven measure of efficiency (Barros, 2003, Cullinane et al., 2006, Noteboom, 2008). That is, the efficiency of a Decision Making Units (DMU) is defined as the relationship between the results obtained and the resources involved in its production. This is reflected in expression (1):

$$Eficiencia = \frac{\sum_{j=1}^{n} WjkOutputjk}{\sum_{i=1}^{m} VikInputik} \quad (1)$$

$$k = 1, \ldots, N$$

Where V_{ic} is the unit weight for input i and W_{ok} is the unit weight of output j for the unit studied k. Under this criterion there are N units, m inputs and n outputs.

3.1. Lineal Regression Multiple.

Linear Regression Multiple model analyzes the influence of several explanatory variables (x_i), also called predictors or independent, on the values taken by another variable called dependent (y), also called explained or answer. This will give us the advantage of using more information in the construction of the model and, consequently, making more precise estimates.

In our case, the number of TEUs that will be manipulated by the container terminals from a series of characteristics and mechanical means that form the set of said terminals may be estimated. If the model is linear, it can be expressed as:

$$y_i = \beta_0 + \sum \beta_i X_{ip} + \varepsilon_i \quad (2)$$

Where y_i is the output variable, X_{ip} is the characteristic matrix, εi is a vector of random errors and β_i is the vector of parameters, β={β_0, β_1,..., β_m}, where β_0 is the intersection or constant term.

A measure of adjustment of great acceptance in the regression analysis is the coefficient of determination R^2. That is, the square of the multiple correlation coefficient. It is a standardized measure that takes values between 0 and 1. It takes the value 0 when the variables are independent and 1 when there is a perfect relationship between them. This coefficient has a very intuitive interpretation. It represents the degree of gain that we can obtain in predicting a variable based on our knowledge of other variables.

On the other hand, the Fisher-Snedecor continuous probability distribution with n and m degrees of freedom (F (n, m)) is associated with a random variable that is obtained from the quotient of a *chi-square* variable with n and m degree of freedom respectively. Therefore, this distribution tends to take positive values. Its density function is very complex and its graph is similar to that of the *chi-square* distribution.

A Fisher-Snedecor random variable (F) is constructed as the ratio: $F = (U_1/n)/(U_2/m)$, where:

- U_1 and U_2 follow a chi-square distribution with n y m degrees of freedom respectively.
- U_1 and U_2 are two statistically independent random variables.

The shape of the graphical representation depends on the values n and m, so that if n and m tend to infinity, this distribution resembles the normal distribution.

The F distribution frequently appears as the null distribution of a statistical test, especially in the analysis of variance.

3.2. Data Envelopment Analysis (DEA).

The methodology *Data Envelopment Analysis* (DEA) is a linear programming technique that facilitates the construction of an envelope surface, efficient frontier or empirical production function, from the available data of the set of entities under study, so that those that determine the envelope are the so-called efficient entities, and allow the evaluation of the relative efficiency of each of the entities.

The DEA analysis developed by Charnes, Cooper and Rhodes (1978) is an extreme and non-parametric method for the estimation of frontiers of production and evaluation of the efficiency of a sample of units of production or Decision Making Units (DMUs), in scientific terminology. The DEA methodology, since it is a non-parametric technique, does not suppose any functional form of the relation between the inputs and the outputs, nor a distribution of the inefficiency. In addition, it is able to handle situations of multiple inputs and outputs, expressed in different units. It is precisely these advantages of DEA that have favored its extensive use.

According to DEA methodology, different types of efficiencies can be measured depending on the unit chosen as the reference: Global Efficiency (Charnes, et al. 1978), also termed CRS efficiency i.e. Constant Returns to Scale; Technical Efficiency (Banker, et al. 1989), also termed VRS efficiency, i.e. Variable Returns to Scale; and Scale Efficiency (Charnes and Cooper. 1989), that is defined as the ratio between the Global and Technical Efficiency values.

To formulate the DEA methodology, suppose there are n numbers units of production (DMUs) to be analyzed, each of which uses m inputs x_{ij} (i = 1,..., m) to produce s outputs yrj (r = 1,..., s). We call X_{ij}> 0 the quantity of inputs i used by the DMU j and we call Y_{rj}> 0 the quantity of outputs r produced by the DMU j.

The DEA models with input or output orientations are based on the proposal of Charnes et al. (1978).

4. Analysis and discussion of results.

This section presents the results obtained using the methodologies presented to determine the port efficiency in its different models and obtain the projections of the input and output variables that originate the container traffic, as well as a discussion of them.

4.1. Results of Lineal Regression Multiple

The objective has been to try to express a variable response (TEUs) according to different possible explanatory variables. The explanatory variables that we have used are: Number of Cranes (NG), Terminal Surface (ST) and length of deepwater berths of more than 14 meters depth (M14). The results obtained from the corrected multiple determination coefficients (R^2) and the Fisher-Snedecor (F) statistic are shown in Tables 3 and 4.

It can be observed that the best results for both coefficients, i.e., the highest values of R^2 and lower values of F, are obtained in those hypotheses where the explanatory variable corresponding to the Number of Cranes (NG) is included.

In the multiple regression analysis, the regression equation does not define a straight line in the plane, as is the case of the simple regression model, but a hyperplane in a multidimensional space. With three explanatory variables and a dependent one, as in our case, a space of four dimensions to be able to construct the dispersion diagram would be necessary.

The F statistic allows to contrast the null hypothesis that the population value of R is zero, and therefore allows us to decide if there is a significant linear relationship between the dependent variable and the set of explanatory or independent variables taken together. The critical level value of F near zero indicates that there is a significant linear relationship. Therefore, it can say that the hyperplane defined by the regression equation gives a good fit to the point cloud. The results obtained from the critical values of F are shown in Table 5. As can be seen, all the values obtained for all the hypotheses in each of the years studied, are close to zero, so that it can be concluded that, having a good fit to the point cloud, the sample considered reflects with much accuracy the relationship between the explanatory variables and the dependent variable considered (main output, manipulated TEUs).

4.2. Results of Efficiency DEA - BCC.

In Table 6 the results obtained after applying the model with variable returns to scale (BCC) and output orientation are shown. Taking into account, the results obtained we find once again that the ports of the Algeciras Bay and Seville are technically efficient, along with the ports of Cartagena, Gijon, Leixoes

Table 3: Values of R2 (Multiple correlation coefficient).

Years	NG/ST/M14	NG/M14	ST/M14	NG/ST	M14	ST	NG
2008	0.9404	0.9442	0.8437	0.9432	0.8267	0.7848	0.9462
2009	0.8987	0.9039	0.8474	0.9063	0.8199	0.8084	0.9108
2010	0.9606	0.9399	0.9149	0.9635	0.8588	0.8822	0.9429
2011	0.9443	0.9418	0.8653	0.9475	0.8343	0.8200	0.9459
2012	0.8965	0.9010	0.8103	0.9027	0.7898	0.7666	0.9075
2013	0.8721	0.8817	0.7647	0.8792	0.7586	0.7129	0.8879
2014	0.8679	0.8780	0.7498	0.8752	0.7493	0.6927	0.8835

Source: Authors.

Table 4: Values of F (Fisher-Snedecor).

Years	NG/ST/M14	NG/M14	ST/M14	NG/ST	M14	ST	NG
2008	79.97	127.87	41.48	125.65	72.53	55.70	264.82
2009	45.34	71.55	42.66	73.59	69.28	64.30	154.10
2010	122.91	118.23	81.64	198.85	92.24	113.33	248.48
2011	85.81	122.45	49.17	136.34	76.50	69.32	263.42
2012	44.32	69.26	33.04	70.55	57.36	50.26	148.18
2013	35.08	56.91	25.37	55.62	48.13	38.24	119.78
2014	33.86	54.99	23.47	53.59	45.83	34.81	114.74

Source: Authors.

Table 5: Critical Values of F.

Years	NG/ST/M14	NG/M14	ST/M14	NG/ST	M14	ST	NG
2008	3.3559E-08	2.8184E-09	2.2753E-06	3.1399E-09	6.5601E-07	3.0435E-06	1.7239E-10
2009	8.0279E-07	9.6275E-08	1.9434E-06	8.1436E-08	8.6054E-07	1.3324E-06	6.0454E-09
2010	2.8358E-09	4.5718E-09	4.3663E-08	1.7896E-10	1.5369E-07	4.2815E-08	2.6350E-10
2011	2.2456E-08	3.6835E-09	8.6589E-07	1.8943E-09	4.7760E-07	8.5754E-07	1.7858E-10
2012	9.0954E-07	1.1682E-07	8.0015E-06	1.0465E-07	2.5750E-06	5.4237E-06	7.8034E-09
2013	3.2207E-06	3.7153E-07	3.2518E-05	4.2467E-07	6.8955E-06	2.3771E-05	3.0207E-08
2014	3.8903E-06	4.5363E-07	4.8451E-05	5.2679E-07	9.0284E-06	3.8707E-05	3.9616E-08

Source: Authors.

and Lisbon, for the 7 years of the studied period, although the latter only it is when the model is aplicated with two outputs. The port of Valencia gets an average close to efficiency (0.9961-0.9982). The eighth port in the ranking is Vigo, which obtains technical efficiency in six of the seven years of the study, with an average value of 0.9442 when 1 output is used and a value of 0.9847 when 2 outputs ae considered. The port of Sines with values of 0.6975 and 0.7537, has a very considerable efficiency indexes, as it happens to the port of Barcelona (0.5823-0.8097). The remaining ports have efficiencies below 50%, which means that they are clearly inefficient.

Port of Algeciras Bay decreases its traffic in the first three years of the study and increases significantly from 2011. The principal reason for that increase is the entry into operation of the container terminal of Total Terminal International (TTI), belonging to the South Korean company Hanjin Shipping. Another factor was the strike in August 2011, of employees of one of the two container terminals of the Port Tánger-Med; because of this, the shipping company Maersk diverted the containers that were due to be offloaded in that terminal to Algeciras instead. The effect of these events is that the port of Algeciras Bay achieved the maximum value of both global and technical efficiency during the five years studied (Gil-Ropero et al., 2015).

The efficiency results of the Algeciras Bay and Cadiz Bay ports are related. Cadiz usually attracts the container traffic that the port of Algeciras Bay is unable to accept for capacity reasons at certain times. However, when the TTIA terminal opened in Algeciras in 2010, thus increasing its capacity, this led to a reduction of 36% in the number of TEUs handled in Cadiz in 2011, compared with 2008. This is reflected in the loss of efficiency by Cadiz during the period studied. Something similar to that described above also happened to the Port of Malaga. Its traffic levels diminished considerably after the opening of the Tanger-Med terminal in 2007.

In the port of Barcelona there was a decline of almost 800,000 TEUs in 2009, because a large proportion of its traffic was transferred to the Port of Valencia. This explains the loss of port efficiency in Barcelona in the period between 2008 and 2014.

If we analyze all the above with what happens to the port of Valencia in the same period, it is observed that its container traffic increases considerably from 2008, without any increase in the storage surface or the number of handling equipment. This increase in the number of containers handled, from almost one million two hundred thousand TEUs from 2007 to 2010, is mainly due to traffic coming from the port of Barcelona. However, in the years 2013 and 2014, there is a slight decrease in the containers handled, and consequently, this makes their efficiencies decrease in the last two years, for both one output and two cases (0.9961-0.9982), although the final average is very close to the maximum value.

These results have been obtained, especially, bet MSC by to consolidate the traffic with the Far East and the United States, with mega-ships that exceeding 20,000 TEUs. Only ports with great concentration of loads, infrastructure and services such as Valencia and Algeciras Bay can accommodate these scales.

The port of Seville is the only river port in the entire Spanish port system. In 2008 and 2009, there was an expansion of its container terminals, but with no deep-water berths of 14 meters or more. This increased capacity generated a significant increase in its container traffic, resulting in maximum Seville's efficiency values.

An unusual evolution is seen in the Port of Bilbao. In 2008 the new Santurce terminal entered into service, doubling the available facilities for containers. However, its container traffic decreased, without recovering, and there was even a reduction in the number of TEUs handled in 2009. The result is that its efficiency values are close to 50% during the period of this study.

The effect of the last years financial and economic crisis for European ports is unprecedented. Therefore, the Spanish container traffic has been affected for this financial tsunami era. Pallis and de Langen (2010) affirmed that in the new context of the financial and economic crisis, port authorities need to pay more attention to risk management. They need to revise expansion projects, and avoid the risk of price wars with public money increasingly funding a market characterized by overcapacity. The economic crisis has resulted in very substantial cargo shifts between ports. More attention to such shifts is needed, for one thing to better understand the risks involved in port development projects.

Conclusions

The main contribution of this work is the application of DEA-based models in the study of the operational efficiency of a sample of the 16 Iberian Peninsula container ports they account for more than 85 per cent of the total container traffic, during the five-year period of 2008-2014.

Previously an analysis of the variables that mainly influence said efficiency has been applied, to give robustness to the results of the same. This analysis has been carried out through the application of Linear Regression Multiple. The techniques presented determine, with a high degree of precision, the role of the main variables of container traffic in the operational efficiency of its terminals.

The models developed in this work have been evaluated through a database obtained from the public entities that managing the ports in Spain and Portugal, but can be applied in other ports of different countries and/or commercial zones that share types of traffic and characteristics.

Summary and comparative the main conclusions are presented:

I. The analysis of the Linear Regression Multiple shows that of all the variables that directly intervene in the traffic of containers there is a fundamental one that is the Number of Cranes. In those combinations in which the variable number of cranes (NG) participates the adjustment is better than those in which it is not considered. This means that it is a fundamental variable to obtain the port efficiency of container terminals.

II. This first analysis shows the robustness of inputs to explain the TEUs handled. This is This has been evidenced with the quality of the results obtained with the values of the corrected multiple determination coefficients (R2) and the Fisher-Snedecor (F) statistic.

Table 6: Summary of results of the Efficiency Analysis DEA BCC Output oriented model (continues)

Ports	2008		2009		2010		2011	
(DMUs)	1 Outp.	2 Outp.	1 Outp.	2 Outp.	1 Outp.	2 Outp.	1 Outp.	2 Outp.
Alicante	0,3846	0,4496	0,2944	0,3646	0,4110	0,4793	0,4075	0,5277
Algeciras Bay	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Cadiz Bay	0,5339	0,6418	0,4880	0,6043	0,4560	0,4560	0,3586	0,4082
Barcelona	0,7658	1,0000	0,5812	0,9604	0,7148	0,9169	0,6262	0,7774
Bilbao	0,4439	0,5234	0,3668	0,4223	0,5214	0,5214	0,5232	0,5364
Cartagena	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Castellon	0,3109	0,4049	0,1851	0,2511	0,4048	0,4471	0,4791	0,5126
Gijon	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Malaga	0,6942	0,7035	0,4608	0,4608	0,5621	0,5621	0,8448	0,8630
Seville	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Tarragona	1,0000	1,0000	1,0000	1,0000	0,5084	0,5185	0,4141	0,4333
Valencia	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Vigo	1,0000	1,0000	0,6097	0,8930	1,0000	1,0000	1,0000	1,0000
Leixoes	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Lisbon	0,6562	1,0000	0,6276	1,0000	0,6855	1,0000	0,6690	1,0000
Sines	0,3731	0,4383	0,3800	0,4963	0,6771	0,7199	0,7064	0,7883

Ports	2012		2013		2014		Average	
(DMUs)	1 Outp.	2 Outp.	1 Outp.	2 Outp.	1 Outp.	2 Outp.	1 Outp.	2 Outp.
Alicante	0,3514	0,6327	0,2895	0,5155	0,2093	0,4572	0,3354	0,4895
Algeciras Bay	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Cadiz Bay	0,3298	0,4033	0,3218	0,3622	0,2747	0,3282	0,3947	0,4577
Barcelona	0,4829	0,6973	0,4438	0,6335	0,4617	0,6824	0,5823	0,8097
Bilbao	0,4942	0,4955	0,4348	0,4746	0,3752	0,4577	0,4514	0,4902
Cartagena	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Castellon	0,5269	0,6244	0,5923	0,7503	0,4975	0,8461	0,4281	0,5481
Gijon	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Malaga	0,5283	0,5283	0,3913	0,3913	0,0886	0,1280	0,5100	0,5196
Seville	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Tarragona	0,2978	0,3668	0,1978	0,2398	0,1520	0,2556	0,5100	0,5449
Valencia	1,0000	1,0000	0,9977	0,9977	0,9752	0,9894	0,9961	0,9982
Vigo	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	0,9442	0,9847
Leixoes	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
Lisbon	0,5203	1,0000	0,5551	1,0000	0,4497	1,0000	0,5948	1,0000
Sines	0,7459	0,8331	1,0000	1,0000	1,0000	1,0000	0,6975	0,7537

Source: Authors.

III. The models used to determine the DEA Efficiency lead to very high results in terms of variable returns to scale. Depending on the model applied, many ports are operating at values very close to their most productive scale size. These high values, obtained with a technique that does not contemplate the statistical properties of the sample, indicates that it would be necessary at a later stage to use a methodology that corrects this aspect.

IV. In Spain, the port of Algeciras Bay obtains in all models the maximum value of efficiency, as well as the ports of Valencia, although the the port of Algeciras Bay has seen its direct competitors, i.e. the ports of Valencia and Barcelona, have benefited in recent years of huge investments under the general headings of the State with which they have improved their connections, settling in certain sections even double and triples rail tracks.

V. In Portugal, the port of Leixoes is in optimum values of operational efficiency. This may be because according to Paixao (2013) Portuguese ports have received substantial investments and undergone improvements but they are not able to compete with the ports on the range of Le Havre - Hamburg where competition is fierce from Spanish ports.

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