DEA-Bootstrapping Analysis for Different Models of Spanish Port Governance

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Abstract: The Spanish port system is subjected to a Data Envelopment Analysis (DEA)-Bootstrapping analysis of its operational and financial efficiency to be compared to two other scenarios. One of these presents a port cluster based on the grouping of ports because of their proximity, and the second scenario proposes a port cluster based on seafronts. The analysis is made up of a DEA-Bootstrapping of two inputs and two outputs for both the operational and financial efficiency analyses. The results of the DEA-Bootstrapping analysis show a series of results that favour these two scenarios against the present situation, as both the operational and financial efficiency are improved in relation to the current scenario or scenario 0.

Keywords: DEA-bootstrapping; efficiency; ports; seafronts; scenarios

1. Introduction

The ports play a role for the development of trade and for the competitiveness of the country, especially in the context of the globalisation of recent decades. In the port sector, the international technological advance has determined a reduction in the costs of commercial exchange over long distances. The result of these changes has been that the port sector has initiated a process of rapid renovation of its installations so that they can respond adequately to the demand for their services [1]. While, in the past, the existence of a certain monopoly power of the ports in a given territory was identified due to the high costs involved in mobilising cargo through an alternative port in the framework of these transformations. The possibilities of opting for different ports have increased, thus, generating an increasingly competitive environment. In this context, port efficiency has become more important as a determinant of the costs and quality of transport, elements that affect the dynamics of foreign trade, and the degree of competitiveness that a country achieves [2].

Although there are many studies that analyse the efficiency of the ports belonging to the current Spanish Port System from a global point of view [3,4], it is evident that the different location of our ports along the peninsular coast and island area makes it possible to foresee that not all Spanish regions compete and will consolidate in the same way in foreign trade due to both their own idiosyncrasy and the strict location of their ports [5].

In this sense, Tongzon [6] concludes that the factors that determine the selection of one or another port, from the point of view of the transporters, are the efficiency of the port as the most important factor, which is followed by the frequency of shipping, the adequate infrastructure, and the geographical location of the port, which is in fourth place.

The application of the word efficiency to be carried out in this article will be: “Efficiency is the relationship between an income and an expense; between an input and an output; between a resource and a product” [7].

The expression in any efficiency relation takes the form of a proportion: an output divided by an input, and it is presented in a mathematical form as follows.
According to Todaro [8], economic efficiency can be defined as the efficiency with which an economic system uses productive resources in order to satisfy its needs. The concept applied to a port system means that it must maximize its profits on the basis of the infrastructures that the ports have, or by investing in these infrastructures in order to maximize their profitability to obtain benefits through their use [9].

This article presents a study of the efficiency of the Spanish port system both of the current model with its 28 Port Authorities, and two scenarios that are proposed, according to the union, or rather the grouping, of port authorities to reduce the port system to 12 Port Authorities in the first scenario proposed, and eight port authorities in the second scenario.

The idea on which this article is based is the Data Envelopment Analysis (DEA) tool, to be able to analyse the operational and financial efficiency of the Spanish port system in the group of its 28 Port Authorities, or, in other words, of its 46 ports of General Interest [10], so that the results can later be compared with those obtained in the two proposed scenarios. The DEA analysis has been carried out in numerous studies, which is why they use this methodology to measure the efficiency of certain port systems, groupings of ports, or, to a greater extent, of the container terminals in different ports throughout the world [11].

This methodology allows introducing uncertainty in the analyzed variables, defining tolerances, or possible variations in the selected inputs and/or outputs of the Port Authorities evaluated. By applying the DEA with tolerances, we not only obtain information regarding the efficiency that each of the ports has from the selected data, but also the level of efficiency that they could reach if the input and outputs considered varied, which allows the consideration of a certain degree of uncertainty in the analysis applied.

In addition, for the application of the DEA analysis, two possible scenarios of grouping ports or port authorities (in the case of the Spanish port system) are included to compare the different efficiencies obtained in an experimental way, as well as to evaluate the viability of these proposals in comparison with the current situation.

This study was centred on the investigation of the efficiency of the port system, using the Data Envelopment Analysis (DEA) as a tool for the numerical obtaining of an indicator of the degree of efficiency obtained by each port.

It should be noted that this research does not aim to analyse port-by-port the ports that make up the Spanish Port System, but to give a vision of an improvement in the efficiency of the port system as a whole. For this reason, the starting point or current situation is presented and two alternatives with two different groupings of ports between them. What is presented is to make the reader see the substantial improvement, weighted by the DEA with some feasible indicators that can be analysed, and that can easily represent the ports in the different sections of the study.

It is also commented that the physical characteristics of the ports have not been taken into account when analysing them, only through the selected input and output indicators, because they are indicators that can reflect the situation of the port in a way that is close to reality, but, when showing the results, the data are shown so that they can be analysed as a whole, and compared with respect to the situations of the foreseen port groupings.

This article is structured on the basis of a small bibliographical review with respect to the port area of the DEA analysis, as numerous studies have been carried out on the basis of efficiency measurements in container port terminals.

In Section 3, the methodology used in the DEA is shown, with the main equations for its development and a figure that illustrates the explanation of the studied literature, which is followed by the disposition of all the values used in the study either as inputs or outputs.

In Section 4, an analysis is made of the results obtained in the three scenarios evaluated as well as small comparisons between them without entering into port-to-port comparisons. Only the comparisons at the level of the proposed governance model are shown.

Finally, the conclusions of this study are analysed.
2. Materials and Methods

The methods for estimating efficiency can be divided into two [12] parametric methods, which estimate a stochastic boundary by econometric techniques, and non-parametric methods, such as DEA, which is based on the resolution of the model by linear programming. Currently, with the help of artificial intelligence and sophisticated computer programs, the resolution and efficiency can be achieved by minimizing the calculation error and obtaining a much more reliable result.

Efficiency is normally understood as a relationship between the effects and the amount of resources used to achieve those effects [13]. The most commonly applied type of efficiency is technical or operational efficiency, understood as the ability to handle more containers [14,15]. This simple definition is expanded by other researchers. For example, Cullinane et al. [16] conducted research based on the stochastic boundary analysis method to examine the relationship between terminal efficiency, terminal size, and ownership type. The output variable was the annual container throughout Twenty-foot Equivalent Unit (TEU), and the input variables were length of the terminal pier, terminal area, and number of cargo handling equipment.

The studies carried out on port efficiency and productivity can be classified into three different groups: those that address partial productivity indicators, those that focus on the study of technological frontiers, and those that focus on the specialization of a given port in a particular field [17]. If the concept of port efficiency is exclusively considered, it is understood that it is linked to productivity, but “getting rid” of this concept, the statistical theory used to measure efficiency employs two predominantly calculated methods (the SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis)).

Charłampowicz & Mańkowski [18] are developing a system for evaluating the economic efficiency of sea container terminals in which the following methodological approach is proposed. A conceptual model of the system for assessing the economic efficiency of maritime container terminals is proposed as a holistic structure in the sense that it is a subsystem of a higher-level management system (1st level), and simultaneously as a system consisting of subsystems or modules (2nd level), which include subsystems or submodules (3rd level). The structure of the system is mentioned above at the 2nd and 3rd level, i.e., the modules and sub-modules.

In recent years, many authors have investigated the efficiency of port areas [19]. These works have mainly used two methods to measure efficiency: Data Envelope Analysis (DEA) and Boostrap DEA models.

Wen, Pham, and Lio and Liu [20–22] introduced all the uncertain DEA models based on the basic DEA model and the theory of uncertainty, but apply them to different basic DEA models. However, the studies by Wen et al. [20] and Lio and Liu [21] only stopped with a set of hypothetical samples while the research by Pham et al. (2016) had been tested and compared with the results obtained from the basic DEA software and directly applied to assess the efficiency of the world’s major container ports in 2016. The paper by Pham et al. [23], therefore, continues to use the uncertainty model of DEA from Pham et al. [21] and is applied in an extensive multi-dimensional study to analyse and evaluate many aspects of the operation of the major container ports over the past five years, which is accompanied by an analysis of the overuse of inputs or shortages in output to provide some suggestions that could increase the efficiency of container ports.

González and Trujillo [17] showed that the efficiency and size of the ports maintained an inverse relationship using the DEA-BCC (Banker, Charnes y Cooper) model in a sample of nine Spanish ports between 1992 and 2000. González and Trujillo [17] quantified the evolution of technical efficiency in the provision of port infrastructure services in the main Spanish port authorities involved in container traffic. The results showed that the reforms led to significant improvements in technological change, but that technical efficiency has changed little on average. More recently, Gil-Ropero et al. [24] analysed the changes in efficiency of the main container ports on the Iberian Peninsula during the period of 2008–2014, namely 13 Spanish and three Portuguese container ports. The evolution of
productivity is measured by the Malmquist productivity index using the DEA methodology. It is concluded that the increase in container traffic is directly related to an increase in the Malmquist productivity index, but with the influence of other variables acting as inputs.

As an application of the DEA in the determination of pure efficiency in other areas, Chang-Feng and Teng et al. [25,26], in the field of transport, particularly rail, analysed the efficiency of pure technology, concluding that it is decreasing the efficiency of scale, it is found in the eastern regions, and about 90% of the mid-western regions are increasing the efficiency of scale. Huang et al. [27] applied data envelope analysis (DEA) to study the performance evaluation of 17 logistics companies listed in China between 2003 and 2006. They concluded that poor performance at scale is the dominant reason for poor performance of logistics firms in China.

Table 1 shows the chronological evolution of studies that have been carried out in the port sector to determine the degree of efficiency of the system as a whole or by a given group of ports. For this purpose, the methodological basis of the Data Envelopment Analysis (DEA) has been used with a series of inputs and outputs, which can sometimes be the same or similar, and the operational scope, mostly in these articles.
| Year | Author | Scope of Study | Input | Output | Model |
|------|--------|----------------|-------|--------|-------|
| 1999 | Martinez-Budria, E. et al. | 26 spanish ports 1993–1997 | (1) Employment of Labour (2) Depreciation of cargo (3) Other jobs | (1) Total load moved between docks (2) Income obtained from the rental of port facilities | DEA-BCC (1) |
| 2001 | Valentine, J.S. y Gray, H.B. | 21 container ports in the world’s top 100 | (1) Total length of moorings (2) Length of container docks | (1) No. of containers (2) Total tonnes of production | DEA-CCR (2) |
| 2003 | Wang, T., Song, D.W. y Cullinane, K. | 28 ports in the TOP 30 (2001) world and 57 terminals | (1) Length of springs (2) Terminal area (3) No. of dock cranes (4) No. of yard cranes (5) No. of Straddle carriers | (1) TEUs handled | DEA-CCR-I DEA-BCC-I Stochastic function of Cobb-Douglas |
| 2003 | Barros, C.P. | 5 Portuguese ports 1999–2000 | Technical Efficiency (1) No. of employees/labor (2) Book value of assets Localised Efficiency (1) Labour costs—Wages and benefits divided by the number of employees (2) Investment cost—equipment and installation expenditure divided by the theoretical value of the fixed assets | (1) No. of ships (2) Cargo movement (3) Gross tonnage of ships (4) Market share (5) Tons of bulk cargo (6) Tons of contained cargo (7) Tons of Ro-Ro traffic (8) Tons of dry bulk cargo (9) Tons of liquids (10) Net income | DEA |
| 2005 | Lin, L. y Tseng, L. | 27 International Container Ports 1999–2002 | (1) No. of spring cranes (2) Length of springs (3) Courtyard equipment (n°) (4) Storage area | (1) TEUs handled | SFA (3) DEA-CCR DEA-BCC |
| 2006 | Cullinane, K. y Wang, T. | 69 Container terminals in 24 European countries 2002 | (1) Length of the terminal (2) Terminal area (3) No. of equipment | (1) TEUs handled | DEA-CCR DEA-BCC |
Table 1. Cont.

| Year  | Author                        | Scope of Study                        | Input                                                                 | Output                                           | Model                  |
|-------|-------------------------------|---------------------------------------|----------------------------------------------------------------------|-------------------------------------------------|------------------------|
| 2011  | Chiu, Y., Huang, Ch. y Ma, Ch. | 30 Regions in China (Coastal, Central, and West) | (1) Fuel consumed  
(2) Passenger vehicles  
(3) Goods vehicles  
(4) Highway Density  
(5) Passenger transport  
(6) Transport of goods  
(7) Traffic accidents  
(8) Jobs  
(9) Fixed assets | (1) Production value  
(2) Polluting industry | DEA                     |
| 2015  | Barros, C.P. y Athanassiou, M. | 4 Portuguese ports and 2 Greeks 1998–2000 | (1) No. of employees/labor  
(2) Book value of assets | (1) No. of ships  
(2) Tons of cargo moved  
(3) Tons of cargo handled  
(4) Tons of containers handled | DEA-BCC  
DEA-CCR |
| 2016  | Gil Ropero, A.                 | Port of Algeciras and the rest of the Port Authorities | (1) Number of cranes  
(2) Surface area of the terminal  
(3) Linear metres of quay with draught > 14 m | (1) TEUs  
(2) Number of container ships | DEA-CCR  
DEA-BCC |
| 2018  | Gil Ropero, A., Turias Domínguez, I. y Cerbán Jiménez, M.M. | 28 Spanish Port Authorities and 7 Portuguese Port Authorities | (1) TEUs | (1) Ships | DEA-CCR  
DEA-Bootstrapping |
| 2020  | Thi Quynh Mai Pham y Gyei Kark Park and Kyoung-Hoon Choi | Top container ports | (1) Mooring length  
(2) Container cranes  
(3) Total area  
(4) Handling capacity  
(5) Average waiting time of the vessel | (1) Performance of container movement  
(2) Vessel call  
(3) Mooring line productivity  
(4) Index of liner shipping connectivity | DEA-CCR  
DEA-BCC |

(1): CCB, formulations used in the DEA method with variable returns.  
(2): CCR, formulations used in the DEA method with constant returns to scale.  
(3): SFA, Stochastic Frontier Analysis. Source: Own elaboration.
The DEA-CCR (Charnes, Cooper y Rhodes) models assume that the technology satisfies, among other things, the property of constant returns to scale, and provide a measure of (overall) technical efficiency. Banker et al. [38] relax this assumption by allowing technology to present variable returns to scale. The operationalisation of this assumption results in the addition of the convexity constraint, thus, removing the influence of the scale of production. The efficiency measure, thus, obtained is a pure technical efficiency measure, i.e., technical efficiency measures “net of any scale effect” [39].

The typology of results that can be obtained as a result of applying the DEA-BCC model to the efficiency assessment of a set of entities is similar to that provided by the DEA-CCR model, except that it is now possible to decompose technical efficiency into pure technical efficiency and scale, as well as to determine, for each particular entity, the type of performance with which it operates locally [40].

3. Methodology

This study deals with efficiency in both its operational and financial aspects. The latter being very little used in ports, more oriented toward banking or the pure business world, since it is more convenient to study the operational efficiency of a port in order to be able to act on the systems that can create “bottlenecks” in the determination of better efficiency.

The studies carried out on port efficiency and productivity can be classified into three different groups: those that deal with partial productivity indicators, those that focus on the study of technological frontiers, and those that focus on the specialisation of a certain port in a particular field [17]. If we attend exclusively to the concept of port efficiency, understanding that it is linked to productivity, but “getting rid” of that concept, the statistical theory used to measure efficiency employs two predominantly calculated methods including the already mentioned SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis).

It is the authors Roll and Hayuth [41] who use, for the first time, the DEA method to analyse port efficiency. To do this, they made a comparison of data from 20 ports, checking that the DEA analysis makes it possible to overcome “certain efficiency specification barriers,” but also pointing out the weaknesses of the system and urging future researchers to remedy them.

The formulation used in output-oriented DEA analysis [24] in this article is as follows (Equations (1)–(5)):

\[
\max \theta = \varphi + \epsilon \left( \sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right) \tag{1}
\]

\[
\sum_{j=1}^{n} (\lambda_j x_{ij}) + S_i^- = x_{io} \quad i = 1, 2, \ldots, m; \tag{2}
\]

\[
\sum_{j=1}^{n} (\lambda_j y_{rj}) - S_r^+ = \theta y_{ro} \quad r = 1, 2, \ldots, s; \tag{3}
\]

\[
\lambda_j \geq 0 \quad j = 1, 2, \ldots, n. \tag{4}
\]

\[
\sum_{j=1}^{n} \lambda_j = 1 \tag{5}
\]

\(y_{ro}\) and \(x_{io}\): \(r\)th output and \(i\)th input for a DMU_o under evaluation.

\(\lambda_j\): the decision variables that represent the weights that DMU \(j\) would place on DMU_o to build its efficient reference set.

\(\theta\): The distance of the input to the casing and, therefore, the measurement of the technical efficiency index.

\(\epsilon\): the lowest actual positive number.

\(S_i^-\) and \(S_r^+\): the possible gaps or excess factors for each entry.

\(\varphi\): free.

The resolution of the model is carried out, according to the two-stage procedure. It will give an optimal solution \((\varphi^*, s^{++}, s^{--})\), so that \(\varphi^* \geq 1\). Thus, the larger sea \(\varphi^*\)'s másinfecte will be the unit evaluated. A unit will be rated as technically efficient if only \(sio\varphi^* = 1\) and all clearances are zero \((s^{++} = 0, s^{--} = 0)\). Otherwise, the unit will be inefficient and the technical efficiency output of the evaluated unit will be equal to \(1/\varphi^*\).
The representation of the DEA-Bootstrapping model, output orientation, is represented in Figure 1.

![Figure 1](image)

Figure 1. Graphic representation of the DEA-Bootstrapping model, output orientation. Source: Reproduced from [24], with permission from Emerald Publishing Limited, 2018.

According to López-Bermúdez [42], the mathematical model used in the DEA methodology assumes the existence of n DMUs (Decision Making Units), in which each consumes a m quantity of inputs to generate the s quantity of outputs. Thus, a DMU$ij$ uses a set of $x_{ij}$ inputs ($i = 1, ..., m$) and generates $y_{ij}$ outputs ($k = 1, ..., s$). The average s-n matrix of the output is designated by $Y$, and the m-n matrix of measurement of the inputs is designated by $X$. In addition, $x_{ij} > 0$ and $y_{ij} > 0$ must be complied with.

The method, as previously mentioned, can be output or input oriented, and the nomenclature of the product matrices is then inverted.

There are usually two types of formulations used in the DEA method, with constant returns to scale (CCR) or with variable returns (BCC). The linear programming approaches of both methods are set out below.

The CCR formulation seeks to maximise (Equations (6)–(8)):

$$h_{j0} = \frac{\sum_{r=1}^{n} u_r y_{rjo}}{\sum_{i=1}^{m} v_i x_{ijo}}$$  

(6)

Subject to:

$$\frac{\sum_{r=1}^{n} u_r y_{rjo}}{\sum_{i=1}^{m} v_i x_{ijo}} \leq 1, \quad j = 1, ..., n, \tag{7}$$

$$u_r, v_i > 0, \text{ to } r = 1, ..., n \text{ and } i = 1, ..., m \tag{8}$$

$y_{ij}$ is the output quantity of the unit $j$;
$x_{ij}$ is the input quantity $i$ of the unit $j$;
$u_r$ is the weighting of the output $r$;
$v_i$ is the weighting of input $i$;
$n$ is the total number of units;
$s$ is the total number of outputs and $m$ is the total number of inputs.

The results are the product of a series of DEA-BCC analyses in which uncorrected efficiencies are obtained (VRS Efficiency), which are subsequently corrected in order to determine the financial efficiency attributable to each port authority (see Figure 2).

![Figure 2](image)

Figure 2. Display of results of the DEA-BCC model. Source: Own elaboration.
3.1. Definition of the Inputs/Outputs

For this analysis, two inputs have been used for each DEA, both for operational and financial analysis. The inputs are related to the operational and economic activity of the port authorities, and two outputs, related to the traffic that the port authority obtains. For this purpose, the year with the most updated reference data has been studied, such as 2018, up to which data has been confirmed and published. In addition, they have been analysed by means of a DEA-Bootstrapping model analysis [43] with orientation in outputs, in which a first efficiency and a margin of error is obtained, to which the inverse formula is corrected and applied to obtain these efficiencies: “Operational Efficiency” and “Financial Efficiency.”

The inputs to be considered have been chosen for the ease of access to such data, and they are inputs that have been used in other studies, in addition to seeking a profile, both operational and financial, for the analysis of the various efficiencies of the system as a whole. Therefore, the inputs for the efficient operational analysis were selected to include the storage area and the length of the berthing line with a draught of more than 4 m and for the efficient financial analysis, the turnover and investments made in the same year were selected. These are a set of inputs that clearly define the scope of the study to be analysed. The revenues shown here are the net income they obtain over a year, i.e., mostly the fees they charge to vessels, terminal operators, etc.

The outputs for the operational analysis have been chosen given the degree of representativeness, since they are data that effectively measure the whole of a system or, in greater detail, the components of it. For this reason, the number of tonnes moved by each port authority and the number of ships it accommodates throughout the year of study are output data, which, in addition to being present in numerous studies, reflect the direct relationship with the storage surface, for the goods transferred from the ship to land or vice versa together with the berthing line, as more ships have to increase in size to accommodate greater quantities of goods. On the other hand, the outputs for the financial analysis have been selected in terms of traffic in tonnes, as this directly affects the turnover recorded by the Port Authority and its EBITDA (Earnings Before Interest Taxes Depreciation and Amortization).

3.2. Scenarios of the Port System

This article presents a series of scenarios or proposals for the Spanish Port System in which port authorities are grouped together [44] and are analysed as a whole in order to draw conclusions on their efficiency with respect to scenario 0 or the starting point, which is no more than the current situation.

Scenario 0 or the current situation of the Spanish port system is made up of 28 port authorities distributed along the whole of the Spanish coast with the exception of one, Seville, which is inland via the navigable river Guadalquivir.

Scenario 1 is made up of the grouping of port authorities due to their proximity, as it may be that, by being close to each other and forming a single port authority, the resources available can be optimised through correct management, avoiding duplication of infrastructures.

Scenario 2 is formed by the grouping of port authorities by the “maritime façades” [45,46]. This means that eight seafronts have been established along the Spanish coast, which means that they are largely grouped together because they belong to the same coastline.

3.3. Visualisation of Data

In this section, tables are attached with all the data of the different inputs and outputs extracted from the database of the different port authorities as well as from the state port database.

The scenarios are proposed as the union between port authorities. Hence, the data are the sum of the whole to propose scenarios with the same infrastructure and earnings based on maintaining the current traffic (see Tables 2 and 3).

Tables 4 and 5 show statistical data on inputs and outputs.
Table 2. Financial inputs and outputs of the different scenarios.

| Port Authorities                  | Turnover (€) | Investment (€) | Traffic (T) | EBITDA (€) |
|-----------------------------------|--------------|----------------|-------------|------------|
| **SCENARIO 0**                    |              |                |             |            |
| A Coruña                          | 31,762,114.53| 4,527,000.00   | 15,703,803.00| 19,432,000.00|
| Alicante                          | 12,067,584.45| 2,201,000.00   | 3,191,163.00 | 7,060,555.00|
| Almería                           | 16,021,150.81| 1,691,000.00   | 7,060,555.00 | 7,356,000.00|
| Avilés                            | 16,376,000.00| 6,269,000.00   | 5,024,863.00 | 8,621,000.00|
| Bahía de Algeciras                | 82,824,044.61| 18,259,000.00  | 107,361,029.00| 39,121,000.00|
| Bahía de Cádiz                    | 19,563,761.86| 4,256,000.00   | 3,955,515.00 | 8,898,000.00|
| Baleares                          | 78,576,783.37| 21,965,000.00  | 16,453,613.00| 41,193,000.00|
| Barcelona                         | 173,527,000.00|49,285,000.00 | 67,756,258.00| 102,397,000.00|
| Bilbao                            | 70,594,000.00| 49,198,000.00  | 35,695,401.00| 37,502,000.00|
| Cartagena                         | 45,935,000.00| 23,127,000.00  | 21,137,627.00| 20,929,000.00|
| Castellón                         | 31,334,907.92| 4,140,000.00   | 21,137,627.00| 30,091,000.00|
| Ceuta                            | 15,506,045.63| 2,759,000.00   | 2,448,438.00 | 2,816,000.00|
| Ferrol-San Cibrao                 | 20,311,671.53| 9,207,000.00   | 13,707,823.00| 12,542,000.00|
| Gijón                            | 42,189,250.00| 6,514,000.00   | 19,699,445.00| 27,746,000.00|
| Huelva                            | 45,291,596.62| 39,386,000.00  | 32,966,864.00| 17,505,000.00|
| Las Palmas                        | 77,659,710.00| 14,497,000.00  | 26,974,184.00| 54,078,000.00|
| Málaga                            | 18,627,805.96| 1,113,000.00   | 3,320,198.00 | 7,328,000.00|
| Marín-Ría de Pontevedra           | 9,745,604.03 | 2,757,000.00   | 2,541,733.00 | 5,940,000.00|
| Melilla                           | 9,758,678.76 | 3,134,000.00   | 873,528.00   | 3,841,000.00|
| Motril                            | 7,714,000.00 | 1,262,000.00   | 2,852,896.00 | 3,091,000.00|
| Pasaia                           | 12,244,000.00| 2,426,000.00   | 3,138,321.00 | 3,875,000.00|
| Santa Cruz de Tenerife            | 46,516,319.33| 24,633,000.00  | 13,051,755.00| 27,627,000.00|
| Santander                         | 22,852,000.00| 8,304,000.00   | 5,984,392.00 | 12,172,000.00|
| Sevilla                           | 20,177,000.00| 4,436,320.00   | 11,276,000.00| 11,276,000.00|
| Tarragona                         | 57,220,018.34| 18,660,000.00  | 30,236,000.00| 30,236,000.00|
| Valencia                          | 138,048,000.00|23,683,000.00 | 97,758,728.00| 26,019,000.00|
| Vigo                             | 31,241,366.12| 8,650,000.00   | 4,362,465.00 | 17,475,000.00|
| Vilagarcía                        | 5,056,758.71 | 843,000.00     | 1,211,306.00 | 2,604,000.00|
| **SCENARIO 1**                    |              |                |             |            |
| Bilbao and Pasajes                | 82,838,000.00| 51,624,000.00  | 38,833,722.00| 41,377,000.00|
| Gijón, Avilés and Santander      | 81,417,250.00| 21,087,000.00  | 29,411,626.00| 31,974,000.00|
| A Coruña and Ferrol-San Cibrao    | 52,073,786.06| 13,734,000.00  | 29,411,626.00| 31,974,000.00|
| Vigo, Marín-Ría de Pontevedra and Vilagarcía | 46,043,728.86| 12,250,000.00  | 8,115,504.00 | 26,019,000.00|
| Huelva, Sevilla and Bahía de Cádiz| 85,032,358.48| 52,121,635.53  | 14,107,177.00| 21,616,000.00|
| Valencia and Castellón            | 169,382,907.92|23,683,000.00 | 97,758,728.00| 102,454,000.00|
| Barcelona and Tarragona           | 230,747,018.34|67,945,000.00 | 99,840,504.00| 132,633,000.00|
| Ceuta and Bahía de Algeciras      | 98,330,090.24| 21,018,000.00  | 109,809,467.00| 41,937,000.00|
| Málaga, Motril, Almería and Melilla| 52,121,635.53| 7,200,000.00   | 14,107,177.00| 21,616,000.00|
| Baleares                          | 78,576,783.37| 21,965,000.00  | 16,453,613.00| 41,193,000.00|
| Santa Cruz de Tenerife and Las Palmas| 124,176,029.33|39,130,000.00 | 40,029,939.00| 81,705,000.00|
| Alicante and Cartagena            | 58,002,584.45| 25,328,000.00  | 37,132,853.00| 36,033,000.00|
Table 2. Continued.

| Port Authorities | Turnover (€) | Investment (€) | Traffic (T) | EBITDA (€) |
|------------------|--------------|----------------|-------------|------------|
| Bilbao, Pasajes, Santander, Gijón and Avilés | 164,255,250.00 | 72,711,000.00 | 69,542,422.00 | 89,916,000.00 |
| A Coruña, Ferrol-San Cibrao, Vigo, Marín-Ría de Pontevedra and Vilagarcía | 98,117,514.92 | 72,711,000.00 | 69,542,422.00 | 89,916,000.00 |
| Huelva, Sevilla and Bahía de Cádiz | 85,032,358.48 | 52,141,000.00 | 41,358,699.00 | 37,679,000.00 |
| Bahía de Algeciras, Málaga, Motril and Almería | 125,187,001.38 | 53,599,000.00 | 120,594,678.00 | 56,896,000.00 |
| Baleares | 78,576,783.37 | 21,965,000.00 | 16,453,613.00 | 41,193,000.00 |
| Alicante, Cartagena, Valencia, Castellón, Tarragona and Barcelona | 320,084,510.71 | 97,413,000.00 | 158,111,063.00 | 271,120,000.00 |
| Santa Cruz de Tenerife and Las Palmas | 124,176,029.33 | 39,130,000.00 | 40,025,939.00 | 81,705,000.00 |
| Ceuta and Melilla | 25,264,274.39 | 5,893,000.00 | 3,321,966.00 | 6,657,000.00 |

Source: Own elaboration.

Table 3. Financial inputs and outputs of the different scenarios.

| Port Authorities | Storage Area (m²) | Trackline with draughts > 4 m (m) | Traffic (T) | Ships (nº) |
|------------------|-------------------|-----------------------------------|-------------|------------|
| A Coruña | 467,421.18 | 12,242.30 | 15,703,803.00 | 1221 |
| Alicante | 198,052.00 | 6411.92 | 3,191,163.00 | 732 |
| Almería | 532,561.00 | 5359.30 | 7,060,555.00 | 1972 |
| Avilés | 546,376.64 | 4841.50 | 5,024,863.00 | 823 |
| Bahía de Algeciras | 3,760,321.71 | 21,075.00 | 107,361,029.00 | 28,913 |
| Bahía de Cádiz | 3,078,851.36 | 9712.00 | 3,955,515.00 | 1197 |
| Baleares | 525,497.00 | 25,517.39 | 16,453,613.00 | 50,366 |
| Barcelona | 5,023,964.14 | 22,890.00 | 67,756,258.00 | 9038 |
| Bilbao | 3,139,476.00 | 22,510.00 | 35,695,401.00 | 2925 |
| Cartagena | 602,880.00 | 4718.30 | 3,944,690.00 | 2203 |
| Castellón | 3,078,851.36 | 7427.30 | 21,137,627.00 | 1856 |
| Ceuta | 131,091.27 | 3453.00 | 2,448,438.00 | 11,147 |
| Ferrol-San Cibrao | 873,594.00 | 12,330.00 | 13,707,823.00 | 1130 |
| Gijón | 2,594,533.55 | 11,719.00 | 15,703,803.00 | 1221 |
| Huelva | 655,144.00 | 10,132.00 | 19,699,445.00 | 1229 |
| Las Palmas | 3,139,026.00 | 22,174.44 | 26,974,184.00 | 12,283 |
| Málaga | 494,331.00 | 7306.00 | 3,320,198.00 | 1764 |
| Marín y Ría de Pontevedra | 183,195.00 | 4261.00 | 2,541,733.00 | 500 |
| Melilla | 11,354.00 | 2004.34 | 873,528.00 | 1776 |
| Motril | 759,785.00 | 3127.00 | 3,852,896.00 | 1357 |
| Pasaia | 481,117.00 | 5383.00 | 3,138,321.00 | 911 |
| Santa Cruz de Tenerife | 1,010,082.00 | 13,725.50 | 13,051,755.00 | 16,400 |
| Santander | 943,445.00 | 7427.30 | 5,984,392.00 | 1626 |
| Sevilla | 1,067,915.00 | 5283.00 | 4,436,320.00 | 1016 |
| Tarragona | 2,479,522.00 | 15,095.00 | 32,084,325.00 | 2554 |
| Valencia | 4,783,331.00 | 28,909.29 | 76,621,101.00 | 7722 |
| Vigo | 745,177.00 | 12,190.00 | 4,362,465.00 | 1726 |
| Vilagarcía | 242,561.00 | 2665.00 | 1,211,306.00 | 336 |
Table 3. Cont.

| Port Authorities | Inputs Operational | Outputs Operational |
|------------------|--------------------|---------------------|
|                  | Storage Area (m²)  | Trackline with draughts > 4 m (m) | Traffic (T) | Ships (nº) |
| Bilbao and Pasajes | 3,620,593.00 | 27,893.00 | 38,833,722.00 | 3836 |
| Gijón, Avilés and Santander | 4,084,355.19 | 23,987.80 | 30,708,700.00 | 3678 |
| A Coruña and Ferrol + San Cibrao | 1,341,015.18 | 24,572.30 | 29,411,626.00 | 2351 |
| Vigo, Marín - Ría de Pontevedra and Vilagarcía | 1,170,933.00 | 19,116.00 | 8,115,504.00 | 2562 |
| Huelva, Sevilla and Bahía de Cádiz | 4,801,910.36 | 25,127.00 | 41,358,699.00 | 4609 |
| Barcelona and Tarragona | 5,589,108.00 | 37,659.29 | 97,758,728.00 | 9578 |
| Ceuta and Bahía de Algeciras | 7,503,486.14 | 51,880.80 | 69,542,422.00 | 7514 |
| Málaga, Motril, Almería and Melilla | 1,798,031.00 | 25,127.00 | 41,358,699.00 | 4609 |
| Baleares | 525,497.00 | 25,127.00 | 41,358,699.00 | 4609 |
| Santa Cruz de Tenerife and Las Palmas | 1,170,933.00 | 19,116.00 | 8,115,504.00 | 2562 |
| Alicante and Cartagena | 800,932.00 | 19,116.00 | 8,115,504.00 | 2562 |
| Bilbao, Pasajes, Santander, Gijón and Avilés | 7,704,948.19 | 51,880.80 | 69,542,422.00 | 7514 |
| A Coruña, Ferrol - San Cibrao, Vigo, Marín - Ría de Pontevedra and Vilagarcía | 2,511,948.18 | 43,688.30 | 37,527,130.00 | 4913 |
| Huelva, Sevilla and Bahía de Cádiz | 4,801,910.36 | 25,127.00 | 41,358,699.00 | 4609 |
| Bahía de Algeciras, Málaga, Motril and Almeria | 5,546,998.71 | 36,867.30 | 120,594,678.00 | 34,006 |
| Baleares | 525,497.00 | 25,127.00 | 41,358,699.00 | 4609 |
| Alicante, Cartagena, Valencia, Castellón, Tarragona and Barcelona | 9,110,195.14 | 65,842.92 | 158,111,063.00 | 24,105 |
| Santa Cruz de Tenerife and Las Palmas | 4,149,108.00 | 35,899.94 | 40,025,939.00 | 28,683 |
| Ceuta and Melilla | 142,445.27 | 5457.34 | 3,321,966.00 | 12,923 |

Source: Own elaboration.

Table 4. Financial statistical values.

| Source: Own elaboration. |
|--------------------------|
| Turnover (€) | Investment (€) | Traffic (T) | EBITDA (€) |
|--------------------------|
| Scenario 0 | 41,383,649.02 | 12,753,750.00 | 20,127,021.82 | 22,969,964.29 |
| Scenario 1 | 96,561,847.72 | 29,758,750.00 | 46,963,050.92 | 53,596,583.33 |
| Scenario 2 | 127,586,771.57 | 42,195,250.00 | 60,866,938.75 | 80,394,875.00 |
| Maximum value | Scenario 0 | 173,527,000.00 | 49,285,000.00 | 107,361,029.00 | 102,397,000.00 |
| Scenario 1 | 230,747,018.34 | 67,945,000.00 | 109,809,467.00 | 132,633,000.00 |
| Scenario 2 | 320,084,510.71 | 97,413,000.00 | 158,111,063.00 | 271,120,000.00 |
| Minimum value | Scenario 0 | 5,056,758.71 | 843,000.00 | 873,528.00 | 2,604,000.00 |
| Scenario 1 | 46,043,728.86 | 7,200,000.00 | 8,115,504.00 | 21,616,000.00 |
| Scenario 2 | 25,264,724.39 | 5,893,000.00 | 3,321,966.00 | 6,657,000.00 |
| Standard Deviation | Scenario 0 | 39,915,755.49 | 13,910,418.17 | 25,708,484.08 | 23,971,447.99 |
| Scenario 1 | 54,723,560.02 | 18,747,603.99 | 35,239,285.77 | 33,980,266.17 |
| Scenario 2 | 87,805,340.21 | 30,409,755.12 | 53,107,329.73 | 81,346,867.42 |

Source: Own elaboration.
Table 5. Operational statistical values.

|                      | Storage Area (m$^2$) | Track-Line with Draughts > 4 m (m) | Traffic (T)            | Ships (nº) |
|----------------------|----------------------|-----------------------------------|--------------------------|------------|
| **Average**          |                      |                                   |                          |            |
| Scenario 0           | 1,402,727.92         | 11,399.65                         | 20,127,021.82            | 5969       |
| Scenario 1           | 3,273,031.82         | 26,599.19                         | 46,963,050.92            | 13,927     |
| Scenario 2           | 4,311,631.36         | 36,285.12                         | 60,866,938.75            | 20,890     |
| **Maximum Value**    |                      |                                   |                          |            |
| Scenario 0           | 5,023,964.14         | 28,909.29                         | 107,361,029.00           | 50,366     |
| Scenario 1           | 7,503,486.14         | 37,985.00                         | 109,809,467.00           | 50,366     |
| Scenario 2           | 9,110,195.14         | 65,842.92                         | 158,111,063.00           | 50,366     |
| **Minimum Value**    |                      |                                   |                          |            |
| Scenario 0           | 11,354.00            | 2004.34                           | 873,528.00               | 336        |
| Scenario 1           | 525,497.00           | 17,796.64                         | 8,115,504.00             | 2351       |
| Scenario 2           | 142,445.27           | 5,457.34                           | 3,321,966.00             | 4609       |
| **Standard Deviation**|                      |                                   |                          |            |
| Scenario 0           | 1,495,594.13         | 8,838.07                          | 25,843,314.02            | 5508.07    |
| Scenario 1           | 2,164,060.40         | 7,060.12                           | 35,239,285.77            | 16,460.26  |
| Scenario 2           | 3,191,272.00         | 18,373.05                          | 53,107,329.73            | 1636.84    |

Source: Own elaboration.

4. Results and Discussion

The results obtained, through the inputs and outputs selected, according to their nature, allow us to obtain a general vision of how our port system is working through the individual analysis of each port authority. Furthermore, these results allow us to know and analyse the port authority displaced from the group of 28, or to analyse it according to the grouping of ports, in their different scenarios, in order to be able to compare the results with each other.

This article shows the operational and financial efficiency by which the infrastructures for the storage of goods and the mooring of ships have been taken into account in order to measure the efficiency with respect to these two very relevant aspects that mark the daily operations of the port. In addition, for the financial efficiency, assets have been taken into account, which is a good that the port authority possesses that can be transferred in monetary units (euros). Therefore, the efficiencies shown here are directly related to the assets that each port authority possesses, in addition to the annual net income from the collection of the different port taxes.

As opposed to the reference outputs in a port system, which are the total traffic moved (chosen for the efficient operational and financial analysis) in tons in a year, and, in this case, the number of ships has also been chosen as an output representative of the operational efficiency, since it is directly related to the income of the different fees charged to a ship. However, this does not mean that the greater the number of ships, the greater the efficiency. Instead, if there is a relationship between the income, the efficiency is calculated with the model and very different values are obtained between the different port authorities.

With an alpha error equal to 0.05 (5%), the following tables of efficiency results are obtained.

The results obtained, in scenario 0 (see Table 6) are outstanding. Of the 28 port authorities, only 5 reach the DEA border value equal to 1.0000 in the operational analysis and 10 in the financial analysis. However, the values obtained in the Bootstrap analysis differ from being close to full efficiency, as the port authorities obtain very different values in operational efficiency. This is not the case in the financial one, as the majority obtain values above 0.7500 efficiency.

The highest operational Bootstrap value is reached by the Port Authority of Huelva (0.85293), and reach pure efficiency in the DEA analysis. In addition, for the highest financial Bootstrap value, the Port Authority of Marín and Ría de Pontevedra (0.97883) reach pure efficiency in the DEA analysis.
### Table 6. DEA results scenario 0 (Current situation).

| DMU No. | DMU Name                  | DEA VRS Efficiency | BOOT Efficiency | BOOT Efficiency | DEA VRS Efficiency |
|---------|---------------------------|--------------------|----------------|----------------|--------------------|
| 1       | A Coruña                  | 0.59554            | 0.50776        | 0.8686         | 0.91278            |
| 2       | Alicante                  | 0.28659            | 0.24684        | 0.76769        | 0.78554            |
| 3       | Almería                   | 0.39935            | 0.36371        | 0.92469        | 1.00000            |
| 4       | Áviles                    | 0.20641            | 0.28241        | 0.80584        | 0.81504            |
| 5       | Bahía de Algeciras        | 1.00000            | 0.74662        | 0.87160        | 1.00000            |
| 6       | Bahía de Cádiz            | 0.90897            | 0.07632        | 0.68081        | 0.68993            |
| 7       | Baleares                  | 1.00000            | 0.67493        | 0.71746        | 0.75528            |
| 8       | Barcelona                 | 0.63111            | 0.52065        | 0.86889        | 1.00000            |
| 9       | Bilbao                    | 0.38413            | 0.32634        | 0.80152        | 0.82697            |
| 10      | Cartagena                 | 1.00000            | 0.83254        | 0.95996        | 1.00000            |
| 11      | Castellón                 | 0.67894            | 0.61534        | 0.89388        | 1.00000            |
| 12      | Ceuta                     | 1.00000            | 0.67732        | 0.27573        | 0.28426            |
| 13      | Ferrol-San Cibrao         | 0.34829            | 0.30412        | 0.95686        | 0.98053            |
| 14      | Gijón                     | 0.35740            | 0.31984        | 0.92362        | 0.97022            |
| 15      | Huelva                    | 1.00000            | 0.85293        | 0.66431        | 0.70194            |
| 16      | Las Palmas                | 0.34808            | 0.26535        | 0.91511        | 1.00000            |
| 17      | Málaga                    | 0.17835            | 0.15205        | 0.87333        | 1.00000            |
| 18      | Marín y Ría de Pontevedra| 0.26652            | 0.22988        | 0.97883        | 1.00000            |
| 19      | Melilla                   | 1.00000            | 0.66117        | 0.63454        | 0.64563            |
| 20      | Motril                    | 0.40027            | 0.33935        | 0.70278        | 0.75394            |
| 21      | Pasaia                    | 0.18689            | 0.17024        | 0.49467        | 0.50784            |
| 22      | Santa Cruz de Tenerife    | 0.59563            | 0.45507        | 0.84652        | 0.86325            |
| 23      | Santander                 | 0.20433            | 0.17973        | 0.79206        | 0.79956            |
| 24      | Sevilla                   | 0.23129            | 0.21407        | 0.83911        | 0.84567            |
| 25      | Tarragona                 | 0.44252            | 0.37922        | 0.79215        | 0.82521            |
| 26      | Valencia                  | 0.71368            | 0.60715        | 0.88024        | 1.00000            |
| 27      | Vigo                      | 0.14159            | 0.12011        | 0.81468        | 0.82521            |
| 28      | Vilagarcía                | 0.26549            | 0.24047        | 0.86799        | 1.00000            |

Source: Own elaboration.

The lowest operational Bootstrap value is attributed to the Port Authority of Vigo, which reach the lowest values in the two analyses (0.14159 and 0.12011, respectively). This may be due to the great variability of its rate income depending on the low growth in the number of ships. In addition, the lowest value financially speaking is obtained in Ceuta, either in the DEA analysis (0.28426) or in the Bootstrap (0.27573).

The average of scenario 0 (current Port System), both the arithmetic and the geometric of operational efficiency is less than 0.5 or 50%, which means that it is inefficient. However, in financial efficiency, it exceeds 0.75 or 75%, which can be assimilated or accepted as efficient, which is not purely efficient but on a scale of efficient or inefficient (see Table 7).

### Table 7. Statistical results of Scenario 0.

|                          | Arithmetic mean | Geometric mean | Standard deviation | Average deviation | Variance |
|--------------------------|-----------------|----------------|-------------------|-------------------|----------|
| DEA VRS Efficiency       | 0.50190         | 0.40576        | 0.80112           | 0.84945           |
| BOOT Efficiency          | 0.41163         | 0.34331        | 0.78136           | 0.82561           |
| BOOT Efficiency          | 0.30271         | 0.22098        | 0.14860           | 0.17062           |
| Average deviation        | 0.26385         | 0.19200        | 0.10636           | 0.13102           |
| Variance                 | 0.09163         | 0.04883        | 0.02208           | 0.02911           |

Source: Own elaboration.

The case of Pasaia is significant because its efficiencies do not exceed, in either case, the 0.5 or 50% of efficiency, which leads us to locate the port authority in the last position, if a scale or ranking was made.

There are cases in which the values of 0.2 or 20% are not reached in the operational bootstrap analysis, such as the cases of Vigo, Santander, Pasaia, Malaga, or the Bay of Cadiz, which are the authorities with the lowest values. It could be assumed that this is due to
low values of good income in total tons, as other port authorities with similar numbers obtain more annual tons of goods.

The results obtained, in scenario 1 (Table 8), are outstanding, as of the 12 Port Authorities that are proposed, 4 reach the DEA border value equal to 1.000 in the operational analysis and eight in the financial one. That is to say, 33.3% of the authorities are purely efficient operationally, and 66.6% are financially efficient of which 3 of the 12 are purely efficient in both efficiencies. In the Bootstrap analysis, the values improve compared to scenario 0, as six out of 12 (50%) exceed the threshold of 0.75 or 75% of operational efficiency, and, in the financial efficiency, all except one, which remains very close to the value, exceed the value of 0.75 or 75%.

Table 8. DEA results scenario 1 (Grouping by proximity).

| DMU No. | DMU Name                      | DEA VRS Efficiency | BOOT Efficiency | BOOT Efficiency | DEA VRS Efficiency |
|---------|--------------------------------|--------------------|-----------------|-----------------|--------------------|
| 1       | Bilbao-Pasajes                 | 0.37542            | 0.34877         | 0.75420         | 0.80640            |
| 2       | Gijón-Avilés-Santander         | 0.29940            | 0.27557         | 0.93189         | 0.94763            |
| 3       | A Coruña-Ferrol + San Cibrao   | 0.59020            | 0.53210         | 0.93880         | 1.00000            |
| 4       | Vigo-Marín + Ría de Pontevedra-Vilagarcía | 0.30695 | 0.25846         | 0.94004         | 1.00000            |
| 5       | Huelva-Sevilla-Bahía de Cádiz  | 0.37664            | 0.34992         | 0.73144         | 0.74222            |
| 6       | Valencia-Castellón             | 0.89026            | 0.86093         | 0.94099         | 1.00000            |
| 7       | Barcelona-Tarragona            | 0.90922            | 0.88019         | 0.94158         | 1.00000            |
| 8       | Ceuta-Bahía de Algeciras       | 1.00000            | 0.80368         | 0.94048         | 1.00000            |
| 9       | Málaga-Motril-Almeria-Melilla  | 1.00000            | 0.76868         | 0.93854         | 1.00000            |
| 10      | Baleares                       | 1.00000            | 0.76516         | 0.81472         | 0.82573            |
| 11      | Santa Cruz de Tenerife-Las Palmas | 0.63435          | 0.56253         | 0.96662         | 1.00000            |
| 12      | Alicante-Cartagena             | 1.00000            | 0.76411         | 0.96717         | 1.00000            |

Source: Own elaboration.

The highest operational Bootstrap value is reached by the port authority formed by Barcelona and Tarragona as a whole (0.88019), which does not reach pure efficiency in the DEA analysis. Additionally, for the highest financial Bootstrap value, the port authority formed by the whole of Alicante and Cartagena (0.96717) reach pure efficiency in the DEA analysis.

The lowest operational Bootstrap value is attributed to the Port Authority formed by Vigo, Marín, and Ría de Pontevedra and Vilagarcía as a whole (0.25846), not coinciding with the lowest value in the DEA analysis. In the financial analysis, it corresponds to the group formed by Huelva, Seville, and the Bay of Cadiz to obtain the lowest value in both analyses. In the DEA analysis, they obtained a financial efficiency of 0.74222 and the Bootstrap of 0.73144.

The average of scenario 1 (first port cluster proposal), both the arithmetic and the geometric of the operational efficiency exceed the value of 0.5 or 50%, which means that they are close to being efficient. However, in the financial efficiency, it exceeds 0.9 or 90%, which can be assimilated or accepted as pure efficiency. In the operational case, a more exhaustive analysis would have to be carried out, but from the results obtained, it could be said that it is not considered efficient (Table 9).
Table 9. Statistical results of scenario 1.

|                      | Arithmetic mean | Geometric mean | Standard deviation | Average deviation | Variance |
|----------------------|-----------------|----------------|--------------------|-------------------|----------|
|                      | 0.69853         | 0.63038        | 0.28594            | 0.26804           | 0.08176  |
|                      | 0.59750         | 0.54665        | 0.22807            | 0.20961           | 0.05202  |
|                      | 0.90397         | 0.90068        | 0.07418            | 0.0617            | 0.0055   |
|                      | 0.94349         | 0.93874        | 0.09070            | 0.07602           | 0.00822  |

Source: Own elaboration.

In the results obtained, in scenario 2 (see Tables 10 and 11), we highlight that of the 8 port authorities that are proposed, 4 reach the DEA border value equal to 1.0000 in the operational analysis and 3 in the financial analysis, that is, 50% of the authorities are purely efficient operationally, and 37.5% are financially efficient in which 3 of the 3 are purely efficient in both efficiencies. In the Bootstrap analysis, the values improve with respect to scenario 0, as 4 out of 8 (50%) exceed the threshold of 0.75 or 75% operational efficiency, and, in the financial efficiency, just over half exceed the value of 0.75 or 75%.

Table 10. DEA results scenario 2 (Grouping by sea fronts).

| DMU No. | DMU Name                                      | DEA VRS Efficiency | BOOT Efficiency | BOOT Efficiency | DEA VRS Efficiency |
|---------|-----------------------------------------------|--------------------|----------------|-----------------|--------------------|
| 1       | Bilbao–Pasajes-Santander-Gijón-Avilés         | 0.49661            | 0.45835         | 0.69902         | 0.74383            |
| 2       | A Coruña-Ferrol + San Cibrao-Vigo-Marín + Ría de Pontevedra-Vilagarcía | 0.65094            | 0.60925         | 0.8485          | 0.88959            |
| 3       | Huelva-Sevilla-Bahía de Cádiz                 | 0.53880            | 0.49961         | 0.73063         | 0.77207            |
| 4       | Bahía de Algeciras-Málaga-Motril-Almería      | 1.00000            | 0.85256         | 0.88816         | 1.00000            |
| 5       | Baleares                                      | 1.00000            | 0.82499         | 0.7382          | 0.77445            |
| 6       | Alicante-Cartagena-Valencia-Castellón-Tarragona-Barcelona | 1.00000            | 0.88084         | 0.89108         | 1.00000            |
| 7       | Santa Cruz de Tenerife-Las Palmas             | 0.66044            | 0.60224         | 0.80962         | 0.85659            |
| 8       | Ceuta-Melilla                                 | 1.00000            | 0.82679         | 0.88586         | 1.00000            |

Source: Own elaboration.

Table 11. Statistical results of scenario 2.

|                      | Arithmetic mean | Geometric mean | Standard deviation | Average deviation | Variance |
|----------------------|-----------------|----------------|--------------------|-------------------|----------|
|                      | 0.79334         | 0.67313        | 0.21260            | 0.20665           | 0.04520  |
|                      | 0.69438         | 0.64795        | 0.15959            | 0.15197           | 0.02546  |
|                      | 0.81138         | 0.80794        | 0.07388            | 0.06701           | 0.00543  |
|                      | 0.87956         | 0.87349        | 0.10318            | 0.09283           | 0.01064  |

Source: Own elaboration.

The highest operational Bootstrap value is reached by the port authority formed by Alicante, Cartagena, Valencia, Castellón, Tarragona, and Barcelona as a whole (0.88084), reaching pure efficiency in the DEA analysis. Furthermore, for the highest financial Bootstrap value, the same grouping obtains a value of 0.89108, reaching pure efficiency in the DEA analysis.

The lowest operational Bootstrap value is attributed to the port authority formed by Huelva, Seville, and the Bay of Cadiz as a whole (0.49961), not coinciding with the lowest value in the DEA analysis. In the financial analysis, it corresponds to the group formed by Bilbao, Pasaia, Santander, Gijón, and Avilés (0.45835), obtaining the lowest value in both analyses (0.49661 DEA).

The average of this last scenario, scenario 2, (proposed grouping by maritime facades), both the arithmetic and the geometric of operational efficiency exceed the value of 0.65 or 65%, which means that they are close to being efficient. However, in financial efficiency, it exceeds 0.8 or 80%, which can be assimilated or accepted as being very efficient. In the operational case, a more exhaustive analysis should be carried out, but the results obtained
raise some doubts regarding efficiency, since the DEA analysis exceeds the threshold of 0.7500 and the Bootstrap does not.

5. Conclusions

With the DEA-Bootstrapping model analysis, the results to be studied have been extracted and satisfactory conclusions have been reached.

First, the overall average of the operational efficiency of the Spanish port system is low, at around 0.5, largely due to the duplication in many cases of the infrastructures of which the system is composed. It is true that, in many cases, the different ports have a wide range of the same installations along our coast. Therefore, this duplication of infrastructures, sometimes over short distances, causes duplication of assets, which does not result in an increase in goods traffic, and even more so, in greater attractiveness to receive a greater number of ships, which, in turn, translates into less income from different port taxes.

Furthermore, the averages of the Spanish port system in scenario 0 (current situation) increase with respect to scenarios 1 (grouping by proximity) and scenario 2 (grouping by sea fronts) both operationally and financially. However, the choice between one scenario being better than the other in cases 1 and 2, would have to be analysed in much more detail with other inputs and outputs in order to extract a much more accurate and correct conclusion, since, from the results extracted, it may be difficult at first sight to guess which model is more efficient than the other. This is because the average value of operational efficiency is lower in scenario 1 (grouping by proximity) than in scenario 2 (grouping by seafront), but the opposite is true in the analysis of financial efficiency, which is higher in scenario 1 (grouping by proximity) than in scenario 2 (grouping by seafront).

In other words, the scenarios show that a port grouping, or a reform of the Spanish port system, favours financial efficiency and, even more so, the operational efficiency of our port system because they go from values of 0.4 in the BOOT analysis and 0.5 in the DEA analysis of operational efficiency, to values above 0.59 and 0.69, respectively.

Secondly, the ports with the greatest financial efficiency are the consolidated ports of the Spanish port system, with a great deal of traffic and with assets designed to favour the attraction of new ships and new goods, and/or to carry out a great deal of operational work in the handling of these cases. Some ports may be unused, but this is due to the large assets they possess that are not expressly dedicated to port use, i.e., their exploitation does not influence the performance of port work by attracting more traffic or by positively influencing the handling of goods entering the port.

Finally, it can be seen that efficiency is improved by looking at a lower number of DMUs, i.e., overall efficiency improves the more the number of port authorities is reduced.

With this, it is intended to show that an improvement of the current Spanish port system and substantial improvements can be obtained in terms of port efficiencies, making our port system much more competitive against new competitors that are capturing traffic. This is translated into greater income and an improvement in the distribution of the infrastructures and resources that our ports currently have, being able to improve in the competition, reducing our costs, and being able to carry out an improvement in our taxes, achieving an increase in the number of ships, and, therefore, of traffics.

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