EFFICIENCY ANALYSIS OF BRAZILIAN PUBLIC CONTAINER TERMINALS

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ABSTRACT

Cargo handling in private and public ports is one of the main activities in trade logistics. A different adaptation on container operations is required, as it plays a different role in terms of performance in port operations in Brazil. The use of data envelopment analysis (DEA) is applied to analyze the relative efficiency in terms of container operations in the Brazilian port terminals. The objective pursued was to identify the different performances of container handling in Brazilian ports and to show possible improvements for less effective ports. The research points out to the changes required in some ports in Brazil in relation to their inefficiencies.

Keywords: *DEA, Brazilian port efficiency, container terminal*

1. INTRODUCTION

The recent globalization of international trade required from countries some responsiveness in investments to improve the main channels of exchange of goods. Brazil has as one of its strengths the territorial extension of its maritime boundary with over eight thousand kilometers, which is the focus of studies and debates on the improvements of performance of public and private port terminals spread around its coast.

Currently, the total cargo handling in Brazilian ports in export and import procedures already represent a share greater than 90% of the Brazilian trade balance, which highlights the importance of the constant modernization of this mode of transportation and port infrastructure, in order to guarantee the agile and efficient service of deadlines of goods. One of the greatest examples is the port of Santos, which, in 2011, handled a total of 86 million tons, being its participation 29.9% of the total cargo handled in organized ports (CNT REPORT, 2012).

In 1993, the enactment of the Law of Ports completely reformulated the concepts in action up to that moment in the Brazilian port setting, introducing stimulus mechanisms of intra- and interport competition. For this end, there was the granting of exploration and provision of services in organized ports to the private sector, thus extinguishing the monopoly of port administrations with the creation of the Port Authority Council (CAP), in addition to establishing the permission for the handling of third party cargoes in Private Use Terminals (TUP). Among other stipulations of the law that provided more managerial and financial autonomy to the port authorities, the occurrence of a greater competition in the system and greater efficiency in the administration of the ports resulted in a decrease in costs for cargo handling.

In the following years up to the present, the Brazilian port sector has been beating records annually in the amounts of all types of cargo handled in its ports, which can be considered as a positive indicator for the Brazilian economy and competitiveness. On the other hand, the increase in the flow of goods has exposed the massive logistical and infrastructural deficiencies in the port terminals of the country.

Taking into consideration the importance mentioned for the Brazilian port system, the present project proposes an evaluation, through the Data Envelopment Analysis (DEA) methodology, of the relative efficiency of the main public container terminals in Brazil. We choose to take into account only public ports because of the official character of the data to be used in the research. As for the fact of the segmentation of the study in relation to container handlers, it was for the selection of terminals with similar operating characteristics, in addition to considering that the goods handled by containers usually have a higher added value.

The main objectives of the project are, in a first part, to analyze the Brazilian port efficiency in the handling of containers in the present day and to build a score among the decision making units (DMUs) considered, taking into account the inputs and products chosen in an attempt to identify the most efficient ports. Two basic models will be tested with output orientation by observing the differences and similarities found in the results, in order to recognize the best model applied to this case. The second part of the work will consist of the analysis of the port terminals that proved to be ineffective, noting, among the outputs, operational or administrative improvement opportunities designed by this method.

Based on comparisons made between the results of the study and the recent investments made, we will discuss the following questions: "What is the current scenario of container handling in the Brazilian public terminals?"; "Is Brazil investing currently in sufficient actions to improve its main channel with foreign trade?"

The applications that can be taken from the study encompass a large extent of questions; however, by answering the questions proposed, we give some support for future decisions to be taken by port managers. These possible changes range from the local scope of small operational and administrative improvements to the preparation of large national plans for port expansions, with major investments, both public and private, as, for example, the recent provisional presidential decree of modernization of ports.

In the next section, a retrospect of research studies that use the DEA method to evaluate the efficiency of ports in Brazil and in the world will be presented. Then, we will lay out the methodology used in the project. Finally, the results will be presented, along with the final remarks that can be observed from them, raising possible targets of future research studies in this proposed path.

2. LITERATURE REVIEW

Several works using the DEA method for relative efficiency analyses have been published, covering the most diverse possible sectors such as air transport (ASSAF, GILLEN, 2012; SOARES DE MELLO *et al*., 2003; CORREIA *et al*., 2011), hospitals (SULKU, 2011; LOBO *et al*., 2010), banking system (CHORTAREAS *et al*., 2013), among others. The vast literature available on the subject shows the global trend of concern to optimize, through this Operations Research tool, processes and to evaluate the operational performance of homogeneous units, thus reducing waste and improving the levels of products supplied.

Related to port efficiency, there are also many published scientific articles, in addition to Master and Doctoral theses, both in Brazil and in other countries. Next, we will describe some relevant articles to be mentioned, emphasizing the choices in the numbers of DMUs, inputs and products of each of them.

In the 1990s, Roll and Hayuth (1993) proposed for the first time the application of DEA in maritime transport, analyzing the efficiency of 20 ports, considering hypothetical data from three inputs - capital, number of employees and type of cargo handled - and four outputs - level of service, cargo handling, satisfaction perceived by the user and amount of moorings. Then, Martinez-Budria *et al*. (1999) evaluated, using the BCC method, 26 port terminals in Spain from 1993 to 1997, using three inputs - staff costs, depreciation rates and other expenses - and two products - total cargo handled and revenue obtained from the lease of port spaces.

In the following decade, several articles were published. Tongzon (2001) applied the methodology to analyze the efficiency of 16 ports, Australian and European, using six inputs - amount of cranes, berths, tugboats, employees, area of the terminal and operation waiting time - and two outputs - total handling of TEU (twenty-foot equivalent unit) containers and working speed of the port. In the same year, Valentine and Grey (2001) evaluated, using the DEA methodology, 31 international container ports for the year of 1998, using as inputs - total length of the berth and length of the container berth - and as outputs - number of containers handled and total handling in tons.

Next, Itoh (2002) made a further analysis using the DEA and considering, through the window method, the improvements of eight major Japanese ports during the period from 1990 to 1999, using as inputs - amount of berths, employees, cranes and total area of the terminal - and as product - annual handling of TEUs.

Barros and Athanassiou (2004) analyzed four Portuguese ports and two Greek ports, during the period from 1998 to 2000, taking into account two inputs - number of employees and capital handled - and four outputs - amount of moorings, handling of general cargo, of containers, and number of containers processed.

In addition to all the above, many other international works approached port efficiency using the DEA technique. Nationally, several articles have already been published, in addition to entire courses focused on the method approach as that developed by Soares de Mello *et al*. (2005), for the Brazilian Symposium on Operations Research.

This work contributes to the bibliography on the subject in the form of a specific analysis on the mechanism of public container handling in Brazil, something not accomplished so far. Using current data (2012), collected directly from official sources, we could identify the main targets of improvements found by the DEA methodology.

Pires *et al*. (2009) applied the DEA to analyze the efficiency of 14 berths of ports exporting iron ore, using as inputs - draft, length of berth and width of berth - and as output - annual cargo handling.

Acosta *et al*. (2011) used the method to analyze 27 port terminals in Brazil, also collecting the data from ANTAQ, considering three inputs - pier extension, depth of the channel and storage area - and one output - general cargo handling.

Bertoloto and Mello (2011) proposed the analysis of 48 ports and terminals of private use (TUP), during the period from 2007 to 2009, separating the ports into four clusters, to then apply the DEA for the efficiency analyses, considering as inputs - total length of berths and maximum draft of berths - and as product - total volume of cargo handled.

As shown above, the data envelopment analysis method has been and continues to be widely studied and applied in the most diverse areas, being one of the main tools used for the evaluation of performance and efficiency. Next, we will present all the methodological characteristics employed in the study.

3. METHODOLOGY

The mathematical method used to compute the relative efficiencies of the public ports analyzed in this article is the Data Envelopment Analysis (DEA), a non-parametric and deterministic model, based on linear programming, which makes use of multiple observations over an efficient frontier determined from the "enveloping" of data.

The great advantage of this approach is the ease to deal with multiple factors that influence the Decision Making Units (DMUs) without having the need to specify through functions the unknown relations between them as shown in Falcão and Correia (2012).

According to Benazic (2012), the principle of the DEA comes from the general definition of efficiency called "Pareto Optimality", which dictates that an economic situation is Pareto optimal if it is not possible to improve the usefulness of an economic factor without degrading the situation of another factor. Thus, in the DEA approach: a DMU can be classified as efficient, if and only if it is not possible to improve an input or output without worsening any other input or output. Thus, one way to characterize the productive efficiency is the relationship between what is produced and consumed in the form of the quotient:

$$Efficiency = \frac{weighted\ sum\ of\ products}{weighted\ sum\ of\ inputs}$$

This can be translated mathematically as follows, when considering the relative efficiency of a DMU_q in relation to the inputs and outputs of all the other ones:

$$DMU_q Efficiency = \frac{\sum_i^s u_i\, y_{iq}}{\sum_j^m v_j\, x_{jq}}$$

Where:

i − Index related to the outputs (products) − $i = 1, 2, .., s$

j − Index related to the inputs − $j = 1, 2, .., m$

q − Index related to the DMUs (decision making units) − $q = 1, 2, .., n$

v_j − Weight marked on the j-th input

u_i − Weight marked on the i-th input

x_{jq} − Matrix X of data related to the inputs from the DMUq

y_{iq} − Matrix Y of data related to the outputs from the DMUq

There are two classical models used in this approach with a fundamental difference between them: the adequacy mode of inefficient DMUs when returning to the efficient frontier. The model proposed by Charnes, Cooper and Rhodes (1978), also known as CCR, works with the constant return to scale, that is, any variation in the inputs generates a proportional variation in outputs. The model proposed by Banker, Charnes and Cooper (1984), also known as BCC, in turn, proposes the addition of a constraint that ensures the convexity of the set of efficient DMUs, generally being used in cases where it is suspected that an increase of inputs does not result in a proportional increase of outputs.

In addition, it is possible to classify the models depending on the orientation, i.e., if there is the desire to analyze the possibility of changes in inputs or products when computing the relative efficiencies of the DMUs; this occurs because of different characterizations of one of the restrictions of the classic problems. If the model is oriented toward inputs, then the reduction of inputs without changing the levels of products is tried; on the other hand, if it is oriented toward outputs, the increase of the levels of return on products, without changing the inputs used, is tried.

3.1. Choices for inputs and outputs

For the choice of factors that will integrate the model efficiency analyses, we took into consideration relevant aspects, both the infrastructural and operational ones, for each port. An important point for that decision is to take into account the orientation of our model. This way, as we tried to identify potential operational improvements in the Brazilian main public ports, such as, for example, increased container handling speed, expansion of berths for a larger number of moorings, improvements in transportation infrastructure of cargoes within the terminals, among others, we used the model oriented towards outputs.

An important detail raised by Cooper, Seiford and Tone (2006) is the limitation on the total number of inputs and outputs, being recommended the use of a number of DMUs that is at least three times greater than the sum of the numbers of inputs and products, making the choice among these factors even more important. This consideration is taken to increase the discriminatory power of this productivity modeling and performance evaluation.

After an evaluation of the time required for all data collection, we decided to work with a number of two inputs and three outputs. Those chosen for the analysis of port efficiency are both indicators of operating performance and effective capacity of the terminals:

Inputs:

- **Extension of berths that can receive container ships**: it is an infrastructural data measured in meters that serves as an operating indicator for the identification of the mooring capabilities of container ships.
- **Port and complementary storage area of containers**: it is a data used in square meters that considers the total amount of cargo that can be deposited at the terminals through leases.

Outputs:

- **Total handling of cargo by containers**: measured in tons of total cargo handled in containers.
- **Amount of moorings of container ships per year**: a measure of the total number of moorings of ships with containers per year at the terminals.
- **Average productivity**: is calculated in units of containers handled per hour of operation. Indicates the average productivity of each port terminal, per hour, in the year of the study.

Some other inputs and outputs that could be considered for this work are: number of employees, annual operating costs, number of equipment for the flowing of cargo, among others. The great reason for the non-use of these parameters is the scarcity of official data related to the mentioned factors, coupled with the fact that the organization and administration of ports is concentrated in State agencies, which only have cumulative values for a group of federative unit terminals, making it impossible the data analysis of individual ports.

3.2. Getting the selected data and DMUs for the study

The sample of data related to inputs and products addressed comprises the year of 2012 and was obtained from the Brazilian National Agency of Waterway Transportation, a government agency whose competence is to implement the policies formulated by the Ministry of Transport and the National Council for Integration of Transport Policies (CONIT), as well as regulate, oversee and inspect the activities of provision of services of water transport and use of port and water infrastructure performed by third parties (ANTAQ, 2012).

In order to obtain the values for the selected outputs, we used the Brazilian *Permanent System of Monitoring of Prices and Operating Performance of Port Services - PORT PERFORMANCE*, which is an interface intended to provide a database and information that will serve as a baseline for calculating prices and operational indicators, necessary for measuring the quality of services provided by port terminals. This service can be accessed publicly and is used for the preparation of studies such as the Statistical Yearbooks developed by ANTAQ.

In addition to the mentioned system, we also used information taken from the port terminals directly from ANTAQ's website, along with the websites of each port, to compose the data needed for both inputs, concerning the physical capacity of operation and storage.

We used in the analysis all public maritime ports that work with the handling of containers under management of the Secretariat of Ports (SEP), excluding, for reasons of inability of obtaining data, the Ports of Forno (RJ) and Porto Velho (RO), amounting to 19 decision making units. The port terminals considered are: Belém (PA), Fortaleza (CE), Imbituba (SC), Itaguaí (RJ), Itajai (SC), Itaquí (MA), Natal (RN), Paranaguá (PR), Recife (PE), Rio Grande (RS), Rio de Janeiro (RJ), Salvador (BA), Santarém (PA), Santos (SP), São Francisco do Sul (SC), São Sebastião (SP), Suape (PE), Vila do Conde (PA) and Vitória (ES).

3.3. Modeling chosen and software used

As mentioned above, the great difference between the CCR and BCC classical models lies in how all the inefficient units are taken to the efficient frontier found by solving the problem. Thus, prior to the application of the different models, we cannot predict the behavior of the return to scale, as we do not know the relationship between the inputs and outputs. Thus, according to Benazic (2012), many authors recommend the application of both models. If the results obtained coincide in considerable proportions, then it is safe to apply the CCR model for the CRS scale (Constant Return to Scale); otherwise, the BCC model for the VRS scale (Variable Return to Scale) is chosen.

Next, we will present the mathematical modeling used, as mentioned in Vincová (2005); in them the models of the envelope type are considered, nomenclature given for the dual formulation of DEA:

CCR - model oriented toward outputs and constant return to scale:

$$\begin{aligned} \text{Maximize} \quad & g_q = \Phi + \varepsilon(e^T s^+ + e^T s^-) \\ \text{Subject to} \quad & Y\lambda - s^+ = \Phi Y_q \\ & X\lambda + s^- = X_q \\ & \lambda, s^+, s^- \geq 0 \end{aligned} \tag{1}$$

BCC - model oriented toward outputs and variable return to scale:

$$\begin{aligned} \text{Maximize} \quad & g_q = \Phi + \varepsilon(e^T s^+ + e^T s^-) \\ \text{Subject to} \quad & Y\lambda - s^+ = \Phi Y_q \\ & X\lambda + s^- = X_q \\ & e^T\lambda = 1 \\ & \lambda, s^+, s^- \geq 0 \end{aligned} \tag{2}$$

Where Y is the matrix of products, X is the matrix of inputs; $\lambda = (\lambda_1, \lambda_2, .., \lambda_n) \geq 0$ is the vector assigned to the productive units; s^+ and s^- are the slack vectors for the inputs and outputs variables; $e^T = (1,1,..,1)$ is the unit vector in R^n; and ε is the non-Archimedean constant determined from the procedure described by Jahanshahloo and Khodabakhshi (2004), a parameter that prevents the occurrence of "pseudo-efficient" DMUs by restricting the weights to an infinitesimal value greater than zero. Moreover, the variable Φ indicates the amount of increase in outputs necessary in order to achieve efficiency.

According to Vincová (2005), analyzing the efficiency of a decision making unit DMU_q, the models above seek a virtual unit characterized by inputs $X\lambda$ and outputs $Y\lambda$, which are linear combinations of the best inputs and products from other units of the population of DMUs. Thereby, for the inputs $X\lambda \leq X_q$ and outputs $Y\lambda \geq Y_q$, the DMU_q can be considered as efficient if no virtual unit is found with the features denoted, or if the virtual unit is identical to the DMU evaluated, for example, $X\lambda = X_q$ and $Y\lambda = Y_q$. Therefore, if this DMU is efficient, the slack vectors will be equal to zero, in addition to the variable Φ being equal to one, and as a consequence $g_q^* = 1$, otherwise, $g_q^* > 1$ and the unit may be considered as inefficient.

The software used for the resolution of the models was the GLPK, using a computer with 8 GB of RAM and a processor i5-3570k with 3.4 GHz.

4. RESULTS

As proposed in the methodology, initially the problem was solved by the CCR and BCC models in order to determine the relationships between Inputs and Outputs, to subsequently perform the necessary projections. Table 1 presents the data used in both models:

Table 1 - Problem data

Ports	Inputs		Outputs		
	Extension of berths (m)	**Storage area (m²)**	**Total handling of cargo in containers (t)**	**Moorings per year**	**Average Productivity (containers/hour)**
Belém	400	59,797	224,310	66	9.116
Fortaleza	900	50,000	707,034	141	17.641
Imbituba	660	152,786	263,025	89	36.014
Itaguaí	810	200,000	4,155,727	456	33.885
Itajaí	1.057	162,491	3,913,188	300	51.645
Itaqui	750	44,700	90,465	37	8.339
Natal	540	15,000	250,960	46	12.587
Paranagua	564	320,000	6,572,801	786	35.756
Recife	1.010	33,000	36,536	13	14.576
Rio de Janeiro	1.082	325,855	5,649,620	916	27.716
Rio Grande	900	235,000	6,170,582	753	34.604
Salvador	617	118,000	2,812,604	456	29.730
Santarem	560	14,200	44,179	20	9.805
Santos	2.783	484,450	31,271,802	2.655	46.421
Sao Francisco do Sul	780	120,000	1,352,785	248	34.341
Sao Sebastiao	660	58,500	4,688	7	2.275
Suape	935	300,000	4,545,650	675	27.154
Vila do Conde	508	26,416	924,071	125	13.129
Vitoria	876	100,000	3,168,454	313	33.370

Source: National Agency of Waterway Transportation

With the data shown in Table 1, the CCR and BCC models were solved using the GLPK Linear Programming software. Tables 2 and 3 present the results obtained. In them, the ports have their scores calculated and their placement put in an efficiency ranking between all terminals considered.

Tables 2 and 3 also have the column Set of Reference with the values of λ, i.e., if a port is considered as efficient, then the lambda referring to it will be equal to 1; otherwise, if it is of low efficiency, then the model itself is able to evaluate which efficient ports can be used as "example" in its improvement; with the values of lambda found, these model ports are listed in the last column.

By observing the results obtained, we can see a great similarity in the values between the two models. The most visible differences are in Belém and Santarém. Both are considered as efficient by the BCC model, but through the CCR model we can see that it is possible to improve them. As previously mentioned, because of the close proximity of the results obtained in the two evaluations, the CCR model is the most recommended one to perform projections and analyses.

The first analysis that can be performed is regarding the frequency of each DMU relatively efficient in the set of references. As stated in Benazic (2012), the frequency of a DMU on the set of references can be considered as an indicator of whether this serves as a model for other units.

Particularly, if a DMU is considered as relatively efficient, but it is not a member of any set of reference, it should not be taken as a model by the other ones considered as inefficient. On the other hand, a high frequency of occurrence in the set of references means a higher probability of an example of a good performance. This way, Table 4 presents the frequency with which each efficient DMU is mentioned as the improvement model by another of low efficiency:

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Table 2 - Results found for the CCR model

Port	Score	Ranking Position	Set of Reference (λ)	
Belém	2.0613	17	Itajaí	0.2723
			Salvador	0.0577
			Vitória	0.0874
Fortaleza	1.3945	14	Itajaí	0.0695
			Natal	0.3267
			Vila do Conde	1.2798
Imbituba	1.	1	Imbituba	1.
Itaguaí	1.1779	11	Itajaí	0.3745
			Paranaguá	0.2873
			Salvador	0.3136
			Santos	0.0211
Itajaí	1.	1	Itajaí	1.
Itaqui	2.6841	18	Itajaí	0.1793
			Natal	1.0380
Natal	1.	1	Natal	1.
Paranaguá	1.	1	Paranaguá	1.
Recife	1.6892	16	Itajaí	0.1793
			Natal	1.0380
Rio de Janeiro	1.3319	13	Paranaguá	0.6167
			Salvador	0.0666
			Santos	0.2490
Rio Grande	1.1100	10	Paranaguá	0.3163
			Salvador	0.7722
			Santos	0.1122
Salvador	1.	1	Salvador	1.
Santarém	1.2171	12	Natal	0.9467
Santos	1.	1	Santos	1.
São Francisco do Sul	1.0970	9	Itajaí	0.5746
			Salvador	0.1456
			Vitória	0.0945
São Sebastião	10.3574	19	Itajaí	0.3017
			Natal	0.6317
Suape	1.4809	15	Paranaguá	0.5985
			Salvador	0.4234
			Santos	0.1208
Vila do Conde	1.	1	Vila do Conde	1.
Vitória	1.	1	Vitória	1.

Source: Calculations of the Author

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Table 3 - Results found for the BBC model

Port	Score	Ranking Position	Set of Reference (λ)	
Belém	1.	1	Belém	1.
Fortaleza	1.3945	14	Natal	0.4032
			Vila do Conde	0.2137
			Vitória	0.3831
Imbituba	1.	1	Imbituba	1.
Itaguaí	1.1779	13	Itajaí	0.3697
			Paranaguá	0.2864
			Salvador	0.3229
			Santos	0.0210
Itajaí	1.	1	Itajaí	1.
Itaqui	2.6841	18	Itajaí	0.2014
			Natal	0.7986
Natal	1.	1	Natal	1.
Paranaguá	1.	1	Paranaguá	1.
Recife	1.6892	15	Itajaí	0.1220
			Natal	0.8480
Rio de Janeiro	1.3319	16	Paranaguá	0.6123
			Salvador	0.1580
			Santos	0.2297
Rio Grande	1.1100	12	Itajaí	0.1326
			Paranaguá	0.3465
			Salvador	0.4087
			Santos	0.1122
Salvador	1.	1	Salvador	1.
Santarém	1.	1	Santarém	1.
Santos	1.	1	Santos	1.
São Francisco do Sul	1.0588	11	Itajaí	0.4150
			Salvador	0.4053
			Vila do Conde	0.1798
São Sesbastião	10.1195	19	Itajaí	0.2600
			Natal	0.2890
			Vila do Conde	0.4510
Suape	1.4373	17	Itajaí	0.5985
			Paranaguá	0.4234
			Salvador	0.1208
			Santos	0.1394
Vila do Conde	1.	1	Vila do Conde	1.
Vitória	1.	1	Vitória	1.

Source: Calculations of the Author

We can note, in Table 4, that the ports of Itajaí and Salvador are considered as the best examples of efficiency, because of the relationship found between inputs and outputs. Specifically in the case of Itajaí, we can note that, in spite of the storage space being average and lower to the ports of Santos and Paranaguá, for example, the speed productivity output is the greatest of all. In the case of Salvador, we can see a relatively small storage space when compared to the other large ports, but a good performance in outputs, especially in cargo handling.
Thus, we can observe that each port terminal of low efficiency has a set of reference that can be followed as a model. Using the results found in the CCR model and with each set of reference well-defined, we can make a projection for each inefficient DMU, so that it reaches the efficient frontier. The projection is based on the procedure described in Vincová (2005).

Table 4 - Frequency in the set of reference

Reference	Number of occurrences in the set of references
Imbituba	0
Itajaí	7
Natal	5
Paranaguá	5
Salvador	6
Santos	4
Vila do Conde	2
Vitória	1

Source: Calculations of the Author

However, we considered as low only the projection for the outputs, as this is the focus of this article. The projection involves using the values found for Φ and s^+ to update the value of the matrix of outputs, i.e.:

$$Y'_q = \Phi Y_q + s^+$$

Where Y'_q represents the projection of the q-th DMU. It is worth noting that for efficient DMUs, $Y'_q = Y_q$, as in these cases $\Phi = 1$, and $s^+ = 0$. Table 5 shows the values found:

Table 5 – Projections to achieve the efficient frontier

Port	Total handling of cargo in containers		Moorings per year		Average Productivity	
	Present	Projection	Present	Projection	Present	Projection
Belém	224,310	460,026	66	135	9.1160	18.6957
Fortaleza	707,034	1,536,551	141	196	17.6409	24.5033
Imbituba	263,025	263,025	89	89	36.0140	36.0140
Itaguaí	4,155,727	4,895,072	456	537	33.8846	39.9130
Itajaí	3,913,188	3,913,188	300	300	51.6450	51.6450
Itaqui	90,465	962,022	37	102	8.3390	22.3232
Natal	250,960	250,960	46	46	12.5865	12.5866
Paranaguá	6,572,801	6,572,801	786	786	35.7559	35.7560
Recife	36,536	596,480	13	94	14.5763	24.5447
Rio de Janeiro	5,649,620	7,255,129	916	1176	27.7161	35.5926
Rio Grande	6,170,582	7,005,824	753	835	34.6036	38.3540
Salvador	2,812,604	2,812,604	456	456	29.7299	29.7299
Santarém	44,179	237,575	20	44	9.8048	11.9152
Santos	31,271,802	31,271,802	2655	2655	46.4209	46.4209
São Francisco do Sul	1,352,785	1,463,795	248	268	34.3405	37.1586
São Sesbastião	4,688	48,495	7	120	2.2749	23.5323
Suape	4,545,650	6,628,149	675	984	27.1541	39.5943
Vila do Conde	924,071	924,071	125	125	13.1288	13.1288
Vitória	3,168,454	3,168,454	313	313	33.3699	33.3699

Source: Calculations of the Author.

We can note that the port of São Sebastião is the port which presents the biggest differences between present and projection, and this is because of the low efficiency found by the CCR. On the other hand, it is noticeable that the port of São Francisco do Sul is very close to the threshold of relative efficiency, so that the projection does not show significant results for this port. Next, a sensitivity analysis will be made upon the selected inputs and outputs.

4.1. Sensitivity Analysis

In this section, we perform a Sensitivity Analysis on the CCR model resulted from the removal of an input or output at a time, while the other remained in the analysis. The extent of berths was removed first, storage area second, total handling of cargo in containers third, moorings per year fourth and finally we removed the average productivity. Then, an analysis was carried out to evaluate how the efficiency varies in each DMU. The output of the analysis can be seen in Table 6. The ports that reach efficiency 1 are considered as efficient, otherwise they are considered as of low efficiency.

Table 6 - Variation analysis of the efficiency of each DMU

Port	CCR Analysis	Input Omitted		Output Omitted		
	All Inputs and Outputs	Extension of berths	Storage area	Total Handling of cargo in containers	Moorings per year	Average productivity
Belém	2.0613	3.8835	2.8222	2.0509	2.1159	4.9928
Fortaleza	1.3945	1.5808	3.3164	1.8900	1.4768	1.9620
Imbituba	1.	3.5760	1.2357	1.	1.	7.6053
Itaguaí	1.1779	2.1621	1.5469	1.2299	1.1829	1.8544
Itajaí	1.	1.5880	1.3699	1.	1.	2.6804
Itaqui	2.6841	4.1252	5.7841	2.6769	2.6841	6.6438
Natal	1.	1.	2.7760	1.	1.	1.7923
Paranagua	1.	2.1574	1.	1.	1.	1.
Recife	1.6892	1.9045	4.5089	1.6839	1.6892	13.9281
Rio de Janeiro	1.3319	1.9924	1.6793	1.2842	1.6943	1.3446
Rio Grande	1.1100	1.6531	1.6520	1.1084	1.1309	1.2810
Salvador	1.	1.3248	1.3769	1.0000	1.0198	1.3492
Santarem	1.2171	1.2171	3.6846	1.2152	1.2171	3.8986
Santos	1.	1.	1.0371	1.	1.	1.
Sao Francisco do Sul	1.0970	2.0750	1.5114	1.0821	1.1238	2.6934
Sao Sebastiao	10.3574	21.5871	18.4694	10.3445	10.3574	45.8365
Suape	1.4809	2.4013	1.9516	1.4581	1.6834	1.5849
Vila do Conde	1.	1.	2.4896	1.	1.	1.1645
Vitoria	1.	1.3304	1.7136	1.	1.	1.7600
Mean	*1.7685*	*3.0294*	*3.1540*	*1.7644*	*1.8092*	*5.4933*

Source: Calculations of the Author.

After examining the results, we can conclude that, in the Brazilian case of public container terminals, the DEA is more sensitive to the removal of Average Productivity than any other input or output. That is, the difference between the results found in the analysis of the CCR model and the result obtained by omitting the average productivity is greater than the result obtained by removing any other input or output. Then, we can note a greater sensitivity in relation to the removal of inputs than the two remaining outputs.

When looking at individual values of efficiency, the Paranaguá and Santos terminals are those with greater efficiency, i.e., they keep the maximum score in almost all the analyses carried out. In the case of Paranaguá, it does not have the maximum score only when we remove the input extension of berths, and, in the case of Santos, when we remove the input storage area. The values of efficiency of the other DMUs vary according to the importance of the input or output that was omitted for that terminal. Finally, the sensitivity analysis showed that a significant impact on the final results is generated when selecting the inputs and outputs used for the DEA.

5. FINAL REMARKS

The study addressed, using the DEA method, the efficiency of Brazilian public container terminals, demonstrating the methodological capacity to analyze multiple decision making units based on a set of data from the year 2012, without the need to specify a functional relationship between the inputs and products selected.

Contrary to what was expected by the authors, there was an unexpected consideration of the work performed: the port of Santos, although the results presented it as an efficient container handling terminal, is not regarded as the "best" model to be followed.

This, in our perception, is because, notwithstanding the collected data having significantly greater dimensions at the port of Santos, the port of Itajaí can perform operations more efficiently; for example, it handles a little less than 13% of what is handled in the port of Santos and, at the same time, reaches an average productivity of greater operation. In this sense, the port of Santos, which comprises the terminals of Santos Brasil, Libra Terminais and Ecoporto Santos, could actually be considered as the largest one in Brazil; however, handling in greater quantity does not necessarily mean handling more efficiently, i.e., taking into consideration the resources used and what was produced, the ports of Itajaí, Salvador, Natal and Paranaguá, in that respective order, are the best models of operation among all Brazilian container terminals.

That way, considering the results, we can answer the questions raised previously. The first one pertains to the current scenario of the Brazilian container terminals, and the second is related to the country's actions to improve this channel with foreign trade.

First, we have to remember that the ports considered in the study can be considered as homogeneous in their basic operation of handling of containers. However, the ports have significant differences when the amount of cargo handled in each of them is observed. Therefore, even though we found eight efficient ports in the study, we do not desire to compare directly one terminal with another, but to use the information gathered to improve the weak points of those considered as less efficient.

Thus, the current scenario of container terminals in Brazil must be considered as a target of several improvements. The country's managers must understand that, currently, only a good logistics integration of all modes of transportation in Brazil is what will make the country a global model of port and transport administration and management.

One of the difficulties for accomplishment the work presented was the collection of official data to serve as inputs and products in the analysis performed. This completely limited both the choice of the amount of inputs and outputs, and the sample size of the container terminals considered.

For future works, the use of different inputs and products to re-evaluate the relative efficiencies of container terminals can generate different results, or, even, a regrouping of the sample, considering the Brazilian terminals of greater container handling alongside other major handling ports around the world, in order to evaluate the relative efficiency on a global basis.

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