Are the grain intermodal terminals in Brazil's Northeastern region efficient?

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Abstract

In the past years, there has been a lot of discussion about the Brazilian Northeastern corridor for grain export. In order to lower distances between production and processing sites, the national government has strived to turn it into the second major corridor of the country, relying on the intermodal transport as the main alternative source to reduce logistics cost. In this sense, the intermodal terminal becomes relevant, once its performance tends to impact the logistics system as a whole. This paper aims to assess the efficiency of intermodal grain terminals in Brazil's Northeastern corridor. Based on a quantitative approach, Data Envelopment Analysis (DEA) was employed to measure the relative efficiency of five terminals in two periods (October 2010 to September 2011; October 2011 to September 2012). It can be concluded that intermodal terminals from the region operate at a low level of efficiency, therefore could be considered inefficient. However, there is significant evidence of efficiency improvements over time. This research may be used as decision support by policy makers of both public and private sector organizations.

Keywords: Agribusiness. Logistics. Performance.

1. Introduction

Since the late 1990s, few countries have obtained such representative growth in the international trade of agribusiness like Brazil. The country has led the production and export of many agricultural products. For instance, it is the largest producer and exporter of coffee, sugar, sugarcane ethanol, and orange juice. The country is also on the top of exports of the soybean complex (e.g. grain, bran, and oil), which is also the main national income generator. Furthermore, it leads the world ranking of bovine and pork meat exports (MAPA, 2011). This growing production is the result of a continuous effort of several factors, encompassing since the research and development of new varieties of plants, chemicals, machinery, handling, and efficiencies of operators. In the case of grain production, it is important to point out the support of the Brazilian Enterprise of Agricultural Research (Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA), that in partnership with field producers, industrials, and private research centers, has made the grain cultivation, specially soybean, possible in the Cerrado region, particularly in Northern state of Mato Grosso (MAPA, 2011), and in the region known as MAPITOBA, area located among the states of Maranhão, Piauí, Tocantins, and Bahia (AGROANALYSIS, 2013).

Thus, the Brazil's Northeastern region has gained evidence in the national agricultural market. According to the National Company of Supply (Companhia Nacional de Abastecimento – CONAB), between the years 2000 and 2010, the region increased 13.17% the area destined for planting and in 40.72% the grain productivity by hectare. In the same period, the production of grain increased by 55.50%, totalizing 7.8 million tonnes (CONAB, 2011). As the two main producing mesoregions (Southern Maranhão and Western Bahia) are located around 800 kilometers from the main consumer centers or the export ports, an efficient logistic system is essential, especially for low value-added products. In this sense, intermodality emerges as an important alternative to reduce costs, leveraging the competitiveness of the Brazilian agricultural enterprises in the world economy.

In this context, the intermodal terminal, the node responsible for transshipping goods from one mode to another, becomes essential to efficiently execute the intermodality. Because the transshipping process involves coordination of several agents, such as shippers, logistics service providers, intermodal service agents and so forth, reaching high effectiveness and efficiency might not be a simple task (ABRAMOVIĆ, LOVRIĆ, STUPALO, 2012). Therefore, its low performance tends to affect negatively the grain distribution system, compromising the competitiveness of the agricultural segment as a whole.

Recognized its importance as an essential link to reduce logistics costs, governmental research agencies have spent part of their budget to support studies in logistics, including intermodal transportation. In Brazil, two projects must be highlighted: the project "ALOGTRANS", which aimed to study the flow of agricultural products in the Brazilian mid-eastern export corridor, funded by Financiadora de Estudos e Projetos (FINEP), and more recently, the project named "Desempenho dos Terminais Multimodais da Cadeia Logística de Grãos", which attempted to measure the operational performance of Brazilian intermodal grain terminals, funded by the Brazilian Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq), which this paper is part of.

Therefore, regarding the increasing importance of the Brazilian Northeastern export corridor as one of the most promising corridors for grain export in the country for the next years, this present paper aims to address the following questions: Are intermodal grain terminals located in the Brazil's Northeastern export corridor efficient? How efficient are they? Have these terminals improved their efficiencies over time? In order to reach the proposed goals, we measured the efficiency scores of five intermodal terminals from the region in two periods (from October 2010 to September 2011, and from October 2011 to September 2012) through a nonparametric technique, Data Envelopment Analysis (DEA), totalizing 10 units of analysis. We also used the Inverted Frontier Method to increase the discrimination among the scores. We expect this research to improve the understanding of this specific, yet very important object, providing relevant information for both public and private agents.

This paper is structured, besides this brief introduction, as follows. In the next section, we present a literature review of necessary concepts for the understanding of this study. In section three we present the material and method used to accomplish the proposed goals. In the fourth section, findings are presented and discussed. In the fifth and last section, we make some final considerations and conclusions. Limitations and suggestions for future studies are also presented.

2. Literature Review

This section is divided into three subsections. The first one shows the concepts of logistics and intermodality. The second one explains the performance model adopted as well as Data Envelopment Analysis, the technique used to measure the technical efficiency of the intermodal terminals. The last one presents a synthesis of the main recent studies which used the DEA approach as the tool to assessing efficiency in logistics and transportation systems.

2.1. Logistics and intermodality

According to Council of Supply Chain Management Professionals (CSCMP, 2014), logistics is part of supply chain management responsible for implementing and controlling the flow and storage of goods, and information, in order to meet customers' needs in the most efficient way. Its current concern, therefore, is how to deliver goods in the right place at the right time, in a precise amount, minimizing errors and maximizing quality of service at the lowest cost possible (BALLOU, 2010). Ballou (2010) also argues that activities such as transportation, inventory management, and order processing are the core activities to reach logistics goals of companies. At the same time that these activities are considered essential for the coordination and achievement of logistical tasks, they also represent the largest slice of the total costs. It means that they must be strictly managed to keep the business profitable.

In Brazil, the logistics system faces a big and old dilemma. On one hand, the productive sector (farmers, industrials etc.) has been modernized itself in order to reduce costs and increase productivity; on the other hand, structural issues, mainly those related to national transportation segment, have compromised not only the agents' performance but also economic and social development of the country (FLEURY, 2006). In low value-added sectors, such as agribusiness, the struggle to maintain production costs low is even harder, given the nature of the industry. The use of more than one mean of transportation arises as an alternative for companies to gain competitiveness against competitors, especially when the road transportation prevails as the main mode of transport, even for loads and/or lengths which are not considered as the most advantageous option (NAZARIO, 2000).

It is important to keep in mind that there is a difference between multimodal and intermodal transportation definition, although both types combine more than one mean of transportation to move goods. However, while multimodal transportation uses only one contract from the origin to final destination, intermodal transportation uses unilateral contracts in each stage of the transportation process (BERTAGLIA, 2005). Although the Brazilian government created a specific law, Lei nº 9.611 (BRASIL, 1998), to regulate and increase the multimodal transportation in the country, fiscal issues among different federation units have inhibited its development. Therefore, we adopted the terms "intermodal transportation" as well as "intermodal terminal" in this paper.

Calabrezi (2005) emphasizes that each mode of transport has its advantage and disadvantage when individually used. However, negative aspects can be minimized with the combination of two or more mean of transportation. Therefore, in order to accomplish this integration, the presence of the intermodal terminal becomes essential to transship grains from one mean of transportation to another (e.g. from truck to train, from ship/barge to train). Figure 1 schematically shows a basic configuration of an intermodal grain terminal.

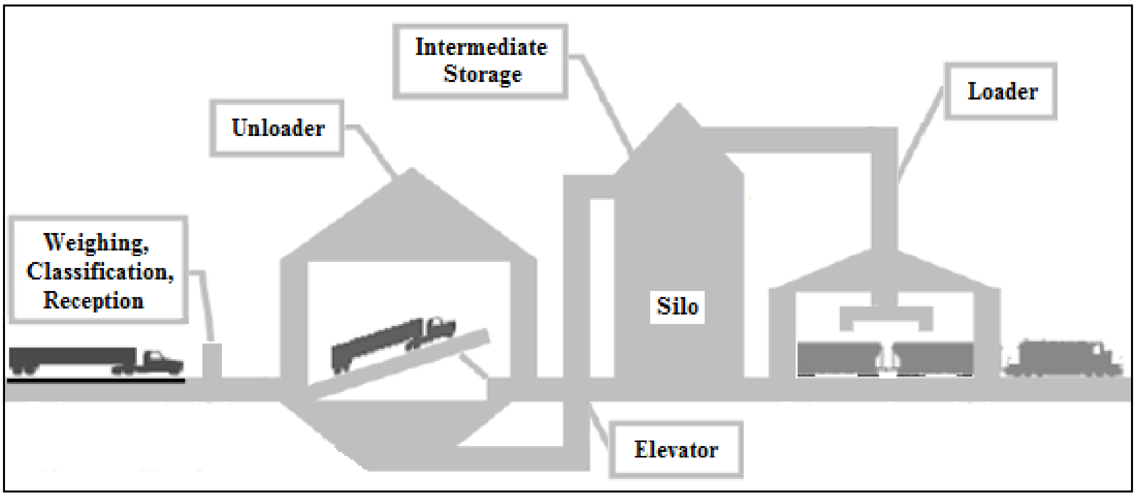

Figure 1: Grain intermodal terminal
Source: Adapted from Calabrezi (2005)

2.2. Performance, Data Envelopment Analysis (DEA), and inverted frontier

The process of performance measurement in logistics has aroused great interest among scholars and practitioners in the past decades. This process has become crucial to managerial success, especially to improve service quality, enhancing supply chains' operations in general. It happens because logistic services tend to become quite similar over time, therefore, performance assessment system could be an alternative to differentiate and gain some competitive advantage over rivals (RAZZOLINI FILHO, 2006). In order to assess the efficiency of intermodal grain terminals from the Brazil's mid-western corridor, Sogabe et al. (2009) proposed a specific model for performance measurement (Figure 2) by adapting the Stern and El-Ansary (1982) and Goldman's (1992) model. In this paper, we concentrated our analysis in the productive efficiency perspective.

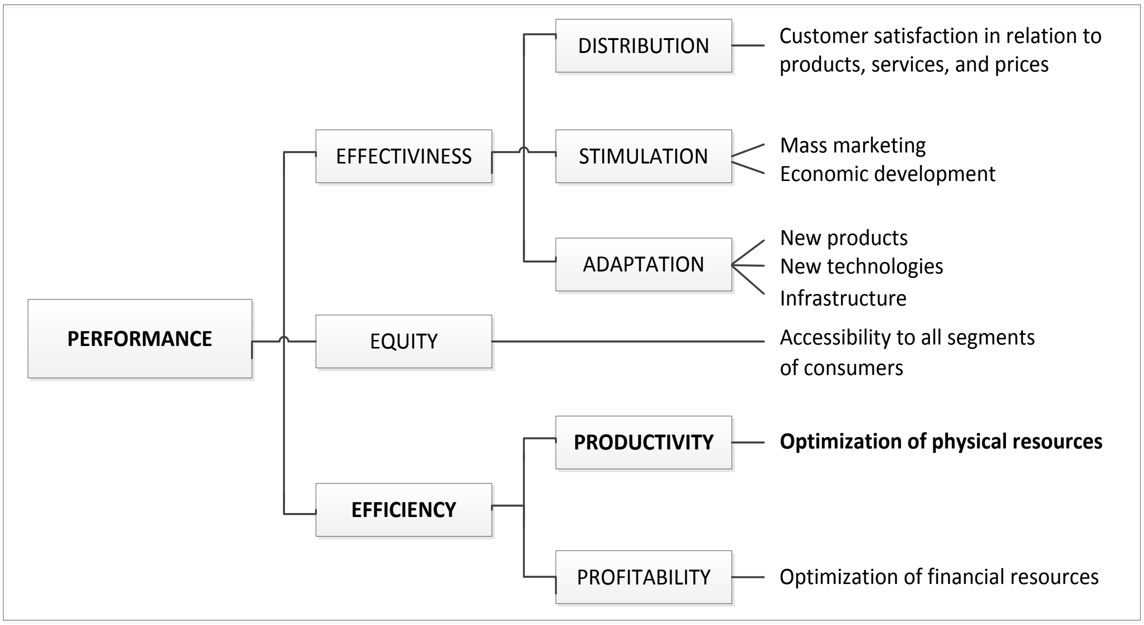

Figure 2: Framework of analysis - performance in intermodal terminals
Source: Sogabe et al. (2009)

The DEA technique allows, through linear programming problem, the use of several Decision Making Units (DMU) as well as multiple inputs and outputs, possibly with different units of measure, in a single integrated model (SOARES DE MELLO et al., 2005; COOPER; SEIFORD; TONE, 2007; NOVAES, 2007; COOK; ZHU, 2008). According to Cook and Zhu (2008), the efficiency frontier is composed by 100% efficient units, those that reached the maximum relative performances. Besides the identification of efficiency scores, DEA may also (1) identify a peer group for each inefficient unit and/or (2) point out how many inputs should be decreased or how many outputs should be increased for each inefficient DMU to reach its maximum efficiency.

Figure 3 compares the behavior of DEA and linear regression. As can be seen, DEA provides the best practice of those DMUs analyzed, creating relative performance scores, whereas linear regression, a parametric approach, predicts the average behavior of the whole set of DMUs (COOK; ZHU, 2008).

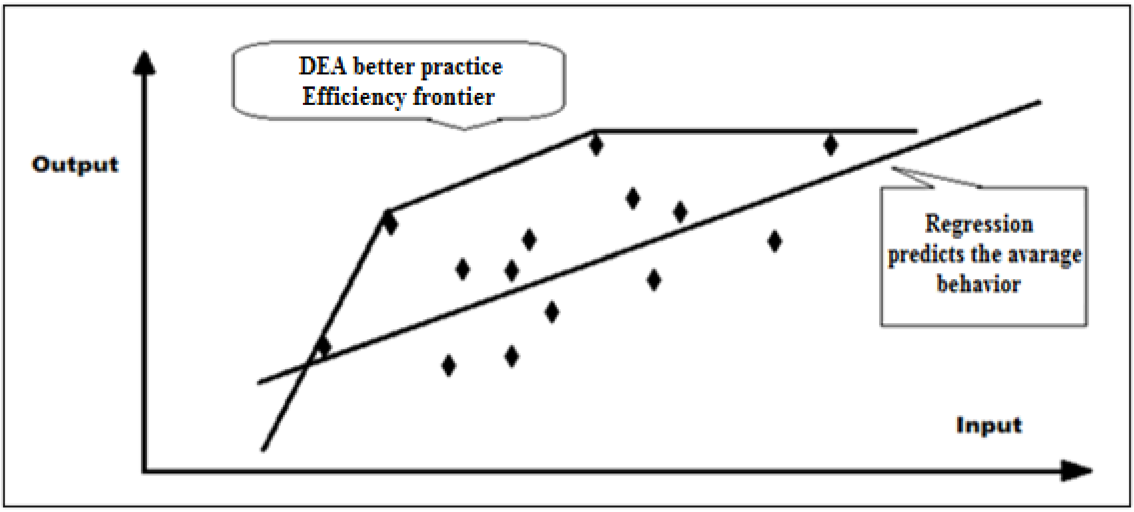

Figure 3: Data envelopment analysis – Efficient Frontier
Source: Cook and Zhu (2008)

There are two basic DEA models in the literature. The first one was initially proposed by Charnes, Cooper and Rhodes (1978) and is commonly called CCR due to the initials of the authors' name. The second one was proposed by Banker, Charnes and Cooper (1984) and is dominated BCC. Both can be either input-oriented, when the aim is to minimize the input consumption, keeping the output unchanged, or output-oriented when the goal is to maximize outcome, keeping input unchanged. The CCR model works on the assumption of constant returns to scale (CRS), building a linear surface through the DMUs relatively efficient, involving the other non-efficient DMUs. The BCC model, on the other hand, uses variable returns to scale (VRS), enabling the maximum productivity to vary in function of production scale, therefore, allowing the participation of DMUs of distinct sizes. Because the terminals of our analysis differ in size, have as inputs variables practically unchanged, and aim to increase the amount of grains transshipped, we adopted the BCC product-oriented model. According to Banker, Charnes and Cooper (1984), its formulation is defined as follows.

$$\text{Min} \sum_{i=1}^{n} v_i x_{ki} + v_k \qquad (1)$$

subject to

$$\sum_{r=1}^{m} u_r y_{jr} + \sum_{i=1}^{n} v_i x_{ji} - v_k \leq 0 \quad (2)$$

$$\sum_{j=1}^{m} u_r y_{rk} = 1 \quad (3)$$

$$u_r , v_i \geq 0 \quad (4)$$

j = outputs; x = inputs; u,v = weights

$r = 1,..., m; i = 1,..., n; j = 1,..., N$

As pointed out by Angulo-Meza and Lins (2002), DEA tends to produce generous scores, resulting in a large amount of efficient DMUs, especially BCC model. In order to increase the discrimination power of the model, several methods are found in the literature, including the Inverted Frontier mothed. The Inverted Frontier method was first introduced by Yamada, Matui and Sugiyama (1994), and its evaluation is seen as a pessimist analysis of each DMU. According to Silveira et al. (2012), the projections from Inverted Frontier are considered to be an anti-target or anti-benchmarks. In this case, it would be those terminals with the worst managerial practices. The method, therefore, creates an efficiency frontier composed of inefficient DMUs (Figure 4).

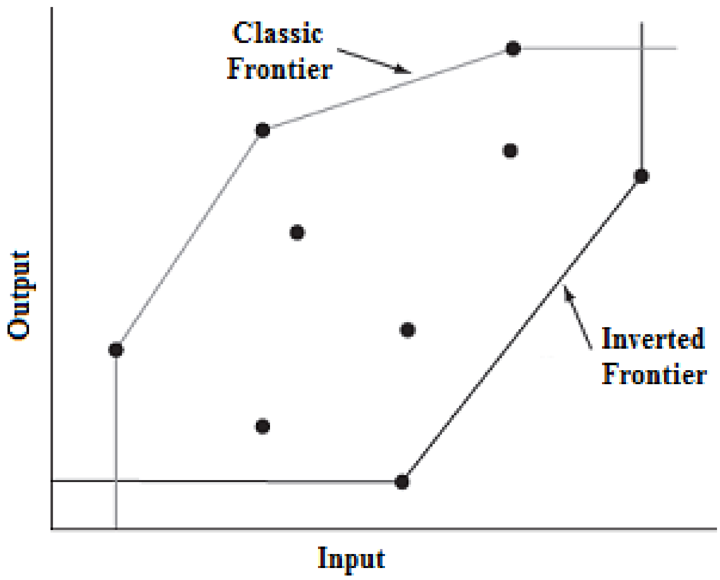

Figure 4: Classic frontier and inverted frontier – DEA BCC
Source: Silveira et al. (2012)

To calculate the Inverted Frontier, inputs are exchanged with outputs of DEA BCC original model. However, to make its usage possible, the score is transformed into an aggregated efficiency by dividing the scores by the highest one found, obtaining the standardized Inverted Frontier. Its formulation is defined as follows.

$$\textbf{\textit{Composite efficiency}} = \frac{standard\ efficiency + (1 - inverted\ efficiency)}{2} \quad (5)$$

3. Material and Methods

3.1 Study area and sample collection

The Brazilian Northeastern grain export corridor is composed of seven intermodal terminals. Five are installed in Porto Franco/MA, where there is an intermodal complex; one is located in São Luís/MA; and one in Salvador/BA. The transportation of the harvest produced in the region is conducted mainly by roadway, and partially by railroad.

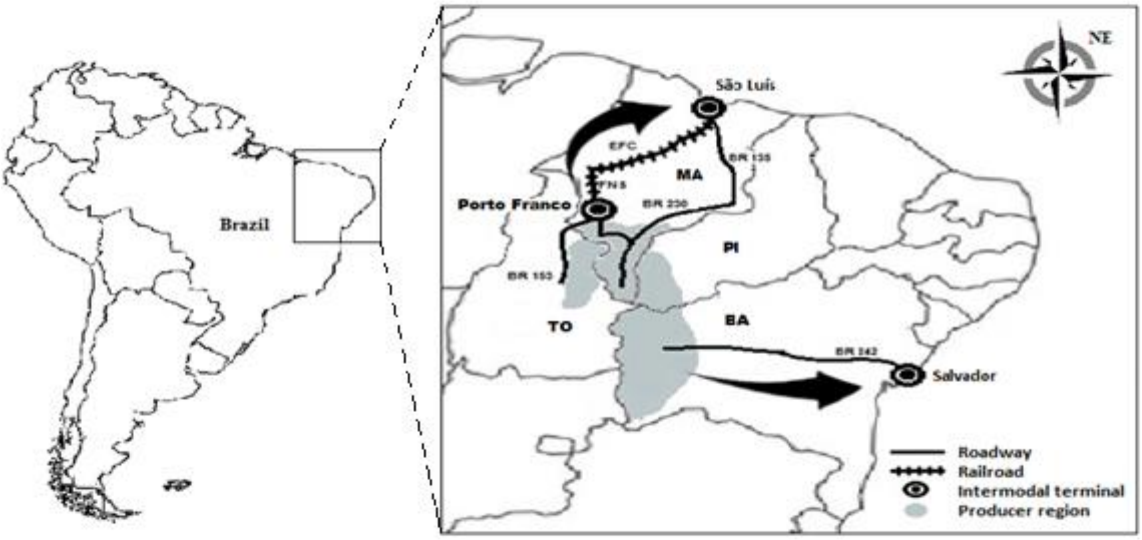

Figure 5: Study area – Brazil's Northeastern corridor for grain export
Source: Developed by the authors

For grains produced in Western Bahia, the largest producing area in the region, the main destination is a private use terminal (Terminal de Uso Privado – TUP) located in the city of Salvador/BA, and its transportation is made through roadway via BR-242. Part of the railroad that will connect the state of Tocantins to the Port of Ilhéus/BA, crossing Western Bahia region, is under construction, and the other part is still awaiting the environmental license to be issued by government agencies. There is no record of grain barge movement on São Francisco River in recent years. For grains produced in Northern Tocantins, Southern Piauí and Maranhão, there are two options of transportation: roadway, via BR-135, and railroad, part via Norte-Sul Railroad (Ferrovia Norte-Sul – FNS), and part via Carajás Railroad (Estrada de Ferro Carajás – EFC), both under concession of Vale S.A. company. In the latter case, both ways lead to a TUP located in São Luís/MA. It is important to mention that the two TUPs previously mentioned are comprised in the sample of this paper.

The sample of this study is characterized as non-probabilistic, purposive and by convenience. Five managers actively involved in operations management (three from Porto Franco/MA, one from São Luís/MA and one from Salvador/BA) agreed to answer a semi-structured questionnaire containing both qualitative and quantitative questions. A terminal manager from Campo Grande/MS was selected as a participant in a pilot test applied two months before the data collection takes place in order to validate and refine the questions. The first data collection involved on-site visit within one single week in November 2011. The data correspond to the period from October 2010 to September 2011. The second data collection took place in June 2013 via e-mail and phone calls, and the data correspond to the period from October 2011 and September 2012. To preserve the anonymity of the participants and companies, names were kept in confidence.

3.2. Variables

The identification of variables that mirrors the DMU performance is an important procedure of any DEA study. There are two common ways to select appropriate variables: theoretically, and empirically. In this study, we used a combination of both approaches, since studies regarding intermodal grain terminal are still incipient. Therefore, our selection was based on studies listed in Table 1. Later on, the selected variables were presented to the senior manager interviewed in the pilot test to validate them. We came to a conclusion that the efficiency of grain terminals relies on how much grain they receive and dispatch within a period. Therefore, the following two inputs and one output were chosen as the variables of the model.

- **Input 1 (nominal reception capacity):** the maximum amount of grains (in tonne) that the terminal can receive in 1 hour.
- **Input 2 (nominal dispatch capacity):** the maximum amount of grains (in tonne) that the terminal can dispatch in 1 hour.
- **Output 1 (annual movement):** the amount of grains (in tonne) transshipped in the terminal each period analyzed.

Table 1: Recent DEA studies on logistics and transportation

Model / Orientation	Author(s)	Focus of analysis
CCR and BCC / Input	Culliane and Wang (2010)	Seaport terminals
BCC / Output	Dias *et al.* (2010)	Airport terminals
CCR and BCC / Input	Hung, Lu and Wang (2010)	Seaport terminals
Not specified / Not specified	Teixeira and Campeão (2010)	Grain terminals
CCR and BCC / Input	Wanke and Affonso (2011)	Third party logistics
BCC / Output	Acosta, Silva and Lima (2011)	Seaport terminals
BCC / Input	Jordá, Cascajo and Monzón (2012)	Urban bus terminals
CCR and BCC / Output	Peralman and Serebrisky (2010)	Airport terminals

Source: Developed by the authors

3.3. Modeling validation

First of all, the variables (inputs and output) were submitted to a correlation test (Table 2) to check if they presented positive correlation coefficients as suggested by Hung, Lu and Wang (2010). Cooper et al. (2001) and Dyson et al. (2001) emphasize the importance regarding the number of DMUs and variables. The authors also suggest that the number of DMUs should to be, at least, equal to the triple of the sum of the inputs and outputs. In this sense, our model meets both requirements.

Table 2: Correlation coefficients among variables

	Input 1	Input 2	Output 1
Input 1	1	0,9670	0,9151
Input 2		1	0,9166
Output 1			1

Source: Research data

Since the terminals sampled aim to increase the amount of grains transshipped and they have heterogenic dimensions (size, and scale), we chose BCC model output-oriented. In other words, the present model intends to maximize the amount of grains transshipped (output) keeping the installed capacity (inputs) unchanged. Assumptions validated, we can conclude that the proposed model has a solid theoretical and methodological validation, therefore, can be considered appropriated to be applied.

4. Empirical Results, Discussion, and Implications

Before starting to present our findings, it is important to point out that DEA results must be carefully interpreted to extract useful and reliable information. Regarding a limited set of variables (inputs and outputs) as well as the number of DMUs, results have to be treated as partials. However, they can be considered a starting point for further discussions, seeking to investigate sources of inefficiencies or performance differences more accurately (LORENZETT; LOPES; LIMA, 2010). Based on controllable variables from a manager's point of view, we built our DEA model under the assumption of product maximization, also known as output-oriented. As inputs, we chose two important infrastructural variables with high impact on the operational performance of grain terminals; the amount of grain transshipped in one year was chosen as the output variable. The choice was based on a theoretical and empirical basis. Because the results present a relative score, it can be used for both individual and general analysis, depending on the goal of the study.

First, we present and discuss the results individually, and then generally. Table 3 presents the data (inputs and output) of each terminal used in the DEA model and its respective BCC score. Sistema Integrado de Apoio à Decisão (SIAD V3.0) was used as the computational tool. This tool was chosen because it provides both basic DEA models (CCR and BCC) and orientations (input, and output), as well as the Inverted Frontier method.

As seen in Table 3, the DMU Porto Franco 3 led the rank of efficiency in the first period (83.33%), reaching the efficiency frontier (100%) in the second year. It means that this terminal was the one which better maximized its installed structure in both periods. The company that runs this terminal also operates one soybean crusher unit and one oil refining unit at the same site. The terminal, therefore, has not operated at its maximum scale, which was also highlighted by the manager interviewed. This fact shows that companies may be vulnerable to conditions outside of their control (such as market variations, market structure and so forth) may also affect their performance (PORTER, 1980). In this specific case, the company's low bargaining power with suppliers (i.e. the railway company) was avoiding it increase its market share. The development of strategic alliances with suppliers and customers could be one strategy to overcome, or at least minimize, this liability.

Table 3: Efficiency scores – BCC Output-Oriented

Period	DMU	Input 1 (tonne/h)	Input 2 (tonne/h)	Output (tonne)	Efficiency Score (%)
Oct.2010 to Sep.2011 (1)	Porto Franco 1	500	700	300,000	31.36
	Porto Franco 2	240	750	120,000	18.83
	Porto Franco 3	160	300	350,000	83.33
	São Luís	1,350	3,500	2,500,000	80.64
	Salvador	1,000	2,000	1,200,000	44.44
Oct.2011 to Sep.2012 (2)	Porto Franco 1	500	700	348,000	36.38
	Porto Franco 2	240	750	220,000	34.52
	Porto Franco 3	160	300	420,000	100.00
	São Luís	1,350	3,500	3,100,000	100.00
	Salvador	1,000	2,000	2,700,000	100.00

Source: Research data

The DMU São Luís also reached the efficiency frontier in the second period and the second most efficient score in the first period. The terminal is the main port for grain export in the Northeastern region, receiving grains by trucks and trains. The manager interviewed stated that the terminal could transship much more grain, although the terminal's core business is to export iron ore. This terminal is managed by the same company which operates the railroad in the region and the only railway option for all companies to move grains produced in the region. Companies in a highly concentrated market may also have an impact on the terminals' efficiency.

Among all terminals sampled, the performance of the DMU Salvador must be highlighted. The terminal improved its operational efficiency by more than 125% in one year. The manager interviewed stated that basically all the grain harvest from Western Bahia that was usually exported through the Port of Ilhéus had to be transferred to DMU Salvador due to its better operational conditions. It is also possible to note that all terminals increased their outputs in the second period at the same time the inputs remained unchanged in both periods. This resulted in higher productivity levels and, consequently, higher efficiency scores in the second period. It is important to point out that terminals became, on average, more efficient in the second period (Mean 74.18%) if compared with the first period (Mean 51.7%).

Because 30% of the DMUs were considered efficient, the Inverted Frontier method was applied in order to find out which terminal (in which period) was better maximizing its operational efficiency. In other words, we aimed to find out which terminal(s) really had the best relative managerial practice. Among three DMUs considered 100% efficient by BCC model (Porto Franco 3, São Luís, and Salvador), only one was effectively operating at maximum efficiency as shown in Figure 6.

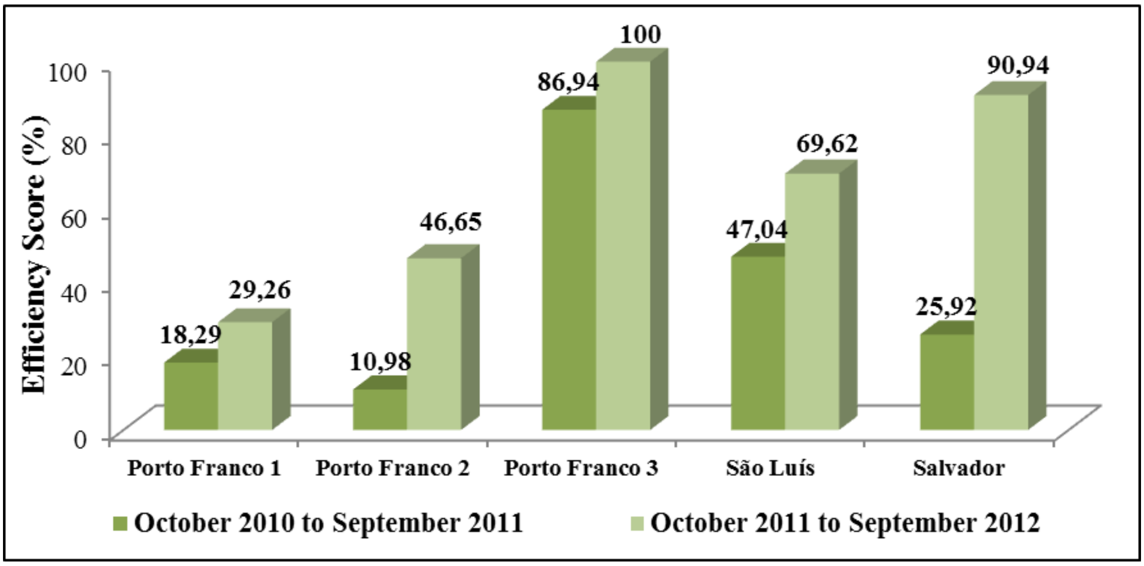

Figure 6: Inverted Frontier Method – Composed Standardized Scores
Source: Research data

By analyzing the standardized composite scores, it is possible to state that the terminals in the region operated with substantial idle capacity. The results corroborate what managers reported while the questionnaires were being applied. In all three terminals from Porto Franco/MA managers were aware of the situation, but pointed out to external factors as major causes of their low scale of operation, especially issues regarding the low quantity of wagons to move grains in the region. We would like to add three other possible reasons of idle capacity in the terminals: 1) the grain production in the region is not enough to fulfill the total capacity of all intermodal terminals from the region; 2) infrastructure of the terminals were overestimated when they were built; 3) multinational trading companies have larger participation on railroad transportation due to their bargaining power. These three hypotheses, however, should be tested in further studies.

Another aspect to be highlighted refers to the narrowing of the efficiency gap between terminals. In the first period, the standard deviation was 30.58 over 29.60 in the second period. This might be evidence that the intermodal transport is becoming more accessible, regardless the size of the intermodal grain terminal. This improvement in efficiency might also have a positive impact on final price since fewer inputs were being spent to produce same or higher outputs.

5. Conclusions

First of all, this is the first study to address the measurement of efficiency of intermodal grain terminals in Brazil's Northeastern region. This is also the first study conducted in Brazil that makes a longitudinal analysis of efficiency in intermodal grain terminals, enabling to assess the evolutionary performance of the sector. Our findings, therefore, bring relevant insights to scholars, policy makers, and managers. Three finds must be highlighted as follows.

First, our results show a significant improvement in the efficiency level of the terminals from one year to another. Thus, there is evidence that intermodality in the region is following the leads from the literature. This scenario tends to increase, especially after the conclusion of North-South and West-East railroads, which will connect large producing areas to seaports in the region. Second, it was found that an increase in the amount of grains transshipped generates a more pronounced effect on efficiency in inland terminals than seaport terminals. However, as load concentrators, seaports tend to transship much more grains if compared to inland terminals. The last but not the least, the analysis revealed that terminals in the region operate with relative idle capacity, corroborating what was stated by Santos and Sproesser (2013). It means that these terminals should focus on increasing scale rather than expand current infrastructure in short/medium-term. This last task, as discussed above, may require the developments of partnership with suppliers and customers. Public policy could also help leverage the attractiveness of the intermodality as a whole in the region by improving conditions of the logistics system and reducing taxes and bureaucracy.

Before we conclude, it is important to stress some limitations of this research. First, we did not have access to financial data of the terminals. The addition of monetary variables would certainly complement this analysis since profitability is an essential for developing an accurate long-term strategic plan. Moreover, future studies could approach different dimensions of how to measure the performance of intermodal grain terminals, expanding the scope of analysis or even continue this research through next years.

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