Efficiency Analysis of Airports Administered by Infraero from 2003 to 2013

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Abstract

The airline industry has earned over the years an important role in the process of globalization and economic development at national and global level. Since public resources are scarce and the industry demand is growing, the use of a tool that analyzes the efficiency of public airports gives visibility to structural problems and enables the mapping of strategies that seek to properly allocate the inputs front of the terminal needs. The objective of this study is to measure and evaluate the operational and financial efficiency of 63 public airports, administered by the Brazilian Airport Infrastructure Company, through the Data Envelopment Analysis Tool (DEA). In addition, to provide an overview of the sector over time, data 2003-2013 are studied by using descriptive statistics. The results showed in the operational analysis that only 12.7% of respondent terminals were efficient in 2010 and 11.1% in 2013. In the financial analysis were effective 9.5% of airports in 2010 and 14.3% in 2013. The results also revealed the need for attention to the sector in seeking to resolve bottlenecks and improve efficiency through modernization, adequate investment in infrastructure and balance between income and expenditure.

Keywords: Efficiency, Airports, Public Expenditure, Infrastructure, Data envelopment analysis

1. Introduction

The globalization process has brought to the airline industry an unprecedented importance in world economic history. It became responsible for the international insertion of a country in the commercial, tourist and cultural flow (Bettini & Oliveira, 2009). Because it is an elastic activity relative to income, as economic growth increases, demand for air traffic increases to levels above economic activity and aggregates growth itself, as a multiplying factor.

In Brazil, The Civil Aviation Secretariat (Secretaria de Aviação Civil - SAC) and the National Civil Aviation Agency (Agência Nacional de Aviação Civil - ANAC) are regulators of the sector. The Brazilian Airport Infrastructure Company (INFRAERO) is responsible for managing public airports, which is the target of this study. According to ANAC (2014), between 2004 and 2013, the annual average growth in domestic passenger air transport demand 13.1% per year, which represented more than 3.7 times the average growth of the Brazilian Gross Domestic Product (3.5% per year), and more than 13 times the population growth (1% per year). In the same period, the number of flights performed grew 83.1% in the domestic market and 68% in the international market. According to ANAC (2014), it is necessary for Brazilian airports to correct their inefficiencies in order to meet the demand growth and the needs for improve quality in the services provided.

In addition, investments can make it possible to improve the efficiency of airport terminals and can cooperate for positive public accounts results.
Productivity gains and better use of assets lead to the airport administration system with self-sufficiency, with revenues at an adequate level, financing its current operations and the expansion of its operational and financial capacity, without injecting public resources. According to the authors above, given the growth projected for the sector, investments will be required by 2030 to increase the current capacity of airports by 2.4 times, or from 130 million to 310 million passengers per year, equivalent to nine airports of Guarulhos a city situated in São Paulo. According to surveys conducted by IPEA (2011), from 2003 to 2010 Infraero made only 44% of the investment projected for its airports in this period.

Therefore, the objective of this article is to measure and evaluate the efficiency of the airports managed by Infraero from operational and financial data using the Data Envelopment Analysis (DEA) tool, determining efficient airports and critical situation. It is expected that this article will give visibility to the need to improve operations in terminals, to properly allocate investments and obtain economic-financial solvency. Avoiding that airports with results with surpluses suffer to supply the results of other deficit airports.

This article is organized as follows: The first section presented the introduction to the topic, with information about the sector and the problem to be studied; Section 2 presents the state of the art, including analysis of the recent panorama of the Brazilian airport industry and exhibitions on public airport concessions and on the efficiency of public spending; In section 3, the methodology used in the production of descriptive statistics and in the measurement of the data by means of the Data Envelopment Analysis method; In Section 4, the results obtained through the chosen methodology are presented and explored, finally in section 5, the final considerations are presented, which have final clarifications and research indications to be made to continue the project developed here.

2. Theoretical Reference

According to IPEA (2010), the growth in demand in the Brazilian airline industry in recent years has not been accompanied by long-term planning, consolidated public policies, correct regulation of the competitive market and improvement in deficiencies in airport infrastructure. Adding the problems with quality of service provided to the end user. Faced with this reality, the challenges for maximizing efficiency, productivity and social benefits for society, along with minimizing costs, are clear.

The discussion of efficiency in public management was carried out using the Data Envelopment Analysis method, by several authors, such as Peña (2008) and Silva et al. (2014). Penan (2008), in an applied study evaluating the efficiency of Public Administration, observes that it is possible to define the inefficient units and the necessary changes in the inputs and/or products in order to make them efficient. Table 1 provides a brief summary of the research covered in this theoretical framework, highlighting the following points: geographical scope, objective, data, method and main conclusions.
Table 1 - Summary of Literature Review

<table>
<thead>
<tr>
<th>Article</th>
<th>Objective</th>
<th>Method</th>
<th>Main Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silva et al. (2014)</td>
<td>Analyze the efficiency of total investment expenditures.</td>
<td>Data Envelopment Analysis</td>
<td>Only the State of Acre was efficient, in the two models used, with no other efficient in the CCR model. In the BCC model, there are five States, including Acre, efficient: Espírito Santo, Piauí, Ceará and Maranhão.</td>
</tr>
<tr>
<td>Ribeiro (2008)</td>
<td>Evaluate the efficiency of public spending in Brazil.</td>
<td>Composite index to measure the performance of public services, confronted by data-wrapping analysis and truncated regression.</td>
<td>Costa Rica, Uruguay, and Chile obtained the best results for the performance of services and for the efficiency of public spending. In the specific case of Brazil, the result was around the average in the evaluation of the public services and below the average in the efficiency of the expenses.</td>
</tr>
<tr>
<td>Pacheco, Fernandes e Santos (2006)</td>
<td>To study the impacts of the changes in the management of Infraero on the performance of the airports administered by it from 1998 to 2001.</td>
<td>Data Envelopment Analysis</td>
<td>In financial terms efficiency improved from 77% to 80%, from 1998 to 2001; In the operational aspect there was deterioration in the performance of the movement of passengers and cargo.</td>
</tr>
<tr>
<td>Pathomsiri et al. (2008)</td>
<td>To evaluate the productivity of 56 airports in the United States of America from 2000 to 2003</td>
<td>Data Envelopment Analysis</td>
<td>He highlighted the importance of examining undesirable outputs in determining the relative productivity of airports.</td>
</tr>
<tr>
<td>Bergiante, Mello e Santo Jr. (2011)</td>
<td>Determine if the investments forecasted at Brazilian airports for the 2014 World Cup and the 2016 Olympic Games are adequate to the demand.</td>
<td>Data Envelopment Analysis</td>
<td>Large dispersion between investments, supply, demand and efficiency in the analyzed airports.</td>
</tr>
<tr>
<td>Almeida e Mariano (2007)</td>
<td>Evaluate operational efficiency.</td>
<td>Data Envelopment Analysis</td>
<td>There was only one airport 100% efficient.</td>
</tr>
</tbody>
</table>

3. Methodology

This is a qualitative and at the same time a quantitative research, the period analyzed was four years, from 2010 to 2013. In this way, will be carried out the evaluation of the efficiency of 63 public airports, which have not yet been granted. This analysis will be done using the Data Envelopment Analysis - DEA method. In addition, to provide an overview of the industry over time, data from
2003 to 2013 are used descriptive statistics. Infraero organizes the operational data. Based on information provided by the airlines and available in the Operational Statistical Yearbooks at Infraero, referring to the airports administered by the company. The data analyzed here can present the degree of reliability impaired after Resolution nº 8/ANAC/2007 in which it revokes the Administrative Rule of the Aeronautics Command nº602/GC5/2000 that established, in its article 7, the obligation to send data by the airlines to the airports, these being passed on to Infraero. Given this, it is possible that, from 2007 there are incomplete data and not demonstrating the totality of the actual movements.

The main operational data used in this work are: passenger handling, domestic and international; air cargo handling, domestic and international; and postal, domestic and international mail handling, as can be seen in Table 2.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Unit of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Handling, Domestic and international.</td>
<td>Boarding and disembarkation (origin and destination), on domestic and international flights, combined passengers and military passengers are excluded.</td>
<td>In thousands</td>
</tr>
<tr>
<td>Air cargo handling, Domestic and international.</td>
<td>Circulation of air cargo in domestic and international flights, referring exclusively, according to Infraero, the hold cargo.</td>
<td>In 1000 tons</td>
</tr>
<tr>
<td>Mail order handling - post office, domestic and international.</td>
<td>Circulation of postcards (Post Office).</td>
<td>In 1000 tons</td>
</tr>
</tbody>
</table>

Source: Own elaboration based on Infraero (2003 to 2013).

The analysis comprises data from 63 airports managed by Infraero between 2003 and 2013, excluding all movements in the airports of Viracopos/Campinas-SP, Guarulhos-SP and Brasília-DF. This action was taken after finding that the data provided by Infraero in 2013 no longer presented the information of those airports due to the concession to the private sector, and the use of its data in years prior to 2013 would compromise any historical series, causing a misinterpretation about the evolution of the air sector. That is, the analyses made in this work do not cover all the airports with regular aviation present in Brazil. The financial data used in this article, produced and made available by ANAC, refer to the 63 (sixty-three) airports administered by Infraero in the years 2010 to 2013 and are derived from the Airports Operational Performance Reports for the years 2010 to 2012, and the Infraero Airports Financial Report for 2013, which changed its name this year due to concessions in 2012. As the 2013 report no longer contained data from Viracopos/Campinas-SP airports, Guarulhos -SP and Brasília-DF, the information for these airports was excluded from previous years, 2010 to 2012, for the same reasons presented for the operational data in the previous item.

The main financial variables analyzed in this research are: total cost, income from unregulated activities and revenue from regulated activities, as
shown in Table 4. The total costs include administrative, financial, operational, depreciation and remuneration of the Union's assets, since art.38 of the Brazilian Code of Aeronautics (BRASIL, 1986). Which establishes that airports constitute universals, assimilated to federal public goods; according with this, assets related to airport infrastructure are owned by the Union and their remuneration of 6% per annum calculated on the difference between the net acquisition value and the accumulated depreciation of the asset represents the cost of the capital invested.

Revenues from non-regulated activities are those derived from activities that do not have tariff regulation and therefore generate alternative revenues. Such as those derived from the operation of the commercial activity (restaurants, bars, bookstores, for example), financial gains and other unregulated services. Revenues from regulated activities are derived from the tariffs charged for the provision of passenger boarding, landing and aircraft servicing, and air cargo storage and cargo handling at each airport.

**Table 3 - List of financial variables used**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Unit of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost</td>
<td>They cover the administrative, financial, operational, depreciation and remuneration of Union assets.</td>
<td>In thousands</td>
</tr>
<tr>
<td>Revenue from unregulated activities</td>
<td>They come from activities that do not have tariff regulation, such as those arising from the exploitation of commercial activity, financial gains, among others.</td>
<td>In thousands</td>
</tr>
<tr>
<td>Revenue from regulated activities</td>
<td>Fees charged for the provision of passenger boarding, landing and aircraft maintenance services, and air cargo storage and capitation, at each airport.</td>
<td>In thousands</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors based on ANAC (2013).

The variables values of the years 2010 to 2012 were updated by the IGP-DI (IPEA) and brought to the price level of the data series of 2013. This price index was chosen because it is a weighted average of IPA (60%), IPC (30%) and INCC (10%), being a macroeconomic indicator that represents the evolution of the price level of agricultural and industrial raw materials, intermediate products and final goods and services.

For better compression of this tool to be used in this research, it is necessary to clarify the concepts of effectiveness, efficiency and productivity. Efficacy is related to the result obtained, without considering the resources and efforts that were employed. That is, the production unit reaching its production goal. Efficiency is a relative concept, it is concerned with the resources being used and what could have been done with the same inputs. Productivity is the quotient between what was produced and what was needed to produce, arising from decision-making that maximizes resource utilization. From this, the producing unit is called the Decision Making Unit - DMU.

The efficiency of the DMUs, considering Data Envelopment Analysis, is defined by the inputs used and the outputs that are generated. A non-efficient unit can become efficient in two ways: reducing resources, keeping products constant
(input-oriented), in the minimum required inputs to have the same output. Or increasing products, keeping inputs constant (output-oriented), or what dealing with the same resources could have produced.

The tool has basically two methods of analysis, the Constant Returns to Scale (CRS) model and the Variable Returns to Scale (VRS) model. The constant scale returns (CRS) model, initially presented by Charnes et al. (1978), works with a nonparametric linear surface, that is, any variation in the inputs produces equal variation in the outputs. The model determines the efficiency by optimizing the division between the weighted sum of the outputs and the weighting sum of the inputs. In homage to the authors, the model of constant returns of scale is also known by the acronym CCR.

On the other hand, the model of variable returns of scale (RSV) presented by Banker et al. (1984), in which any variation in the inputs does not produce equal variation in the outputs. It replaces proportionality between inputs and outputs by convexity, that is, the efficient boundary is a concavity, unlike the previous model. Also in homage to the authors, the model of variable returns of scale is also known by BCC. In the present paper we have chosen to use the BCC model. Since it considers variable returns and will be able to better explain the efficiency of a population that contains large and small airports, either operationally or financially.

In the BCC model, the efficiency of the DMU is represented by the following equations, in which Effo is the efficiency of the DMUo, however it is given by the inverse of $\text{Eff}_o$ and represented by the variable $h_o$ ($h_o = 1/\text{Eff}_o$), $h_o$ being indicative of how much all products should be multiplied, keeping resources constant, aiming for DMUo to reach the efficient border. The variables $v_i$ and $u_j$ are the weights of the inputs $i$, $j$, respectively. $x_{io}$ and $y_{io}$ are the inputs and outputs of the DMU, respectively. Equation (01) indicates orientation to inputs and (02) orientation to outputs:

(01) Minimize $h_o$, subject to

$$h_o x_{io} - \sum_{k=1}^{n} x_{ik} \lambda_k \geq 0, \forall i ; -y_{jo} + \sum_{k=1}^{n} y_{jk} \lambda_k \geq 0, \forall j; \sum_{k=1}^{n} \lambda_k = 1$$

$$\lambda_k \geq 0, \forall k$$

(02) Maximize $h_o$, subject to

$$x_{io} - \sum_{k=1}^{n} x_{ik} \lambda_k \geq 0, \forall i ; -h_o y_{jo} + \sum_{k=1}^{n} y_{jk} \lambda_k \geq 0, \forall j; \sum_{k=1}^{n} \lambda_k = 1$$

$$\lambda_k \geq 0, \forall k$$

Transformed into a dual linear programming (PPL) problem, in which $v$, and $u$, are conditioned dual variables $\sum_{k=1}^{n} \lambda_k = 1$, we have:

(03) Inputs-oriented: Maximize

$$\text{Eff}_o = \sum_{j=1}^{s} u_j y_{jo} + u_\star.$$

Subject to
\[ \sum_{i=1}^{r} v_i x_{io} = 1; - \sum_{i=1}^{r} v_i x_{ik} + \sum_{j=1}^{s} u_j y_{jk} + u_* \leq 0, \forall k; v_i, u_j \geq 0, u_* \in \mathbb{R} \]

(04) Output-oriented: Minimize

\[ \text{Eff}_o = \sum_{i=1}^{r} v_i x_{io} + v_*, \text{Subject to} \]

\[ \sum_{j=1}^{s} u_j y_{jo} = 1; - \sum_{i=1}^{r} v_j x_{ik} + \sum_{j=1}^{s} u_j y_{jk} + v_* \leq 0, \forall k; v_i, u_j \geq 0, u_* \in \mathbb{R} \]

The BCC model, as mentioned before, was used in this work, in which it is intended to use the minimum resources given a fixed level of products. The orientation was chosen after the variables of airport revenues, passenger movements, cargo and mail boxes, domestic and international, had inherent characteristics and variations not related to the air sector, but to market and geographic conditions, such as inflation, levels Income, exchange, locality, among others. The same thinking was developed for the choice of input orientation in the work of Castro and Loureiro (2013), which measured the efficiency of the 66 Brazilian airports operated by Infraero with data from the years 2010 and 2011.

It was used the SIAD software, which means Integrated Decision Support System, version 3.0, developed and made available by researchers from the Federal Fluminense University - UFF (Mello et al., 2005). The software measures efficiency through Data Envelopment Analysis, using linear programming. The data analyzed in the program refer to the years 2010 and 2013 and are segregated into operational and financial. For the operational analysis, the total costs and as outputs were the sum of the domestic and international passenger movement (output1) and the sum of the movement of air cargo and postal mail, domestic and international (output2). For the financial analysis, the total costs were used as input, and as outputs the revenues of unregulated activities (output1) and revenues from regulated activities (output2).

Four efficiency analyzes were carried out, two for operational efficiency, for the years 2010 and 2013, and two for the financial year, of the same years. After that, and considering that in all the analyzes the same set of 63 airports were used and always the same variables, it was possible to identify which airports reached the efficient border. That is, the maximum value of the index, in 2010 and later in 2013. In addition, it was also possible to compare the results obtained for the year 2010 to 2013, obtaining the variations of the indices of each of the terminals and identifying who maintained it, improved or worsened efficiency. It is worth mentioning that such analyzes allow visibility to bottlenecks and help in making decisions that will improve the airport infrastructure and the quality of services provided to its users.

4. Data Analysis

Graph 1 shows the number of passengers flown annually on board and disembark (origin and destination), on domestic and international flights, together with passengers in connection with and excluding those on military flights.
Graph 1 – Annual passenger movements (2003 - 2013)

According to the previous graph, it was verified that, between 2003 and 2013, there was a 160.3% growth in total movement, with a 163% evolution in domestic movement and 118% in international movement, with participation in the total of 5.8% in 2003 and 4.8% in 2013. The standard deviation in the international circulation is higher than in the domestic one. Taking as a base the year 2013, it is possible to perceive that 70.4% of the international movement and 38% of the national movement are concentrated in four airports of the Southeast region.

Graph 2 shows the movement of air cargo in domestic and international flights, referring exclusively, according to Infraero, the cargo of hold.

Graph 2 - Annual Air Cargo Movement

Between 2003 and 2013, there was a growth of 16.8% in total turnover, with a 12% increase in domestic and 31.5% in international traffic, with a share of 24.5% in 2003 and 27.6% in 2013. In general, Graph 02 shows a constant movement, with a standard deviation, in the international air cargo transport, presenting values more pronounced than in domestic transport. Taking as a parameter the year 2013, it is possible to notice that the Galeão-RJ Airport represents 44.1% of the international traffic and the Airport of Manaus-AM 26.5% of the national, considering only the set of airports studied.

The movements of postal and mail, domestic and international, from 2003 to 2013, in which there was a 19.8% reduction in total turnover, with a drop of 20.3% in domestic movements and 6.7% in the international market, with a share of 3.9% in 2003 and 4.6% in 2013. There is a positive movement in 2006 and 2007, driven by a seasonal increase in postal mail at the airport of Salvador/BA, with
growth in total participation from 2005 to 2006, from 10.9% to 26%, Manaus/AM airport, with an increase in total participation from 2006 to 2007, from 4.8% to 23%, 1% in domestic aviation and from 12.5% to 86.8% in international, without significant relocation of other airports to them.

Graph 3 shows the sum of the annual movements of airfreight and postal mail, respectively, in domestic and international, in order to better demonstrate the information regarding the circulation of material elements between the years 2003 and 2013.

**Graph 3 - Annual Air Cargo + Bad Mail**

![Graph 3 - Annual Air Cargo + Bad Mail](image)

Source: Prepared by the authors based on data from Infraero (2003 to 2013).

In the years 2003 to 2013, there was a 9.5% increase in total turnover, with a 4.3% increase in domestic and 30% in international traffic, with a share of 20.4% in 2003 and 24.3% in 2013. When compared to the number of passenger movements, it can be seen that freight traffic and postal mail have grown at a much lower level. Based on the financial data of the 63 airports managed by Infraero, it can be seen that from 2010 to 2013, total costs increased by 31.1%, regulated revenues grew by 36.3% and unregulated revenues by 41.3%. In the four years analyzed, the average value of total costs was R$ 3 billion, of regulated revenues of R$ 1.4 billion, with a share of total revenue of 57.4% in 2013, and for unregulated revenues was 1 billion, with a share of total revenue in 2013 of 42.6%.

In all the years analyzed in this study, the standard deviation was high, that is, there are airports that, due to their size and high traffic, have a greater influence on total costs and revenues compared to smaller airports that have low activity. The discrepancy is evidenced by the fact that, in 2013, only 20% of the airports analyzed accounted for approximately 70% of total costs and 80% of total revenues.

It can be seen, according to Graph 4, that total costs in all years exceed the total revenues that airports generate. Evidencing an imbalance between revenue and expenditure and requiring, on the part of the Union, capital contributions and incremental investments to sustain the continuity of operation of these airports. The airport that had the best situation, with financial balance, revenues equal to or greater than the costs, and remained thus, in the four years, was the airport of Curitiba-PR. The airport that presented the worst situation for the four years studied, with the cost around 26 times higher than the revenue in 2013, was that of Uruguaiana-RS.
Also in this area, in 2013, for example, the cost was 31.8% higher than the revenues generated. In addition, in 2013, for each R$ 1 (one real) of regulated revenue generated was obtained R$ 0.74 (Seventy-four cents) of unregulated revenue.

Based on the analysis of the data of 2010 and 2013 by means of the model of variable returns of scale inputs-oriented given the present set of data and variables, it was identified that in operational terms, on a scale of 0 to 1, the index Average is 0.5580 in 2010 and 0.5899 in 2013. In 2010, only 8 airports were considered efficient (index = 1), as can be seen in table 1, which also shows the variables used in the model.

In Table 4 it is possible to segregate the efficient airports into groups from the movement of passengers and/or cargo and mail at their terminals, these groups being classified as large, intermediate and small movement. This classification may also be related proportionally to the size of the airport, in which the large ones will have greater movement and those of smaller size. In 2010 the group of efficient airports classified as large-scale is composed of the terminals of Galeão/RJ, Congonhas/SP and Manaus/AM. The intermediate group is formed by the airports of Curitiba / PR, Fortaleza/CE and Vitória/ES. Finally, in 2010, the small efficient airports, and lower traffic, were those of Criciúma/SC and Teresina/PI. Separating them by geographic region, it is possible to identify that in 2010, of the airports managed by Infraero considered operationally efficient, three
are from the southeast region; two from the northeast region; two from the south region; and only one from the north region.

While in 2013, 7 airports were considered efficient, and 6 airports considered efficient in 2010 are in 2013 remaining with indexes in the maximum border, are: Galeão/RJ, Congonhas/SP, Manaus/AM, Fortaleza/CE, Vitória/ES and Criciúma/SC. The airports of Curitiba/PR and Teresina/PI, which were considered efficient in the 2010 analysis, left the border efficient, with a reduction of 5.2% (0.9482) and 12.2% (0.872), respectively. And the Confins/MG Airport, after growth of 38.1% in the index from 2010 to 2013, reaches the border and enters the ranking.

**Table 5 - Most efficient airports in operational terms in 2013 (Index = 1)**

<table>
<thead>
<tr>
<th>Initials</th>
<th>Nome</th>
<th>Input (in thousands)</th>
<th>Output (in thousands)</th>
<th>Output (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBGL</td>
<td>Galeão international airport</td>
<td>743,946.62</td>
<td>17,115</td>
<td>140,160</td>
</tr>
<tr>
<td>SBSP</td>
<td>Congonhas airport</td>
<td>348,967.99</td>
<td>17,120</td>
<td>62,460</td>
</tr>
<tr>
<td>SBEG</td>
<td>Manaus international airport</td>
<td>184,490.04</td>
<td>3,077</td>
<td>62,460</td>
</tr>
<tr>
<td>SBCF</td>
<td>Confins international airport</td>
<td>166,632.03</td>
<td>10,301</td>
<td>21,116</td>
</tr>
<tr>
<td>SBFZ</td>
<td>Fortaleza international airport</td>
<td>92,962.74</td>
<td>5,953</td>
<td>45,649</td>
</tr>
<tr>
<td>SBVT</td>
<td>Vitória airport</td>
<td>51,231.09</td>
<td>3,451</td>
<td>14,681</td>
</tr>
<tr>
<td>SBCM</td>
<td>Criciúma/Forquilhinha airport</td>
<td>2,087.67</td>
<td>70</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

Since Data Envelope Analysis compares DMUs, based on a set of pre-established variables, these airports (index = 1) are considered as reference airports, or benchmarks, since other airports may use them as information, models and experiences that will assist them in improving their performance. On the other hand, airports in a critical situation, those whose rates were so low that they deserve special attention in order to identify the factors that are making them so inefficient in operational terms, that is, the expenditures made there are at a good level Superior to its real need, considering its movement of passengers, cargo and mail bags. That is, airports with indices less than 0.30. Among these are the São José dos Campos-SP Airport, with an index equal to 0.2194 in 2010 and 0.0703 in 2013, with an efficiency reduction of 67.9% and a cost increase of more than 4 Times. However, according to Infraero (2013), this is due to additional investments made by the company to expand and modernize the airport, without having a counterpart in the outputs.

By comparing the changes in the indices from 2010 to 2013, it is possible to identify that there are two extremes: on one hand airports that have increased efficiency in the four years, and on the other hand terminals that have reduced efficiency. It is worth mentioning, among those that have improved, the Parnaíba/PI airport, with an index rising from 0.377 to 0.939, in which it assumes
that the growth of the airport efficiency indicator is associated with the reduction that there was, from 2010 to 2013, 45% in its costs and 74.5% in its cargo handling. In the same line, we highlight the Júlio Cesar/PA airport, now with a worsening of the 40.4%, generated by an inverse situation to that reported above, with increased costs and the movement of air cargo. Based on this, and that there were no relevant impacts on the movement of passengers in both cases, it can be concluded that the costs with the movement of cargo are more representative than the costs with the circulation of passengers.

Based on the analysis of the data of 2010 and 2013 by the model of variable returns of scale, oriented to inputs, given the present set of data and variables, it was identified that in financial terms, in a scale of 0 to 1, the average index is of 0.5127 in 2010 and 0.5824 in 2013. Here the analysis is restricted to monetary items, in which it is intended to minimize costs given the same level of revenue generation.

In 2010, only 6 airports were considered efficient (index = 1), as observed in Table 6, all of which were also operationally efficient in the analysis made for 2010, except for the Jacarepaguá/RJ airport, which was considered a reference terminal due to its high generation of unregulated revenues. Of its total revenue, in 2013, 91.6% represented non-operating revenue inserted within the final activity of an airport, a fact that explains that it was not considered operationally efficient. On the other hand, the airports of Fortaleza/CE, Vitória/ES and Teresina/PI, which were efficient in the analysis in operational terms for the year 2010, did not obtain the same success in the analysis in financial terms of the same year, that is, they did not reach the efficient frontier.

Table 6 - Most financially efficient airports in 2010 (Index = 1)

<table>
<thead>
<tr>
<th>Initials</th>
<th>Nome</th>
<th>Input (in thousands)</th>
<th>Output (in thousands)</th>
<th>Output (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBGL</td>
<td>Galeão international airport</td>
<td>632,046.52</td>
<td>178,678</td>
<td>209,844</td>
</tr>
<tr>
<td>SBSP</td>
<td>Congonhas airport</td>
<td>213,235.53</td>
<td>109,423</td>
<td>134,762</td>
</tr>
<tr>
<td>SBEG</td>
<td>Manaus international airport</td>
<td>153,556.65</td>
<td>27,698</td>
<td>113,142</td>
</tr>
<tr>
<td>SBCT</td>
<td>Curitiba international airport</td>
<td>78,762.00</td>
<td>35,035</td>
<td>73,660</td>
</tr>
<tr>
<td>SBJR</td>
<td>Jacarepaguá airport</td>
<td>16,600.23</td>
<td>20,433</td>
<td>487</td>
</tr>
<tr>
<td>SBCM</td>
<td>Criciúma/Forquilhinha airport</td>
<td>1,826.49</td>
<td>182</td>
<td>117</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

In an approach similar to the one made for the operational analyzes, it is possible to segregate efficient airports into groups based on the magnitude of costs and revenues at their terminals. As can be seen in Table 6, which are classified as large, intermediate and small results production. It can also relate the classification in proportion to the size of the airport, in which the larger ones will
have higher revenues and costs than the smaller ones. In 2010, the group of efficient airports classified as being very cost-efficient and composed of the terminals of Galeão/RJ, Congonhas/SP and Manaus/AM. The airports of Curitiba/PR and Jacarepaguá/RJ form the intermediate group. Finally, in 2010, the airport of Criciúma/SC can be classified in the small group and lower results. Separating them by geographic region it is possible to identify that in 2010, of the airports managed by Infraero considered to be financially efficient, three are from the southeast region, two from the south region and only one from the north region. This indicates that there is a regional concentration of financially efficient airports managed by Infraero in the south and southeast of the country.

In 2013, already with better results, there were 9 efficient terminals, listed in Table 7, in which the same airports considered efficient in the financial analysis for 2010 were maintained, and the inclusion of 3 new airports: Confins/MG, Florianópolis/SC and Porto Alegre/RS, which reached the efficient border after growth in the index, from 2010 to 2013, of 28.8%, 42.2% and 20.7%, respectively.

In addition, comparing with the operational analysis made for 2013, it is possible to perceive that belt airports considered financially efficient were also considered in operational terms, being the airports of Galeão/RJ, Congonhas/SP, Manaus/AM, Confins/MG, and Criciúma/SC. On the other hand, the airports of Fortaleza/CE and Vitória/ES, which were efficient in the analysis in operational terms for the year 2013, did not obtain the same success in the analysis in financial terms for the same year, that is, they did not reach the border efficient. Likewise, the airports of Porto Alegre/RS, Curitiba/PR, Florianópolis/SC, and Jacarepaguá/RJ, were identified as financially efficient for the 2013 analysis and were not considered operationally efficient in the analysis of the same year. That is, for the latter case, it is assumed that even with positive financial results, such as those observed at the four airports, their costs are higher than the real need to pay for the movements of passengers and/or freight and mail.

Table 7 - Most financially efficient airports in 2013 (Index = 1)

<table>
<thead>
<tr>
<th>Initials</th>
<th>Nome</th>
<th>Input (in thousands)</th>
<th>Output (in thousands)</th>
<th>Output (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total cost</td>
<td>Revenue from unregulated activities</td>
<td>Revenue from regulated activities</td>
</tr>
<tr>
<td>SBGL</td>
<td>Galeão international airport</td>
<td>743,946.62</td>
<td>228,825.10</td>
<td>318,797.75</td>
</tr>
<tr>
<td>SBSP</td>
<td>Congonhas airport</td>
<td>348,967.99</td>
<td>141,450.52</td>
<td>135,219.91</td>
</tr>
<tr>
<td>SBEG</td>
<td>Manaus international airport</td>
<td>184,490.04</td>
<td>47,382.33</td>
<td>120,431.35</td>
</tr>
<tr>
<td>SBCF</td>
<td>Confins international airport</td>
<td>166,632.03</td>
<td>71,900.62</td>
<td>106,989.17</td>
</tr>
<tr>
<td>SBPA</td>
<td>Porto Alegre international airport</td>
<td>157,985.88</td>
<td>70,428.91</td>
<td>88,434.16</td>
</tr>
<tr>
<td>SBCT</td>
<td>Curitiba international airport</td>
<td>114,968.70</td>
<td>47,258.17</td>
<td>90,839.65</td>
</tr>
<tr>
<td>SBFL</td>
<td>Florianópolis international airport</td>
<td>61,775.46</td>
<td>34,932.27</td>
<td>37,142.94</td>
</tr>
<tr>
<td>SBJR</td>
<td>Jacarepaguá airport</td>
<td>26,028.22</td>
<td>26,021.37</td>
<td>2,392.57</td>
</tr>
<tr>
<td>SBCM</td>
<td>Criciúma/Forquilhinha airport</td>
<td>2,087.67</td>
<td>307.6</td>
<td>413.53</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors
Performing the same segregation by groups made for 2010, for 2013, the group of efficient airports classified as high capacity for generating results is composed of the terminals of Galeão/RJ, Congonhas/SP, Manaus/AM, and including Confins/MG and Porto Alegre/RS. The intermediate group is formed by the airports of Curitiba/PR and Florianópolis/SC. Finally, in 2013, in the small magnitude group of results generation are the airports of Jacarepaguá/RJ and Criciúma/SC. Separating them by geographic region, it is possible to identify that in 2013, among the airports managed by Infraero considered to be financially efficient, four are from the southeast region, four from the south, and one from the north. Which again indicates, as happened in 2010, financially efficient airports are in the south and southeast of the country.

5. Discussion

The main objective of this work was to measure and evaluate airport efficiency through the study of 63 airports of Infraero and to highlight the operational and financial bottlenecks, serving as input for the reduction of public expenses and for the improvement of the quality of the services rendered. Noting the results found for the four analyzes carried out in financial and operational terms for 2010 and 2013, no airport managed by Infraero was considered efficient in the Midwest region.

It is worth mentioning that in June 2015, the Federal Government has decided to grant the terminals of Fortaleza/CE, Salvador/BA, Florianópolis/SC, and in order to improve the infrastructure of the airline industry and the quality of services provided to users of Porto Alegre/RS, currently administered by Infraero. It is interesting to observe that among the four analyzed, three of them were considered efficient in the results obtained in this work. The Fortaleza/CE airport reached the operationally efficient frontier in 2010 and 2013 and the airports of Florianópolis/SC and Porto Alegre/RS were financially efficient for the year 2013. In the same line are the Galeão/RJ, efficient in the four analyzes. And Confins/MG, efficient in the two analyzes of 2013. Which were already granted to the private sector in 2014. This situation presupposes that the choice of the airports is not random, being focused on the airports that most attract the private sector, are able to capture greater investments in airport assets and that cover a greater number of users with the benefits that will be generated.

In the data analysis, descriptive statistics and Data Envelopment Analysis (DEA) were used, applied to the variables of passenger, cargo and mail handling, domestic and international. Of total costs generated and revenues obtained, both operational and non-operational. The results obtained in the analysis of 2010 and 2013 show that only 14.29% of the terminals were considered efficient, considering the best scenario, which occurred in 2013 in financial terms with 9 airports at the efficiency frontier. This demonstrates the need for a reassessment of the management of these airports and of the decision-making processes, aiming to change the current reality, either through concessions to private initiative or through effective investments and management qualification.
The choice of this topic is mainly due to the growing expansion of the aviation sector in Brazil and the need to study it in the search to understand and design measures that will make the terminals productive, technological, meeting the demand with quality and reducing the public expenses. Because, as McKinsey & Company (2010) argues, productive airports that use their assets to the best of their ability can achieve self-sufficiency, that is, by raising revenues to adequate levels that can finance their current operations and expand their activities without the need of public funds.

Future research should analyze the efficiency of the terminals in the Brazilian Regions and relate them to the GDP per capita of the cities or states, showing the economic and operational particularities of each locality. Studies are also recommended to identify the effects on the operational efficiency of the airport units that received public investments for the improvement of the airport infrastructure.

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Received: April 6, 2017; Published: April 29, 2017