Relative Efficiency of International Airlines

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Abstract

In this paper the results are published of a post-doctorate research done at the Brazilian Aeronautics Technological Institute (ITA) in 2006. The purpose of this paper is to evaluate and to discuss the relative efficiency of the main Brazilian carriers in the period from 2000-2006 by comparing their operational and relative efficiency with international airlines chosen from among benchmarks in this industry. These data, originally collected in 2008, were updated according to the IATA yearbook for the period 2012-2016. For this purpose, the airlines were grouped into 3 classes: Full Cost Companies (FCC's), Low Cost Companies (LCC's) and Regionals and 4 scenarios were established. In two of these scenarios (I and II), they were compared, independently of the category and in two of them (scenario III and IV) the comparison was established with airlines of the corresponding class (FCC's and Regionals). In the survey, 41 international carriers were selected in North and South American, European and Asian markets. The method used in this research is the Data Envelopment Analysis (DEA), which is a well-known family of mathematical programming tools, based on the Frontier approach. The results obtained with the utilization of software's like EMS, and Frontier Analyst allowed to conclude that large airlines with high load factors and a concomitant production of passenger and cargo had the best efficiency score.

Keywords : *Effciency, relative efficiency, airlines performance, international airlines efficiency.*

1. Introduction

Until recently, scheduled passenger and freight services were heavily regulated in most countries in both domestic and international markets. Meanwhile, there is a consensus among air transport specialists that unnecessary restrictive regulations may have led to significant losses in efficiency. The governments of different countries, among them

Brazil, have recognized this limitation and started a deregulation process in the last decade, aiming to improve efficiency and cost reductions in air transport by enhancing competition among carriers. This article is based on research undertaken for a post-doctoral research project called "*Productivity Analysis of the International Air Transport Industry,*" done at the Brazilian Aeronautics Technological Institute.

2. The paper structure

A short introduction to the paper is made in Section 1. The structure of the paper can be seen in Section 2. An overview of the Brazilian air transport market and industry is shown in Section 3. A short theoretical framework for the paper is in Section 4. Section 5 deals with the DEA method. Data and simulation scenarios utilized in the paper, as well as the sampling criteria are explained in Section 6. The research results are discussed in Section 7, and finally the conclusion is presented in Section 8.

3. The Brazilian air transport industry

The Brazilian air transport domestic market is the largest Latin American market. According to the Air Transportation Action Group, Brazilian airlines held in 2010 a 4.6% share in America's international passenger market, transporting 7.2 million passengers a year. The number of passengers transported by Brazilian airlines on domestic and international flights between July 2017 and June 2018 surpassed the 100 million mark. The data, recently released by the Brazilian National Civil Aviation Agency (ANAC), show that 100.87 million people were transported in this period. Of this total, 91,947,666 passengers were transported on domestic flights, and 8,924,824 passengers on international flights.

The Brazilian air transport industry was responsible for 3% of Brazilian GDP with a direct impact of US$ 6.7 billion and indirect impact of US$ 18 billion, generating about 35,000 direct jobs in 2008. From the end of the 1970's to the end of 2005, the air transport industry's share in the Brazilian transportation matrix went from 0.7% to 2.7%. The annual growth rate was 6.5% between 1997 and 2001.

With two million aircraft taking off and landing in Brazil every year, the value of the air transport industry becomes obvious. But the removal of the artificial barriers that are inhibiting the industry in Brazil is of special importance. Air transport in South American terms contributes 3% of GDP in Chile, 3% in Ecuador and 2.1% in Colombia. With only 1.4% of GDP in 2018, air transport in Brazil still has many possibilities for growth, according to a recent IATA press release.

The International Air Transport Association (IATA) announced recently new data showing that aviation and aviation-induced tourism support 1.1 million jobs and contribute with US$32.9 billion to Brazil's GDP, an amount equivalent to 1.4% of the country's GDP.

The competition for leadership in the Brazilian air transport market, continues fiercely. Data released by the Brazilian Association of Airline Companies (ABEAR) at beginning of 2018 showed that in the domestic market GOL Linhas Aereas maintains a slight advantage in the domestic market with a total of 34.25%, closely followed by LATAM (merger of Tam and the Chilean LAN), with 33.26%, Azul, with 18.33% and Avianca Brasil with 14.16% market share, complete the ranking.

4. Theoretical framework

Deregulation of the US airline industry in 1978 initiated an abundance of literature concerned with the effect these recent changes have had on productivity (and, similarly, whether changes to European legislation would precipitate similar observed productivity advances). The demonstrable effects of successful US deregulation and ongoing inefficiency in the industry may have influenced the European Commission to introduce certain reforms to promote competition and thus increase the efficiency and productivity of the European airlines. In Europe, the benefits of the common aviation market did not attend the expectations, due to the entry and exit barriers to new competitors, as reported in European Commission (1999), to the reorganization of the concessionary companies in Marin (1995), and to the intra-countries net optimization, as mentioned by Lapautre (2000).

Studies focusing on the effects of bilateral agreements showed that the benefits to consumers are just maximized with the effective competitors' entry into the market, according to Caves and Higgins (1993), and Gillen *et al*. (1998). Schefczyk (1993) was one of the first authors to present a measurement model of airlines operational performance using inputs like ton-kilometres and operating costs.

The outputs used for this model were revenue pax-kilometres and operational income, whereby the DEA method was used to analyse the performance of the 15 largest international airlines in 1990. Cathay Pacific, Federal Express, Singapore Airlines and United were pointed out in this study as the most efficient, with a score of 100%. The four European companies in the sample, British Airways, Iberia, KLM and Lufthansa were considered inefficient, with score below 100%.

Distexhe and Perelman (1994) aimed at their study to evaluate the consequences of the air transport deregulation by measuring the efficiency and the productivity of 33 airlines operating in 3 market groups: Asia and Australasia, Europe and North America, in the 1977 – 1988 period. The production frontiers of these airlines were built up in this study, using the DEA method and Färe's approach (2001) to evaluate Malmquist's productivity, by decomposing this index into technical progress and efficiency gains. Good *et al*. (1995) analysed the efficiency and the productivity observed differences among European and American companies in the 1976 – 1986 period.

The authors used two alternative methods - a parametric method, using statistical estimates, and a non-parametric method, using Linear Programming Problems (LPP). The companies were classified according to specific productivities and efficiency differences observed along the time. Fethi *et al.* (1999) applied the DEA methodology to detecting and modelling the efficiency of European airlines with the purpose of formulating air transport regulation policies in Europe. The analysis was based on data from 17 European airlines, in the 1991-1995 period, and focused on the initial period of the air transport liberalizing reforms in Europe.

Soares de Mello *et al.* (2003) compared the relative efficiency of the Brazilian airlines in 1998-2000, where each company was considered as a different DMU in each one of the three years. The DEA (input oriented) with constant returns to scale (CRS) was the method used in this study. ARAUJO et al. (2006) assessed the relative efficiency of the Brazilian air transport industry in the 1999-2001 period, also using the DEA method with variable returns to scale (VRS). Two scenarios were used in this study to analyze the national and regional airlines, which showed a great performance difference between these airlines category.

5. The DEA method

The method used in this research is the Data Envelopment Analysis (DEA), which is a well-known family of mathematical programming tools, based on the Frontier approach (Farrel, 1957), for assessing the relative efficiency of a set of comparable processing units (a.k.a. decision making units, DMU). For an extensive DEA description see Seinford & Thrall (1990). Conventional DEA models are based on Linear Programming and consider continuous inputs and outputs, but there are many occasions in which some inputs and/or outputs can only take integer values. One of the strong points of DEA is its non-parametric character, which means that only the observed inputs consumptions values and outputs production amounts are needed in order to properly assess the relative efficiencies of the DMU.

DEA begins with the definition of the Decision Making Units (DMU), where various resources (inputs) are converted into outcomes (outputs). Using inputs and outputs for all DMU, it is possible to develop a production possibility set using assumptions such as that interpolated input-output combinations are feasible, inefficient input-output combinations can exist, and output can not be produced without any input. In DEA models, the relative efficiency of a DMU is equal to a weighed sum of outputs divided by the weighted sum of inputs. The weights used in the consideration are obtained from a *Fractional Programming Problem*, linear made, which attributes to each DMU the efficiency maximization weights.

The advantage of the DEA method in comparison to other production models, is its capacity to incorporating multiple inputs and outputs for the calculation of a unique efficiency measure. At first, the DEA formulation allows total flexibility in the choice of weights; more advanced models allow the incorporation of weights restrictions, according to Allen et al. (1997), that result from specialists' judgments, given the relative importance of each variable.

There are two classic DEA models: (i) THE *CCR model* (also known as *CRS* or *Constant Returns to Scale*), which considers constant returns to scale, as proposed by Charnes *et al.* (1978), and that takes on a proportionality between inputs and outputs; (ii) the *BCC* or *VRS* model (*Variable Returns to Scale*), according to Banker *et al.* (1984), that considers variable returns of scale, or in other words, that substitutes the proportionality axiom by the convexity axiom.

Traditionally, are possible two radial orientations for those models, in the search for the efficiency frontier: inputs orientation, when it is desired to minimize the available inputs, without any change in the output level, and output orientation, if the objective is to maximize the production volume, without changing any input.

There are two equivalent formulations (Dual Linear Programming Problems) of traditional DEA models. In a simplified way, it can be said that one of the formulations (*multipliers-model*) uses the reason of the weighted sums of outputs and inputs, to each DMU in the most favorable way, under consideration of certain conditions.

In the other formulation (*Envelope Model,* the viable production area is defined and it uses the projection of each DMU in the area frontier; in this case, the inefficient DMU's are located inside the efficiency frontier and the efficient units on the border. In the equation sets (1) and (2) the DEA/CCR multipliers-model and the inputs oriented envelope-model, are represented, respectively. Each DMU k, k = 1... n, is considered as a production unit, that uses r inputs x_{iko}, i = 1…r, to produce s outputs y_{jko}, j = 1…s; x_{io} and y_{jo} are the inputs and outputs of the DMU o. In the model (1), v_i e u_j are the weights calculated by the model for the *inputs* e *outputs*, respectively.

$$\text{Min} \sum_{i=1}^{r} v_i x_{io}$$

$$\sum_{j=1}^{s} u_j y_{jk} = 1 \tag{1}$$

$$-\sum_{i=1}^{r} v_i x_{ik} + \sum_{j=1}^{s} u_j y_{jk} \leq 0, \forall k$$

$$u_j, v_i \geq 0, \forall j, i$$

In model (2), the efficiency of the *DMU o* analyzed is given by $1/h_o$ and λ_k represents the contribution of the DMU k in the objective (target) determination of the *DMU O*.

$$\text{Max} \quad h_o$$
$$\text{subject to}$$

$$x_{io} - \sum_{k=1}^{n} x_{ik} \lambda_k \geq 0, \forall i$$

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

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

$$(2)$$

5.1 DEA Strengths

DEA can be a powerful tool when used properly. A few of the characteristics that make it powerful are:

- DEA can handle multiple input and multiple output models;
- It doesn't require an assumption of a functional form relating inputs to outputs;
- DMUs are directly compared against a peer or combination of peers, and
- Inputs and outputs can have very different units.

5.2 Limitations and restrictions of the DEA Method

The same characteristics that make DEA a powerful tool can also create problems. An analyst should keep these limitations in mind when choosing whether or not to use DEA.

- Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems.

- DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a "theoretical maximum."

- Since DEA is a nonparametric technique, statistical hypothesis tests are difficult and are the focus of ongoing research.
- Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive.

6. Data and simulation Scenario

The information and data for the year 2000 and 2005 were collected from international and Brazilian publications: World Air Transport Statistics (IATA), the Digest of Statistics (ICAO); Fleet and Personnel Series (ICAO), the Financial Data Series (ICAO) and the Brazilian ANAC commercial aviation yearbook. These data were updated with air transport data obtained from the IATA yearbook for the period 2012-2016.

6.1 Inputs and Outputs

As input variables, it was chosen: the total number of employees (*labor*), the number of available fleet seats (representing the 'static' fleet capacity - *capital*) and operating expenses, and as output: Revenue Seat-km and and Revenue Ton-km.

6.2 Sampling criteria for the choice of the DMU´s

41 carriers were selected and grouped as follows:

- 25 full service companies (FSC);
- 6 low-cost/low fare companies (LCC) and

- 10 regional airlines.

The airlines were sampled according to the following criteria:

(i)   representativeness and importance of the airlines in their markets (North and South American, European and Asian airlines);

(ii)   carriers whose data availability and previous studies indicated good operational performance and productivity were chosen.

- The airlines included in the sample are detailed below:

  o   *FSC* - Aeroflot, Aerolineas, Air Canada, Air France, Alitalia, Austrian, American Airlines, British Airways, China Southern, Continental, Delta, Iberia, JAL, Korean, Lan, Lufthansa, Malev, SAS, Singapore Airlines, Swiss, TAP, Thai, Turkish Airlines, TAM and VARIG;

  o   *LCC - Air Berlin (still operating at the time of this study), Air Europa, US Airways, GOL, Jet Airways, and Virgin Express;*
  o   *Regionals – Alaska, Oceanair, Pantanal, Passaredo, Portugalia Airlines, Rico, TAF, Total, US Airways.*

6.3 Simulation Scenarios

Following simulation scenarios are considered for the study:

Scenario I - FSC's, LCC's and Regionals, variable returns to scale; inputs: number of employees, fleet and operating expense; output: Revenue Seat Kilometers (RSK) and Revenue Ton Kilometers (RTK);

Scenario II - FSC's, LCC's and Regionals with variable returns to scale; inputs: number of employees and fleet; output: transported passengers and RTK

Scenario III - Regional and LCC's with constant and variable returns to scale with same inputs and outputs as above;

Scenario IV - Regionals and LCC's with constant and variable returns to scale; inputs: number of employees and fleet; output: passengers transported;

In all scenarios the simulation was made under the consideration of: a) no weight constraint and b) 10% weight constraint for all inputs.

7. Research Results

7.1 Relative efficiency of the airlines

The scenarios were implemented and executed by means of two software's, both running DEA algorithms: the Efficiency Measurement System (EMS), a free software used in Windows platform; and the Frontier Analyst (a registered Banxia Software). The intention of using two distinct software's is to validate the results and to obtain a better precision for the adjustments values λ's and the slacks (a measure of inefficiency).

In all scenarios, the simulation is made by means of DEA/VRS models or CRS models, input oriented, as it exists the interest to verify in how much it is possible to diminish the airline inputs, by keeping constant their output levels. To use constant returns to scale means to the producers to be able to linearly scale the inputs and outputs without increasing or decreasing efficiency. The assumption of CRS may be valid over limited ranges and its utilization must be justified. A DEA/CRS simulation tends to lower the efficiency scores, while a DEAVRS simulation tends to raise the efficiency scores.

The choice of a VRS and a CRS DEA model depends on the objective analysis for each scenario. In the two first scenarios, a VRS model was chosen for the analysis of the airlines efficiency, due to the scale efficiency effect to

make possible airlines comparisons of different sizes. For example, how to compare airlines operating at national and international scale, with a fleet made up of great aircrafts as B747, MD11and A340 with regional airlines operating propeller technology and small jets, without taking into account variable returns into scale?

The intention, by formulating scenarios I and II, is to evaluate all companies, independently of their category, and operating aspects concerning both transport: passenger (outputs: RSK and Transported passengers) and freight (output: RTK). The operational is considered with inputs like number of employees, fleet and operating expense. The difference between the above scenarios is the insertion of the input operating expense in scenario I.

As a result of the definition of these scenarios, it is possible to get a comparison of how efficiently airlines are operating their fleet and personnel. Scenario I is also simulated with only 13 DMU's for which their operating expenses are available. The efficient airlines (e.g. those on the efficiency frontier) in the scenario 2 were: Air Berlin, American Airlines, Delta, JAL, Singapore Airlines and TAF.

Among them are large airlines (the so called "Full Service" airlines), which obtained a high score, mainly due to the large proportion of their outputs (transported passengers and RTK) and two smaller carriers, a low-cost company (Air Berlin) and TAF (a small Brazilian regional company with a fleet of 7 B 737-700 aircrafts). This was possible due to the fact, the model considers variable returns to scale.

Graph 1 presents the result of the airlines relative efficiency, as simulated in Scenario I, under two considerations: a) without weight restrictions and b) with a 10% input weight restriction. The results obtained in the chosen scenarios, with and without input weights restriction are coherent, i.e., there is a little variation in the relative efficiency score, and consequently, in the rank among the 13 analyzed DMU's.

As presupposed in the theory, the DEA model, with weight restriction, is the most rigorous, resulting in only three companies with the maximum score: America Airlines, Malev and Singapore Airlines. On the other hand, the model without weight

Lufthansa and Thai. In all other scenarios, the simulations results, accomplished with and without weight restrictions restriction, allowed four more companies, to reach the efficiency frontier: Jet Airline, Air China, are very close.
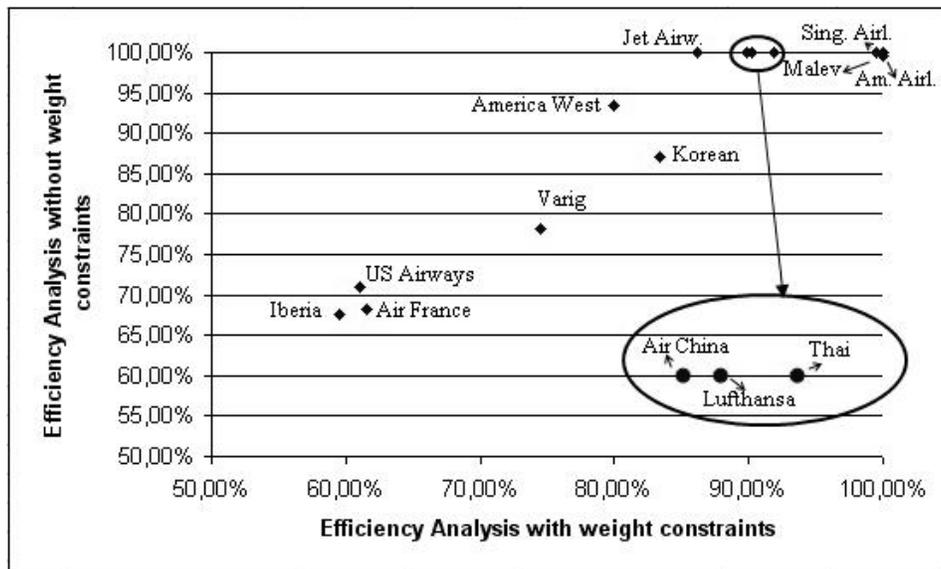
Graph 1: Efficiency score comparison of airlines with and without weight restriction (scenario I). Source: the authors.

It is important to observe that the incorporation of weights represents a challenge in terms of efficiency models. It is important to derive them, to have in mind clear analysis objectives what makes necessary the inclusion of specialists'.

In those cases, support tools, like the AHP (Analytical Hierarchy Process), are used in the weights definition, starting from the information supplied by specialists to obtain an overview of the operating characteristics of the airlines, as shown in Graph 2.
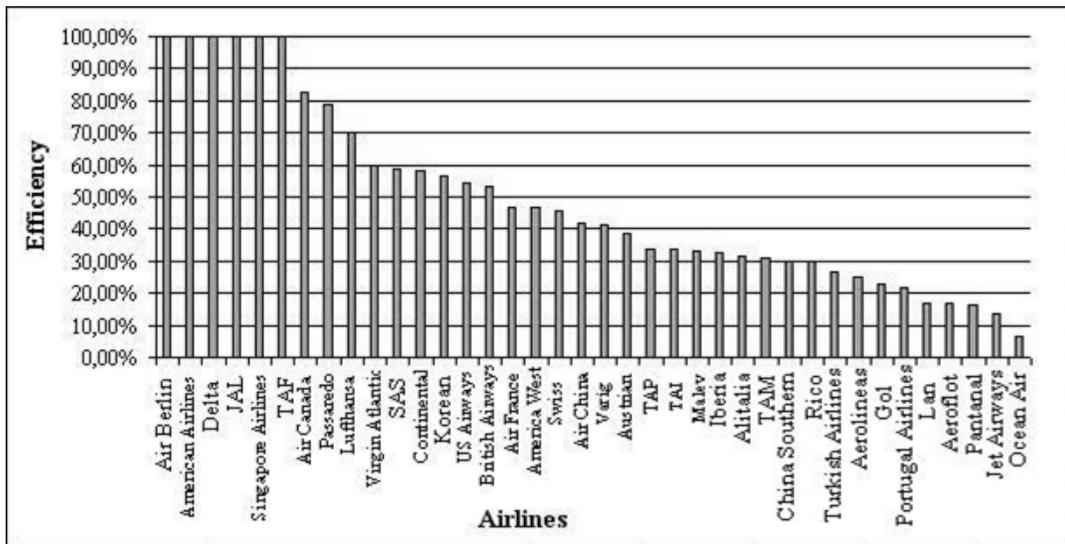
Graph 2: Efficiency score rank of sampled airlines (scenario II) . Source: the authors.

Air Berlin, in spite of being a recent regional company, has an outstanding performance in highly competitive markets, and became the second largest German airline, thanks to a "lean" personnel structure, investments in modern aircrafts and a standardized fleet. At the beginning, the company only flew to serve tourism operators.

Now, it links German airports with the main European cities and it still makes regular flights into Mediterranean cities, Portugal and of North Africa. In January 2005, Air Berlin grouped together the existent product lines into a single designation - Euro Shuttle. As a result of large investment and a company expansion, as shown through the DEA model, it was in all the scenarios it participated, either efficient or close to the efficiency frontier. TAF, in spite of a size reduction, prior to 2000, presented recovery evidences, besides a fleet diversification with the addition of cargo planes of large capacity, used into the service of the Brazilian Mail and Telegraph Company, as reported by (Soares de Mello *et. al*, 2001).

In this context, it should be emphasized the performance of Singapore Airlines and Air Berlin which achieved the efficiency frontier in all simulated scenarios. In the case of Singapore Airlines, its performance can be explained by its operation concentration in prosperous Asian markets and in important markets like the Middle East, Europe, North America and Pacific Southeast, the intensive operation (16 h a day) of a young fleet made up of 90 large planes B747-400, B777 and A340-500 [Star Alliance, 2007]. Its fleet has an average age of 6 year, and operates 90 destinations.

Due to the small sample of DMU's (6 low-costs and 10 regional airlines), scenarios III and IV were proposed, with the objective to analyzing regional and low-fare/low cost companies, under consideration in the scenario III of 2 inputs (number of employees and fleet) and 2 outputs (transported passenger and RTK) and 2 inputs (the same as in the scenario III) and 1 output (transported passenger).

It was proposed a comparative analysis, in the above scenarios, of airlines to verifying the growing importance of the transport of passenger and cargo for regionals and low-cost companies (scenario III) and only passenger (scenario IV). Especially for the Brazilian regional companies, cargo transport is strategically assuming a growing importance for the industrial production, due to the inherent characteristics of speed, flexibility and safety, mainly in the transport of high value added goods (Lima et al, 2007). In a first moment the proposed scenarios were simulated with constant returns to scale, what had as a consequence a more rigorous evaluation of the relative efficiency.

TABLE 1: Efficiency score comparison with and without returns to scale using the DEA-method-Scenarios III e IV. Source: the authors.

DMU's	Scenario III		Scenario IV	
	CRS	VRS	CRS	VRS
AirBerlin	100,00%	100,00%	100,00%	100,00%
Virgin Atlantic(UK)	100,00%	100,00%	39,40%	44,05%
GOL	75,98%	77,69%	75,98%	77,69%
Air Europa	63,24%	66,24%	58,68%	62,03%
AirChina	62,77%	100,00%	44,40%	77,05%
TAF	53,71%	100,00%	8,59%	100,00%
US Airways	50,04%	100,00%	45,62%	100,00%
America West	48,66%	68,52%	43,17%	60,27%
Jet Airways(India)	45,52%	47,45%	45,29%	47,24%
Alaska	45,31%	50,60%	41,01%	41,12%
Portugalia Airlines	18,46%	27,05%	18,46%	27,05%
Rico	15,30%	40,32%	15,30%	40,32%
Pantanal	8,48%	41,32%	8,48%	41,32%
Oceanair	4,42%	20,83%	4,42%	20,83%
Total	4,42%	16,66%	4,42%	16,66%
Passaredo	2,46%	100,00%	0,92%	100,00%

In Table 1 are compiled the simulations results of scenarios III and IV, with and without returns to scale. As it can be observed, the DEA/CRS method with constant returns to scale, made the comparison to smaller airlines, unfavorable. By comparing the small airlines with variable returns to scale, however, these obtained a much better score. This is the case of Passaredo and TAF, Brazilian regional airlines, that reached the efficiency frontier when simulating the DEA/VRS model.
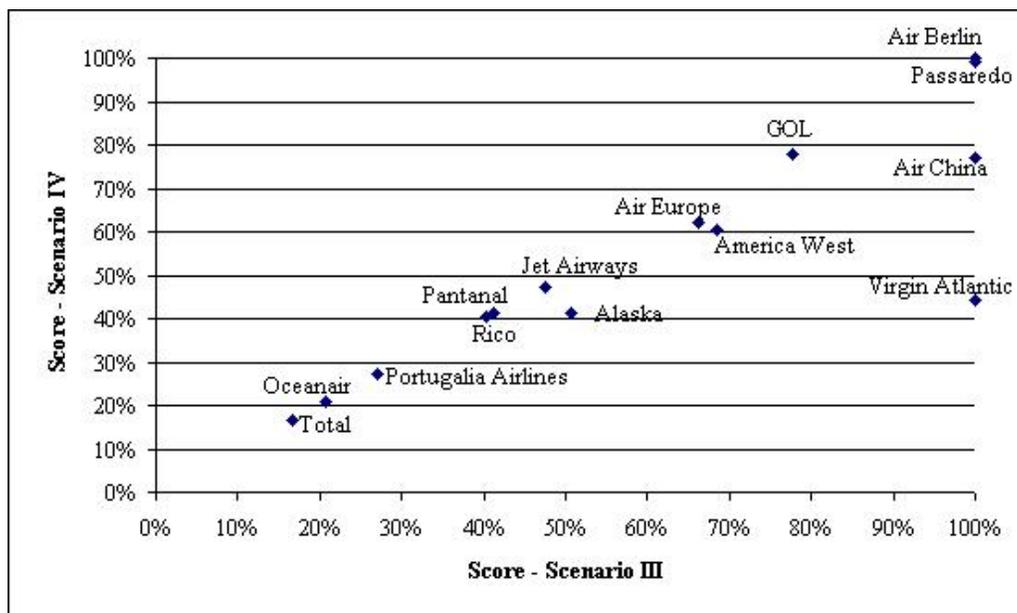
Graph 3: Efficiency score comparison of LCC's and regional airlines Source: the authors.

In graph 3, it can be depicted a comparison among scores of scenarios III and IV. It can be observed that some airlines maintained exactly the same punctuation in both scenarios: Portugalia Airlines, Rico, Pantanal, Oceanair and Total. GOL Transportes Aereos showed a regular efficiency in both models (app.77%).

GOL is the Low-cost airline, which had the in recent years the largest expansion in the Brazilian market, reaching already in 2002, the status of an international airline, according to Araujo *et al.* (2006). It should be remarked, however, that TAM, currently, the largest Brazilian was not compared in scenarios III and IV. Some companies considered efficient, according to their efficiency score in the scenario III, did not reach the efficiency frontier in scenario IV (China and Virgin Atlantic). The low-cost airline Virgin Atlantic had a relative efficiency score under 50% in scenario IV, possibly, due to the low participation of the output RTK.

8. Conclusion

The objective of this paper is to compare the relative efficiency of Brazilian airlines with those of international companies. The research made possible the application of the DEA method with both variants VRS and CRS and with and without weight restrictions. It was not possible, however, in this research, to consider different operating conditions among American airlines that operate in a hub-and spoke system and South American and Asian companies operating point to point.
The results obtained with the utilization of software's like EMS, and Frontier Analyst allowed
to conclude that large airlines with high load factors and a concomitant production of passenger and cargo like American Airlines, Delta Airlines and JAL had the best efficiency score. In scenario II, Air Berlin (LCC with 50 aircrafts and 80 destination) and Singapore Airlines, operating aircrafts intensively and in long distances, also achieved the efficiency frontier, as shown in Fig. 2. In scenario III, Air Berlin and Virgin Atlantic obtained a 100% relative efficiency with and without inputs weights restrictions.

Among the Brazilian regional airlines, due to the personnel structure, both Passaredo and TAF, when compared under conditions of variable returns to scale, reached also, the efficiency frontier. In scenarios III and IV, GOL obtained a relative efficiency of appr. 76%. Among the American regionals, the US Airways, when compared under variable returns to scale, is also positioned on the efficiency frontier. Concerning the Asian LCC's and regional airlines, the best performance was that of Air China with a 100% score of relative efficiency, when compared with variable returns to scale.

Acknowledgments

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Biographies

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