Efficiency of Airports

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Abstract

Performance evaluation reveals itself as extremely useful tool, since there is no opportunity to an operator improve its efficiency if major indicators weren´t controlled and measured. DEA is one of the methods used to do performance analysis, which allows to assess the relative efficiency of a group of operators.

For this reason, DEA was the chosen method to evaluate a set of 145 airports spread along Europe, Asia/Pacific and North America with the major objective to realize the airport models that operated in a more efficient way, not only with an input orientation, but also with an output orientation, in 2010. The DEA model adopted as inputs the number of gateways, the number of employees, the total length of runways and other operational costs. As outputs, the number of flights and the workload unit were the chosen ones.

Amongst 145 airports, only 21 airport were considered efficient with an input oriented model and 18 with an output oriented model. Furthermore, airports from Asia/Pacific operated more efficient than European or North American counterparts. Regarding its business model, private airports revealed less inefficiencies than public or public-private airports, as well as airports managed by individual entities were found to operate in a more efficient way than airports managed through holding companies. It was also possible to conclude that airports located in regions under economic regulation were more efficient than airport without airport regulation in output oriented model, whereas in input oriented models there were no difference.

Keywords: DEA, efficiency, airports, management models, economic regulation

1 Introduction

The air transport market plays a key role in global economic development, promoting job creation, tourism and trade over a time span that bears no comparison with alternative means of transport (European Commission, 2012).

This market has increased in size considerably over the years. Forecasts made by the European manufacturer of commercial aircraft - Airbus - point to growth of world air traffic of 4.7% per year until 2032 (Airbus, 2013).

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In Europe this growth will be sustained, among others, by globalization as witnessed over the past few years, by the growth of emerging economies like India, China and Brazil and by the average European GDP growth at 1.9% (European Commission, 2012).

In turn, according to the same forecast, the European air transport market will grow 3.8% per year up to 2032. One of the strategic objectives set by the European Commission (2000) at a meeting of the European Council in Lisbon was "*…to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion*". Thus, it becomes extremely important to study all the variables associated with the air transport industry, including the efficiency of airports, because the contribution of this industry to the competitiveness of the European continent can be of great importance in the coming years (European Commission, 2000).

One of the worldwide phenomena that has become apparent over the past few years, with special focus since the 90s, is the total or partial privatization of airports, which until recently were exclusively public domain. It all started in the UK, when the local government decided to privatize the British Airports Authority. Afterwards this privatization was followed by many others elsewhere in Europe, and the degree of investment and private management in each airport can span from totally private management to the management of outsourced parts of the airport (Qin, 2010).

Currently there are three main models of management applied to the infrastructure of airports: airports managed by public entities through public-private partnerships (PPPs) contractual types (mainly concession contracts), and partially or fully privatized airports (PPP institutional type). However, there also exists already the privatization of activities within its value chain. One example is the ground-handling companies, such as Groundforce Portugal and similar companies in other European countries (Cruz and Marques, 2011)

The reason for change in the type of management at airports is related to the fact that it was realized that airports are not limited to only serve as a support structure for the aeronautical industry, but are the basis for an entire business with huge involvement and tremendous regional economic impact. This comes from a paradigm in which airports were considered as mere public services, where the key was to have the airport operational for takeoffs and landings, trying its best to cover the cost of these activities, to a new paradigm in which the airport is seen as a lever of the economy, which seeks to satisfy all the needs of users, with a more careful approach to the logistics involving its operations (Ashford et al., 1979).

For this reason, a consortium of investors in the airports business, which become responsible for the administration, totally or in cooperation with local governments, began to emerge. Currently, groups such as Vinci, responsible for the concession of several airports in France and in Portugal, the Fraport or CAI (Changi Airports International), responsible for the management of airports around the world, are some of the large companies involved in the air transport market.

Considering all these facts, from the importance of aviation to the economic development of each region’s market, through the increase in global air traffic forecasts, and the recent change in the management structure of airports, including efficiency in evaluating the performance of European airports becomes of utmost importance. This will not just assess the current situation but will also allow setting goals and priorities for improvement.

2 Airports Analysis

2.1 Description

According to Betancor and Rendeiro (1999), an airport's main function is the exchange of passengers and cargo between land and air transport, through the combined operation between aircraft, runways, aprons, taxiways, terminals, and control towers, among others. However, a large part of airports are not just a mere physical structure that serves to support the transport of passengers and goods, but instead are denominated as "airport cities" or "aerotropolis" to allow urban and economic development of the regions where they are inserted, through a synergistic relationship between air routes related to the airport and commercial development in the area (Ashford et al. 1979).

The activities that take place within the physical space of an airport can be divided into three groups: operational services, support services and commercial activities. Operational services are the core activities, support services are considered as aeronautical services that deal with both aircraft (cleaning, fueling and loading) and the processing of passengers, while commercial activities are not aeronautical services and involve a wide variety of services that can be found inside the airport or nearby (Ashford et al. 1979).

2.2 Business model

Until the early 80s, airports were managed directly by government or indirectly through public companies. However, after that date the idea began to interiorize that this method of administration was inefficient and therefore unsustainable, so a change of philosophy of airport activity was required (ACI, 2010). The reasons for this change were the inefficiency of airports, the lack of public funds for their funding and the liberalization of the European aviation market that has increased its competitiveness.

Currently, one of the major constraints that airports have faced is their inability to finance themselves. This, combined with strong prospects of increased market share over the next few years, has increased the pressure on the financing of expansions that allow airports to deal efficiently with this increased demand. As public finances of most European countries are under tight restraint, increasingly private investments coming from large corporate groups interested in partial or total management of airports began to appear, in particular through public-private partnerships (PPP) (Cruz e Marques, 2011). Figure 1 and Figure 2 represents the geographic distribution of airports according to its business model.

Region	Public	Private	Public-private	Total
America	68	0	0	68
Europe	23	4	24	51
Asia/Pacific	11	7	8	26
Total	102	11	32	145

Figure 1. Public and private airports

Region	Individual	Holding	Total
America	68	0	68
Europe	30	21	51
Asia/Pacific	23	3	26
Total	121	24	145

Figure 2. Airports managed individually and through holdings

Since the efficiency under economic regulation and without economic regulation was other proposed objective of this study, Figure 3 displays the geographic distribution of these kinds of regulation.

Region	Not Regulated	Regulated	Total
America	0	68	68
Europe	15	36	51
Ásia/Pacífic	4	22	26
Total	19	126	145

Figure 3. Economic regulation of airport

3 Literature Review

DEA (Data Envelopment Analysis) has been a widely used methodology in airport sector. There are a significant variety in terms of the scope of each study: from an analysis specific to a group of airports of a limited region, like the ones done in United States of America by Gillen and Lall (2001) or in Argentina by Barros (2008), to a wide scope covering a whole continent as the analysis done in European airports by Pels *et al.* (2001).

As expected, there was a great diversity of variables used in each study, according to the defined objectives. However, it was extremely important to do a literature review to understand the most used variables and their impact in the efficiency results. Figure 4 and Figure 5 shows the most used inputs and outputs, respectively, in the literature review performed.

Inputs	Frequency
Terminal size (m^2)	4
Runways (no.)	3
Aircraft parking positions (no.)	3
Áirport size (m^2)	2
Remote aircraft parking positions (no.)	2
Employees (no.)	2
Runways area (m^2)	1
Gates (no.)	1
Baggage collection belts (no.)	1
Public parking spots (no.)	1
Length of runways (m^2)	1
Check-in counters (no.)	1
Baggage claims (no.)	1
Labour cost (€)	1
Invested capital (€)	1
Operational cost (excluding labour cost) (€)	1
Ramps (no.)	1
Landings (no.)	1
Takeoffs (no.)	1

Figure 4. Inputs used in the literature review

Outputs	Frequency
Passengers (no.)	5
Cargo (kg)	4
Flights (no.)	2
Aircrafts (no.)	2
Commuter movements (no.)	1
Aeronautical revenues (EUR)	1
Commercial revenues (EUR)	1
Landings (no.)	1
Takeoffs (no.)	1

Figure 5. Outputs used in the literature review

4 Performance Measurement

4.1 Data Envelopment Analysis

Performance measurement is crucial for the efficiency assessment of a group of DMU. In general, performance methodologies can be divided in parametric or non-parametric models, which in turn, can be dismembered according to the use of an efficiency frontier (Marques e Silva, 2006).

DEA is one of those methods, and it is characterized as a non-parametric model which uses an efficiency frontier. According to Culinnane *et al*. (2005), DEA allows an efficiency assessment of a group of DMU. In turn, DMU is defined as an entity that consumes a certain quantity of inputs to produce a certain amount of outputs, and its efficiency is measured according to the conversion of inputs in outputs.

It is worth noting that DEA doesn´t assess the absolute efficiency of DMU. It only evaluates the relative efficiency of DMU given that the assessment only takes in account the study sample.

The weight of each variable is determined through fractional programming according to the efficiency maximization of DMU. The ones located in the efficiency frontier are considered as efficient operators and its efficiency value is equal to 1. The remaining DMU are considered inefficient and its inefficient score depends on its proportional distance to the efficiency frontier.

DEA models have been developed to assess efficiency in different ways: input-oriented models and output-oriented models. Input-oriented models are based in the minimization of inputs assuming the same level of outputs, while output-oriented models are based in the maximization of outputs assuming the same level of inputs (Barros e Athanassiou, 2004). In each of these orientation models, there is the possibility to use CCR model (Charnes *et al*., 1978) which assumes constant returns to scale, or BCC model which uses variable returns to scale (Banker *et al*., 1984).

4.2 Models, Orientation and Data

As mentioned before, efficiency assessment of a set of airports is the main objective of this study.

The sample analyzed contemplated 145 airports: 51 located in Europe, 26 in Asia/Pacific and the remaining 68 headquartered in North America. Taken together they accounted about 51% of world air traffic in 2010 (ACI, 2011). The great majority of the countries that belongs to the sample only have one airport. The most represented countries were United States of America with 60 airports, followed by Canada with 9 airports. All data of inputs and outputs used to assess the efficiency of airports was retrieved from the annual report of Air Transport Research Society (ATRS, 2012). The analysis was done for the year 2010.

Regarding DEA models, input oriented-model and output-oriented model were the chosen ones, both of them using constant returns to scale and variable returns to scale.

The selection of the appropriate inputs and outputs for DEA models took in account the objectives of the study, the operation process of an airport, the literature review and data availability. This step was critical once a bad choice of the descriptive variables of an airport could lead to misleading results.

Thus, the number of boarding gates, the number of employees, the total length of runways and other operational costs were the variables selected as inputs of an airport. The chosen outputs were two: flights and workload-unit.

It is important to make a note related with the input “other operational costs”. This input reflects the operational cost of an airport, excluding employees’ wages. The operational cost related with employees were contemplated by the input “number of employees”. If the number of employees and the whole operational cost were considered simultaneously, there would be a redundancy.

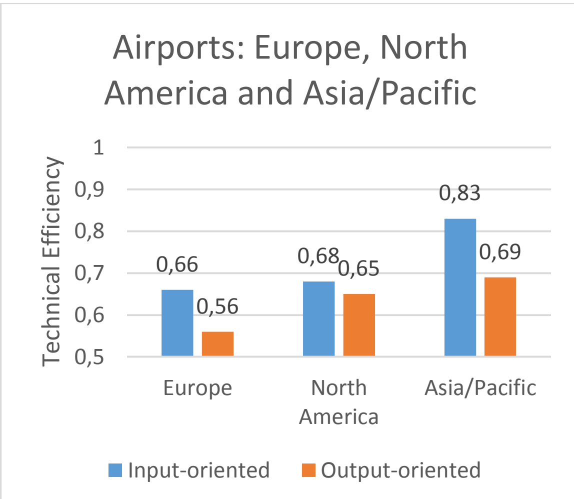
5 Results

5.1 Efficiency Scores

All efficiency values presented in the following tables were obtained assuming variable returns to scale As defined in the objectives, several

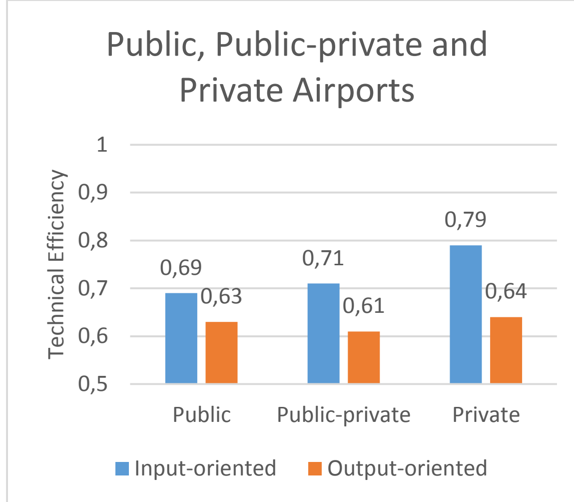
efficiencies comparisons should be made. In general terms, the airports under input-oriented model performed better than under output-oriented model: an average efficiency score of 0,70 and 0,63, respectively. Overall, 21 airports revealed efficient under input-oriented model, and only 18 under output-oriented model.
The efficiency comparison under input and output-oriented models by region is displayed in Table 1.

Table 1. Europe, North America and Asia/Pacific airport



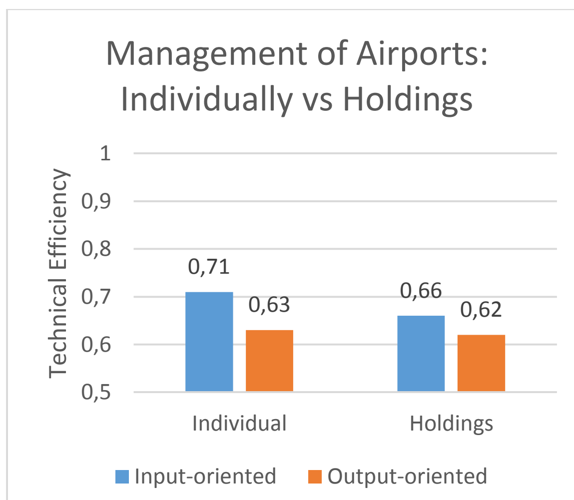
The main conclusion of the observation of the Table 1 is that airports from Asia/Pacific presented efficiency scores considerably higher than airports from Europe or North America: while the average technical efficiency under input-oriented model of airports in Asia/Pacific were 0,83, the European and North American counterparts presented efficiencies scores of 0,66 and 0,68, respectively. The difference between these geographic regions under output-oriented models were significantly smaller. Furthermore, the efficiencies under input-oriented models were superior than output-oriented models in all geographic regions represented.
Regarding efficient airports in input-oriented model, 31% of Asia Pacific airports were efficient, against 15% in North America and only 6% in Europe. In output-oriented model, the number of efficient airports decreased: 23% of Asia/Pacific airport were considered efficient, 15% in Norte America and only 4% in Europe.

Table 2. Public, public-private and private airports



Regarding business model, private airports revealed less inefficiencies than public or public-private airports in input and output-oriented models, as can be seen in Table 2. The level on inefficiency in input-oriented model in private airports were 0,21, while in public and public-private airport were 0,31 and 0,29, respectively. The difference under output-oriented models were smaller: private airports had an efficiency score of 0,64, public-private airports had 0,61 and public airports had 0,63.

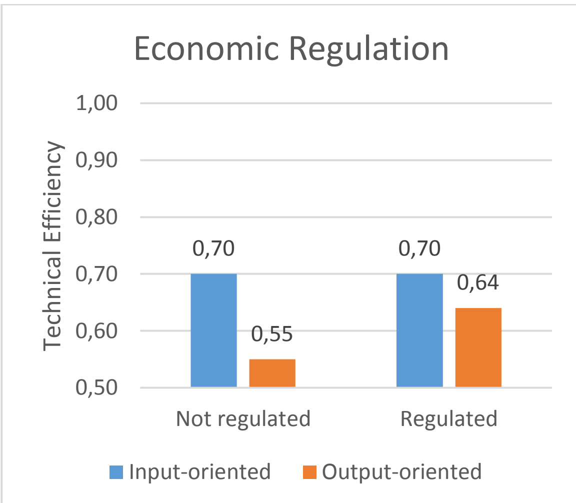
Table 3. Individually managed airports and management through holding companies



One other aspect related to the business model of an airport is related with individually managed airports or management through holding companies.

Similarly to the previous analysis, airports revealed to be more efficient in the minimization of its inputs than in the maximization of its outputs, as illustrated in Table 3. Furthermore, airports managed individually operated more efficient than airports managed by holding companies: 5 percentage points in input-oriented model and 1 percentage point in output-oriented model.

Table 4. Economic regulation in airports



About economic regulation in airport, Table 4 shows that there wasn´t any difference in input-oriented model between regulated and not regulated airports. Both had an average efficiency score of 0,70. In output-oriented model, regulated airports operated more efficient than not regulated airports: regulated airports had an efficiency score of 0,64 and not regulated airports had an efficiency score of 0,55.

5.2 Slacks and Targets

Input and output slacks of airports are related with their efficiency scores. They represent an excessive input or a missing output. The input and output slacks for input-oriented model are listed in Table 5.

Table 5. Input and output slacks in input-oriented model

Variable	Slack
Total length of runways (m)	120
Employees (no.)	298
Boarding gates (no.)	1
Other operational costs (EUR million)	10,7
Flights (no.)	3.619
Workdload-unit (no.)	3.567.656

The slack of total length of runways is very low, as well as the slack of boarding gates. In turn, the employees´ slack and the slack of other operational cost are too large to be ignored. The number of flights and workload-unit are in the same situation. So, this means there is a great potential of improvement, mainly in these 4 variables.

Table 6. Input and output slacks in output-oriented model

Variable	Slack
Total length of runways (m)	154
Employees (no.)	368
Boarding gates (no.)	1
Other operational costs (EUR million)	16,7
Flights (no.)	4.107
Workload-unit (no.)	1.355.831

Table 6 represents the slacks under an output-oriented model. Similarly to an input-oriented model, in output-oriented model, the slacks of the total length of runways and boarding gates are low. However, regarding the remaining variables under an output-oriented model, there was an increase in slacks of employees, other operational costs and flights and a decrease in workload-unit.

Table 7. Efficiency targets for Lisbon airport in input-oriented model

Inputs/Outputs	**Target**	**Current (2010)**
Total length of runways (m)	3.595	6.205
Boarding gates (no.)	27	47
Employees (no.)	171	296
Other operational costs (EUR million)	56.957.553	98.311.498
Flights (no.)	138.131	138.131
Workload-unit (no.)	19.002.447	14.983.171

Table 7 represents the efficiency targets for Lisbon airport under an input-oriented model. For this airport become efficient, it would make significate changes in its structure of inputs and outputs. Reductions of 2.610 meters in runways total length, 20 boarding gates, 125 employees and about 41 million euros in other operational costs were some of the measures that would have to be implemented. Beyond these, an increase of 5 million in workload-unit would also be necessary to Lisbon airport become efficient under an input-oriented model.

Table 8. Efficiency targets for Lisbon airport in output-oriented model

Inputs/Outputs	**Target**	**Current (2010)**
Total length of runways (m)	6.205	6.205
Boarding gates (no.)	47	47
Employees (no.)	296	296
Other operational costs (EUR million)	98.311.498	98.311.498
Flights (no.)	210.496	138.131
Workload-unit (no.)	23.294.138	14.983.171

Regarding an output-oriented model, there wouldn´t be necessary changes in inputs, as represented in Table 8. Nevertheless, to Lisbon airport operate efficiently, it would have to increase the flights 52% and the workload-unit in 55%.

5.2 Conclusions

Amongst 145 airports, only 21 obtained the maximum value of efficiency in input-oriented model, while in output-oriented model only 18 were considered efficient. Regarding average efficiency, with input-oriented model the level of efficiency was 0,70, while in output-oriented model the value was 0,63. Thus, it is possible to conclude that analyzed airports are more efficient in input minimization than in output maximization.

Efficiency analysis by region also allow to notice that airports located in Asia/Pacific were considerably more efficient than its counterparts in Europe and North America in input oriented-model, as well as in output-oriented model. On the other hand, European airport were found to be the more inefficient in both kinds of orientation. Given that it was forecasted an increase of demand in Asia, it would be interesting to realize if airports located in this continent will maintain this level of efficiency. European and North American airports will have to look for their Asiatic counterparts, to implement measures to decrease the efficiency difference between them.

Other group of airport in analysis was related to the management of airports: public, public-private or private. Similarly to some literature review in this field, this analysis allow to conclude that private airports operated more efficient than public or public private airports. The difference in input-oriented models was 8 percentage points and 1 percentage point in output-oriented model. However, as the management airports paradigm is changing, it is expected an increase in efficiency score of airports.

Between individually managed airports and airports managed trough holding companies, individually managed airports revealed to be managed in a more efficient way. In input-oriented model, the efficiency difference is 5 percentage points, and in output-oriented model is 1 percentage point. So, it would be recommended that the majority of airports remain to be managed individually. However, the tendency registered in the last years doesn´t show that this is going to happen.

Lastly, the comparison between airport with and without economic regulation suggests that both of them have the same level of efficiency in input-oriented model, while in output-oriented model airports under economic regulation operated more efficient than the remaining in 9 percentage points. Therefore, it is possible to conclude that an airport that faces an economic regulation policy tends to be more efficient than an airport without any kind of economic regulation policies.

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