Air transport performance: current evidences about the efficiency of Italian airports

Juan Gabriel Brida*

Universidad de la República,
Montevideo-Uruguay,
Free University of Bolzano,
Piazza Università 1, I-39100 Bolzano, Italy
Fax +39-(0)471-013009
E-mail: JuanGabriel.Brida@unibz.it
*Corresponding author

Vincenzo Fasone

Kore University of Enna,
Cittadella Universitaria,
94100 Enna, Italy
E-mail: vincenzo.fasone@unikore.it

Pablo Daniel Monterubbianesi

Instituto de Investigaciones Económicas y Sociales del Sur,
Universidad Nacional del Sur-CONICET,
Argentina
E-mail: pmonteru@uns.edu.ar

Sandra Zapata-Aguirre

Kore University of Enna,
Cittadella Universitaria,
94100 Enna, Italy
E-mail: sandra.zapataaguirre@unikore.it

Abstract: This paper analyses the performance of Italian airports. We construct and estimate a data envelopment analysis, under Charnes, Cooper and Rhodes (CCR), Banker, Charnes and Cooper (BCC) and superfficiency models, in order to obtain efficiency scores for 14 airports for the period 2009–2011. In addition, we use a Malmquist Index for measuring the evolution of the productivity of individual airports along the time. The results show that Genoa, Rome, Naples, Bergamo and Bologna exhibit the best practices when distributing efficiently their production factor available to face an increase in the demand, keeping this behavior during all the period under study. These airports are efficient in both constant return to scale (CRS) and variable return to scale (VRS), indicating that scale is the prevailing source of efficiency.

Keywords: airport; Italy; productivity; performance measurement; benchmarking; data envelopment analysis; DEA.

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Biographical notes: Juan Gabriel Brida is a Full Professor at the Department of Quantitative Methods, Faculty of Economics, Universidad de la República, Uruguay. His research interests and expertise are in the areas of economic dynamics, mathematical economics and tourism economics. He has a degree in Mathematics from Universidad de la República, Uruguay and a PhD in Economics from University of Siena.

Vincenzo Fasone is an Assistant Professor at the University Kore of Enna, Faculty of Economics and Law, where he serves as the Chair of the degree course in Accounting and Business Administration. He has participated in numerous national and international conferences and he has published books (including *The Corporate Strategy of Airport Companies: Key Issues and Trends*) and several articles in scientific journals on the topics of transportation and tourism, government business development and performance improvement and development in the perspectives of public-private partnership.

Pablo Daniel Monterubbianesi is a Bachelor and Doctor in Economics from the Universidad Nacional del Sur, Bahía Blanca, Argentina. He holds a Postdoctoral Fellowship from CONICET and he is a Teaching Assistant in the Department of Economics at the Universidad Nacional del Sur in undergraduate and postgraduate subjects. His main research areas are three: tourism economics, economic growth and health economics. He has published numerous papers in peer review journals.

Sandra Zapata-Aguirre is a PhD candidate in Air Transport and Tourism Management at the Free University of Enna (UNIKORE) in Sicily, Italy. She has a degree in Tourism Management from Colegio Mayor de Antioquia in Colombia and has a Master in Management and Planning of Tourism from University of Alicante in Spain. She is a member of the research group GIET at the Colegio Mayor de Antioquia. Her research interests include applied researches related to cruise ship and air transport industry, culture tourism and tourism industry' impacts on destinations. She has been involved in different research projects both in Colombia and Italy.

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1 Introduction

Efficiency measures have been well known by airport managers who are aware of its importance as a suitable guideline in strategic planning and in analysing the competitive position of these organisations in the airport industry (Bazargan and Vasigh, 2003). Benchmarking their airport infrastructures against equivalent airports is a way for airport operators to ensure competitiveness.

Airports provide a wide range of services and facilities to passengers, shippers, airlines, and others. The airport industry is varied and heterogeneous with a high degree of quality differentiation, different ownership and regulatory structures (see also Fasone and Maggiore, 2013), different mixes of services and operating characteristics, etc. Consequently, measuring and comparing the performance of airports is a complex matter. Because of the increasing strategic importance of airport infrastructures in the movement of people and cargo (Barros and Dieke, 2007), the analysis of airports efficiency is crucial. As stated by Sarkis (2000), analysing airport operational efficiency has implications for a variety of stakeholders: airlines can schedule and set at airports that are more efficient; municipalities want their airport be efficient in order to attract more business and tourists, and the government can use this kind of information to help to determine the effectiveness of funding airport improvement projects.

Different airport performance measures and methodologies have been developed and applied along the time (Martín et al., 2013; Martini et al., 2013; Barros, 2011). Previous studies can be classified into two groups according to the approach used: a parametric [econometric – stochastic frontier analysis (SFA)] or a non-parametric method [data envelopment analysis (DEA)] methodology. A comprehensive literature review on a number of methods for measuring airport efficiency, including both DEA and SFA, is presented in the very recent article by Liebert and Niemeier (2013).

The parametric methodology SFA estimates a production (cost) function using regressions with a precise functional form that relates inputs to outputs. Efficiency is then estimated as the actual outputs observed divided by the predicted outputs from the regression for a certain level of inputs. Explanatory variables are usually introduced directly as parameters of the regression model to account for the sources of variation in efficiency. Recent studies that have applied this methodology include those of Chang et al. (2013), Martín et al. (2013), Martín and Voltes-Dorta (2011) and Barros (2011).

The non-parametric methodology is based on a set of mathematical programming formulations defined as DEA – (Sarkis, 2000) and it is normally used to evaluate the relative efficiency of a decision-making unit (DMU; in this case, an airport) with multiple inputs and multiple outputs (see Yiu et al., 2008b) With this approach a DMU's efficiency is found by solving a linear programming problem. Since the advent of the DEA in 1978 (Charnes et al., 1978), the methodology is one of the most accepted and widely used in the economic efficiency studies.

From the pioneer work of Gillen and Lall (1997) an exponential growth of studies applying DEA methods in the airport industry has emerged, summarising more than 50 papers, especially from 2008. Just to mention some authors with regular presence in the literature: Martín and Roman (2001, 2007), Barros and Dieke (2007, 2008), Barros et al. (2012, 2013), Curi et al. (2008, 2010, 2011), Morrison (2009), Yiu and Wing (2011), Yiu et al. (2008a, 2008b) and Yu (2004, 2010a, 2010b). Lam et al. (2009) and Adler et al. (2013) offer recent literature reviews on DEA studies of airport efficiency.

Up to 2007, few works have focused on European airports (Murillo-Melchor, 1999; Parker, 1999; Martín and Román, 2001; Martín-Cejas, 2002; Pels et al., 2001; Barros and Sampaio, 2004; Martín and Roman, 2007). But Since 2008 to date it is possible to find more than 20 studies which have mainly covered cases such Spain (Tapiador et al., 2008; Lozano and Gutiérrez, 2011), Italy (Barros and Dieke, 2007, 2008; Curi et al., 2008, 2010, 2011; Gitto and Mancuso, 2012), and, in few cases France (Barros et al., 2013) and Noruega (Merkert and Mangia, 2012).

Over the last years the scenario of the airport industry has evolved, becoming more business-oriented and being more pressure to operate efficiently. In fact, greater elasticity in managing business operations has been legislated and important modifications have been introduced in national and international regulations according to a market-oriented perspective (Gillen, 2011; Graham, 2008; Doganis, 1992). On the other hand, demand for air travel in 2012 grew slowly following a relatively strong 2011 that was highlighted by improving consumer confidence and falling unemployment, despite continuing pressure of debt restructuring in Europe and the USA (FAA, 2013).

More recently, one of the main innovations refers to the growing attention given towards the development of the 'non-aviation' dimension in the context of general airport business activities (Graham, 2003; Halpern et al., 2012 and see Fasone et al., 2012; Fasone and Maggiore, 2012; Fasone and Scuderi, 2012 for the case of Italian airports). Given the mentioned factors and the fact that last studies concerning Italian context cover the period 2000 to 2006, the main goal of this work is to provide current evidences about Italian airports efficiency within the mentioned context, and to obtain results that can provide airport operators key useful information for improving their infrastructures by benchmarking them against similar airports. To achieve this objective, we construct and estimate a DEA in order to obtain efficiency scores for 14 airports for the period 2009–2011. In addition, we use a Malmquist Index for measuring the evolution of the productivity of individual airports along the time, and finally, a superefficiency model is applied in order to discriminate between the efficient units.

The remainder of the paper is organised as follows. The section that follows presents a review of the Italian benchmarking studies. Section 3 provides a description of the data and presents some summary statistics. Section 4 explains the methods that are used in the study to measure efficiency and productivity change. The major results are discussed in Section 5, Section 6 concludes the paper.

2 Review of the Italian context

Regarding our geographical scope, in this paper very few works have used DEA as the technique to evaluate Italian airports efficiency as presented in Table 1.

Table 1 Research studies on Italian airports efficiency

Authors	*Methodology*	*Units – period*	*Inputs*	*Outputs*	*Main results*
Barros and Dieke (2007)	Multiple DEA Models (cross-efficiency and the super-efficiency); Mann–Whitney U-test in the second stage to test some hypotheses	31 airports; 2001–2003	Labour cost, capital invested, operational costs excluding wage costs	Number of planes, number of passengers, general cargo, handling receipts, aeronautical sales and commercial sale	On average, almost all airports authorities operated at a high level of pure technical efficiency and displayed scale efficiency. Airports technically efficient at CRS present also technical efficiency at VRS
Malighetti et al. (2007)	DEA, Malmquist index	34 airports; 2005–2006	ATM model: airport area, length of runway, number of aircraft parking positions APM model: terminal surface, number of check-in desks, number of aircraft parking positions, number of lines for baggage claims	ATM model: number of aircraft movements APM model: number of passenger movements	Airports exhibit better results in the management of passengers' movements rather than aircraft movements. In the ATM model, a lot of inefficiencies are presented in small and regional airports while larger ones are close to saturation.
Barros and Dieke (2008)	DEA – Simar and Wilson procedure (used to bootstrap the DEA scores with a truncated regression)	31 airports; 2001–2003	Labour cost, capital invested, operational costs excluding wage costs	Number of planes, number of passengers, general cargo, handling receipts, aeronautical sales and commercial sale	Contextual variables that determine the efficiency on Italian airports are *hub* and *private operation management* Also, parameters such WLU and belong to the north part of the country increase efficiency.
Curi et al. (2008)	DEA	19 airports; 2000–2004	Cost of labour, runway area, residual (non-labour, non-capital) operating costs	Number of aircraft movements, number of passengers, freight cargo	Ten airports on the efficiency frontier, at least one of the five years. Concerning returns to scale, six airports should consider an expansion given their operation in the area of increasing returns to scale. Seven airports operate in the area of decreasing returns to scale

Table 1 Research studies on Italian airports efficiency (continued)

Authors	*Methodology*	*Units – period*	*Inputs*	*Outputs*	*Main results*
Curi et al (2010)	A bootstrapped DEA/Simar and Wilson procedure	36 airports; 2001–2003	Labour costs, capital invested and operational costs	physical and financial variables: number of planes and passengers, tons of cargo, aeronautical sales, handling receipts and commercial sales	Airports are in capacity to improve their technical efficiency by making a better allocation of their inputs. Airports holding a total concession agreement show better efficiency scores than those holding a partial one.
Curi et al (2011)	A bootstrapped DEA/Simar and Wilson procedure	18 airports; 2000–2004	Employees (units), Number of runways (units), Apron size (m2)	Number of movements (units); Number of passengers (units); Amount of cargo (tones)	Airport size is not an enough factor for improving operational efficiency levels given both regional and national airports present similar results to those observed for the two national airport systems.
Gitto and Mancuso (2012)	A bootstrapped DEA/Simar and Wilson procedure	28 airports; 2000–2006	Labour cost, capital invested, soft costs	Number of movements (aircraft landing and taking off) and number of passengers	Total concessions positively affect the level of efficiency for non-airside operations. Airports managing more than 2 million of passengers improved their level of physical efficiency thanks to the liberalisation of ground handling.

One of the first studies known (Barros and Dieke) dates back to the 2007. Authors assessed 31 airports relying on a combination of financial and operational balanced panel data for the period 2001-2003. With an output orientation, researchers applied four DEA models, these are, CCR, BCC, Cross-efficiency DEA and super-efficiency DEA. Inputs used are operating and capital-related while outputs are physical and financial-related. Main results of the analysis may be summarised as follows:

1 there are many airports on the efficiency frontier

2 almost all airports operate at a high level of pure technical efficiency (TE)

3 the airports technically efficient at CRS (constantan return to scale) present also TE at variable return to scale (VRS) and this is, the central source of efficiency is scale

4 under the BCC model, pure TE is attributable to management skills which resulting 26 efficient airports and 3 inefficient signifying that the majority of airports are well managed.

From the results of the cross-efficiency and super-efficiency DEA, authors test some hypothesis from the efficiency scores. Findings in this regard reveal smaller airports tend to have lower scores than larger ones (in line with Murillo-Melchor, 1999); public airports have lower scores than private ones; also, the higher work-load unit (WLU) of airports the higher efficiency scores.

Malighetti et al. (2007) apply a DEA approach under a constant return to scale (CRS) and a VRS to 34 Italian airports for the period 2005–2006. The analysis is divided into two perspectives: ATM (aircraft movements) frontier and air passengers' movements (APM) frontier. Results for the first one report, nine airports on the VRS frontier (between small and large airports); inefficiency is presented in smaller airports where capacity is spare while larger ones are working at 100% of capacity or close it. Regarding returns to scale, airports that exhibit increasing are Bergamo, Catania, Naples; on the other hand, there are those reporting decreasing such Rome-Fiumicino, Milan-Malpensa, Venice, Palermo and the rest of great and small regional airports. Only Linate and Cagliari presented an optimal scale since they have constant returns to scale. Regarding the second perspective, APM, on average, all airports have TE and scale efficiency (SE) being the scores higher than ATM model ones. This suggest Italian airports are more efficient when managing passengers rather than aircraft movements. As in the ATM model, a lot of inefficiencies are presented in small and regional airports while larger ones are close to saturation. Regarding returns to scale, airports that exhibit increasing are Milan-Linate, Naples, the majority of great regional airports and all the smaller ones. In contrast, Milan-Malpensa and Venice reveal decreasing returns to scale. On the other side, Rome-Fiumicino, Bergamo, Catania, Palermo and Rome-Ciampino present the most favourable scale (CRS). From these results, authors suggest that smaller airports should increase the number of passengers in order to get better capacity utilisation. This will increase the operation scale allowing obtaining further benefits of lower average costs.

Barros and Dieke (2008) include in their DEA analysis the Simar and Wilson two-stage procedure as an alternative to improve methodologies using DEA. As in Barros and Dieke (2007) the sample corresponds to data from 31 Italian airports for the period 2001-2003. Efficiency scores are presented for both models CCR and BCC. According to their truncated bootstrapped two stage regression, the contextual variables that determine the efficiency on Italian airports are *hub* and *private operation management*. As pointed by Gillen and Lall (1997), Sarkis (2000), Malighetti et al. (2007) and Fung et al. (2008), airports operating as a hub increase the efficiency. The use of the variable private operation management is a difference with Parker (1999) study. Also, parameters such work load unit (*WLU*) and *belong to the north* part of the country increase efficiency.

Curi et al. (2008) choose an output-oriented model in which efficiency for 19 Italian airports (period 2000–2004) is analysed by taking into account CRS, VRS and SE. Their analysis reports ten airports on the efficiency frontier, at least one of the five years. Naples is the only that appears the whole period on the frontier, followed by Bergamo, Pescara and Trapani with four out of five years. Concerning returns to scale, the analysis evidences that Bologna, Alghero, Lamezia, Pescara, Trapani and Verona should consider an expansion given their operation in the area of increasing returns to scale. On the other side, seven airports operate in the area of decreasing returns to scale: Ancon, Genoa, Palermo, Pisa, Rome-Fiumicino/Ciampino, Turin and Venice. Regarding the trend considering VRS envelopment surface, ten airports improve or remain their efficiency given they are already efficient. With respect to the efficiency scale, Bergamo, Catania, Milan-Linate/Malpensa and Naples are the unique operating in this condition. In general terms, during the period studied, authors conclude that great part of the Italian airports improve their own efficiency both technical and SE.

Curi et al. (2010) use a panel data from 36 Italian airports (2001–2003) in order to evaluate the effects of the government policy about concession agreements, privatisation and network configuration on the performance of national airport industry. Authors apply a two-stage DEA with bootstrapping. In the first stage two DEA models are run, revealing from one side that they are in capacity to improve their TE by making a better allocation of their inputs. On the other side, lower efficiency averages are found in the model 2. Also results show variation between both models for the case of Genoa and, draw the attention on the performance of Rome and Milan. The latter airports operate as hub and this is a factor that, in different studies has proved to be one of the efficiency determinant as shown in Gillen and Lall (1997), Sarkis (2000), Malighetti et al. (2007), Barros and Dieke (2008) and Fung et al. (2008). Regarding the results of the truncated model authors consider that in the period analysed, Italian airports improve their investments of capital. Airports holding a total concession agreement show better efficiency scores than those holding a partial one. And when the majority ownership is public, airports tend to be more efficiency than private ones.

Again, Curi et al. in 2011, contrast the performance of 18 Italian airports under a physical and a financial perspective for the same period, 2000–2004. After run a bootstrapped DEA, authors find that airport size is not an enough factor for improving operational efficiency levels given both regional (Bergamo, Bologna, Napoli, Turin and Verona) and national (Catania and Venice) airports present similar results to those observed for the two national airport systems (Milan Linate/Malpensa and Rome Ciampino/Fiumicino). Under the physical perspective it is found that Bergamo shows the highest average but a moderate level under the financial perspective. Genoa shows a negative performance concerning the capacity to exploit efficiently its airside and landside infrastructures.

Finally, Gitto and Mancuso (2012), following the same methodology from Curi et al. (2011), covering the period 2000–2006. Results show a progressive decreasing regarding physical operations along the period. The best level both in physical and financial activities are reported to Cagliari airport. After applying a bootstrapped estimation, main conclusions indicate that total concessions positively affect the level of efficiency for non-airside operations. Airports managing more than two million of passengers improved their level of physical efficiency thanks to the liberalisation of ground handling. Lastly, seasonality in passengers' movements negatively contributes both to the physical and financial measures.

3 Data

Forty-six commercial airports are registered in the Italian Statistical Register of Air Transportation. Source of considered data is the National Authority for Civil Aviation. With the aim to analyse the productivity growth and evaluate the economic performance of airports in Italy during the period 2009–2011 by considering their relative technical efficiencies, only 'total concession' airports were considered. Accordingly 25 Italian airports were identified.

Thus, this 'judgmental sampling' reduces the population from 46 (total commercial airports) to 25 (airports in 'total concession'). A judgmental method uses a non-probabilistic sampling technique and it is often used to obtain illustrative outlines of specific realities through the use of particularly representative cases (Saunders et al., 2003). Judgmental sampling design is usually used when a limited number of units possess the trait of interest such as in this specific case of total concession airports. It is the only viable sampling technique in obtaining information from a very specific group of units.

Within the 25 total concession airports due to availability of data 14 units are included in the research. The units in the sample have covered on average 86.6% of the total number of passengers, 94% of cargo and 84% of ATM. Moreover, they reached, in the same period, 87% of WLUs.

Table 2 List of selected airports

	Airports	
No.	*Company*	*Airport*
1	AdF	Florence
2	AdG	Genova
3	AdP	Puglia
4	AdR	Rome
5	GEASAR	Olbia
6	GESAC	Naples
7	GESAP	Palermo
8	SAB	Bologna
9	SAC	Catania
10	SACBO	Bergamo
11	SAGAT	Turin
12	SAT	Pisa
13	SAVE	Venice
14	SEA	Milan

In addition, as shown in Table 2, 14 airport companies were considered, because of some airports are managed by the same company, AdR (Roma), SEA (Milano) and AdP (Puglia) are 'multi-airport companies' (i.e., these companies manage more than one airport).

Moreover, frontier models require the identification of inputs and outputs. Several criteria can be used in the selection. The first empirical criterion is the availability of inputs and outputs. Second, a literature survey can provide supporting evidence as can the professional opinion of the airport managers.

In this analysis, we include three inputs and three outputs. The inputs are:

- *Labour:* annual number of hours of labour, expressed in full time equivalent (FTE).
- *Gates:* number of gates at the airport.
- *Assets:* total value of the assets of the airport, expressed in Euros. It should be mentioned that the inclusion of this variable slightly modifies the interpretation of the results. Thus, when we analyse TE, it must be interpreted as a combination of technical and allocative efficiency.

On the other side, the outputs are:

- *passengers:* annual number of passengers at the airport
- *cargo:* annual tons of cargo at the airport
- *air transport movements:* annual number or air transport movements at the airport (departures and landings).

4 Methodology

DEA is a data-oriented approach for evaluating the performance of a set of entities called decision making units (DMUs) which convert multiple inputs into multiple outputs. DEA is a methodology directed to frontiers and proves particularly adept at uncovering relationships that remain hidden from other methodologies (Cooper et al., 2011).

The initial DEA model was originally presented by Charnes, Cooper, and Rhodes (CCR) (1978), and was based on the earlier work of Farrell (1957). The purpose of the DEA is to construct a non-parametric frontier on benchmarks, such that all observed points remain on the frontier of production or below. Efficiency of each DMU is obtained from a measurement of the ratio of all outputs on all inputs. This involves finding the values of the weights for each input and each product, so that efficiency of each DMU is maximised, subject to the constraint that all efficiency measures must be less than or equal to one.

Formally, we assume that each DMU have K inputs and M outputs. The i^{th} DMU will be represented by the vectors x_i and y_i. The matrix (K × N) of inputs and (MxN) of outputs represent the data of the N DMUs. As mentioned, the efficiency of each DMU is obtained from a measurement of the ratio of the outputs relative to the inputs, $u' y_i / v' x_i$ where u is the vector of dimension $M \times 1$ of the output weights and v is the vector of dimension $K \times 1$ of the input weights. The linear programming problem to find the optimal weights can be defined as follows:

$$Max_{u,v}\left(u'y_i/v'x_i\right)$$

subject to

$$u'y_j/v'x_j \leq 1, \ j = 1, 2, \ldots, N$$

$$u, v \geq 0$$

It seeks to determine the values of *u* and *v* that maximise the efficiency of the i^{th} DMU, incorporating at the same time the constraint that efficiency measures of each DMU are less than or equal to 1. However, this formulation has a drawback linked to the existence of infinite solutions. This problem is solved from the incorporation of the restriction $vx_i = 1$. Thus, the problem will be formulated as:

$$Max_{u,v}\left(u'y_i\right)$$

subject to

$$v'x_i = 1$$

$$\mu'y_j - v'x_j \leq 0, \ j = 1, 2, \ldots, N$$

$$\mu, v \geq 0$$

The change in the notation *u* and *v* to μ and *v* is justified by the transformation of the optimisation process to avoid infinite solutions. This way of defining the problem is known as the multiplier form of linear programming problem (Parra-Rodríguez, 2007).

For the purposes of calculation and interpretation of the results, it is convenient to define the problem in its dual form in which it is defined as:

$$Min_{\theta,\lambda}\theta$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0$$

θ is a scalar and λ a vector of dimension $N \times 1$ of constants. The obtained value of θ is the efficiency of the ith DMU and will be between 0 and 1, taking, as mentioned, a value of 1 if the DMU is on the frontier, that is, if it is technically efficient.

The original CCR model supposes the existence of CRS. The CRS assumption is only appropriate when all DMU's operate on an optimal scale. In imperfect competition, it may be that the DMUs do not work on the optimum scale. Banker et al. (1984) suggested an extension of the CRS DEA model to explain the situations with VRS. This model, known as BCC, adds to the CCR model a convexity restriction. Formally, we define the problem as:

$$Min_{\theta,\lambda}\theta$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

$N1$ is a vector of dimension $N \times 1$ of ones. Many studies have decomposed the scores obtained from a VRS DEA into two components, one due to scale inefficiency and one due to 'pure' technical inefficiency. This can be done applying a CRS model and a VRS model on the same data. If there is a difference in the two scores for a particular DMU, this indicates that the DMU has scale inefficiency, and this inefficiency can be calculated as the ratio between the VRS score and the CRS score.

The CCR and BCC models are useful to identify the inefficient DMUs but are weak in discriminating among the efficient ones (Barros, 2006). Andersen and Petersen (1993) propose a classification method of the efficient units, which consists of comparing the DMU being evaluated (DMU 0) with a linear combination of all sample units where the DMU 0 is excluded. Thus, it is possible that an efficient unit may increase proportionately their inputs and remains efficient, obtaining in this case the DMU under consideration a score greater than unity. For this reason, the method is known as superefficiency (Coll Serrano and Blasco Blasco, 2006).

In addition to analysing the relative efficiency of different organisations, it is important to consider the productivity growth, since it is one of the bases of the increase in real income and welfare improvement. Therefore, the level and the increasing productivity are particularly important economic indicators. Malmquist (1953) presents alternative methods for measuring the evolution of productivity, which have three main advantages over more traditional ones:

1 they do not require assumptions about the behaviour of the DMUs under analysis

2 there are based on distance functions, so inputs and outputs prices are not required

3 they may decompose elements that explain the causes of productivity change (Parra-Rodríguez, 2007).

Thus, it is possible to use linear programming DEA to measure the change of the production activity, through the Malmquist index. This index allows, at the same time, to classify the productivity change into technological change and TE change.

A final issue that should be mentioned regarding DEA models is related to the fact that, to solve the linear programming problem, it is necessary to specify the orientation of the system (inputs or outputs). As a general rule, in competitive markets DMUs are output- oriented, since inputs are under the control of the DMU. On the contrary, when we are facing monopolistic markets, the DMUs are considered input-oriented, since the output is endogenous (Barros, 2006). In the case under review (Italian airports), each DMU decides on inputs, while outputs are exogenous variables, so we chose to conduct an output-oriented analysis.

5 Results

5.1 CCR, BCC and superefficiency models

We estimate an output-oriented DEA model for the mentioned years, assuming that airports maximise profits. When estimate BCC model, i.e., assuming the existence of variable returns, it is possible to decompose TE into two components: pure TE and SE. The VRS ratio indicates pure TE while the CRS ratio combines the pure TE and the SE.

Table 3 shows the results of applying the CCR and BCC models. We see that there are five airports that have worked efficiently in the period under review: Genoa, Rome, Naples, Bergamo and Bologna. These airports are located to big cities and distributed geographically three in the North part of Italy, one in the centre part and other in the south. Here we can note that it seems there is no connection between airports efficiency and tourism passengers' flows.

Moreover, there are also some airports as Puglia, Venice and Olbia operating in its optimal scale but that present problems of pure TE. A case that deserves special attention is Milan MPX-LIN Airports. These airports work with pure TE but exhibits significant problems of scale, which puts it far from functioning efficiently. The rest of the airports in the sample generally exhibit both pure technical and scale inefficiency. We will consider these cases when we introduce Malmquist analysis later.

Table 3 CCR and BCC scores (2009 to 2011)

Airport (DMU)	*Year*	*CCR score*	*BCC score*	*Scale efficiency*	*Returns*	*Average pure technical efficiency (rank)*	*Average scale efficiency (rank)*
Bergamo (BGY)	2009	1.000	1.000	1.000	Constant	1.000 (1st)	1.000 (1st)
	2010	1.000	1.000	1.000	Constant		
	2011	1.000	1.000	1.000	Constant		
Bologna (BLQ)	2009	0.940	0.960	0.979	Increasing	0.987 (6th)	0.993 (6th)
	2010	1.000	1.000	1.000	Constant		
	2011	1.000	1.000	1.000	Constant		
Catania (CTA)	2009	0.812	0.866	0.937	Increasing	0.889 (8th)	0.959 (11th)
	2010	0.834	0.865	0.963	Increasing		
	2011	0.915	0.935	0.978	Decreasing		
Florence (FLR)	2009	0.784	0.784	1.000	Constant	0.804 (12th)	0.945 (12th)
	2010	0.650	0.650	1.000	Constant		
	2011	0.817	0.978	0.834	Decreasing		
Genoa (GOA)	2009	1.000	1.000	1.000	Constant	1.000 (1st)	1.000 (1st)
	2010	1.000	1.000	1.000	Constant		
	2011	1.000	1.000	1.000	Constant		
Milan (MXP-LIN)	2009	0.724	1.000	0.724	Decreasing	1.000 (1st)	0.734 (14th)
	2010	0.746	1.000	0.746	Decreasing		
	2011	0.733	1.000	0.733	Decreasing		

Table 3 CCR and BCC scores (2009 to 2011) (continued)

Airport (DMU)	*Year*	*CCR score*	*BCC score*	*Scale efficiency*	*Returns*	*Average pure technical efficiency (rank)*	*Average scale efficiency (rank)*
Naples (NAP)	2009	1.000	1.000	1.000	Constant	1.000 (1st)	1.000 (1st)
	2010	1.000	1.000	1.000	Constant		
	2011	1.000	1.000	1.000	Constant		
Olbia (OLB)	2009	0.767	0.767	1.000	Constant	0.821 (11th)	1.000 (1st)
	2010	0.885	0.885	1.000	Constant		
	2011	0.811	0.811	1.000	Constant		
Palermo (PMO)	2009	0.966	1.000	0.966	Increasing	0.970 (7th)	0.971 (10th)
	2010	0.869	0.937	1.000	Increasing		
	2011	0.923	0.973	0.948	Decreasing		
Pisa (PSA)	2009	0.949	1.000	0.949	Increasing	0.858 (9th)	0.972 (9th)
	2010	0.739	0.754	0.980	Increasing		
	2011	0.807	0.819	0.986	Increasing		
Puglia (BRI-BDS-FOG-TAR)	2009	0.765	0.769	0.995	Increasing	0.854 (10th)	0.988 (8th)
	2010	0.830	0.855	0.970	Increasing		
	2011	0.938	0.939	0.999	Increasing		
Rome (FCO-CIA)	2009	1.000	1.000	1.000	Constant	1.000 (1st)	1.000 (1st)
	2010	1.000	1.000	1.000	Constant		
	2011	1.000	1.000	1.000	Constant		
Turin (TRN)	2009	0.624	0.706	0.884	Increasing	0.672 (14th)	0.913 (13th)
	2010	0.578	0.653	0.884	Increasing		
	2011	0.638	0.657	0.970	Increasing		
Venice (VCE)	2009	0.682	0.682	0.999	Increasing	0.699 (13th)	0.992 (7th)
	2010	0.658	0.660	0.996	Increasing		
	2011	0.748	0.756	0.982	Increasing		

Table 4 shows the result of the suppereficiency models for the sample (2009 to 2011). We include only the results of the efficient airports because this model rescales the coefficients of the efficient airports keeping with the same value the coefficients of the non-efficient DMUs.

Table 4 Superefficiency scores (2009 to 2011)

Airport (DMU)	*2009*	*Rank*	*2010*	*Rank*	*2011*	*Rank*
Bergamo	3.768	1	3.035	1	2.954	1
Bologna	0.940	5	1.004	5	1.042	5
Genoa	1.435	2	1.559	2	1.750	2
Naples	1.352	3	1.124	4	1.196	3
Rome	1.113	4	1.126	3	1.112	4

We can see that clearly Bergamo airport is, within the set of efficient airports, which has better performance along time. This shows the excellent management of its resources performing this airport. Moreover, Bologna airport, although being efficient, it is the one with worst performance in this group.

As mentioned, it may be of interest to consider the evolution of the productivity of individual airports along the time. This analysis will be done following by applying Malmquist index.

Table 5 Malmquist Index evolution (2009 to 2011)

Airport (DMU)	*Year*	*TFP Malmquist index*	*Technical efficiency change*	*Technological change*	*Pure technical efficiency change*	*Scale efficiency change*
Bergamo	2009/10	0.992	1.000	0.992	1.000	1.000
	2010/11	1.010	1.000	1.010	1.000	1.000
Bologna	2009/10	0.938	0.940	0.998	0.960	0.979
	2010/11	1.031	1.000	1.031	1.000	1.000
Catania	2009/10	0.969	0.973	0.996	1.001	0.972
	2010/11	0.911	0.911	0.999	0.925	0.985
Florence	2009/10	1.260	1.205	1.045	1.130	1.066
	2010/11	0.843	0.796	1.059	0.886	0.897
Genoa	2009/10	0.990	1.000	0.990	1.000	1.000
	2010/11	0.995	1.000	0.995	1.000	1.000
Milan	2009/10	0.912	0.970	0.940	1.000	0.970
	2010/11	0.963	1.017	0.947	1.000	1.017
Naples	2009/10	1.004	1.000	1.004	1.000	1.000
	2010/11	1.043	1.000	1.043	1.000	1.000
Olbia	2009/10	0.899	0.866	1.037	1.041	0.832
	2010/11	1.164	1.090	1.067	0.915	1.190
Palermo	2009/10	1.138	1.111	1.024	1.066	1.042
	2010/11	0.975	0.941	1.036	0.962	0.977
Pisa	2009/10	1.227	1.283	0.956	1.326	0.968
	2010/11	0.907	0.915	0.992	0.920	0.993
Puglia	2009/10	0.894	0.922	0.970	0.899	1.025
	2010/11	0.944	0.885	1.066	0.911	0.971
Rome	2009/10	0.938	1.000	0.938	1.000	1.000
	2010/11	0.978	1.000	0.978	1.000	1.000
Turin	2009/10	1.063	1.079	0.985	1.079	0.999
	2010/11	1.000	0.906	1.103	0.993	0.912
Venice	2009/10	0.997	1.036	0.962	1.033	1.003
	2010/11	0.882	0.879	1.003	0.873	1.007

5.2 Malmquist model

As we mention, Malmquist index measures the change of the total factor productivity (TFP). At the same time, it allows us to divide the productivity change into technological change and TE change. This efficiency change can also be divided in pure TE change and SE change.

This analysis is relevant in our case due to the importance of the TPF in the operation of the airports today. The possibility of evaluate this productivity and of divide it into different components is a very useful tool in this sense. Although we are considering in the analysis only three years, the dynamic characteristics of the airport industry allow us to obtain relevant conclusions.

As each airport exhibits a particular evolution in the productivity, we will consider each case individually. The results of the application of Malmquist index to Italian airports is presented in Table 5.

First, we will consider the case of Bergamo. Being one of the airports located in the frontier, it shows a constant productivity along time, with just a little reduction in technology between 2009 and 2010. Bologna, Genoa and Naples show a similar performance, having also a constant productivity along time.

Catania airport suffers for all the period (from 2009 to 2011) a decrease in productivity, particularly produced by a reduction in TE (pure and scale). Florence airport shows an increase in the productivity from 2009 to 2010. This increase is produced mainly by an improvement in the TE, in particular in the pure TE. On the other hand, from 2010 to 2011 this airport presents a decrease in the productivity produced by a reduction in TE (pure and scale). Furthermore, Milan airports have a permanent decreasing in their productivities caused mainly by a negative change in technology.

Olbia, Palermo and Pisa airports present a particular behaviour. Their productivities vary irregularly from 2009 to 2011 emerging from TE changes, both pure and scale. Puglia airport has a permanent decreasing in the TFP, caused by a reduction in TE and, particularly, in pure TE. In the case of Roma airport, we can see a small reduction in productivity along time, caused totally by a negative technological change. In spite of that, this airport, one of the most important in the world, remains in the frontier, being one of the most efficient airports of Italy. Finally, Venice airport has a permanent decreasing in the productivity, caused by technological changes from 2009 to 2010 and by changes in pure TE from 2010 to 2011.

6 Conclusions

In this paper we consider the efficiency of Italian airports for the period 2009–2011 using DEA. First, we consider the efficiency of airports in each year, assuming alternatively the existence of constant and decreasing returns. Subsequently, we analyse the evolution of the productivity of each airport along time through Malmquist index.

The results show that Italian airports operate efficiently, being located most of them on the frontier or close to it. Particularly, Genoa, Rome, Naples, Bergamo and Bologna exhibit the best practices when distributing efficiently their production factors available to face an increasing in the demand, keeping this behaviour during all the period under study. These airports are efficient considering both CRS and VRS, indicating that scale is the prevailing source of efficiency. In particular, given that in the BCC model, pure TE is linked to management skills (Barros and Dieke, 2007) it can be stated these airports are well managed.

These results exhibit some coincidences with those found in the previous reviewed studies. It is the case of Bergamo, since 2000 up to now the airport has shown to be technically efficient. The expansion of its operation has been strategically managed. Recent investments (i.e., the enlargement of arrivals area and departure zone) have boosted passengers figure to 8.338.656 in 2011, being one of the busiest airports in Italy. Other reasons could explain its remarkable performance can be linked to the fact of being a popular airport for low-cost carriers including Wizz Air and Ryanair, which operates a large base at the airport; also the airport operates with a relative small infrastructure and few capital.

Regarding Naples it seems its private management continues keeping the airport operations on the right way (Curi et al., 2008). From a cost perspective, this airport can allow itself further investments in order to increase passengers' movements without incurring on increases of average costs. In the case of Rome keep benefiting from the fact of being the main international hub in the country.

Excluding Barros and Dieke (2007) study, our results regarding Genoa differ from the rest of the precedent studies, which revealed efficiency values under the unity in the period 2000-2006. This airport was far from the efficiency frontier in spite of its increase in the number of passengers. These new results can obey to a better management of the inversions made by the airport, which leads to a notorious decreasing in average costs.

Regarding scale, it would be feasible to exploit the increasing returns to scale for increasing the level of its operation both Puglia and Venice airports. In the case of Puglia airports, consistently with its specific configuration, under the management of a single legal entity the company manages a complex multi-airport system that results in a step of strong growth. This evolutionary trend has occurred since 2003 and significant growth rates in passenger traffic have been registered. In 2009, the indicator that measures the number of aircraft movements amounted to 44,395 between landings and take-offs, the number of passengers almost 4 million units and transport of cargo, 3,400 tons (ENAC, 2010). In the last few years, AdP's management has tried to anticipate the corporate collapse of national carrier (i.e., Alitalia airlines) by developing the supply of air mobility from Puglia airports of type 'point to point', with the gradual implementation of a low cost fares structure in domestic and international routes, to the detriment of the management model 'hub and spoke' of Alitalia that for example favoured in the recent past the transition from the airports of Rome-Fiumicino and Milan-Malpensa.

With regard to Milan airports, Malpensa exhibits significant problems of scale and this puts it far from functioning efficiently. This could be the result of a not well careful evaluation of its capacity expansion.

Airports operating in the condition of increasing return to scale are Pisa, Puglia, Turin and Venice. These airports should consider the expansion in order to reach their optimal level of efficiency. Airport operators want to implement strategies so that increase the movements of passengers (Curi et al., 2008). Among these airports, Puglia and Venice are the closest to the efficiency of scale.

Additionally, as explained below, superefficiency method indicates that, within the set of efficient airports, Bergamo is the airport which has better performance along time. Possible reasons for these results were mentioned above.

Regarding the analysis of productivity over time, the results are dissimilar. While some airports have a positive trend in productivity, others suffer a fall over time, being the reasons of these changes also different in each case.

As a main limitation of this study, it should be noted that the sample is heterogeneous *per se* in different aspects. For instance it includes two international hubs of Milan and Rome and its spokes. Moreover three companies (SEA SpA, AdR SpA, SEAP SpA) manage more than one airport. This concerns the two hubs (Fiumicino and Malpensa), which are administered respectively with a low-cost carrier airport (Ciampino) and an additional structure that is mainly utilised by domestic and EU flights (Linate). Puglia Airports Company controls four airports that are located in different areas of the same administrative region (Puglia), but they are directed to the same traveler 'target' since the mix between low cost and standard airlines is substantially similar, and the destination of flight is domestic and EU airports. Finally, other elements of diversity are also related to traffic volume, dimensions, composition of flights (domestic, EU, international), relevance of low cost carriers, number and quality of transportation, links to urban centres, the average consumer's characteristics (e.g., business vs. tourists), etc. In particular some airports have been interested by a significant raise of passengers due to low cost flights. This aspect of modern civil aviation was considered as one of the sources of time variability in all airports.

Thus, the contribution of this paper is twofold: first, to the literature it presents the first analysis of Italian airports in which DEA and Malmquist index are both used by considering on the input side also financial assets. Second, due to the dissimilar results for each single airport it seems to propose the use of an *ad hoc* approach in order to manage in a better way the various infrastructures existing in the Italian country and this it should help to assess the consequences of specific managerial recommendations in order to improve the efficiency of firms.

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