Efficiency in Italian Airports Management: The Implications for Regulation

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Abstract

In this paper we apply an input oriented DEA model to study the efficiency of Italian airports. Two output dimensions have been considered: the aircraft movements and the passenger movements. Concerning the aircraft movements, only 30% of the airports are efficient and 74% exhibit increasing returns to scale. The Malmquist index relating to productivity scores show that the average total factor productivity change is -0.04%. When instead passenger movements are considered we observe a higher efficiency: the number of efficient airports is greater (48%) and the Malmquist index is equal to 0.3%. Since both productivity indeces are higher than the level observed for the whole Italian economy, we can argue that the airport management sector seems to be more efficient than the Italian average.

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1 Introduction

The air transportation sector has shown important developments during the last decades. Both the regulators and the players have introduced several changes that make this sector particularly dynamic and with interesting future perspectives. On the regulation side, several successive decisions have opened the market to new comers, have increased the effective competition among incumbent firms, and have adopted more efficient regulation schemes to compute airports" fares. On the players side, new business models have deeply renewed the competitive arena, especially with the appearance and progressive strengthening of the low cost carries.

In this new context both the airports management and pricing play a crucial role. On the one hand, the new regulation approaches, mainly based on price cap methods, help to develop a pricing more oriented to efficiency, and to start a phase of competition between airports. Within a given area both passengers and freights show a sufficiently high propensity to move, and so an airport has to chance, by charging lower fares than its local competitors, to modify the carriers decisions and to increase the its number of connections supplied. On the other hand, this competitive trend may be induced by an effective regulation scheme, where airports have an incentive to improve the their efficiency, and, through it, to increase both their profit margins and market shares. However, an effective regulation needs a severe assessment about each airport efficiency status. In this way both the airports and the regulator know the best practices over various dimensions of airport operations within the industry, and how their performance compare to the best industry practices.

These issues are particularly relevant for the Italian air transportation market, which represents the fourth one at an European level, and where a price cap regulation has recently been introduced. The CIPE Act 86/2000 and the Law 248/2005 have set up a new regulatory framework, where each airport need to adopt costs accounting procedures inspired to transparency criteria, and where fares for take offs, landings, passengers, freights and security activities are set in a public contract, covering five years. The new fares will change during this period according to the difference between the general economy inflation rate and an efficiency target. The latter is estimated by the regulator, and it is based on each airport features and its benchmarking with the other airports. These considerations point out the goal of this paper: to assess the current efficiency in management of Italian airports and to present a method to compute the efficiency targets for the regulation period.

The efficiency in the airports' management has been investigated by several contributions. Gillen and Lall [1997], Sarkis and Talluri [2004] and Oum and Yu [2004] have studied efficiency in the US market, Pels *et al.* [2003] have run a research on the European market. The analysis of the UK airports has been conducted by Parker [1999], while the contributions of Yoshida [2004] and Yoshida and Fujimoto [2004] regard the Japanese market. Australian airports have been investigated by Hooper and Hensher [1997] and Abbott and Wu [2002], while Pacheco and Fernandes [2003] have analyzed the case of Brazilian airports. All these studied have identified a production frontier using a non parametric method (the Data Envelopment Analysis—DEA) and have assessed different performances.[1] To the best of our knowledge this

[1] Martin–Cejas [2005] investigates the efficiency of Spanish airports using a traslog

paper is the first attempt to apply the DEA analysis to Italian airports.

We apply an input oriented DEA model to a sample of Italian airports (27 out of 37), specifying two output dimensions: the aircraft movements and the passenger movements. Our results are that many airports can improve their efficiency. Concerning the aircraft movements, only 8 Italian airports out of the 27 examined (about 30%), are located on the frontier, and 20 out of 27 (74%) exhibit increasing returns to scale. We have also found that among the 4 largest airports there is a prevalence of decreasing returns to scale in aircraft movements. The Malmquist indeces relating to productivity scores show that the average change in efficiency between 2005 and 2006 is equal to 2% and that the technological change is -2%. The average total factor productivity change is -0.04% (negative but higher than that observed for the whole Italian economy). When instead passenger movements are considered we observe an higher efficiency level. The average distance from the efficient frontier is lower than that observed for the aircraft movements, and the number of efficient airports is greater (13 out of 27, 48%). Only 14 airports have increasing returns to scale (55%), while 5 airports exhibit constant returns to scale (19%). Again we observe that the majority of the largest airports have decreasing returns to scale. The Malmquist indeces show an average efficiency change equal to 0.9%, and a technological change equal to -0.6%. The total factor productivity index is positive and equal to 0.3%. Hence we can argue that the airport management sector seems to be more productivity than the whole Italian economy, and that airports are more efficient in managing passenger movements rather than aircraft movements.

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function.

About 48% of the analyzed airports have a productivity increase between 2005 and 2006, while 9 out of 27 (33%) have a decrease in productivity. We have also computed the regulation target relating to efficiency on the basis of the obtained results. The average x–factor for the aircraft movement is 1.58%, while for the passenger movements is equal to 1.27%. These threshold levels may act as a maximum target for price cap regulation.

The paper proceeds as follows. In Section 2 we present the DEA model and the productivity measures adopted in this paper. In Section 3 we describe our data set and show some summary statistics about Italian airports. Our estimated results about the production frontier and productivity performances are reported in Section 4, while concluding comments are highlighted in Section 5.

2 The DEA model and productivity measures

The determination of the efficiency in the management of an airport involves the estimation of a production frontier, so that inefficiency is measured as the distance of an airport from that frontier. We adopt a non–parametric approach, a DEA model (see Gillen and Lall [1997]), where a sequence of linear programming problems creates a piecewise linear frontier, implicitly assuming that outputs can be fully explained from the inputs. Under the DEA model, the efficiency of an airport is estimated relative to the performance of other airports. Both input and output–oriented models can be estimated: an input oriented DEA model investigates how to produce a given output with the minimum level of inputs, while an output oriented one analyzes how to get the maximum output for a given level of inputs. The two models estimate the same frontier, but the efficiency measures of the inefficient decision making unit (i.e. a single airport) may be different. In this paper we focus on a input oriented DEA model, since we assume that the decisions concerning the output levels are out of control of the airports' management.

The DEA approach has two models: a Constant Return to Scale (CRS) model and a Variable Return to Scale (VRS) model. The VRS is useful to distinguish between Technical Efficiency (TE) and Scale Efficiency (SE), and it assumes that each airport is compared with other airports of similar size. A VRS DEA model input oriented maximizes weighted outputs over weighted inputs, subject to the condition that for every airport this efficiency is smaller than or equal to 1 (see Charnes *et al.* [1978]). Assume that there are L airports with m outputs and n inputs, then for an airport indexed as 0, the measure of efficiency is

$$\begin{aligned} Max_{u,v} \quad & \frac{\sum_{i=1}^{m} u_i y_{i,0}}{\sum_{j=1}^{n} v_j x_{j,0}} \\ s.t. \quad & 1 \geq \frac{\sum_{i=1}^{m} u_i y_{i,l}}{\sum_{j=1}^{n} v_j x_{j,l}}; \quad l = 1, ..., L \\ & u_i, v_j \geq 0 \end{aligned} \tag{1}$$

The maximization problem shown in (1) can have an infinite number of solutions, as shown by Coelli [1996].[2] The above problem has is equivalent to the following one, which, in addition, avoids the problem due to infinite solutions:

[2]Suppose that u^* and v^* are solutions to (1). Coelli [1996] showed that for any θ, also θu^* and θv^* are solutions to the same problem, so that, since θ cannot be identified, there is an infinite number of solutions.

$$
\begin{array}{lll}
Max_{u,v} & \sum_{i=1}^{m} \mu_i y_{i,0} & \\
s.t. & 0 \geq \sum_{i=1}^{m} \mu_i y_{i,l} - \sum_{j=1}^{n} v_j x_{j,l}; \quad l = 1, ..., L & \\
 & \sum_{j=1}^{n} v_j x_{j,0} = 1 & \\
 & u_i, v_j \geq 0 &
\end{array} \tag{2}
$$

The dual of the maximization problem (2) is the following one:

$$
\begin{array}{lll}
Min_{h,\lambda} & h_0 & \\
s.t. & \sum_{l=1}^{L} \lambda_l y_{i,l} \geq y_{i,0}; \quad i = 1, ..., m & \\
 & h_0 x_{j,0} - \sum_{l=1}^{L} \lambda_l x_{j,l} \geq 0; \quad j = 1, ..., n & \\
 & \sum_{l=1}^{L} \lambda_l = 1 & \\
 & h_0, \lambda_l \geq 0 &
\end{array} \tag{3}
$$

which is composed by $L + 1$ unknowns and a lower number of constraints, equal to $n + m$. For this reason this envelope problem is usually preferred to (2) and adopted in all the contributions mentioned before. The same approach is used in this contribution. The constraint $\sum_{l=1}^{L} \lambda_l = 1$ is included to the problem to distinguish between TE and SE. An intuition of this result is displayed in Figure 1. TE is given by the horizontal segment between the location of the generic decision making unit and the closest segment on the frontier. The latter coincides with h_0 in problem (3). SE is instead equal to horizontal segment between the linear combination on the VRS frontier corresponding to the unit 0, and the same linear combination on the CRS frontier. The latter is obtained as the solution of a problem similar to (3), and identifies only one efficient decision making unit. The idea is that

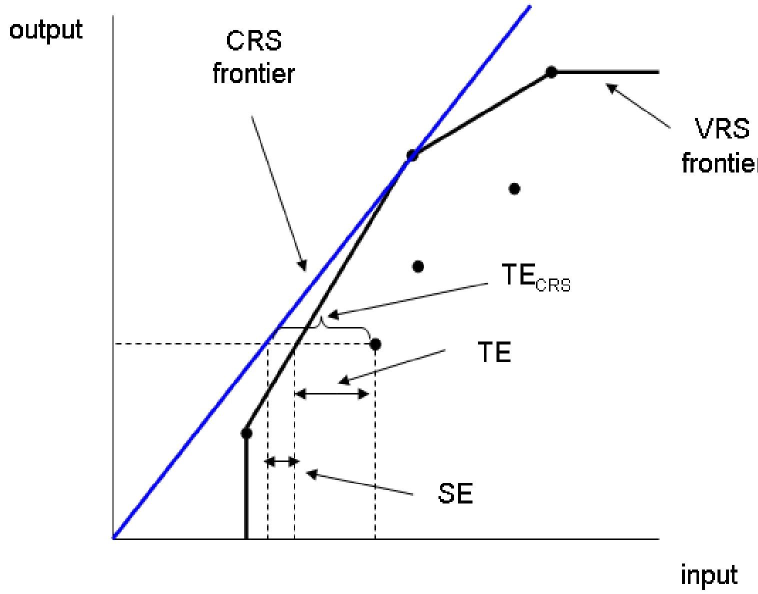

Figure 1: DEA input oriented, TE *vs* SE

under the CRS model each unit vary all the inputs, while some of them are constrained under the VRS model. If SE = 1 the unit is efficient, since it is on the CRS frontier. If instead SE < 1 then the SE estimate indicates only that the VRS are prevailing, but not the direction of these returns. The latter is identified by running another program with the following constraint: $\sum_{l=1}^{L} \lambda_l \leq 1$ (instead than the constraint $\sum_{l=1}^{L} \lambda_l = 1$). Then if the estimate of SE is lower than one and h_0 from this new program is equal to (lower than) h_0 under program (3), we have decreasing (increasing) returns to scale.

Moreover, we can adopt the DEA approach to compute the Malmquist input oriented total productivity index, which can be employed to identify the dynamics of the generic decision making unit, i.e. whether it has reduced or increased its distance from a production frontier that can vary over time.

To compute the Malmquist index we start by defining $h_0^t(x_t, y_t)$ as the input distance function relative to the production frontier, i.e. a minimal proportional decrease of the observed period t input under the period t technology. The Malmquist DEA approach derives an efficiency measure from one year relative to the prior year, while allowing the best practice frontier to shift (due to technological progress). Following Färe *et al.* [1994], DEA is used to build a total factor productivity index between period t and period $t+1$ (or a generic future period $t+s$):

$$M(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{h_0^t(y_{t+1}, x_{t+1})}{h_0^t(y_t, x_t)} \times \frac{h_0^{t+1}(y_{t+1}, x_{t+1})}{h_0^{t+1}(y_t, x_t)} \right]^{1/2} \tag{4}$$

where M is the input oriented total factor productivity index. An equivalent way of writing the Malmquist index, useful to specify that the total factor productivity change has two components, i.e. the Efficiency Change (EC) and the Technical Change (TC) is as follows:

$$\begin{aligned} M(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{h_0^{t+1}(y_{t+1}, x_{t+1})}{h_0^t(y_t, x_t)} \\ \times \left[\frac{h_0^t(y_{t+1}, x_{t+1})}{h_0^{t+1}(y_{t+1}, x_{t+1})} \times \frac{h_0^t(y_t, x_t)}{h_0^{t+1}(y_t, x_t)} \right]^{1/2} \end{aligned} \tag{5}$$

where

$$EC = \frac{h_0^{t+1}(y_{t+1}, x_{t+1})}{h_0^t(y_t, x_t)} \tag{6}$$

$$TC = \left[\frac{h_0^t(y_{t+1}, x_{t+1})}{h_0^{t+1}(y_{t+1}, x_{t+1})} \times \frac{h_0^t(y_t, x_t)}{h_0^{t+1}(y_t, x_t)} \right]^{1/2} \tag{7}$$

The intuition underlying the Malmquist index and the two components given by EC and TC can be provided using Figure 2. Suppose that the production of a single output y involves a unique input x, and that there are two observations, at period t and $t+1$. The two frontiers are given by OF_t and OF_{t+1} so that there is a shift in the production frontier over time. We also assume that the decision making unit we are considering is inefficient at both periods, given that is located at points A (at time t) and B (at

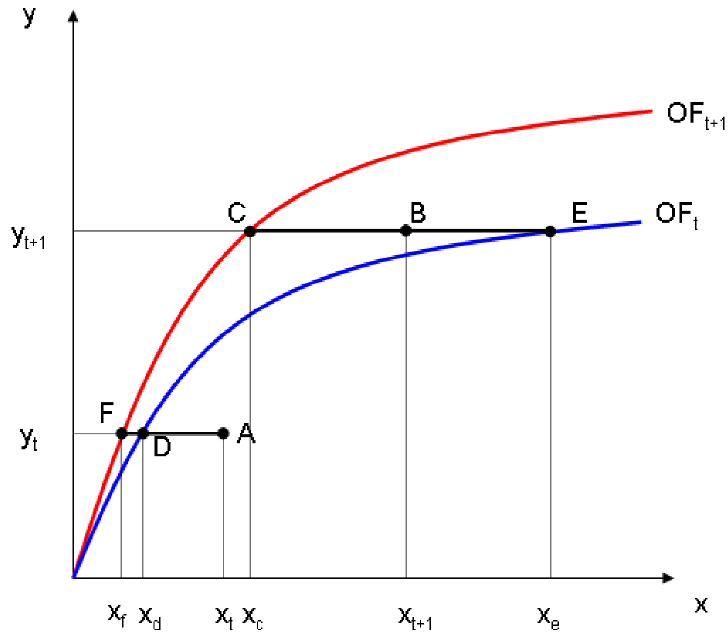

Figure 2: Total Factor Productivity over time and EC vs TC

time $t+1$). This implies that the change of this unit over time depends on both its position relative to the corresponding frontier (i.e. the technical inefficiency or efficiency change EC) and the position change in the frontier itself (technological change TC). By applying expression (6) we obtain that $h_0^{t+1}(y_{t+1}, x_{t+1}) = CB, h_0^t(y_t, x_t) = DA$. Hence:

$$EC = \frac{x_c/x_{t+1}}{x_d/y_t}$$

This implies that if $EC = 1$ the decision making unit has not recovered efficiency during the observed period, while if $EC < 1$ ($EC > 1$) the unit has improved (decreased) its efficiency. Furthermore, from (7) we get: $h_0^t(y_{t+1}, x_{t+1}) = BE, h_0^{t+1}(y_t, x_t) = DA, h_0^t(y_t, x_t) = DA, h_0^{t+1}(y_t, x_t) = FD$. Hence we can write:

$$TC = \left(\frac{x_e/x_{t+1}}{x_c/x_{t+1}} \times \frac{x_d/x_t}{x_d/y_f} \right)^{1/2}$$

Again, if $TC = 1$ the distance between the two frontiers at t, computed taking point A as reference, is equal to the distance between the two frontiers at $t+1$, taking point B as reference. If instead $TC < 1$ ($TC > 1$) the distance between the two frontiers at t is greater (lower) than the distance between the two frontiers at $t+1$. Moreover we can write: $EC = h_0^{t+1}/h_0^t$, while $TC = \left(\frac{h_0^t}{h_0^{t+1}} \times \frac{x_e/x_{t+1}}{x_d/x_t}\right)^{1/2}$. The technical efficiency change (i.e. EC) under CRS can be further decomposed into scale efficiency and pure technical efficiency under VRS. As mentioned before, scale efficiency is defined as being the extent to which a decision making unit can take advantage of returns to scale by altering its size towards the optimal scale (which is defined as the region in which there are CRS in the relationship between outputs and inputs), while pure technical efficiency is given by the difference between the observed ratio of combined quantities of output to input and the ratio achieved by best practices institutions that can be attributed to managerial practices and not scale.

We follow Pels *et al.* [2003] model of airport activities, such that an airport can be regarded as an interface between airlines and the passengers. Hence we need to consider both air transport movements (ATM) and air passenger movements (APM) and to treat ATM both as an output (for aircrafts movements) and as an input (for passenger movements). ATM can be considered as an intermediate good that is produced by the airport and consumed in the production of APM. This means that we can estimate both an efficiency in ATM (without considering APM) and also an efficiency in APM (where ATM is treated as an input).

3 The data

The data set used is this contribution is composed of information from collected statistics regarding a sample of 27 Italian airport for the period 2005–2006. The Italian market is composed by 37 airports. Since we need data on inputs, such as the number of parking positions or the lines of baggage claims, we had to contact directly each airport and to build a new data set. We run a direct investigation covering all the airports, but only 27 (73%) provided the necessary information. We estimated a input oriented DEA model concerning both ATM and APM. Hence we have two output variables for each airport: the yearly number of aircraft movements (ATM) and the yearly number of passenger movements (APM). The former output, as already mentioned, is treated as input when APM is considered as output. When dealing with the ATM frontier we consider the following inputs: the entire area of the airport (AREA), the total length of the runways (RUNWAYS), the total number of the aircraft parking positions (PARKING). The analysis of the APM frontier involves instead the following inputs: the yearly number of aircraft movements (ATM), the terminal surface (TERMINAL), the number of check–in desks (CHECK), the number of the aircraft parking positions (PARKING) and the number of lines for baggage claim (CLAIM). Table 1 presents descriptive statistics for each output and input variable in the sample data.

	2005				2006			
	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum
APM (number)	4.081.942	6.281.745	283.492	28.683.456	4.421.576	6.746.659	237.997	30.288.704
ATM (number)	52.496	68.315	6.864	308.284	54.938	71.846	6.579	316.004
TERMINAL (sm)	41.366	78.462	3.000	329.000	44.297	77.859	6.000	329.000
PARKING (number)	27,3	25,1	7,0	115,0	28,5	24,8	7,0	115,0
CHECK (number)	44,3	65,4	6,0	267,0	47,5	65,0	6,0	267,0
CLAIM (number)	4,3	2,8	2,0	14,0	4,6	2,9	2,0	14,0
AREA (hectares)	317,8	333,9	55,0	1.605,0	319,3	333,3	61,0	1.605,0
RUNWAYS (meters)	3.651	2.603	1.688	14.895	3.651	2.603	1.688	14.895

Source: **Assaeroporti and our elaborations**

Table 1: Descriptive statistics for Italian airports

The average number of passengers increases from 2005 to 2006, but also its variability across airports, measured by its standard deviation. The same observations hold for the average number of aircraft movements. Among inputs, RUNWAYS is the unique one unchanged between the two years. All other inputs have increased, on average, and their variability across Italian airports as well, but for the lines of baggage claims (CLAIM). In 2006 the typical Italian airport has a terminal surface of 44.297 sm, about 28 aircraft parking positions, about 47 check–in desks, 5 lines of baggage claims and it is extended on an area of 319 hectares.

4 Results

Table 2 shows the results regarding the efficiencies of Italian airports relating the ATM model. The average TE (i.e. the mean of the technical inefficiency concerning ATM for the 27 Italian airports) is equal to 0.82 in 2005. There are 8 efficient airports, with $TE = 1$, i.e. located exactly on the VRS frontier. The average SE in 2005 is 0.65. Only three airport are efficient. In 2006 the average TE is 0.83 (slightly higher than 2005, i.e. the airports are on average closer to the frontier) and 8 airports are on the frontier. The average SE in 2006 is 0.62, and again only 3 airports are efficient.

		2005				2006			
Airport	Code	CRS	VRS (TE)	CRS/VRS (SE)	RS	CRS	VRS (TE)	CRS/VRS (SE)	RS
Alghero	AHO	0,43	1,00	0,43	IRS	0,41	1,00	0,41	IRS
Ancona	AOI	0,35	0,74	0,47	IRS	0,28	0,77	0,37	IRS
Bari	BRI	0,34	0,74	0,47	IRS	0,40	0,82	0,49	IRS
Bergamo	BGY	0,47	0,61	0,77	IRS	0,46	0,63	0,74	IRS
Bologna	BLQ	0,66	0,72	0,92	IRS	0,65	0,75	0,86	IRS
Brescia	VBS	0,27	0,83	0,33	IRS	0,26	0,85	0,31	IRS
Brindisi	BDS	0,23	0,62	0,37	IRS	0,24	0,63	0,37	DRS
Cagliari	CAG	1,00	1,00	1,00	CRS	1,00	1,00	1,00	CRS
Catania	CTA	0,89	0,95	0,93	IRS	0,71	0,83	0,86	IRS
Florence	FLR	0,81	1,00	0,81	DRS	0,61	1,00	0,61	IRS
Genoa	GOA	0,41	0,62	0,66	IRS	0,43	0,63	0,68	IRS
Lamezia T.	SUF	0,24	0,81	0,30	IRS	0,26	0,85	0,31	IRS
Milan LIN	LIN	1,00	1,00	1,00	CRS	1,00	1,00	1,00	CRS
Milan MXP	MXP	0,59	1,00	0,59	DRS	0,59	1,00	0,59	DRS
Naples	NAP	1,00	1,00	1,00	CRS	0,72	0,81	0,88	IRS
Olbia	OLB	0,50	0,69	0,73	IRS	0,50	0,73	0,69	IRS
Palermo	PMO	0,70	0,74	0,94	DRS	0,76	0,76	1,00	DRS
Pescara	PSR	0,27	0,96	0,28	IRS	0,32	0,98	0,32	IRS
Rimini	PSA	0,16	0,81	0,20	IRS	0,17	0,82	0,20	IRS
Rome CIA	CIA	0,84	0,92	0,91	IRS	0,82	1,00	0,82	IRS
Rome FCO	FCO	0,85	1,00	0,85	DRS	0,87	1,00	0,87	DRS
Turin	TRN	0,58	0,63	0,92	IRS	0,59	0,69	0,85	IRS
Trapani	TPS	0,25	1,00	0,25	IRS	0,25	1,00	0,25	IRS
Treviso	TSF	0,40	0,85	0,48	IRS	0,39	0,89	0,44	IRS
Trieste	TRS	0,20	0,57	0,36	IRS	0,20	0,61	0,32	IRS
Venice	VCE	0,69	0,72	0,96	DRS	0,68	0,69	0,99	DRS
Verona	VRN	0,40	0,58	0,70	IRS	0,40	0,66	0,61	IRS

Table 2: DEA efficiency results, ATM

Concerning the returns to scale, in 2005 19 airports out of 27 has increasing returns to scale, i.e. they would benefit from a proportional expansion of all the considered inputs, while 5 exhibit decreasing returns, i.e. they should shrink the input endowments. The remaining 3 have constant returns to scale, i.e. they have reached a minimum efficient scale of operation. In 2006 the number of airports with IRS increases to 20: Florence swaps from DRS in 2005 to IRS in 2006, Naples from CRS to IRS. Airports with DRS are 5 (Brindisi had IRS in 2005), while only 2 airports (Cagliari and Milan Linate) have CRS. In the Appendix we report the peer airport for each decision making unit with reference to 2006 (see Table A1).

The 4 largest Italian airports, Rome Fiumicino, Milan Malpensa, Milan Linate and Venice, have DRS (Fiumicino, Malpensa and Venice) or (CRS (Linate). For the 3 airports with DRS this means that, concerning the aircraft movements, a proportional increase in all inputs considered in this paper would produce a less than proportional increase in ATM, i.e. the marginal cost of an additional aircraft movement is increasing. These airports are probably experiencing a congestion in ATM and they need further capacity.

The individual Malmquist indices are presented in Table 3.

Airport	VRS 2005	VRS 2006	Technical Efficiency change TEC	Technical change TC	Total factor productivity change TFPC
Alghero	1,00	1,00	1,00	0,99	0,99
Ancona	0,74	0,77	1,04	0,95	0,98
Bari	0,74	0,82	1,11	0,92	1,02
Bergamo	0,61	0,63	1,03	0,98	1,01
Bologna	0,72	0,75	1,04	0,99	1,03
Brescia	0,83	0,85	1,01	0,98	1,00
Brindisi	0,62	0,63	1,03	0,98	1,01
Cagliari	1,00	1,00	1,00	0,94	0,94
Catania	0,95	0,83	0,87	0,93	0,81
Florence	1,00	1,00	1,00	0,93	0,93
Genoa	0,62	0,63	1,01	0,99	1,00
Lamezia T.	0,81	0,85	1,05	0,95	1,00
Milan LIN	1,00	1,00	1,00	1,13	1,13
Milan MXP	1,00	1,00	1,00	1,17	1,17
Naples	1,00	0,81	0,81	0,91	0,74
Olbia	0,69	0,73	1,05	0,96	1,01
Palermo	0,74	0,76	1,03	1,04	1,07
Pescara	0,96	0,98	1,02	0,98	1,00
Rimini	0,81	0,82	1,02	0,98	1,00
Rome CIA	0,92	1,00	1,09	0,94	1,02
Rome FCO	1,00	1,00	1,00	1,03	1,03
Turin	0,63	0,69	1,09	0,95	1,04
Trapani	1,00	1,00	1,00	1,00	1,00
Treviso	0,85	0,89	1,05	0,95	1,00
Trieste	0,57	0,61	1,07	0,94	1,00
Venice	0,72	0,69	0,96	1,09	1,05
Verona	0,58	0,66	1,14	0,89	1,01

Table 3: Individual Malmquist Indices, ATM, 2005 to 2006

The change in efficiency (EC) between 2005 and 2006 is on average equal to 2%, while the mean of TC is -2%. The average change in TFPC is equal to -0.037%. However, the OECD has reported a decrease in productivity for the whole Italian economy in 2004, equal to -0.9% (the latest score available). Hence the performance of the air transportation sector, relating to ATM, seems to be higher that the whole Italian economy. For 13 airports we have obtained an increase in the TFPC between the 2 years considered, while productivity is decreased in 6 airports.

It is interesting to note that the four largest Italian airports are the unique ones with $TC > 1$: hence the largest airports show an higher ability to exploit the technical progress.

We have also computed, with a regulation goal, the x–factor to apply at the typical 5–years price cap period. To get the x–factor we applied the following methodology: First we assume that a single airport should guarantee yearly at least the average TFPC. This means in the ATM case -0.037%. Then we consider a second component, based on the idea that each airport should recover, if it is inefficient, efficiency, i.e. it has to catch up the frontier. TE signals inefficiency that is directly under the control of the airport's management. Hence we compute the difference Δ between the efficient frontier and the position of each airport in 2006, i.e. TE_{06}. For instance, looking at Table 3, this means for Alghero $\Delta = 0$ (the airport is on the frontier) and for Ancona $\Delta = 0.13$. We assume that only half of this distance may be recovered during the 5 years regulatory period, and then we compute the yearly target, given by $(1 + \Delta)^{1/5} - 1$. By applying this methodology we obtain an average x–factor equal to 1.58%. Hence this should be the maximum target that the regulator might apply to a price cap period for the aircraft movement fares. This maximum level may be reduced since not all of an airport's inefficiency is due to the management: for instance, as remarked by Pels *et al.* [2003], inefficiency may derive from input indivisibility (i.e. a new runway may take time to reach the optimal planned output), from government limitations (e.g. no flights during some hours), from climatic conditions (e.g. foggy or windy days), and to airlines inefficiencies. Hence the regulator may choose an x–factor lower than 1.58%, taking into account of these other sources of inefficiencies.

The results concerning the APM DEA model are shown in Table 4. On average the 27 airports have a technical efficiency in 2005 equal to 0.89 (they are at about 11% distance from the efficiency frontier), lower than the score reported for ATM, and to 0.83 if we take scale efficiency into account (the inefficiency is much lower than the ATM case). We can say that, in general, Italian airports are more efficient in APM than ATM. The number of efficient airports in 2005 according to TE is 12, which increases to 13 in 2006. If we observe SE, only 5 airports are on the frontier in 2005, while they increase to 7 in 2006. Many airports change status between 2005 and 2006 if we consider SE: Bergamo, Naples, Palermo and Turin reach the CRS frontier in 2006, Bologna instead is placed on the frontier in 2005 and at a very little distance in 2006, Treviso is on the frontier in 2005 and it is instead at a fairly high distance in 2006. The peer airports for each decision making unit when APM is considered as output are shown in Table A2 in the Appendix.

		2005				2006			
Airport	Code	CRS	VRS (TE)	CRS/VRS (SE)	RS	CRS	VRS (TE)	CRS/VRS (SE)	RS
Alghero	AHO	0,96	1,00	0,96	IRS	0,97	1,00	0,97	IRS
Ancona	AOI	0,27	1,00	0,27	IRS	0,32	1,00	0,32	IRS
Bari	BRI	0,76	0,77	0,98	DRS	0,73	0,76	0,95	DRS
Bergamo	BGY	0,97	1,00	0,97	DRS	1,00	1,00	1,00	CRS
Bologna	BLQ	0,71	0,71	1,00	DRS	0,69	0,70	0,99	IRS
Brescia	VBS	0,40	0,84	0,48	IRS	0,24	0,92	0,26	IRS
Brindisi	BDS	0,79	1,00	0,79	IRS	0,75	1,00	0,75	IRS
Cagliari	CAG	0,88	0,95	0,93	DRS	0,81	0,82	0,99	DRS
Catania	CTA	1,00	1,00	1,00	CRS	1,00	1,00	1,00	CRS
Florence	FLR	0,61	1,00	0,61	IRS	0,61	1,00	0,61	IRS
Genoa	GOA	0,42	0,54	0,78	DRS	0,44	0,55	0,79	IRS
Lamezia T.	SUF	0,88	1,00	0,88	DRS	0,96	1,00	0,96	DRS
Milan LIN	LIN	0,80	0,92	0,87	DRS	0,96	0,98	0,98	DRS
Milan MXP	MXP	0,90	0,92	0,97	DRS	0,90	0,91	0,99	DRS
Naples	NAP	0,96	0,99	0,97	IRS	0,97	0,97	1,00	IRS
Olbia	OLB	0,56	0,57	0,98	DRS	0,56	0,57	0,98	DRS
Palermo	PMO	0,91	0,93	0,98	DRS	1,00	1,00	1,00	CRS
Pescara	PSR	0,35	1,00	0,35	IRS	0,31	1,00	0,31	IRS
Rimini	PSA	0,43	0,99	0,43	IRS	0,47	0,95	0,49	IRS
Rome CIA	CIA	1,00	1,00	1,00	CRS	1,00	1,00	1,00	CRS
Rome FCO	FCO	1,00	1,00	1,00	CRS	1,00	1,00	1,00	CRS
Turin	TRN	0,58	0,58	0,99	DRS	0,54	0,54	1,00	IRS
Trapani	TPS	0,59	1,00	0,59	IRS	0,49	1,00	0,49	IRS
Treviso	TSF	1,00	1,00	1,00	CRS	0,79	1,00	0,79	IRS
Trieste	TRS	0,39	0,67	0,58	IRS	0,41	0,67	0,62	IRS
Venice	VCE	0,77	0,81	0,95	DRS	0,87	0,93	0,93	DRS
Verona	VRN	0,72	0,73	0,98	DRS	0,80	0,82	0,97	DRS

Table 4: DEA efficiency results, APM

Concerning returns to scale, in 2005 the airports with IRS in APM are 10, while in 2006 they become 14. All airports with IRS in 2005 have the same status in 2006, plus other 4 airports: Bologna, Genoa, Turin and Treviso. Decreasing returns to scale have been identified in 2005 in 13 airports, hence the majority of the Italian investigated airports: of them 3 airports (Bologna, Genoa and Turin) in 2006 report IRS, and 2 (Bergamo and Palermo) reach the efficient size coinciding with CRS in 2006. The latter is observed in 2005 for 4 airports (Catania, Rome Ciampino, Rome Fiumicino and Treviso), and for 5 airports in 2006 (Bergamo, Catania, Palermo, Rome Ciampino and Rome Fiumicino). In 2006 14 airports have IRS and 8 exhibit DRS. The number of airports with CRS is higher under APM than ATM: this is a confirmation that it is easier to reach the optimal size in managing passengers rather than aircraft movements. Moreover, many airports show

DRS under APM, while the majority exhibits IRS under ATM. No airport has the optimal score for both APM and ATM.

Between the four largest airports 3 (Milan Linate, Milan Malpensa and Venice) have DRS in APM, while Rome Fiumicino has CRS.

The productivity scores, i.e. the Malmquist Indeces for APM, are reported in Table 5. On average the Italian airport sector has reported an increase of 0.9% in efficiency (EC) between 2005 and 2006. The mean TC is instead -0.6%. The sector performance regarding the total factor productivity change TFPC is equal to 0.3%. Recall the for ATM we reported a negative average TFPC. Hence the airports productivity is greater for passengers rather than for aircraft movements.

Airport	VRS 2005	VRS 2006	Technical Efficiency change EC	Technical change TC	Total factor productivity change TFPC
Alghero	1,00	1,00	1,00	1,03	1,03
Ancona	1,00	1,00	1,00	1,00	1,00
Bari	0,77	0,76	0,99	1,02	1,01
Bergamo	1,00	1,00	1,00	1,11	1,11
Bologna	0,71	0,70	0,98	1,04	1,02
Brescia	0,84	0,92	1,10	0,91	1,00
Brindisi	1,00	1,00	1,00	0,99	0,99
Cagliari	0,95	0,82	0,86	1,01	0,87
Catania	1,00	1,00	1,00	0,89	0,89
Florence	1,00	1,00	1,00	0,86	0,86
Genoa	0,54	0,55	1,03	0,94	0,97
Lamezia T.	1,00	1,00	1,00	1,05	1,05
Milan LIN	0,92	0,98	1,06	1,02	1,08
Milan MXP	0,92	0,91	0,99	1,03	1,02
Naples	0,99	0,97	0,98	0,89	0,87
Olbia	0,57	0,57	0,99	1,05	1,04
Palermo	0,93	1,00	1,08	0,97	1,05
Pescara	1,00	1,00	1,00	1,00	1,00
Rimini	0,99	0,95	0,96	1,04	1,00
Rome CIA	1,00	1,00	1,00	1,27	1,27
Rome FCO	1,00	1,00	1,00	1,04	1,04
Turin	0,58	0,54	0,93	1,02	0,95
Trapani	1,00	1,00	1,00	0,99	0,99
Treviso	1,00	1,00	1,00	0,66	0,66
Trieste	0,67	0,67	1,00	1,00	1,00
Venice	0,81	0,93	1,16	1,04	1,21
Verona	0,73	0,82	1,12	0,98	1,09

Table 5: Individual Malmquist Indices, APM, 2005 to 2006

If we examine each airport individually, we can observe the following important results: (1) 6 airports report an increase in efficiency, since EC is higher than 1. Among them two–digits percentage increases are for Venice (+16%) and Verona (+12%). (2) 8 airports score a decrease in efficiency, given that $EC < 1$. Among them it is worth mentioning Cagliari (-14%). (3) The results for the TFPC highlight that 13 Italian airports have improved their productivity between 2005 and 2006: relevant results have to be remarked for Rome Ciampino (+27%), Venice (+21%) and Bergamo Orio al Serio (+11%). (4) There are 9 airports marking a decrease in productivity between the two years considered: among them two–digits percentage reductions are observed for Treviso (-33%), Florence (-14%), Naples and Cagliari (-13%) and Catania (-11%).

Under APM not only the 4 largest airports have $TC > 1$: this means that also the medium size airports are able to exploit the benefit of technological progress in managing passengers. We have also computed the average x–factor to be applied to the price cap regulation related to the passengers fares, i.e. based on the productivity scores obtained from the APM model. The maximum target is equal to 1.27%, i.e. is lower than the target obtained for ATM.

5 Conclusions

This paper has investigated the efficiency of Italian airports, by applying an input oriented DEA model to two production processes: the aircraft movements and the passenger movements. It has been shown that many airports can improve their efficiency. Concerning the aircraft movements we show that only 8 Italian airports, out of the 27 examined (about 30%) in this contribution, are located on the frontier, and that 20 out of 27 (74%) exhibit increasing returns to scale; only 2 airports (7%) have constant returns to scale. We have also found that among the 4 largest airports there is a prevalence of decreasing returns to scale in aircraft movements. The Malmquist indeces relating to productivity scores show that the average change in efficiency between 2005 and 2006 is equal to 2% and that the technological change is -2%,. Moreover we have found that the four largest airports are the unique ones with an index of technological change higher than 1: hence it seems that, concerning the aircraft movements, only the airports with larger size are able to exploit the technical progress. The average total factor productivity change is -0.04% (negative but higher than that observed for the whole Italian economy). We observe an increase in productivity in 13 out of 27 airports (48%), and a decrease for 6 out of 27 (22%).

The results when instead passenger movements are considered are the following ones: the average distance from the efficient frontier is lower than that observed for the aircraft movements, and the number of efficient airports is also greater (13 out of 27, 48%). Only 14 airports have increasing returns to scale (55%), while 5 airports exhibit constant returns to scale (19%). Again we observe that the majority of the largest airports have decreasing returns to scale. The Malmquist indeces show an average efficiency change equal to 0.9%, and a technological change equal to -0.6%. The total factor productivity index is positive and equal to 0.3%. Hence we can argue that the airport management sector seems to be more productivity than the whole Italian economy, and that airports are more efficient in managing the passenger movements rather than the aircraft movements. About 48% of the analyzed airports have a productivity increase between 2005 and 2006, while 9 out of 27 (33%) have a decrease in productivity.

We have also computed the regulation targets relating to efficiency on the basis of the obtained results. The average x–factor for the aircraft movement is 1.58%, while for the passenger movements is equal to 1.27%. These thresholds might be regarded as the maximum target for price cap regulation: effective targets might be reduced by taking into account of inefficiencies not under control of the airport's management (e.g. inputs indivisibilities, governmental limitation, airlines inefficiencies), which cannot be separated at this stage of the analysis. The latter is left for future research.

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APPENDIX

Airport	VRS TE 2006	Benchmark							
Alghero	1,00	1,00	Alghero						
Ancona	0,77	0,39	Florence	0,01	Rome CIA	0,59	Trapani		
Bari	0,82	0,62	Florence	0,16	Rome CIA	0,23	Trapani		
Bergamo	0,63	0,72	Florence	0,28	Milan LIN				
Bologna	0,75	0,18	Cagliari	0,54	Florence	0,28	Milan LIN		
Brescia	0,85	0,16	Florence	0,00	Rome CIA	0,84	Trapani		
Brindisi	0,63	0,37	Alghero	0,02	Milan LIN	0,61	Trapani		
Cagliari	1,00	1,00	Cagliari						
Catania	0,83	0,22	Cagliari	0,53	Florence	0,25	Milan LIN		
Florence	1,00	1,00	Florence						
Genoa	0,63	0,22	Cagliari	0,78	Florence	0,00	Milan LIN		
Lamezia T.	0,85	0,64	Florence	0,36	Trapani				
Milan LIN	1,00	1,00	Milan LIN						
Milan MXP	1,00	1,00	Milan MXP						
Naples	0,81	0,21	Cagliari	0,49	Florence	0,31	Milan LIN		
Olbia	0,73	0,03	Cagliari	0,90	Florence	0,06	Milan LIN		
Palermo	0,76	0,84	Cagliari	0,16	Milan LIN	0,00	Trapani		
Pescara	0,98	0,31	Florence	0,69	Trapani				
Rimini	0,82	0,23	Florence	0,77	Trapani				
Rome CIA	1,00	1,00	Rome CIA						
Rome FCO	1,00	1,00	Rome FCO						
Turin	0,69	0,16	Cagliari	0,13	Florence	0,12	Milan LIN	0,60	Rome CIA
Trapani	1,00	1,00	Trapani						
Treviso	0,89	0,20	Cagliari	0,50	Florence	0,30	Trapani		
Trieste	0,61	0,85	Florence	0,15	Trapani				
Venice	0,69	0,50	Cagliari	0,50	Milan LIN				
Verona	0,66	0,45	Florence	0,44	Rom CIA	0,11	Trapani		

Table A1: Peer airports, ATM

Airport	VRS Efficiency 2006	Benchmark									
Alghero	1,00	1,00	Alghero								
Ancona	1,00	0,22	Trapani	0,78	Treviso						
Bari	0,76	0,74	Alghero	0,08	Catania	0,18	Palermo				
Bergamo	1,00	1,00	Bergamo								
Bologna	0,70	0,16	Alghero	0,65	Catania	0,19	Lamezia T.				
Brescia	0,92	1,00	Trapani								
Brindisi	1,00	1,00	Brindisi								
Cagliari	0,82	0,70	Alghero	0,30	Catania	0,01	Rome FCO				
Catania	1,00	1,00	Catania								
Florence	1,00	1,00	Florence								
Genoa	0,55	0,02	Lamezia T.	0,04	Palermo	0,13	Rome CIA	0,81	Trapani		
Lamezia T.	1,00	1,00	Lamezia T.								
Milan LIN	0,98	0,23	Alghero	0,54	Rome CIA	0,22	Rome FCO				
Milan MXP	0,91	0,34	Catania	0,66	Rome FCO						
Naples	0,97	0,00	Alghero	0,24	Bergamo	0,16	Catania	0,06	Palermo	0,53	Rome CIA
Olbia	0,57	0,81	Alghero	0,15	Catania	0,03	Palermo				
Palermo	1,00	1,00	Palermo								
Pescara	1,00	0,80	Trapani	0,20	Treviso						
Rimini	0,95	0,01	Alghero	0,99	Trapani						
Rome CIA	1,00	1,00	Rome CIA								
Rome FCO	1,00	1,00	Rome FCO								
Turin	0,54	0,49	Alghero	0,51	Catania						
Trapani	1,00	1,00	Trapani								
Treviso	1,00	1,00	Treviso								
Trieste	0,67	0,00	Rome CIA	0,67	Trapani	0,33	Treviso				
Venice	0,93	0,65	Bergamo	0,30	Rome CIA	0,05	Rome FCO				
Verona	0,82	0,01	Alghero	0,09	Bergamo	0,07	Catania	0,49	Lamezia T.	0,34	Palermo

Table A2: Peer airports, APM