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Bootstrapping the Malmquist indexes for Italian airports

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ABSTRACT

This paper uses data envelopment analysis to assess the operational performance of 28 Italian airports during the period of 2000 through 2006. Recent developments in bootstrapping techniques are used to correct total factor productivity estimates for bias and to assess the uncertainty surrounding such estimates. This study found that the Italian airport industry experienced a significant technological regress, with few airports achieving an increase in productivity led by improvements in efficiency. Moreover, the paper shows that the form of ownership (public majority vs. private majority) of an airport management company does not significantly affect performance. In contrast, this type of the concession agreement has positive and significant effects on airport productivity. Finally, the paper highlights the existence of a productivity gap between airports located in the North-Central part of the country and those located in the south.

1. Introduction

In the last years, the air transport industry experienced, at the worldwide level, a rapid growth characterized by a volatile business environment (Doganis, 2001) due mostly to the structural changes caused by governmental interventions aimed at reducing the local monopoly power of airports. In the European Union, a series of directives have boosted competition on both the "air side" and the "ground side" (Albers et al., 2005; Schmidberger et al., 2009). In Italy, the European directives have been accompanied by the progressive change of the concession agreements between government and airport management companies and by the privatization of the airports (Curi et al., 2008, 2010). In this new context, where airports face a more severe demand for efficient and good-quality services, the introduction of benchmarking tools can be useful in developing consistent measures of airport performance and in investigating potential efficiency improvements. In fact, it is essential both for airport managers and the government to identify the best practices in a range of airport operations and to provide the best services in the most efficient manner (Forsyth, 2003).

This paper employs a dataset of 28 Italian airports observed over a seven-year period from 2000 through 2006. The main purpose of the paper is to calculate the Malmquist index, which is a measure of the total factor productivity (TFP), in order to shed light on the effects of policy interventions. The Malmquist index is measured through a well-known non-parametric technique, Data Envelopment Analysis (DEA), which allows productivity change to be decomposed into efficiency and technical changes. DEA has been applied in various fields (Ma et al., 2002; Tsekouras et al., 2004; Iturralde and Quirós, 2008; Liu and Wang, 2008; Dervaux et al., 2009; Tsekouras et al., 2010 among others). However, in the present paper, we employ it in an inferential setting by using a bootstrap methodology (Simar and Wilson, 1999). Departing from previous studies on the Italian airports (Barros and Dieke, 2007, 2008; Malighetti et al., 2007; Curi et al., 2008, 2010), we analyze, in an inferential setting, the impact of privatization, concession agreement and airport location on total factor productivity, technical change and efficiency change.

The next section reviews the literature addressing the evaluation of airport performance. Section 3 focuses on the Italian airport industry. Section 4 describes the dataset as well as the input and output variables used in the analysis. Section 5 discusses the non-parametric methodology and the bootstrap procedure. Section 6 points out the results, and Section 7 is the conclusion.

2. Empirical literature: a survey

In recent decades, three main methodologies have been employed to measure productivity in the airport industry: the parametric stochastic frontiers, the non-parametric frontiers and the index numbers (see Table 1). Parametric frontiers require strong assumptions about the production technology. In contrast, the methodologies based on non-parametric techniques and index numbers require no specification of the functional form. However, the last methodology lacks statistical properties, which precludes

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making inferences on the productivity measures (Hooper and Hensher, 1997).

Starting with the seminal works of Douganis et al. (1995), Hooper and Hensher (1997) and Gillen and Lall (1997), recent papers focused mainly on analyzing the airport industry in the United States (e.g., Sarkis, 2000; Gillen and Lall, 2001; Sarkis and Talluri, 2004), Spain (Murillo-Melchor, 1999; Martìn and Romàn, 2001; Martín-Cejas, 2002), Brazil (Fernandes and Pacheco, 2002, 2003), Japan (Yoshida and Fujimoto, 2004), the United Kingdom (Barros, 2008b; Barros and Weber, 2009), China (Fung et al., 2008) and Portugal (Barros, 2008a). Significantly, there appear to be relatively few cross-country studies: Adler and Berechman (2001), Oum et al. (2003, 2006) and Pels et al. (2001, 2003).

Table 1
Summary of studies on airport benchmarking.

Methods	Papers
Parametric stochastic frontier	Pels et al. (2001, 2003) Martín-Cejas (2002) Barros (2008a, 2008b); Abrate and Erbetta (2010)
Non-parametric frontier (DEA)	Gillen and Lall (1997) Murillo-Melchor (1999) Sarkis (2000) Adler and Berechman (2001) Gillen and Lall (2001) Martìn and Romàn (2001) Pels et al. (2001) Fernandes and Pacheco (2002, 2003) Sarkis and Talluri (2004) Yoshida and Fujimoto (2004) Barros and Dieke (2007); Malighetti et al. (2007) Barros and Dieke (2008) Fung et al. (2008) Curi et al. (2008, 2010) Barros and Weber (2009) Barros and Assaf (2009)
Index numbers	Douganis et al. (1995) Hooper and Hensher (1997) Oum et al. (2003) Yoshida and Fujimoto (2004)

As far as the Italian case is concerned, two papers by Barros and Dieke (2007, 2008) analyzed the technical efficiency of 31 airports during the period of 2001–2003. They found high values of technical efficiency, positively affected by drivers such as size, private management and high levels of workload units. Works by Malighetti et al. (2007), Curi et al. (2008, 2010) and Abrate and Erbetta (2010) extended the findings by Barros and Dieke and pointed out the existence of low levels of efficiency among Italian airports. Departing from the previous papers, we analyze the productivity evolution, emphasizing the role of ownership, concession agreement and location.

3. Industry characteristics: institutional setting and economic disparities

The Italian airport industry has a number of peculiar features resulting from the continuing evolution of the institutional setting (Curi et al., 2010) and from the disparities in economic growth among regions of the country (e.g., Marrocu and Paci, 2010).

The privatization of airports in Italy began in the middle of the 1990s with two laws, 537/93 and 351/95, but most Italian airports continue to be managed by stock companies owned by a public majority (such as local councils) rather than by private majority shareholders. In our analysis, the share of airports controlled by a private majority is 25% (see Table 2). The effect of privatization on productivity is still an open question in the

Table 2
Airport code, management companies, ownership, concession agreement and location.

Airport (IATA CODE)	Airport Company	Ownership (1=private majority, 0=public majority)	Concession agreement (1=Total, 0=others)	Geographic position (1=South; 0=North-Center)
Alghero(AHO)	SOGEAAL SpA	0	0	1
Ancona(AOI)	AERDORICA SpA	0	0	0
Bari(BRI)	SEAP SpA.	0	1	1
Bergamo(BGY)	SACBO SpA	0	1	0
Bologna(BLQ)	SAB SpA	0	0	0
Brindisi(BDS)	SEAP SpA.	0	1	1
Cagliari(CAG)	SOGAER SpA.	0	0	1
Catania(CTA)	SAC SpA	1	1	1
Firenze(FLR)	Aerop.Firenze SpA.	1	1	0
Foggia(FOG)	SEAP SpA.	0	1	1
Genova(GOA)	Aer. Gen. SpA	0	1	0
Lamezia(SUF)	SACAL SpA	0	1	1
Milano Linate(LIN)	SEA SpA	0	1	0
Milano Malpensa(MXP)	SEA SpA	0	1	0
Napoli(NAP)	GESAC SpA	1	1	1
Olbia(OLB)	GEASAR SpA.	0	0	1
Palermo(PMO)	GESAC SpA	0	0	1
Pescara(PSR)	SAGA SpA	0	0	1
Pisa(PSA)	SAT SpA	0	0	0
Rimini(RMI)	AERADRIA SpA.	0	0	0
Roma Ciampino(CIA)	ADR SpA	1	1	0
Roma Fiumicino(FCO)	ADR SpA	1	1	0
Taranto(TAR)	SEAP SpA.	0	1	1
Torino(TRN)	SAGAT SpA	0	1	0
Treviso(TSF)	AER TRE SpA.	1	0	0
Trieste(TRS)	Aerop. Fr. Ven. Giu. SpA.	0	0	0
Venezia(VCE)	SAVE SpA	1	1	0
Verona(VRN)	Aer. Cat. SpA	0	0	0

literature. Parker (1999) analyzed the impact of privatization on 22 British airports and found no impact on airport efficiency. Australian airports were studied by Hooper and Hensher (1997) and by Abbott and Wu (2001), and those studies also found that privatization has no impact on efficiency. Barros and Sampaio (2004) studied 10 airports and argued that Portuguese airports should be privatized. Oum et al. (2006) studied 116 airports around the world and concluded that airports owned and managed by a mixed enterprise with a government-owned majority are significantly less efficient than airports that are 100% publicly owned and operated airports. For the Italian case, the paper by Malighetti et al. (2007) indicates that privatization enhances airport efficiency.

However, in Italy, the privatization process cannot be analyzed without considering the conditions that regulate the access and the management of the airport facilities. In our sample, 57% of management companies hold a total concession agreement (see Table 2): the company gets all of the airport's revenues for 40 years and is responsible for the infrastructure (land-side and air-side) maintenance and development. The other forms of concession agreements, which have a maximum duration of 20 years, are the partial and precaria. In the partial concession agreement, airport management company revenues come from infrastructures involving passenger and freight terminals. The State collects revenues from runways and parking positions, and it is responsible for their maintenance and development. With the precaria concession agreement, airport companies manage only the passenger and freight terminals. The companies receive only the revenue that is related to commercial activities inside the terminals. All remaining activities are managed by the State. Because both the partial and precaria agreements limit the operations, revenues and costs of the airport management company, we consider each, in what it follows, to be a unique type of concession agreement, labeled non-total agreement.

An analysis of the data in Table 2 shows that the management companies characterized by a private majority and by total concession agreement constitute 21.4% of the sample. Companies with a public majority are equally distributed between total agreements and non-total agreements. Among companies with a private majority, 85% hold a total concession. Thus, the above analysis indicates that the privatization process of the airport management companies is proceeding slowly (Curi et al., 2010). So, a consequent reduction in government funding could be accelerated by a change in the type of concession agreement (AGCM, 2004). Finally, in 2010, the Italian government has defined the new ‘‘Italian Airport Master Plan'' with the objective of rationalizing investment in regional airports (Percoco, 2010). In fact, regions in the North-Central area of Italy have better infrastructure than the national average, although the regions are considered to be lacking within Europe as a whole. Italy's southern regions have always been regarded as being peripheral to the core of the national and European economy. Thus, an analysis of the relative productivity of these two areas of Italy – South and North-Central – could be helpful to identify the government policies aimed to reduce the gap.

4. Data and variables

Italy has 42 airports, managed by 37 companies (ENAC, 2001–2007). Our sample consists of 28 airports (a balanced panel) and covers about 96%, 99% and 99% of the total number of passengers, movements and cargo, respectively, registered in Italy from 2000 to 2006. Small airports have been excluded due to the lack of economic data.

Data have been collected from the two sources: airport annual statistics (ENAC, 2001–2007) and balance sheets of airport management companies (TELEMACO, 2009). These sources have to be carefully employed because some airports are managed by the same company, and the companies provide only aggregated balance sheets. Therefore, they enter into the analysis as single units. The problem arises for the following airports: Roma Ciampino and Fiumicino, Milano Linate and Malpensa, and Bari, Brindisi, Foggia and Taranto. All the monetary variables have been divided by the GDP deflator.

In the present study, the limitations in the data available do not allow us to separate the analysis of efficiency between air passenger and air transport movements (Gillen and Lall 1997, 2001; Pels et al., 2001, 2003; Barros and Assaf, 2009).

Therefore, we measure the global productivity of the airports, employing both physical and monetary variables (Hooper and Hensher, 1997; Sarkis, 2000; Fernandes and Pacheco, 2003; Oum et al., 2003; Sarkis and Talluri, 2004; Barros and Dieke, 2007, 2008; Barros, 2008b). Outputs include the number of passengers, the amount of cargo, the number of aircraft movements, the aeronautical revenues and the non-aeronautical revenues. Three inputs are used: labor cost, capital invested and soft costs. The labor cost is measured as the cost of labor. Capital invested is expressed by book value of assets. Finally, soft costs, according to Oum et al. (2003), are measured by all of the expenses not directly related to capital and personnel. Table 3 shows the descriptive statistics.

5. Methodology

To examine the issues raised in the previous sections, we employ DEA (Charnes et al., 1978) to compute the Malmquist productivity index (Färe et al., 1992). We use an output-orientated model because it accounts for the objective of exploiting the

Table 3
Summary statistics, 2000–2006.

Variables	Definition	Min	Max	Mean	Variation coef.
Outputs					
number of movements (*nm*)	number of plans that lands and takes-off from the airport	5076.00	379,542.00	60,088.68	1.48
number of passengers (*np*)	number of passengers arriving or departing and passengers stopping temporarily	114,024.00	3,512,1826.00	4,402,276.66	1.73
amount of cargo (*ac*)	amount of cargo in tons	489.00	446,596.00	37,474.63	2.29
aeronautical revenues (*ar*)	sales to planes in millions of euros	1544.00	394,360.00	41,542.04	1.78
non-aeronautical revenues (*nar*)	sales to passengers in millions of euros	297.35	245,767.00	24,622.11	2.30
Inputs					
labor cost (*lc*)	labor cost in millions of euros	969.12	263,458.00	19,888.32	1.99
capital invested (*ci*)	book value of fixed assets in millions of euros	1481.13	2,375,682.24	171,888.59	2.89
soft costs (*sc*)	operational costs excluding labor and capital costs	966.76	186,562.76	23,627.01	1.64

facilities to satisfy the steady growth demand in the aviation market (Martìn and Romàn, 2001). However, following the papers by Simar and Wilson (1998, 1999), we analyze the productivity evolution of airports in an inferential setting. In fact, as noted by the two authors, the traditional DEA estimator is biased by construction (downward for output orientation) and is affected by the uncertainty resulting from sample variation.

In a deterministic setting, the Malmquist index for each airport, or Decision Making Unit (DMU), is obtained by solving four DEA problems (see Thanassoulis et al., 2008; Simar and Wilson, 2008 for details). The DEA basic model, which assumes constant returns to scale everywhere (Shepard, 1970), measures the distance $\Delta_{i,t}(y_{i,t},x_{i,t})$ of airport i, at time t, relative to technology existing at the same period and it is always less than one. Computing the Malmquist index requires additional distance functions to be defined: $\Delta_{i,t+1}(y_{i,t},x_{i,t})$ is the distance of airport i at time t, relative to technology at the period $t+1$.

The Malmquist output-oriented index between periods t and $t+1$, can be defined as (Färe et al., 1992, 1995)

$$M_i^{t,t+1}=\frac{\Delta_{i,t+1}(y_{i,t+1},x_{i,t+1})}{\Delta_{i,t}(y_{i,t},x_{i,t})}\left(\frac{\Delta_{i,t}(y_{i,t+1},x_{i,t+1})}{\Delta_{i,t+1}(y_{i,t+1},x_{i,t+1})}\frac{\Delta_{i,t}(y_{i,t},x_{i,t})}{\Delta_{i,t+1}(y_{i,t},x_{i,t})}\right)$$
$$=EC_i^{t,t+1}TC_i^{t,t+1} \tag{1}$$

where $EC_{i,t}$ and $TC_{i,t}$ represent the efficiency change and technological change, respectively. Efficiency $M_i^{t,t+1}$ $EC_i^{t,t+1}$or $TC_i^{t,t+1}$ greater (or less) than one indicate productivity growth (or decline) for the DMU i ($i=1,2,\ldots,n$) between period t and $t+1$. However, relation (1) does not allow us to determine whether changes in productivity, efficiency or technology are real or merely artifacts of the fact that we do not know the true production frontiers and must estimate them from a finite sample (Simar and Wilson, 1999). Thus, we employ a consistent bootstrap estimation procedure for correcting and obtaining confidence intervals for the Malmquist index and its components EC_t and TC_t. The idea underlying the bootstrap is to approximate the sampling distribution of the $\hat{M}_i^{t,t+1}$ the unknown true values of $M_i^{t,t+1}$ we generate through the DGP process a series of pseudo datasets to obtain bootstrap estimate $\hat{M}_*^{t,t+1}$ Simar and Wilson (1998) discussed the problems that arise for bootstrapping in DEA models and they suggested the use of a smooth bootstrap procedure. In addition, the Malmquist index uses panel data, with the possibility of temporal correlation. For this reason, Simar and Wilson (1999) modified the bootstrap algorithm for efficiency scores to preserve any temporal correlation present in the data by applying a bivariate smoothing procedure. The procedure can be summarized as follow:

1. Compute the Malmquist productivity index $\hat{M}_i^{t,t+1}$ for each airport $i=1,2,\ldots,n$, by solving the DEA models as described in Färe et al. (1992, 1995).
2. Calculate the pseudo dataset $\{(x_{it}^*,y_{it}^*); i=1,\ldots,n; t=1,2\}$ to obtain the reference bootstrap technology by using bivariate kernel density where the bandwidth was selected following the normal reference rule.
3. Compute the bootstrap estimate of the Malmquist index $\hat{M}_{i,b*}^{t,t+1}$ for each airport through the pseudo sample obtained in step 2.
4. Repeat steps 2 and 3, B times (number of bootstrap replications) in order to obtain the bootstrap sample $\{\hat{M}_{i,1*}^{t,t+1},\ldots,\hat{M}_{i,B*}^{t,t+1}\}$
5. From the bootstrap sample, compute bias-corrected estimates and confidence intervals for the Malmquist index by selecting the appropriate percentiles.

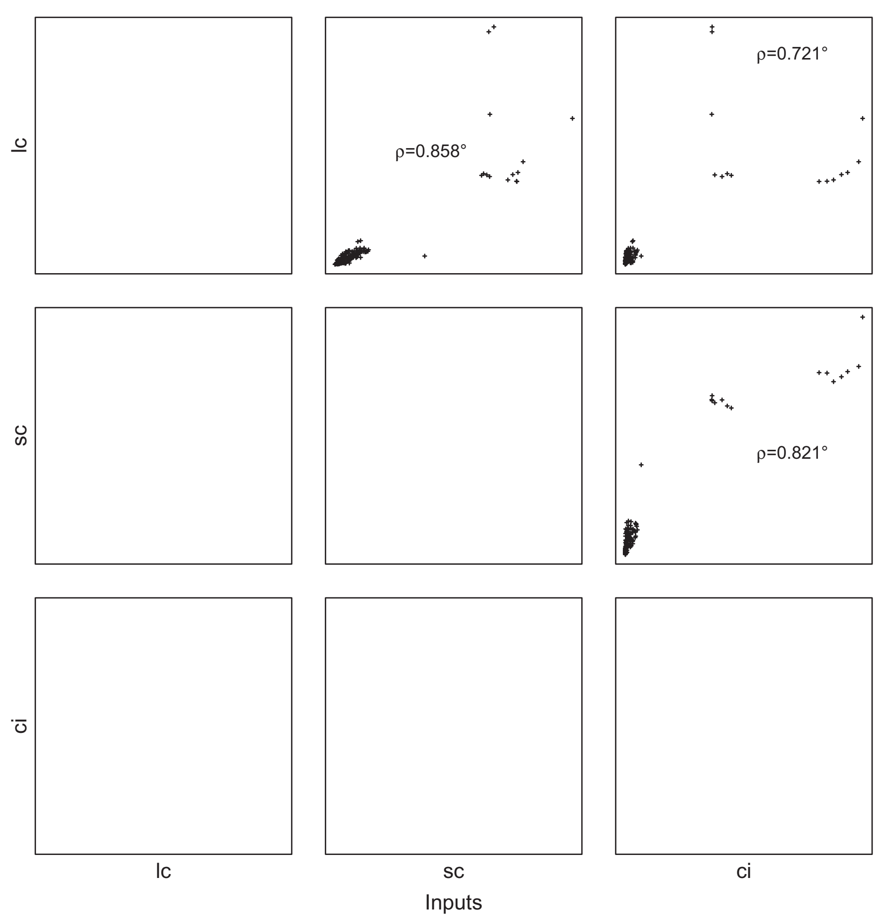

Fig. 1. Input (output) scatter plot. ρ=correlation coefficient.

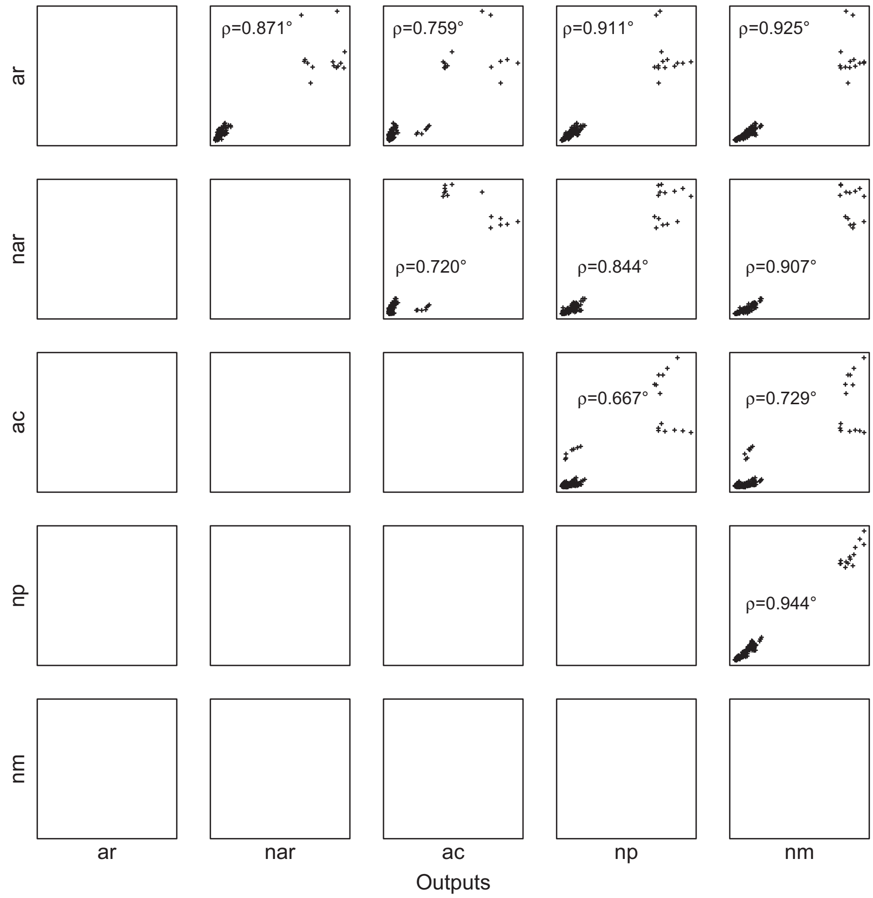

Fig. 1. (*continued*)

The bias-corrected estimates of the Malmquist index, are obtained from:

$$\hat{M}_i^{t,t+1}=\hat{M}_i^{t,t+1}-\widehat{bias}_i=2\hat{M}_i^{t,t+1}-B^{-1}\sum_{b=1}^{B}\hat{M}_{i,b*}^{t,t+1}\quad i=1,\ldots,n \tag{2}$$

However, the correction of the bias introduces additional noise, which increase the variance of the estimator. Thus, as rule of thumb, Simar and Wilson (1999) recommended that one not correct for the bias unless $\left|\widehat{bias}_i\right|>\sqrt{3}\widehat{std}(\hat{M}_{i,b*}^{t,t+1})$, where $\widehat{std}(\hat{M}_{i,b*}^{t,t+1})$ is the sample standard deviation of the bootstrap values. The construction of the confidence intervals is obtained sorting the values $\{\hat{M}_{i,b*}^{t,t+1}-\hat{M}_i^{t,t+1}\}_{b=1}^{B}$ in increasing order and deletes the $((\alpha/2)\times 100)$-percent of the elements at either end of the sorted list. Then, for setting $-\hat{a}_\alpha^*$ and $-\hat{b}_\alpha^*$ (with $\hat{a}_\alpha^*<\hat{b}_\alpha^*$), which is equal to the endpoints of the sorted array, the estimated $(1-\alpha)$-percent confidence interval for the productivity index is

$$\hat{M}_i^{t,t+1}+\hat{a}_\alpha^*\leq M_i^{t,t+1}\leq \hat{M}_i^{t,t+1}+\hat{b}_\alpha^* \tag{3}$$

Relations (2) and (3) are similarly computed for the two components of the Malmquist index: efficiency change and technological change. With the obtained confidence interval for the Malmquist index and its components, it is possible to determine whether productivity improvement (or decline) is significant at the established confidence level. The smooth bootstrap procedure for productivity was implemented using the FEAR package (Wilson, 2008).

6. Empirical results

6.1. Preliminary analysis

As pointed out by the literature on DEA, an excessive number of inputs and/or outputs with respect to the number of observations causes in a large number of efficient units (Simar and Wilson, 2008). Therefore, in what it follows, we first analyze the relationship among inputs (outputs), and then we reduce the number of variables by employing the methodology proposed by Daraio and Simar (2007). Fig. 1 shows the scatterplots among input (output) variables.

There is a clear linear dependence among variables. This dependence allows us to reduce the number of variables by aggregating them in factors with minimum loss of information. The factor input (output) is obtained as the weighted sum of the original variables with weights represented by the values of the first eigenvalue of the input (output) matrix. Mathematically, a factor, $\mathbf{F}$, is given by: $\mathbf{F}=\mathbf{X}\mathbf{a}$. Where, $\mathbf{X}$ is the matrix of the input (output) variables and $\mathbf{a}$ is the first eigenvector of the matrix $\mathbf{XX}'$. The capacity of a factor to summarize the information contained in the original variables is expressed by the inertia, which is computed by dividing the first eigenvalue by the sum of all eigenvalues of the matrix $\mathbf{XX}'$. A value close to 1 indicates an accurate representation. The output and input factors and their relative inertias are shown in Table 4.

The percentage of inertia explained by the two factors is about 97%. Therefore, it is appropriate to summarize the information of the full data matrix by the two factors.

6.2. Productivity, efficiency and technological change

Table 5 shows the changes in productivity and its components, relations from (1) to (3), for the Italian airports from 2000 to 2006.

Looking at the bias-corrected Malmquist index, $\tilde{M}$, we have six airports that showed an improvement in productivity and fifteen, which that have a decline in productivity. For two airports, changes were not statistically significant. The geometric mean of bias corrected Malmquist index reveals that the global performance of the industry is characterized by a decrease $((1-0.827)\times 100=-17.3\%)$. The positions in the ranking of the airport systems of Milano and Roma, which include the two Italian hubs of Fiumicino and Malpensa, confirm the results of previous studies that indicate that hub status contributes to efficiency (Barros and Dieke, 2008; Sarkis, 2000; Chi-Lok and Zhang, 2009). The bias-corrected efficiency change, $\tilde{E}C$, is statistically significant for just 11 airports. The average value, +22.1%, denotes a catch-up in their efficiencies. However, seven airports have substantially increased (+71.7%) and four have decreased $((1-0.672)\times 100=-32.8\%)$ their efficiencies.

The change in the technical efficiency measures the diffusion of best-practice technology in the management of the activity. That change can be attributed to investment in new technologies related to the core activities as well as to the introduction of technologies that allow a better integration of the airport with the market needs of the served area (Nucciarelli and Gastaldi, 2009). The bias corrected technological change index, $\tilde{T}C$, is less than one for all airports and it is statistically significant for twenty-one of the twenty-three airports. Thus, in the future, new technological investments should be carried out by the Italian airports in order to increase their productivity. The computation of the Malmquist index for sub periods, by two years time spam, does not change the above main findings (for further discussion see Gitto and Mancuso, 2009). The only additional result is, the attended, negative impact of the tragedy of the 11th September 2001 on travel and tourist demand (Barros and Assaf, 2009). Now, in order to obtain further insight, the productivity results are grouped by the institutional and geographic variables.

In Table 6, the quartile position for the Malmquist index has been analyzed with respect to the ownership form and the type of concession agreement.

From the analysis of Table 6 we noticed that the capital control does not affect the distribution of the productivity. On the contrary, the type of concession seems to produce a positive impact on productivity. In order to test the above evidence, we

Table 4
Factors, inputs, outputs and inertia.

Factors	Original variables	Inertia
Outputs		
o_1	aeronautical revenues (*ar*), non-aeronautical revenues (*nar*), number of passengers (*nm*) and number of movements (*nm*);	0.976
o_2	amount of cargo (*ac*)	
Inputs		
i_1	capital invested (*ci*) and soft cost (*sc;*)	0.972
i_2	labor cost (*lc*)	

Table 5
Summary of results for the Italian airports between 2000 and 2006.

Airports (IATA CODE)	M	$\tilde{M}$	EC	$\tilde{E}C$	TC	$\tilde{T}C$
Alghero(AHO)	0.350	0.348**	0.502	0.514**	0.697	0.672**
Brindisi, Bari, Foggia and Taranto(BRI, BDS, FOG and TAR)	0.472	0.484**	0.665	0.706**	0.709	0.680**
Rimini(RMI)	0.556	0.581**	0.722	0.729**	0.770	0.793**
Catania(CTA)	0.587	0.588**	0.785	0.773**	0.747	0.759**
Olbia(OLB)	0.605	0.622**	0.873	0.921	0.693	0.668**
Firenze(FLR)	0.678	0.678**	0.960	0.984	0.707	0.685**
first quartile (i)						
Cagliari(CAG)	0.665	0.679**	0.877	0.900	0.759	0.749**
Palermo(PMO)	0.667	0.685**	0.931	0.958	0.717	0.712**
Trieste(TRS)	0.705	0.722**	0.961	0.979	0.734	0.734**
Ancona(AOI)	0.734	0.727**	0.933	0.931	0.786	0.777**
Napoli(NAP)	0.767	0.743**	1.091	1.081	0.703	0.683**
Pisa(PSA)	0.781	0.793**	1.023	0.994	0.763	0.793
second quartile (ii)						
Bergamo(BGY)	0.839	0.849**	1.000	0.909	0.839	0.861
Pescara(PSR)	0.931	0.931	1.196	1.167	0.778	0.793**
Verona(VRN)	0.974	0.977**	1.344	1.367**	0.724	0.709**
Bologna(BLQ)	0.984	0.984	1.304	1.328**	0.755	0.737**
Treviso(TSF)	0.970	1.000	1.068	1.041	0.908	0.946
third quartile (iii)						
Lamezia(SUF)	1.100	1.105**	1.403	1.327	0.784	0.820**
Torino(TRN)	1.224	1.252**	1.628	1.668**	0.752	0.748**
Milano Linate and Malpensa(LIN and MXP)	1.340	1.344**	1.599	1.560**	0.838	0.856**
Venezia(VCE)	1.404	1.417**	1.892	1.920**	0.742	0.735**
Genova(GOA)	1.683	1.654**	2.243	2.134**	0.751	0.766**
Roma Ciampino and Fiumicino(CIA and FCO)	1.774	1.800**	2.224	2.275**	0.798	0.787**
four quartile (iv)						
geometric mean	0.837	0.827	1.105	1.221	0.757	0.743
Improvement	6	6	12	7	0	0
No change	0	2	0	12	0	2
Decline	17	15	11	4	23	21

M=Malmquist index, EC=efficiency change, TC=technological change; ~=bias correction. ** Significance at 5% level. 5000 bootstrap replications.

Table 6
Distribution of the Malmquist index by ownership and concession agreement.

Quartile rank	Malmquist		
	Public	Private	%
Ownership			
i	17.39	8.70	26.09
ii	21.74	4.35	26.09
iii	17.39	4.35	21.74
iv	17.39	8.70	26.09
%	73.91	26.09	100.00
	Non-Total	Total	%
Concession agreement			
i	13.04	13.04	26.09
ii	21.74	4.35	26.09
iii	17.39	4.35	21.74
iv	0.00	26.09	26.09
%	52.17	47.83	100.00

use the distributions obtained through bootstrap. In fact, one of the advantages of the Simar and Wilson technique is the possibility of making inferences without using a non-parametric test, such as the Mann Whitney U-test (Brockett and Golany, 1996; Grosskopf and Valdmanis, 1987). In Figs. 2 and 3, the confidence intervals, at the 95% confidence level, for the Malmquist index and the technological change are reported, respectively. The efficiency change has not been considered, given the scarcity of significant values.

From the two figures we can conclude, at the 5% significance level, that:

a. Airports owned and managed by a mixed enterprise with a public majority are not significantly less productive than those with a private majority;
b. A total concession agreement produces a significant increase in airport productivity;

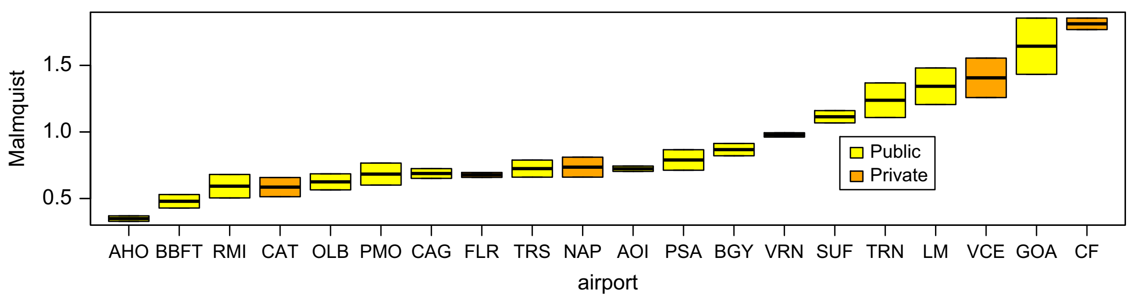

Fig. 2. Malmquist confidence intervals by concession agreement and ownership.

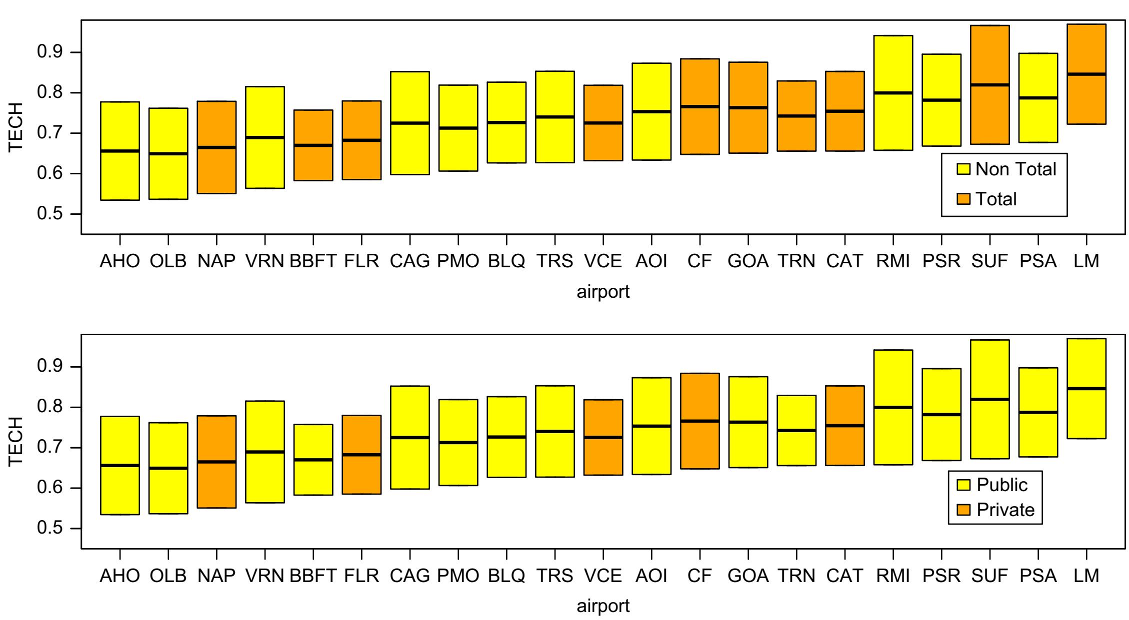

Fig. 3. Technological change confidence intervals for the type of concession by agreement and ownership.

c. No significant differences are produced by the type of concession agreement or by the capital composition on airport technological change.

The last analysis concerns the distribution of the Malmquist index and of the technological change index respect to the airport location (Table 7).

Table 7 shows that the airports located in the South present the worst results in productivity and technological change. Confidence intervals for the above analysis are reported in Fig. 4.

With a significance level of 5%, we can conclude that:

a. Airport location has a significant impact on productivity;
b. No significant differences are produced by the airport location on technological change.

The explanation may be that North-Central area has a higher GDP (Marrocu and Paci, 2010), that more people travel by air in those regions, that more intense domestic and international trading activities exist there and that more airport facilities are built to provide better connecting services with other transport infrastructures.

Table 7
Distribution of Malmquist and technological change index by airport location.

Quartile	Country Area		
	North-Center	South	%
Malmquist			
i	8.70	17.39	26.09
ii	13.04	13.04	26.09
iii	17.39	4.35	21.74
iv	21.74	4.35	26.09
%	60.87	39.13	100
TECH			
i	8.70	17.39	26.09
ii	17.39	8.70	26.09
iii	17.39	4.35	21.74
iv	17.39	8.70	26.09
%	60.87	39.13	100

7. Conclusions

In recent years, the airport industry around the world has been under growing pressure to be more financially self-sufficient and less reliant on government support. Many airports around the world have been commercialized and/or privatized so that airports are operated more like a business. However, the impact of privatization on productivity is still an open question in the related literature. In the present study, we evaluated the productivity evolution, from 2000 through 2006, of the Italian airports by applying the Malmquist index to a sample of 28 airports covering about 96%, 99% and 99% of the total number of passengers, movements and cargo, respectively.

The utilization of the consistent bootstrap procedure proposed by Simar and Wilson (1998, 1999) has allowed us to correct and to obtain confidence intervals for the Malmquist index and its two components: efficiency change and technological change. In this connection, we provide significant evidences that, Italian airports globally experienced an average decrease in productivity. In particular, the Malmquist index shows that the Italian airport industry appears as a polarized structure where the two airport systems of Milano and Roma and few airports (Genova, Lamezia, Torino and Venezia) experienced a productivity growth, whereas the remaining airports are characterized by a steadily decline. Furthermore, the analysis of technological change indicates that most of the future policy intervention should be directed to enhancing the technological level of the Italian airport industry. Contrary to initial expectations, we found evidence that airports owned and managed by a mixed enterprise with a government-owned majority are not significantly less efficient than airports with a publicly owned majority. There is statistical evidence that airport management companies that get all of the airport revenues and are responsible for the whole infrastructure (air-side and land-side) have increased productivity more than those airports that have a limitation in the operations and services. Thus, granting airports a total concession will allow them to increase their productivity in the future. Finally, the results confirm that most of the future government intervention to improve the productivity of the Italian airport industry should be directed in the south area of the country.

Further research is needed to determine whether the decrease in the global performance of productivity is confirmed in a different time period, to explore the sources of the technological regress and

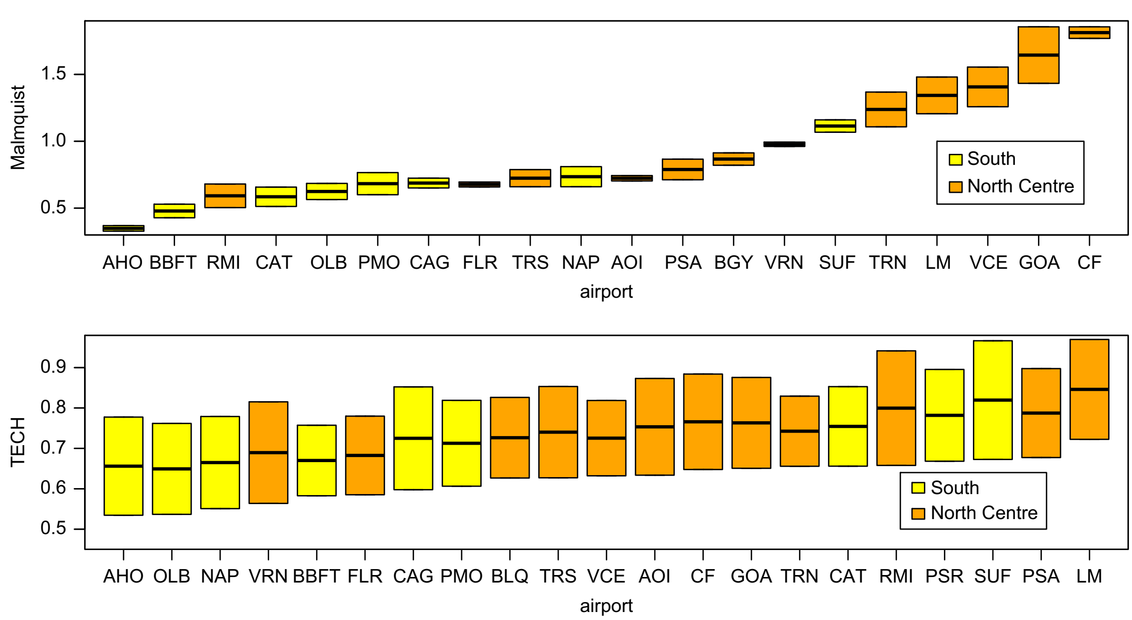

Fig. 4. Malmquist and Technological change confidence intervals by airport localization.

to examine other factors that might affect productivity change. In addition, a separate analysis of airport operations (land-side vs. air-side) might yield further policy implications.

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