Investigating returns to scope and operational efficiency in airport business: an input distance function approach

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Investigating returns to scope and operational efficiency in airport business: an input distance function approach

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Abstract: In the last years air transport industry underwent a strong deregulation trend worldwide. Particular attention was put by US as well as EU policy makers to develop higher competition between potential suppliers of ground handling services. Hence, it is taking growing relevance the decision by airports' managers at any airport size to fully or partially out/in-source handling operations. Furthermore, commercial business is becoming increasingly interesting in light of revenues diversification opportunity. Using a stochastic input distance function approach we develop a model to test whether economies or diseconomies of scope among outputs occur as well as to evaluate the technical and scale efficiency conditions on a sample on Italian small and medium airports. Scope diseconomies connected to operational size are found between airside aeronautical and handling activities. On the contrary, scope economies occur anywhere between aeronautical and commercial operations. This paper improves the existing literature under two points of view. First it provides evidence on the highly debated theme of outsourcing and diversification opportunities for airports. Secondly, it uses a methodology which allows to get estimates without incurring in the a-priori assumption of overall cost-minimisation behaviour.

Keywords: Airport, stochastic input distance function, returns to scope, outsourcing.

Jel Codes: C30, L25, L93, M11

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1 Introduction

Airports activities are diversified. This directly descends from the nature of airports' operations, which involve both airside and landside services. In addition, non-aeronautical commercial business including revenues from retail activities and license allotment to external operators supplying shop, restaurant, duty-free, car parking services, etc. are assuming growing importance. This gives rise to the strategic opportunity for an airport to focus on traditional airside activities or to enter commercial activities, which are not traditionally considered as core business (Oum *et al.*, 2003).

This strategic planning of the diversification pattern has been recently emphasized by the worldwide trend in the airport industry, which is undergoing a deep restructuring process. In particular, a liberalization of the ground handling service was brought in. Indeed, lack of competition among companies offering landside operations, generally managed in sole right way by airports, was recognized to be costly for airlines and in some cases prevented them from offering efficient and high-quality services to their customers. This process has been favored by the increasing competition among air carriers, demanding more efficient airport services in order to reduce the cost of providing air transport service and attract passengers.

The deregulation trend originated in US and then was followed by the acknowledgment by EU policy makers of the need to change access rules to the air transport market. The European Directive 67/1996 created the conditions for all potential operators in handling services provision to enter the market without restrictions. Since then a growing tendency to the creation of an open handling service market at European Community level arose. As a consequence, many airports in recent years chose to contract out or lease out to external companies part or the totality of their aeronautical handling operations. If this lead to economic advantages is an empirical issue, which is largely unexplored. Although few papers try to investigate the role of outsourcing strategy on airport performance (Oum *et al.*, 2003; Oum and Yu, 2004), no study, as far as in our knowledge, has investigated the multi-output nature of airport operations by testing the presence of returns to scope. In this paper we explore the problem of the economic advantages from the joint provision of handling and airside operations as well as aeronautical and commercial activities using return to scope measures, derived using an input distance function approach. This would turn out to provide evidence which may be relevant to decision makers, especially in the light of the recent organizational evolution of the sector.

The analysis was carried out on a sample of Italian airport management companies (representing almost the totality of the international airports), observed between 2000 and 2005. This context seems suitable for our purposes, given that the liberalization process, enforced by law in 1999 (Legislative Decree 18/1999), induced many airports to start a deep outsourcing process of handling operations, which turned out to provide a declining share of handling revenues on total revenues of around 16% (from 47% in 2000 to 31% in 2005). The outsourcing model took the form of an operational unbundling by which production of handling services were allotted to external suppliers, moving to them both rights on revenues and resources endowment. At the same time, Italian airports developed a higher involvement in commercial activities, whose revenue share increased from 16% to 22%.

This paper is organized as follows. In the next section we provide a discussion on the airports' performance measurement (in particular with regards to the choice of inputs and outputs) and how this problem has been treated in the literature. Section 3 presents the input distance function methodology and its potential for applications to the analysis of the returns to scope. After the description of the dataset (Section 4), we illustrate the econometric model and the variables that are used (Section 5). Results are discussed in

Section 6, with regards to technical efficiency, and returns to scale and scope. In the final Section some concluding remarks are made.

2 Literature background: performance measurement in the airport sector

A major concern with airport industry deals with performance measurement. This is not an easy task, as airports are complex structures, which offer both airside and landside services to passengers and airlines. More in details, Doganis (1992) distinguishes among three types of activities: essential operational services (including all aeronautical activities), handling services (including all landside support to aeronautical operations within the terminal area) and commercial services (including concessions, car parking and all other retail activities which grant revenues to airports).

Worldwide privatization and corporatization of airports as well as regulation purposes by governments raised the need to develop consistent overall performance measures, in order to monitor cost efficiency and carry out meaningful benchmarking. In this light, partial (capital or labor) productivity measures, widely used in early analyses on airports sector, present evident shortcomings. Indeed, they can be misleading when looking at changes in productivity, as productivity enhancement for one input may occur at the expenses of another.

Different parametric and non-parametric estimation techniques have been developed and adopted in order to provide reliable performance measures, using a variety of inputs and outputs specifications.

In one of the first exploratory studies, Hooper and Hensher (1997) applied a revenue-weighted Total Factor Productivity (TFP) approach in order to estimate productivity of a set of six Australian airports. All outputs were aggregated into a single output and all inputs into a single input index. Similarly, Nyshadham and Rao (2000) used TFP to investigate productivity of 24 European airports. A better output specification is provided in Gillen and Lall (1997), where airports are defined as providing two different classes of activities, terminal and airside services. They applied Data Envelopment Analysis (DEA) to a sample of 21 U.S. airports and computed separate service-related performance measures. On the same perspective, Pels *et al*. (2003) distinguished between two outputs, air passengers' movements and air transport movements, each of them requiring its own inputs. They applied both DEA and Stochastic Frontier Analysis (SFA) over a sample of 33 large European airports. Martin and Roman (2001) studied 37 Spanish airports considering physical outputs (passengers, tons of cargo and aircraft movements) and cost of labor, capital and materials as inputs. Sarkis (2000) provided a robustness analysis using different DEA models over a sample of 44 U.S. airports. Technology is based on operating costs, employees, gates and runway as inputs and operating revenues, passengers, aircraft (commercial and general aviation) movements and tons of cargo shipped as outputs. Moreover, he advances a discussion on whether characteristics such as being hub airport or belonging to Multiple Airport System positively affect efficiency. De La Cruz (1999) evaluated the performance of 16 large Spanish airports using monetary variables – namely infrastructure, operational and commercial revenues – as proxies of supplied services and total economic cost as the unique input. Pacheco and Fernandez (2003) presents a bi-dimensional analysis, with data on 35 Brazilian domestic airports, where both managerial and infrastructure efficiency are modeled, each of them requiring its own input and output bundles. As for managerial efficiency, revenue types (operating, commercial and other miscellaneous revenues), domestic passengers and cargo were included as outputs, while employees, payroll and operating expenses were included as inputs. Yoshida and Fujimoto (2004) collected data for 67 Japanese airports with the aim to explore technical performance and over-investment issues, using both DEA and endogenous-weighted TFP (EW-TFP) index methods. Their dataset contains passengers, cargo and aircraft movements as outputs and runway length, terminal size, access cost (an estimated value including both monetary and time costs to achieve airport location) and number of employees as inputs. Abbott and Wu (2002) applied Malmquist TFP index and DEA to analyze the efficiency of 12 main Australian airports, using passengers and freight cargo as outputs and staff employed, capital stock in constant dollar terms and runway length as inputs. Total Factor Productivity and Variable Factor Productivity indices have also been calculated in two studies by Oum *et al*. (2003) and Oum and Yu (2004) involving main worldwide airports, the latter proving a judgment on whether managers succeeded to efficiently use variables factors given infrastructures and facilities level. Both these studies take into consideration the role on efficiency measures played by potential explanatory factors within managerial control (in particular, the operational outsourcing of handling services and the diversification towards commercial activities) and other non-discretionary factors depending on airport's specific operations and environment characteristics. Martin-Cejas (2002 and 2005) investigates 31 Spanish airports using a translog cost function specification. Outputs are expressed by passengers and freight cargo, and inputs by labor and capital, for which price information is considered. It is pointed out that multi-output specification performs better than aggregate output models in estimating technology parameters. Craig et al. (2005) estimates the conditional input demands based on a generalizes McFadden cost function using a sample of 52 US airports under different organizational forms, whereby a spending managerial behavior which deviates from cost minimization is modeled. Number of flights is the unique output and prices of labor, capital and materials are considered.

In summary, looking at the literature, many papers tried to examine airport performance using TFP or DEA-based methodologies, which are essentially non-parametric approaches, but few adopted parametric techniques. This study contributes to the literature by introducing the use of a parametric input distance function approach to model airports' production, thus providing a framework for the evaluation of the effects of outsourcing and diversification strategies on airports' performance.

3 Modeling technical efficiency and scope economies measures

3.1 Input distance function approach

As noted above, our major concern deals with two main aspects on airport industry that much differentiate our study from previous empirical papers on this topic. First, we try to estimate airports economic performance using an input distance function, which presents many advantages with respect to traditional approaches like cost frontiers and Data Envelopment Analysis. Secondly, we investigate whether outsourcing of handling services in Italian airports actually provided advantages, and whether a linkage between outsourcing-based benefits and operational size there exists.

Let x be the input vector (x_1, x_2, …, x_N) and y the output vector (y_1, y_2,…,y_M), the input distance function is defined as:

$$D_I(y,x) = \max\{\delta: x/\delta \in L(y)\} \qquad (1)$$

where $L(y)$ indicates the production possibility set including all the input combinations that can produce y given a certain technology. The subscript I indicates that the distance function is calculated under an input-orientation framework, which means that inputs are minimized for a given output level[1]. The value of the distance parameter δ gives the maximum inputs contraction that is necessary to put x/δ on the boundary of the

[1] For completeness, an alternative approach can be the estimation of an output distance function, where outputs are maximised given the inputs. The choice of the methodology depends on whether one assumes that either outputs or inputs can be better adjusted in order to achieve efficiency. In this context we are concerned over the potential for resources saving that might be attained through a rationalisation of the airports operations. Thus, an input- framework has been adopted.

production possibility set. By construction, the scalar δ assumes values ≥ 1, being equal to 1 when efficiency holds.

Following Fare and Primont (1995) the input distance function has to respect some regularity conditions. The expression $D_I(x,y)$ is non-decreasing, linearly homogeneous and concave in the inputs and non-increasing in the outputs.

The advantage of the input distance function stems from the fact that it is specified as function of multi-input and multi-output bundles and does not require information on input market prices, which are often difficult to obtain, unless deriving them in an endogenous way under an econometric perspective. Rather, the input distance function allows the identification of input-specific shadow prices, which are the "virtual" prices supporting the managers' input demand. This comes from the duality with the shadow cost function $C(y,w^s) = \min\{w^s x: D_I(y,x) \geq 1\}$ where w^s denotes the vector of implicit (non-observed) input shadow prices (for more details on the duality properties, see Fare and Primont, 1995).

As a consequence, as argued in Fare and Grosskopf (1990), the input distance function does not hypothesize an overall cost-minimizing behavior, which is instead implicit in the traditional cost function approach. Stating it better, managers are assumed to minimize costs on the basis of input shadow prices, which may differ from market input prices.[2] This is particularly useful in all the circumstances where regulation or a non-competitive environment make inappropriate to assume managers being able to optimally select the input mix (Atkinson and Halvorsen, 1984, 1986). This is likely to be the case of Italian airports, which are typically publicly-owned[3] and whose behavior may be driven by goals different from a mere cost minimization.

[2] When considering an overall cost minimization perspective, this means that the optimal input demand levels are efficient under a technical but not an allocative point of view.

[3] Owners are, in large proportion, local public bodies like commercial chambers, regions, provinces and municipalities. In the few cases wherein airports underwent privatisation, it assumed the form of public/private partnership, leaving a large firms' control to public owners.

Moreover, the input distance function is a natural measure of technical efficiency, contrary to the cost frontier models whose predicted excess cost is contemporary due to both technical and allocative effects.

For estimation purposes, applying Shephard's lemma to the input distance function (Blackorby and Russell, 1989) it is possible to define the following short-run system of equations:

$$\ln(1) = \ln D_I(y,x,k) + \varepsilon$$

$$\frac{w_i x_i}{C(y,w)} = \frac{\partial \ln D_I(y,x)}{\partial \ln(x_i)} + u_i \qquad \text{for } i = 1,\ldots, N\text{-}1 \qquad (2)$$

where x and y are the same as above and k is a vector of quasi-fixed inputs. The first equation is the input distance function in log form and the second represents the derived variable input cost share for the i-th input[4]. $C(y,w)$ is the cost of producing M outputs at the $N\times1$ input price vector. Based on this definition, a firm is technically inefficient if the log-distance function, $\ln D_I(y,x)$, is greater than ln(1), or, in other words, the distance function $D_I(y,x)$ is greater than 1. The first partial derivative of the log-distance function with respect to $\ln(x_i)$ in the right-hand side of the share equation represents the optimal input share. Deviation from this optimal share is due to allocative inefficiency and noise, which are both incorporated into the disturbance term, u_i. The error terms ε and u_i are, as usual, zero mean normally distributed random noise.

The fitted values of the input distance function can be used to estimate the Farrell measure of technical efficiency for each observation. As fitted values of the log-distance function are distributed around zero, they need to be rescaled by adding the absolute value of the most negative residual thus yielding estimates of $\ln D_I(x,y)$ to be greater or equal to zero (Greene, 1980; Grosskopf et al., 2001).

[4] Due to singularity problems, input distance function must be estimated jointly with N-1 cost share equations. However, estimates do not change depending on which share is dropped.

$$\xi_n = \frac{1}{\exp[\ln D_n + |\min(\varepsilon_n)|]} \qquad (3)$$

3.2 Scope economies measurement

When multi-output technology is modeled, one might draw the question whether economies or diseconomies of scope hold. Scope economies are traditionally defined, within a cost function framework, as the opportunity for a firm to get cost advantage by jointly producing two or more outputs with respect to the case where it is more convenient to produce them separately (Baumol *et al.*, 1982). Joint production advantages basically stem from cost complementarities among outputs, which arise when there may be potential for managers to achieve higher performance by sharing common resources over individual products, or organizing inputs in a way that allows reducing resources over-use. Based on a cost function approach, cost complementarities between output *i* and *j* are said to exist if:

$$\frac{\partial^2 C(y,w)}{\partial y_i \partial y_j} < 0 \qquad (4)$$

that is if a marginal increase in one output, y_j, allows reducing marginal cost of producing the other output, y_i.

As noted, when input prices are non readily available or cost-minimization assumption is likely to be violated, cost function is not appropriate, and the resort to an input distance function may be preferred. In light of this, Hajargasht *et al*. (2006) provided a way to obtain an expression for economies of scope taking information on the first and second partial derivatives from an input distance function.

First we define the vectors of the cross second partial derivatives of the distance function $D_I(y,x,k)$ as:

$$h_i = \left(\frac{\partial^2 D}{\partial y_i \partial x_1} \cdots \frac{\partial^2 D}{\partial y_i \partial x_N} \right) \tag{5}$$

and

$$h_j = \left(\frac{\partial^2 D}{\partial x_1 \partial y_j} \cdots \frac{\partial^2 D}{\partial x_N \partial y_j} \right)^{-1} \tag{6}$$

Then, using duality relationship between cost and distance function economies of scope between outputs *i* and *j* are said to exist if:

$$\frac{1}{C}\frac{\partial^2 C}{\partial y_i \partial y_j} = \frac{\partial D}{\partial y_i}\frac{\partial D}{\partial y_j} - \frac{\partial^2 D}{\partial y_i \partial y_j} + h_i \times \begin{pmatrix} \frac{\partial^2 D}{\partial x_1^2} + \frac{\partial D}{\partial x_1}\frac{\partial D}{\partial x_1} & \cdots & \frac{\partial^2 D}{\partial x_1 \partial x_N} + \frac{\partial D}{\partial x_1}\frac{\partial D}{\partial x_N} \\ \vdots & \ddots & \vdots \\ \frac{\partial^2 D}{\partial x_N \partial x_1} + \frac{\partial D}{\partial x_N}\frac{\partial D}{\partial x_1} & \cdots & \frac{\partial^2 D}{\partial x_N^2} + \frac{\partial D}{\partial x_N}\frac{\partial D}{\partial x_N} \end{pmatrix}^{-1} \times h_j < 0 \tag{7}$$

It should be noted that this definition of returns to scope is conditional upon the calculation of first and second input distance function derivatives with respect to both outputs and inputs. This allows flexibility in the input mix, which is not left fixed but can be adjusted so as to achieve the minimum cost[5].

4 Dataset description and sample output/input data

Our database is relative to 26 airport management companies, representing all Italian airports with at least 100,000 yearly passengers, observed from 2000 to 2005. Economic information were collected from the balance sheets, while traffic data and technical information were gathered from the annual statistic publications of ENAC and from the ASSAEROPORTI website[6]. A large part of the whole Italian traffic (around 60 million of passengers) is concentrated on the two main airport systems of Milan and Rome, while the remaining demand is distributed around a high number of small and medium

[5] In another paper, Coelli and Fleming (2004), using a translog input distance function, derived a measure of diversification economies by simply taking the sign of the second partial derivative of the distance function with respect to outputs *i* and *j*. This measure does not enable input mix to be adjusted and, hence, it is not equivalent to scope economies in a proper sense.

scale airports. In the statistical analysis presented below, we decided to exclude from the sample the two major airports in order to have a more homogeneous sample and to focus our study on the operating performance of small and medium scale airports. Summary statistics for the main variables are shown in Table 1.

The typical multi-output nature of airports is represented under two different aspects. On the one hand, the extent of airport operations can be described by means of physical measures of outputs, such as, the total number of passengers per year (*PAX*), the total tons of freight cargo and mail (*CARGO*) and the total number of aircraft movements (*MOV*). On the other hand, it is interesting to observe the revenue performances by nature. We distinguish among three categories of revenues. The first one, which include all airport *FEES* (relative to landing, passengers, cargo, security), is related to the whole infrastructure operations and is strictly influenced by price regulation. The second is given by ground handling revenues (*HANDL*), i.e. all assistance services complementary to aeronautical operations (loading and unloading of baggage, ticketing, check-in, aircraft assistance on ground, etc.), which have been liberalized, as discussed above. For a given level of passengers, the relative amount of handling revenues indicates how much an airport company keeps these services under his responsibility or gives them in *outsourcing* to third parties. Finally, commercial revenues (*COMM*) refers to all the retail activities and their weight measures the degree of airport *diversification* towards non-aeronautical activities. On average, in our sample, fees represent the most important part of revenues (43 per cent), followed by handling (36 per cent) and by commercial ones (21 per cent), however the revenue mix varies significantly among the sample depending on managerial strategies.

[6] Publicly available at www.enac-italia.it and www.assaeroporti.it.

As for inputs, the variable cost was divided into labor cost (*LAB*) and other soft costs (*SOFT*), given by the sum of materials and services expenses[7]. The monetary cost of labor was preferred to the number of employees given the large and diversified use of part-time contracts in the sector[8]. Three physical measures of quasi-fixed capital input were available: the sum of the total length of runways (*RNW*), the apron area dedicated to aircraft parking (*APRON*), and the total area of the airport surface (*SURF*).

5 Model specification

The main objective of this paper is to investigate how airport company performances evolved during the period after handling liberalization, and how managerial strategies such as outsourcing of handling services and diversification to non-aviation activities may have had an impact. We decided to estimate parametrically an input distance function, which has the theoretical advantages described in Section 3, adopting a translogarithmic specification, which is twice differentiable and flexible.

Among the various possible measures of output, we chose to include the number of passengers (probably the most commonly used output in airport literature) along with the amount of handling revenues and commercial revenues. Given that cargo operations are quite marginal to most of our airports, the number of passengers is the variable that best capture the output of the infrastructure, and is indeed the most correlated with the amount of fees revenues (correlation = 0.98), and with respect to the latter is not affected by price regulation[9]. For a given number of passengers, a variation in handling and commercial revenues is very likely to detect, respectively, a change in outsourcing

[7] Due to the heterogeneous nature of this input, a representation in physical terms is not possible.
[8] Usually different employment formula problem is overcome by referring to the full-time equivalent number of employees. Unfortunately, such information is unavailable for most airports.
[9] We also estimated an alternative model where aeronautical output is represented by Work Load Units, defined as number of passengers + 10*tons of cargo. The results are not shown but they are very similar to those obtained just using Y_{PAX}.

and non-aviation diversification strategies; thus, this mix of output is consistent with our research purposes.

Two variable inputs (*LAB* and *SOFT*) were specified. The high correlation among the three available measures of capital input described in Table 1 and the need of saving degree of freedoms in the estimation lead to the choice of reducing the capital inputs to two (*APRON*, *SURF*).[10] Finally, we included time dummy variables in order to capture an eventual time-shift of the distance function.

Our short-run translog input distance function can be written as follows (for details see Grosskopf and Hayes, 1993; Coelli and Perelman, 1999;; Kumbhakar and Lovell, 2000; Atkinson and Primont, 2002; Atkinson *et al*., 2003):

$$\begin{aligned} \ln(1) = \alpha + \sum_i \beta_i \ln Y_i + \sum_r \beta_r \ln X_r + \sum_f \beta_f \ln K_f + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln Y_i \ln Y_j + \\ + \frac{1}{2}\sum_r \sum_s \beta_{rs} \ln X_r \ln X_s + \frac{1}{2}\sum_f \sum_g \beta_{fg} \ln K_f \ln K_g + \frac{1}{2}\sum_i \sum_r \beta_{ir} \ln Y_i \ln X_r + \\ + \frac{1}{2}\sum_i \sum_f \beta_{if} \ln Y_i \ln K_f + \frac{1}{2}\sum_r \sum_f \beta_{rf} \ln X_r \ln K_f + \sum_t \gamma_t T_t + \varepsilon \end{aligned} \quad (8)$$

where Y is the vector of outputs (i, j = *PAX*, *HANDL*, *COMM*); X is the vector of variable inputs (r, s = *LAB*, *SOFT*); K is the vector of quasi-fixed inputs (f, g = *SURF*, *APRON*) and T represents the time dummy variables (t = 2001, 2002, 2003, 2004, 2005). All the variables were divided by their geometric mean; therefore the associated parameters directly give elasticity estimates at the sample mean.

Eq. (8) was jointly estimated with one of the variable input cost share equation (alternatively represented by the share of labor cost or the share of soft cost on the overall variable cost, C):

$$\frac{X_r}{C} = \beta_r + \sum_s \beta_{rs} \ln X_s + \sum_i \beta_{ir} \ln Y_i + \sum_f \beta_{rf} \ln K_f + u_r \quad (9)$$

[10] Alternative combinations of two capital inputs as well as the simultaneous use of all the three capital variables were tested and lead to very similar results.

In addition, the appropriate restrictions on parameters were imposed in order to satisfy the symmetry conditions

$$(\beta_{ij} = \beta_{ji};\ \beta_{rs} = \beta_{sr};\ \beta_{fg} = \beta_{gf};\ \beta_{ir} = \beta_{ri};\ \beta_{if} = \beta_{fi};\ \beta_{rf} = \beta_{fr})$$

and the homogeneity of degree one in inputs

$$(\sum_r \beta_r = 1;\ \sum_s \beta_{rs} = 0, \forall r;\ \sum_r \beta_{ir} = 0, \forall i;\ \ \sum_r \beta_{rf} = 0, \forall f\ ).$$

6 Estimation results

6.1. Model estimation

The system of equations (8)-(9) was estimated via iterated SUR and the results are shown in Table 2. All first order parameters associated to inputs and outputs, which directly give the estimated elasticities at the sample mean, are significant at the 5 per cent level. As expected, a negative sign is associated to outputs (a marginal increase in the output given all the other factors implies an improvement in the efficiency, i.e. a decrease of the distance) while, conversely, a positive sign is associated to variable inputs. As to the fixed inputs, both proxies used in our estimation show a negative sign, suggesting that (at the sample mean) an increase in capacity is able to improve short-run productive efficiency.

Time-dummies are highly significant and negative, indicating that the performance differences among firms have increased during this period. This may be a consequence of the liberalization of handling services, which has created new challenges as well as new opportunities in terms of airport companies management strategies, thus creating potential for higher performance gaps.

Table 3 shows the operational efficiency measures. The results reported in the first column – computed using eq. (3). – indicate an average efficiency of 0.75, with a minimum value of 0.52, confirming that there are significant margins for improving performances of airport companies. From the coefficient of the input distance function, short-run returns to scale (RTS) can be computed as follows (see for details, Fare and Primont, 1995; Atkinson and Primont, 2002; Atkinson *et al*., 2003):

$$RTS = -\frac{1}{\frac{\partial \ln D}{\partial \ln Y_{PAX}} + \frac{\partial \ln D}{\partial \ln Y_{HANDL}} + \frac{\partial \ln D}{\partial \ln Y_{COMM}}} \tag{10}$$

Values greater than 1 (lower than 1) indicate increasing RTS, which in turns means that higher average productivity may be obtained by enlarging (reducing) the operational size of the airport company, given the actual capacity. At the sample mean[11], the returns to scale elasticity is equal to 1.222 (Table 3, column 2), and was proven to be different from unity at 1 percent level, indicating that the average firm can benefit from a proportional increase of all outputs. We also computed punctual returns to scale elasticity values, which range from high increasing to mildly decreasing returns to scale (0.88).

We are particularly interested in testing the existence of economies / diseconomies of scope. Following the procedure described in Section 3 (eq. 5-7), this requires the computation of first and second partial derivatives of the distance function (for the analytical derivation in the case of the translog functional form, see the paper of Hajargasht *et al*., 2006). Results for returns to scope are shown in Table 3 (column 3-5). We remind here that values lower than 0 denote cost complementarities whereas positive values mean that scope diseconomies occur. The results at the sample mean highlight the presence of significant diseconomies of scope between passengers and handling revenues (*Scope_PAX_HANDL*). Therefore, outsourcing of ground handling services seems to be a valid managerial strategy, coherently with the empirical evidence

[11] Note that at the sample mean, equation (10) reduces to the inverse of the sum of the first order coefficient relative to the three outputs, taken with negative sign.

provided by Oum *et al*. (2003). Punctual values are sensibly diversified; this may be justified in light of the high variability of managerial choices in terms of handling outsourcing in the years after the liberalization. We will provide a more careful analysis on this issue in the next Section. No conclusive evidence was found, at the sample mean, about significant scope economies between commercial revenues and passengers (*Scope_PAX_COMM*) or commercial and handling revenues (*Scope_HANDL_COMM*). Though, all punctual values related to the cost complementarities between passengers and commercial revenues (column 4) show a negative sign, indicating on the whole a potential for diversification into commercial business.

6.2. Implications for airport capacity investments and outsourcing strategies

A deeper analysis on returns to scale and scope allows providing some further indications over the managerial strategic choices of airport companies. A first aspect is related to the decisions concerning infrastructure investments, which are connected to the operational scale and the capacity utilization. Since in our sample we have generally increasing short-run returns to scale, this means that the majority of Italian airports can benefit – in terms of average variable cost of production – from the general trend of increase in the demand (+ 23 per cent of passengers from 2000 to 2005), without the need to further invest in capacity. Nevertheless, if the value of *RTS* is below 1, it signals the situations in which an increase in capacity may become necessary and its impact on long-run cash flows should be evaluated. To better analyze this issue, we estimated equation (11), resorting to a Least Square Dummy Variable (LSDV) estimator.[12]

[12] P-values in parenthesis. Tests for regression: F (5,118) = 2323.92 (0.000). R-square: Within = 0.94; Between = 0.96; Overall = 0.95. Regressors in log values mean that the relationship is not linear.

$$RTS = \underset{(0.000)}{1.92} - \underset{(0.000)}{0.30}\ln Y_{PAX} - \underset{(0.000)}{0.24}\ln Y_{HANDL} + \underset{(0.058)}{0.21}\ln Y_{COMM} + \underset{(0.000)}{0.06}\ln K_{SURF} + \underset{(0.000)}{0.27}\ln K_{APRON} \tag{11}$$

As expected, both our proxies for capital highlight a positive sign in the regression, while an increase in the number of passengers progressively exhausts existing returns to scale. When considering the other two outputs, it should be noted that both the amount of handling and commercial revenues are intrinsically linked to the passengers volumes and consequently, their variability pinpoints a different intensity of the corresponding activities at a given level of traffic flows. The output mix affects the *RTS* patterns: while a high intensity of handling activities has a negative impact on *RTS*, a high intensity of commercial activities is connected with higher variable cost savings induced by a proportional increase in all outputs. This evidence is coherent with the direction of returns to scope (Table 3, column 3 and 4), and it can also be explained in the light of the characteristics of these activities. Indeed, it appears reasonable to conceive that the increase of the operational scale is more beneficial for retail commercial activities.

Equation (11) allows us to construct Table 4, which shows how *RTS* increase as the fixed input constraints relaxes (moving from the left to the right of each line). Moreover, for a given level of infrastructure capacity, one can see how *RTS* gradually become exhausted as outputs increase (moving from the top to the bottom of each column). This can be interesting in a long-run perspective to determine the timing of infrastructure investments in order to approximate the optimal operational scale (*RTS* = 1), given a certain prediction over the future trend (or target) of traffic flows.

A second interesting aspect is concerned with the option of outsourcing handling activities to third parties, to which airport operators are giving serious consideration. Such activities are seen as functional to the smooth running of an airport, but, nonetheless, deemed a non-core activity and one that could perhaps be better managed outside. When focusing on evidence of returns to scope between passengers and handling revenues, punctual values were highly variable, indicating that, while at the sample mean there is significant evidence about the existence of scope diseconomies, different firms' strategies can greatly affect this value. If we observe the evolution during time of punctual values measured for some firms involved in a process of outsourcing of its ground handling services (most evident cases are Bologna, Palermo, Turin and Venice), we find that they moved from a situation of relevant scope diseconomies to a situation which is close to optimal (or even revealing weak scope economies). Defining the degree of outsourcing (*OUT*) as the inverse of the percentage of handling revenues over the total revenues,

$$OUT = \frac{Y_{FEES} + Y_{HANDL} + Y_{COMM}}{Y_{HANDL}} \tag{12}$$

we found a relationship (see Table 5) between the existence of scope diseconomies and the different combination of firm size (expressed as the number of passengers) and *OUT*. Particularly interesting, all large observations (over the median value of around 1,500,000 passengers) with a low degree of outsourcing (under the median value of *OUT* variable) were found to have scope diseconomies. The percentage decreases to 54% when small observations are considered, for the same outsourcing index category. One could then argue that a convenience for large firms would exist to outsource handling activities. The percentages decrease when passing to high outsourcing index category, in correspondence to each size class, obviously indicating that outsourcing benefits exhaust when firms move to a relatively high outsourcing regime.

We decided to further investigate this relationship with a *LSDV* regression between returns to scope and both airport size (measured by log of passengers) and outsourcing index, whose results are shown in equation (13).[13]

$$Scope\_PAX\_HANDL = \underset{(0.000)}{-15.58} + \underset{(0.000)}{1.14} \ln Y_{PAX} - \underset{(0.000)}{0.20} OUT \qquad (13)$$

The positive relationship between firm size and returns to scope suggests that the outsourcing strategy is particularly convenient when the airports, as well as the complexity of the management, reach a critical size.

On the basis of the fitted value of equation (12), Table 6 tries to give some further indications on this critical value, showing the returns to scope coefficients for different combinations of airports' size (Y_{PAX}) and handling revenue (*HR*) shares (corresponding to the inverse of *OUT* variable). We recall that returns to scope coefficients equal to zero indicate an optimal output mix, whether negative (positive) values reveal scope economies (diseconomies). Until the number of passengers is below 1,000,000, outsourcing is not convenient, since the structure is too small and must maximize all the possibilities of increasing revenues, including those coming from ground handling services. Only starting from a value of 1,500,000 – 2,000,000 passengers, airport companies should start to consider outsourcing strategies, in order to focus more opportunely on airside activities (and eventually on the commercial business). In fact, when airports' size increases, the percentage of handling revenues that might be considered as optimal progressively decreases. As an example, when the number of passengers is equal to 1,000,000, the best mix of output would imply an *HR* ratio greater than 50% (typically indicating an airport structure where handling is made internally). Conversely, when the number of passengers is equal to 4,500,000, it seems that the best mix of output is attained in correspondence to a percentage of handling

[13] P-values in parenthesis. Tests for regression: F (2,118) = 50.53 (0.000). R-square: Within = 0.46;

revenues of around 10% (suggesting an airport structure where the handling outsourcing process is substantially completed). One reason why outsourcing is likely to be more attractive for largest airports may be given by the higher requirements in terms of advanced technologies (for example those concerning the design and installation of baggage screening systems) and allows for quick reply to changes in technological environment (Gilley and Rasheed, 2000).

7 Conclusions

In this paper we estimated a translogarithmic input distance function providing a methodological framework for evaluating efficiency conditions and strategic opportunities for airport companies, in terms of operating scale and output diversification. We applied this approach to the case of small and medium size Italian airport companies over the period following the ground handling liberalization (2000 to 2005).

Results points out that performance differences among firms have worsened during this period, suggesting that liberalization has created new challenges as well as new opportunities in terms of airport companies management strategies, which have been kept differently by firms. At the sample mean (corresponding to around 1,500,000 passengers) we find statistically significant increasing return to scale (1.22) as well as diseconomies of scope between airside and landside aeronautical activities, indicating outsourcing of handling operations as successful strategy. Scope economies between airside and commercial activities were estimated over the entire sample even if the value at the sample mean did not reach the statistically significant region. A more detailed analysis of returns to scope indicates that outsourcing ground handling services

Between = 0.33; Overall = 0.30. Log values for passengers mean that the relationship is not linear.

is more advantageous for largest airports (starting from a minimum critical size of around 1,500,000 passengers) – in particular those facing a problem of congested capacity – which should benefit from devoting to the core airside operations and upgrading their commercial activities.

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TABLES

Table 1. Summary statistics

Variable	Mean	Standard deviation	Min	Max
PAX (n°)	1,831,497	1,493,484	28,312	5,871,415
CARGO (tons)	11,837	23,446	0	136,339
MOV (n°)	29,834	20,146	1,803	79,994
FEES (1.000 €)	9,671	8,767	82	40,676
HANDL (1.000 €)	8,072	7,087	175	34,002
COMM (1.000 €)	4,630	4,680	28	19,029
LAB (1.000 €)	7,727	5,936	370	27,121
SOFT (1.000 €)	10,673	7,918	306	31,495
RNW (km)	3,443	1,413	1,650	7,012
APRON (km^2)	104,456	70,253	14,400	370,000
SURF (km^2)	2,356,528	1,182,587	550,000	5,820,000

Table 2. Iterated SUR Estimates of the system of equations (8)-(9)

Regressor [a]	Coefficient	P-value	Regressor	Coefficient	P-value
Y_{PAX}	-0.342	0.000	$Y_{HANDL}\, X_{LAB}$	0.002	0.004
Y_{HANDL}	-0.372	0.000	$Y_{HANDL}\, X_{SOFT}$	-0.002	0.004
Y_{COMM}	-0.104	0.001	$Y_{COMM}\, X_{LAB}$	0.000	0.635
X_{LAB}	0.419	0.000	$Y_{COMM}\, X_{SOFT}$	0.000	0.635
X_{SOFT}	0.581	0.000	$Y_{PAX}\, K_{SURF}$	-0.040	0.663
K_{SURF}	-0.141	0.000	$Y_{PAX}\, K_{APRON}$	0.232	0.059
K_{APRON}	-0.094	0.042	$Y_{HANDL}\, K_{SURF}$	0.019	0.787
$Y_{PAX}\, Y_{HANDL}$	0.090	0.182	$Y_{HANDL}\, K_{APRON}$	0.142	0.038
$Y_{PAX}\, Y_{COMM}$	0.050	0.521	$Y_{COMM}\, K_{SURF}$	0.063	0.527
$Y_{COMM}\, Y_{HANDL}$	0.101	0.048	$Y_{COMM}\, K_{APRON}$	-0.193	0.105
$Y_{PAX}\, Y_{PAX}$	-0.316	0.008	$X_{LAB}\, K_{SURF}$	-0.003	0.019
$Y_{HANDL}\, Y_{HANDL}$	-0.348	0.000	$X_{LAB}\, K_{APRON}$	-0.007	0.000
$Y_{COMM}\, Y_{COMM}$	-0.021	0.779	$X_{SOFT}\, K_{SURF}$	0.003	0.019
$X_{LAB}\, X_{SOFT}$	-0.231	0.000	$X_{SOFT}\, K_{APRON}$	0.007	0.000
$X_{LAB}\, X_{LAB}$	0.231	0.000	T_{2001}	-0.143	0.001
$X_{SOFT}\, X_{SOFT}$	0.231	0.000	T_{2002}	-0.230	0.000
$K_{SURF}\, K_{APRON}$	0.162	0.091	T_{2003}	-0.262	0.000
$K_{SURF}\, K_{SURF}$	-0.018	0.862	T_{2004}	-0.322	0.000
$K_{APRON}\, K_{APRON}$	-0.164	0.184	T_{2005}	-0.365	0.000
$Y_{PAX}\, X_{LAB}$	0.000	0.871	*_constant*	0.307	0.000
$Y_{PAX}\, X_{SOFT}$	0.000	0.871			

Equation	*Obs*	*Parameters*	*RMSE*	*R-square*	*Chi-square*	*(P-value)*
ln1	144	32	0.1256	-	53,023	(0.000)
Share_*LAB*	144	6	0.0064	0.9968	44,266	(0.000)

Table 3. Summary of results

	Efficiency scores (1)	*Returns to scale (RTS) (2)*	*Scope PAX_HANDL (3)*	*Scope PAX_COMM (4)*	*Scope HANDL_COMM (5)*
Value at the sample mean (p-value)		1.222 (0.000)	0.165 (0.015)	-0.063 (0.123)	0.021 (0.786)
Values at point					
Average	0.75	1.26	-0.02	-0.42	-0.14
Minimum	0.52	0.88	-0.97	-2.21	-0.79
25 %	0.68	1.08	-0.07	-0.28	-0.14
Median	0.75	1.24	0.02	-0.06	-0.02
75 %	0.82	1.40	0.06	-0.02	0.00
Maximum	1	2.13	0.64	0.00	0.18

Table 4: Fitted values of RTS for different combination of outputs and capital

	$K_{[\lambda=25\%]}$	$K_{[\lambda=50\%]}$	$K_{[\lambda=75\%]}$	$K_{[\lambda=100\%]}$
$Y_{[\lambda=10\%]}$	1.56	1.71	1.87	2.17
$Y_{[\lambda=20\%]}$	1.38	1.53	1.70	2.00
$Y_{[\lambda=30\%]}$	1.21	1.36	1.53	1.83
$Y_{[\lambda=40\%]}$	1.14	1.28	1.45	1.75
$Y_{[\lambda=50\%]}$	1.13	1.27	1.44	1.74
$Y_{[\lambda=60\%]}$	0.97	1.12	1.29	1.59
$Y_{[\lambda=70\%]}$	0.88	1.03	1.20	1.50
$Y_{[\lambda=80\%]}$	0.84	0.98	1.15	1.45
$Y_{[\lambda=90\%]}$	0.79	0.94	1.11	1.41
$Y_{[\lambda=100\%]}$	0.61	0.76	0.92	1.23

λ indicates the quantile values over our sample, for both capital inputs (K) and outputs (Y)

Table 5. Diseconomies of scope between passengers and handling

		OUT	
		Low	*High*
$\boldsymbol{Y_{PAX}}$	*Low*	54% [(a)]	23%
	High	100%	32%

(a) % of observations with positive values of returns to scope (diseconomies)

Table 6. Fitted values of returns to scope for different combination of passengers and handling.

	OUT			
Y_{PAX}	2.00 [*HR* = 50%]	3.00 [*HR* = 33%]	5.00 [*HR* = 20%]	10.00 [*HR* = 10%]
300,000	-1.498	-1.697	-2.096	-3.094
600,000	-0.702	-0.902	-1.300	-2.298
1,000,000	-0.116	-0.315	-0.714	-1.711
1,500,000	0.350	0.151	-0.248	-1.245
2,000,000	0.680	0.481	0.082	-0.915
3,000,000	1.146	0.947	0.548	-0.450
4,500,000	1.612	1.412	1.013	0.016
6,000,000	1.942	1.742	1.344	0.346

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