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A Comparative Analysis of Productivity Change in Italian and Portuguese Airports

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Abstract:

In this paper, we analyze efficiency and productivity of Italian and Portuguese airports, by using the directional distance function and the Luenberger productivity indicator. The key advantage of this approach is that both input contraction and output expansion are considered. The model generates efficiency scores, ranking the airports in the sample. We conclude that inputs and outputs play a major role in airports efficiency. According to this methodology, it can be stated that some Italian and Portuguese airports are efficient and that productivity increased in most of the cases.

Keywords: Italian and Portuguese airports, Luenberger productivity indicator.

1. Introduction

The purpose of this paper is to consider a new application of a non-parametric frontier model in airports. Over the last decade or so a growing literature, using a variety of approaches, has emerged dealing with the issue of productivity in airports (Gillen and Lall, 1997, 2001; Parker, 1999; Murillo-Melchor, 1999; Hooper and Hensher (1997), Sarkis (2000), Humphreys and Francis (2002), Fernandes and Pacheco (2002), Pels, Nijkamp and Rietveld, 2001,2003), Sarkis and Talluri (2004), Yoshida and Fujimoto (2004) and Yoshida (2004).

This paper aims to extend the established literature on airport productivity by applying the Luenberger indicator (Chambers, 1996) to estimate and decompose productivity change. Earlier studies of airport productivity tend to employ nonparametric techniques and Malmquist (1953) productivity indexes. The Luenberger indicator is a difference-based measure whereas the Malmquist index is a ratio-based measure.[1,2] Luenberger (1992) introduces the shortage function which has the desirable properties of accounting for both input contractions and output improvements, and establishing duality between the shortage function and the profit function (Chambers et al, 1998). Thus, the indicator can accommodate either an input or output perspective corresponding to cost minimisation or profit maximisation. We employ the Luenberger productivity indicator of Chambers (1996) to estimate productivity change and its constituents for a sample of Italian and Portuguese airports between 2001 and 2003.

Analysing the productivity characteristics of European airports is of interest because if productivity has improved then it should be reflected in better performance, lower customer prices and improved service quality. It may also reflect more customer oriented operations if productivity gains are translated in prices. Analysing productivity differences of airports

[1] Productivity measures based on differences are termed “indicators” whilst measures based on ratios are termed “indexes”. Chambers (1996, 2002) and Diewert (1998, 2000) discuss the two approaches.
[2] The theoretical and empirical relationships between the Luenberger indicator and Malmquist productivity index are discussed by Boussemart et al (2003).

across European countries can benchmark the performance of similar units and possibly indicate the different strategies undertaken by airport units across national markets (Adler and Berechman, 2001; Pels, Nijkamp and Rietveld, 2001, 2003).

The remainder of the paper is organised as follows: section 2 presents the methodology framework adopted. Section 3 presents the data and the results. Section 4 is devoted to the discussion and conclusion.

2. Methodological Framework

In proposing new, more flexible, measures involving production theory, Chambers et al. (1996, 1998) introduced the "directional distance function"[3], which is the transposition in production theory of Luenberger's (1992) "benefit function" in a consumer context. The directional distance function determines a shortcut in one direction which permits an observed production unit to reach the production frontier. In economic terms, this function makes it possible to evaluate the scale of the economies which can be achieved and the possible improvements in production. It also provides a "benchmark" by defining a reference point to be reached. The principal advantage of this function lies in its ability to take account simultaneously, and in a broader context, of both inputs and outputs. This function therefore measures the smallest changes in inputs and outputs in a given direction which are necessary for a firm to reach the production frontier, rendering it an indicator of firm performance.

Let the technology be described by a set, $T \subseteq R_+^N \times R_+^M$, defined by

$$T_t = \{(x_t, y_t) : x_t \text{ can produce } y_t\} , \qquad (1)$$

where $x_t \in R_+^N$ is a vector of inputs and $y_t \in R_+^M$ is a vector of outputs at the time period *t*.

Throughout this paper, technology satisfies the following conventional assumptions[4]:

A1: $(0,0) \in T_t, (0, y_t) \in T_t \Rightarrow y_t = 0$ i.e., no fixed costs and no free lunch;

A2: the set $A(x_t) = \{(u_t, y_t) \in T_t; u_t \leq x_t\}$ of dominating observations is bounded $\forall x_t \in R_+^N$, i.e., infinite outputs are not allowed with a finite input vector;

A3: T_t is closed;

A4: $\forall (x_t, y_t) \in T_t, (x_t, -y_t) \leq (u_t, -v_t) \Rightarrow (u_t, v_t) \in T_t$, i.e., fewer outputs can always be produced with more inputs, and inversely (strong disposal of inputs and outputs);

A5: T_t is convex.

The directional distance function generalises the traditional Shephard distance function (1970). Directional distance functions project input and/or output vector from itself to the technology frontier in a preassigned direction. In the case of a radial direction out of the origin, we retrieve the classical Shephard distance function. The directional distance function is defined as follows.

The function $D_t : R^{n+p} \times R^{n+p} \rightarrow R \cup \{-\infty\} \cup \{+\infty\}$ defined by

$$D_t(x_t, y_t; g) = \begin{cases} \sup\{\delta : (x_t - \delta h; y_t + \delta k) \in T_t\} & if \quad (x_t - \delta h; y_t + \delta k) \in T_t, \delta \in R \\ -\infty & otherwise \end{cases} \quad (2)$$

is called directional distance function in the direction of $g = (h, k)$.

To operate the approach, it is necessary to take an appropriate direction. We do this by considering the direction $g = (x, y)$. Then, the directional distance function is similar to the proportional distance function introduced by Briec (1995, 1997). This distance function is

[3] See also Färe and Grosskopf (2000) for an overview of the directional distance function.
[4] See Shephard (1970) and Färe et al. (1985) for thorough analysis of their implications on technology.

based on simultaneous proportional modifications of inputs and outputs; it generalises Debreu's and Farrell's measure and is equally straightforward to interpret.

To estimate the proportional distance function, we use a non-parametric approach (see Banker and Maindiratta, 1988; Varian, 1984). The technology can be written as:

$$T_t = \left\{ (x_t, y_t), x_t \geq \sum_j \theta_j x_t^j, y_t \leq \sum_j \theta_j y_t^j, \sum_j \theta_j = 1, \theta_j \geq 0, j = 1, \ldots, J \right\}. \quad (3)$$

The linear program that calculates the values of the directional distance function is given by[5]:

$$D_t(x_t, y_t) = \max \delta_t$$

$$\text{s.t. } x_t - \delta_t x_t \geq \sum_j \theta_j x_t^j , \quad (4)$$

$$y_t + \delta_t y_t \leq \sum_j \theta_j y_t^j ,$$

$$\sum_j \theta_j = 1 , \; j = 1 \ldots J .$$

Suppose that an individual airport is represented by a production vector (x_t, y_t) with corresponding technology T_t, and then the production vector is changed to (x_{t+1}, y_{t+1}) with corresponding technology T_{t+1}. In order to assign a cardinal measure to the productivity change we can use the directional distance function in one of two ways; corresponding to using either the initial technology at *t* or the final technology at *t+1* as reference. In this case, the Luenberger productivity indicator proposed by Chambers (1996) can be employed to evaluate productivity change. The productivity indicator is constructed as the arithmetic mean of the productivity change measured by the technology at T_{t+1} and the productivity change measured by the technology at T_t.

The Luenberger productivity indicator is defined as[6]:

$$L(z_t, z_{t+1}) = \frac{1}{2}\left[D_{t+1}(z_t; g) - D_{t+1}(z_{t+1}; g) + D_t(z_t; g) - D_t(z_{t+1}; g)\right]. \qquad (5)$$

Positive growth (decline) is indicated by positive (negative) value. Unlike the Malmquist index, the Luenberger productivity indicator is additively decomposed as follows:

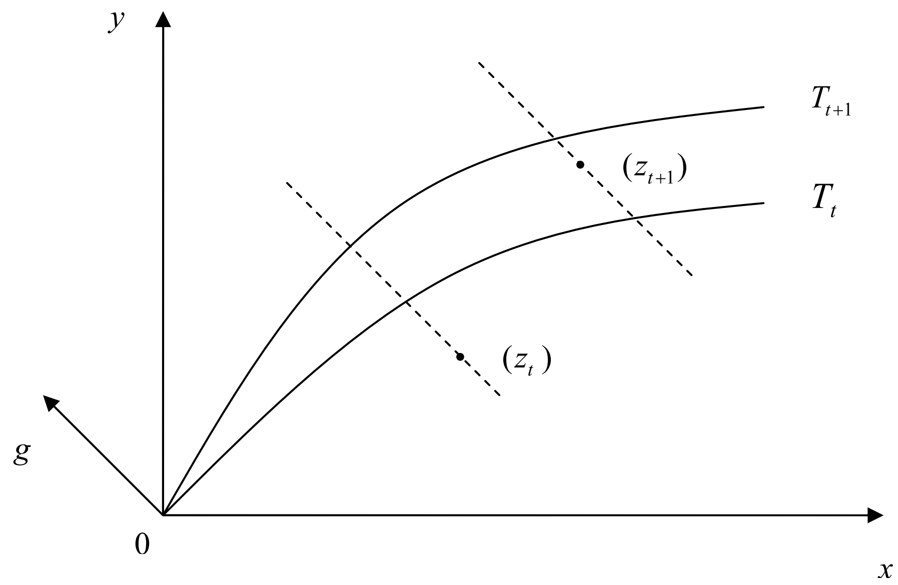
$$L(z_t, z_{t+1}) = \left[D_t(z; g) - D_{t+1}(z_{t+1}; g)\right] + \frac{1}{2}\left[D_{t+1}(z_{t+1}; g) - D_t(z_{t+1}; g) + D_{t+1}(z_t; g) - D(z_t; g)\right], \qquad (6)$$

where the first term (inside the first brackets) measures efficiency change between time periods t and t+1 while the arithmetic mean of the difference between the two figures inside the second brackets expresses the technological change component, which represents the shift of technology between the two time periods. This decomposition was inspired by the breakdown of the Malmquist productivity index in Färe et al. (1989). For a complete overview of the decompositions of productivity measures, see Grosskopf (2003). Figure 1 illustrates the Luenberger productivity indicator.

[5] All the computations are programmed in Mathematica language with the mathematica 5.0 software.

[6] We simplify the notations by posing $z_t = (x_t, y_t)$.

Figure 1. The Luenberger productivity indicator



3. Data and Results

We use the dataset on Italian and Portuguese airports under the period 2001-2003. The data for the Portuguese airports was obtained from, Transportation statistics, published by INE - Portuguese Statistical Agency, (Barros and Sampaio, 2004 and Barros, 2006). The data on Italian airports was obtained in Annuario Statistico available in the Italian Ministero Della Infraestrutura e dei transporti, Barros and Dieke (2007).

We construct efficiency and productivity measures for Italian and Portuguese airports. Airports are assumed to produce six outputs: (i) number of passengers, (ii) number of planes, (iii) general cargo, (iv) aeronautical sales and (v) handling receipts and (vi) commercial sales, from two inputs: (vii) operational costs, (viii) capital invested. The descriptive statistics are shown in Table 1.

Table1. Characteristics of variables

Variables	Minimum	Maximum	Mean	Stand. dev.
Outputs				
Passengers	7222	25809828	2547117	4817306
Planes	52	293790	30481	54813
Cargo	0	26103618	759484	2996743
Aeronautical receipts	0	206550	15043	37968
Handling receipts	0	272486	12246	35305
Commercial receipts	0	235406	14617	41252
Inputs				
Operational costs	114	498970	35233	87543
Capital	106	2795018	109163	403837

The Luenberger productivity indicators are calculated using linear programming techniques. The results are presented in Table 2, with the Luenberger productivity indicator (L) decomposed into its constituents: technical efficiency change (the diffusion or catch-up component - EFFCH); and technological change (the innovation or frontier-shift component - TECH). EFFCH represents the diffusion of best-practice technology in the management of airport activities and it is attributable to investment planning, technical experience, and management and organisation. TECH results from innovations and the adoption of new technologies by best-practice airport in each country.

Table 2. Productivity Changes in Italian and Portuguese Airports (2001-2003)

Airports	**EFFCH**	**TECH**	**L**
Lamezia Terme	0.5463	0.2226	0.7689
Funchal	0.591	0.1655	0.7566
Reggio Calabria	0.5254	0.2013	0.7267
Rimini – Miramare	0.5218	0.1709	0.6928
Genova – Sestri	0.4754	0.2097	0.6851
Alghero – Fertilia	0.4621	0.2185	0.6806
Bari-Palese Macchie	0.3131	0.3563	0.6694
Crotone	0.4718	0.1941	0.6659
Pisa - San Giusto	0.4282	0.2209	0.649
Forli	0.4666	0.1671	0.6338
Olbia - Costa Smeralda	0.3988	0.23	0.6288
Pescara	0.4154	0.2052	0.6206
Perugia - Sant'Egidio	0.4068	0.2117	0.6185
Palermo - Punta Raisi	0.1626	0.3883	0.5509
Firenze – Peretola	0.2609	0.274	0.5349
Cagliari – Elmas	0.1004	0.4223	0.5228
Trieste - Ronchi dei Legionari	0.3546	0.1597	0.5143
Napoli – Capodichino	0.0288	0.485	0.5138
Catania – Fontanarossa	0.0888	0.391	0.4798
Bergamo-Orio aal Serio	0.000	0.4537	0.4537
Venezia – Tessera	0.000	0.4451	0.4451

Torino – Caselle	0.002	0.4417	0.4436
Bolzano	0.3544	0.0717	0.4261
Verona – Villafranca	0.0291	0.3653	0.3944
Trapani – Birgi	0.0283	0.3425	0.3709
Bologna-Borgo Panigale	0.0438	0.3216	0.3654
Ancona – Falconara	0.1738	0.1756	0.3495
Parma	0.1077	0.1825	0.2902
Roma - Fiumicino	0.000	0.2709	0.2709
Cuneo - Levaldigi	0.2699	-0.036	0.2339
Milano - Malpensa	0.000	0.2054	0.2054
Porto	0.3605	-0.1894	0.1712
Treviso - Sant'Angelo	0.000	0.0606	0.0606
Faro	0.314	-0.3487	-0.0348
Porto Santo	0.000	-0.0362	-0.0362
Lisboa	0.000	-0.208	-0.208
Ponta Delgada	0.2915	-0.5088	-0.2173
Santa Maria	0.1776	-0.5217	-0.3441
Horta	-0.3025	-0.5129	-0.8154
Flores	0.000	-1.6659	-1.6659
Mean	**0.2217**	**0.1051**	**0.3268**
Median	**0.2192**	**0.2053**	**0.4494**
St.Dev.	**0.2153**	**0.3893**	**0.4696**

From Table 2, we observe the productivity change score (L) is mixed, being positive for almost all airports and negative for some of them. In terms of productivity decomposition, it is clear that both factors – technical efficiency and technological change –drive the productivity change in the Italian and Portuguese airports. The TECH average score value is equal to 0.1051 which is a relative small value. The EFFCH average score value is 0.2217 which is also a relative small value. Based in this values it can be concluded that there is room for the airports analysed to improve their productivity.

Overall, we observe five combinations of technical efficiency change and technological change. (i) In the first group, we find airports where improvements in technical efficiency co-exist with improvements in technological change. These are the best-performing airports. As the airports are ranked according to the Luenberger productivity indicator, table 2 identifies the most efficient airports. At the top we have the best airport, an Italian airport: Lamezia-Terme with a Luenberger indicator of 0.7689, signifying that its productivity improved by simultaneously both contracting inputs and expanding outputs by 76.89%. (ii) The second group includes airports where negative technological change co-exists with positive efficiency change (Cuneo, Porto, Faro, Ponta Delgada and Santa Maria). These are airports with problems in innovations that results in decreasing technological change, but with an improvement in technical efficiency that drives the technological change up. (iii) In the third group we find airports in which nil technical efficiency co-exists with improvements in technological change (Bergamo, Venezia, Roma, Milano and Treviso). These are the airports without technical efficiency improvement but a positive technological change that ensures a positive Luenberger productivity indicator. (iv) In the fourth group, we find airports in which nil technical change co-exists with deterioration of technological change (Porto Santo, Lisbon and Flores). These are the airports without innovations and without innovations in management practices that result in nil technical efficiency. (v) The fifth group includes airports with negative technological change co-exists with negative technical efficiency. A sole airport is found with this result: Horta. This is the worst airport in the sample.

4. Discussion and Conclusion

A Luenberger productivity indicator is used to estimate and decompose productivity growth on observations of Italian and Portuguese airports between 2001 and 2003.. The present set of results using an alternative productivity measure can confirm the consistency of previous research.

There is productivity growth in the majority of airports analysed, which is driven by improvements simultaneously by technological change and technical efficiency. This finding is consistent with previous research on Italian airports (Barros and Dieke, 2007) and Portuguese airports (Barros and Sampaio, 2004). We observe evidence that almost all airports are catching-up with European best practice defined by the two countries analysed: Italy and Portugal. Technical efficiency change is as important as technological change in driving productivity growth. Possible explanations for this feature of the results are that investment is matched by upgraded managerial practices, derived from increasing European integration and globalisation in airports. The Portuguese airports with exception of Funchal are the least efficient in the sample.

Several policy implications arise from the results. First and foremost, it is clear that there is considerable room for improving technical efficiency if Portuguese are to catch-up with industry best practice at European level. Technical inefficiency is a consequence of one or more of the following factors: (i) structural rigidities that create principal-agent problems (Jensen and Meckling, 1976). The principal-Agent relationship relates to the difficulty of controlling those empowered as managers acting on behalf of the owner (the government of public airports); (ii) rigidities associated with EU labour markets which give rise to collective-action problems (Olson, 1965). Workers can get a free ride on the management's own efforts to improve performance. This situation happens when the labour laws does not link job tenure to performance, an unfortunate traditional procedure in the public labour market.; (iii) organisational factors associated with X-efficiency (Leibenstein, 1966); The X-efficiency is related to the fact that the production function is not completely specified or known, the contracts for labour are incomplete and not all inputs are marketed on equal terms to all buyers. Inefficiencies associated with incomplete markets exist everywhere, but are particularly prevalent in regulated markets. In this situation, the managers may be unable to adopt the correct strategy, since they do not know what it should be; and (iv), dimensional factors associated with scale and scope economies. Due to any, some or all of these factors, some airports may produce at a level below the maximum possible output, given the production environment. Arguably, changing the ownership structure of airports, through privatisation might reduce some of the above problems. However, this would need to be considered against the role that smaller, local-oriented airports play in regional economic development.

Given that technological change (innovation) is a driver of productivity growth in the Italian and Portuguese airport activity, an appropriate policy recommendation is for capital accumulation, which determines the adoption of technology by best practice airports, thereby shifting the efficient frontier. Another policy recommendation in this context is for larger or centralized airports to merge and acquire smaller airports, in order to develop economies of scale. Indeed, the group structure, which a feature of airports at European level, is ideally suited for this strategy.

However, the general conclusion is that there is room for improvement in the management of some Italian airports and almost all Portuguese airports. Regarding the decrease or nil technical efficiency observed in the Portuguese airports, a possible explanation comes from recent evidence that emerged to confirm the prevailing perception amongst Portugal-based business managers from overseas that incompetence and inefficiency are rife among their Portuguese counterparts. This evidence comes from an exhaustive survey carried out jointly by Ad-Capita Executive Recruitment and Research and the Cranfield School of Management, UK (see report in pdf: "Can Portuguese Managers Compete?" at www.adcapita.com). The study highlights areas which are certainly applicable to the current Portuguese airports management, reinforcing our findings and considerations about the causes of existing inefficiencies.

The benchmarking of different country airports allows discerning more clear specific national causes that are difficult to rise up in single national studies. Therefore the present research calls for more inter-European benchmark studies, allowing the comparison of different units of different countries in order to disentangle operational causes of efficiency from cultural causes.

References

Adler, N., and J. Berechman (2001): 'Measuring Airport Quality from the Airlines Viewpoint: An Application of Data Envelopment Analysis', *Transport Policy*, 8, 171-181.

Banker, R.D., Maindiratta, A., 1988. Nonparametric analysis of technical and allocative efficiency in production. Econometrica 56, 1315-1332.

Barros, C.P. and Sampaio, A. (2004) Technical and Allocative Efficiency in Airports. International Journal of Transport Economics, 31,3, 341-354.

Barros, C.P. and Dieke, P. U.C. (2007) Performance Evaluation of the Italian Airports with Data Envelopment Analysis. Mimeo.

Barros, C.P. (2006) Technical Efficiency in the Portuguese Airports with a Stochastic Cost Frontier Model. Oum, T. (edit.) *OCDE* (forthcoming).

Boussemart, J.P., Briec, W., Kerstens, K., Poutineau, J.C., 2003. Luenberger and Malmquist productivity indices: Theoretical comparisons and empirical illustration. Bulletin of Economic Research 55, 391-405.

Briec, W., 1995. Une nouvelle approche de la mesure de l'efficacité productive. Phd Thesis, EHESS, GREQAM.

Briec, W., 1997. A graph type extension of Farrell technical efficiency measure. Journal of Productivity Analysis 8, 95-110.

Chambers, R.G., 1996. A new look at exact input, output, and productivity measurement. Department of Agricultural and Resource Economics, Working Paper 96-05, University of Maryland.

Chambers, R.G., 2002. Exact nonradial input, output, and productivity measurement. Economic Theory 20, 751–765.

Chambers, R.G., Chung, Y., Färe, R., 1996. Benefit and distance functions. Journal of Economic Theory 70, 407-419.

Chambers, R.G., Chung, Y., Färe, R., 1998. Profit, directional distance functions, and Nerlovian efficiency. Journal of Optimization Theory and Applications 98, 351-364.

Diewert, W., 1998. Index number theory using differences rather than ratios. Department of Economics Discussion Paper 98–10, Vancouver: University of British Columbia.

Diewert, W., 2000. Productivity measurement using differences rather than ratios: A Note. School of Economics Discussion Paper 2000/1, Sydney: University of New South Wales.

Färe, R., Grosskopf, S., 2000. Theory and Applications of Directional Distance Functions, *Journal of Productivity Analysis*, 13, 93-103.

Färe, R., Grosskopf, S., Lindgren, B., Roos, P., 1989. Productivity developments in Swedish hospitals: a Malmquist output index approach, in A. Charnes, V. W. Cooper, A. Lewin and L.

Seiford (eds.), Data Envelopment Analysis: Theory, Methodology and Applications, Boston: Kluwer Academic Publishers.

Färe, R., Grosskopf, S., Lovell, C.A.K., 1985. The measurement of efficiency of production. Klüwer Academic Publishers, Boston.

Fernandes, E. and Pacheco, R.R. (2002). Efficient Use of Airport Capacity, *Transportation Research: Part A- Policy and Practice*, 36 (3) 225-38.

Gillen, D. and Lall, A. (2001). Non-Parametric Measures of Efficiency of US Airports," *International Journal of Transport Economics*, 28 (3), 283-306.

Gillen, D. and Lall, A. (1997). Developing measures of Airport Productivity and performance: an application of Data Envelopment Analysis. Transportation Research, Part E, 33 (4), 261-273.

Grosskopf, S., 2003. Some remarks on productivity and its decompositions. Journal of Productivity Analysis 20, 459-474.

Hooper, P.G. and Hensher, D. A. (1997). Measuring Total Factor Productivity of Airports: An Index Number Approach. Transportation Research: Part E- Logistics and Transportation Review, 33 (4), 249-59.

Humphreys, I. and Francis, G. (2002). Performance Measurement: a review of airports. International Journal of Transport Management, 1, (2), 79-85.

Jensen, M.C., Meckling, W., 1976. Theory of the firm: managerial behaviour, agency costs and capital structure. Journal of Financial Economics 3, 305-360.

Leibenstein, H., 1966. Allocative efficiency vs. 'X-efficiency`. *American Economic Review* 56, 3, 392-414.

Luenberger, D.G., 1992. Benefit function and duality. Journal of Mathematical Economics 21, 461-481.

Malmquist, S., 1953. Index numbers and indifference surfaces. Trabajos de Estatistica 4, 209-242.

Murillo-Melchor, C. (1999). An analysis of Technical Efficiency and Productive Change in Spanish Airports using the Malmquist Index. International Journal of Transport Economics, 26 (2), 271-92.

Olson, M., 1965. *The logic of collective action: Public goods and the theory of groups*. Cambridge, MA: Harvard University Press.

Parker, D. (1999). The performance of BAA before and after privatisation. Journal of Transport Economics and Policy, 33,2,133-146.

Pels, E.; Nijkamp, P. and Rietveld, P. (2003) Inefficiency and scale economics of European airport operations. Transportation Research Part E, 39, 341-361.

Pels, E.; Nijkamp, P. and Rietveld, P. (2001). Relative Efficiency of European Airports. Transport Policy, 8, 183-192.

Sarkis, J. (2000). Operational Efficiency of Major US Airports. Journal of Operations Management, 18, (3), 335-251.

Sarkis, J. and Talluri, S. (2004). Performance-based clustering for benchmarking of US airports. Transportation Research Part A, 38, 329-346.

Shephard, R.W., 1970. Theory of Cost and Production Functions. Princeton University Press, Princeton NJ.

Yoshida, Y. and Fujimoto, H. (2004). Japanese-airport benchmarking with DEA and endogenous-weight TFP methods: testing the criticism of overinvestment in Japanese regional airports. Transportation Research Part E, 40, 533-546.

Yoshida, Y. (2004) Endogeneous-weight TFP measurement: methodology and its application to Japanese-airport benchmarking. Transportation Research Part E, 40,151-182.

Varian, H.R., 1984. The nonparametric approach to production analysis. Econometrica 52, 579-597.