A benchmarking analysis of Spanish commercial airports. A comparison between SMOP and DEA ranking methods

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GARS London Workshop
10-11 Nov, 2006

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The aim of this paper

- **To analyze the relative performance of each individual Spanish airport**
- **To fully rank both efficient, as well as inefficient airports.**
- **To compare six different approaches of benchmarking based on DEA and SMOP making a comparison between them**
  - **SMOP (2)**
  - **Cross-efficiency matrix**
  - **Super-efficiency (2)**
  - **Virtual efficiency (champion performer)**

The background

- **Overall picture based on some partial productivity ratios**
  - **total cost per WLU; operating cost per WLU; capital cost per WLU; labor cost per WLU; WLU per employee; WLU per unit asset value; total revenue per WLU and aeronautical revenue per WLU.**
- **Data envelopment analysis (DEA), total factor productivity (TFP) and stochastic frontiers (SF)**
- **Excellent revisions**
  - **(Francis et al., 2002; Humphreys and Francis, 2002; Oum et al., 2003)**

AENA

- AENA (Aeropuertos Españoles y Navegación Aérea) is one of the largest airport operators in the world.
- AENA is a public owned company that manages the total airport system and air traffic control in Spain.
- Nine of the fifty largest European airports are located in Spain.
- AENA is not subsidized by the State
- The company has created a filial AENA Desarrollo Internacional to obtain airport management concessions abroad in Latino America.
  - Mexico, Colombia and Cuba, it is also bidding for Uruguay's Carrasco International Airport in Montevideo, and the five Peruvian airports expected to be next on the privatization process.

The data

- **34 Spanish airports that have different size**
- **Outputs**
  - **Air traffic movements**
  - **Number of passengers**
  - **Number of tons of cargo**
- **Inputs**
  - **Labor expenditures**
  - **Capital expenditures**
  - **Material expenditures**

Benchmarking and DEA

- **Seminal paper of Charnes et al. (1978)**
  - **DEA methodology is described as a "mathematical programming model applied to observed data that provides a new way of obtaining empirical estimates of extremal relationships”**
- **Numerous applications in a wide area of contexts:**
  - **education, health care, banking, armed forces, sports, transportation, agriculture, retail stores and electricity suppliers.**

Multiplier-DEA VRS output efficiency

$$\min_{v\mu} \sum_{i=1}^{m} v_i x_{io} + v_o$$

$$s.t.$$

$$\sum_{i=1}^{m} v_i x_{ij} + v_o - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0 \quad (j = 1 \cdots n),$$

$$\sum_{r=1}^{s} \mu_r y_{ro} = 1$$

$$where\ v_i, \mu_r \geq 0, v_o\ \ free$$

Cross-efficiency DEA model

- **Cross-efficiency matrix**

$$h_{kj} = \frac{\sum_{i=1}^{m} v_{ik} x_{ij} + v_k}{\sum_{r=1}^{s} \mu_{rk} y_{rj}}, \left(k = 1, \cdots, n,\ j = 1 \cdots n\right)$$

- **h_{kk} is the standard inefficiency score**
- **the performance of airport j is evaluated by the weights of airport k.**
- **Average cross-efficiency**

Advantages of this method

- **All the elements of the cross-efficiency matrix have been considered**
  - **not only the elements of the diagonal**
- **All the airports are evaluated with the same sets of weight vectors.**
- **The minimum value of cross-efficiency is 1, which occurs if airport j is efficient in all the runs**
  - **All the airports evaluate unit j as efficient.**
- **DEA scores may be non-comparable, since each element uses different weights**

Super-efficiency ranking methods.

- **Andersen (1993)**

$$\min_{\nu\mu} \sum_{i=1}^{m} \nu_i x_{io} + \nu_o$$

$$s.t.$$

$$\sum_{i=1}^{m} \nu_i x_{ij} + \nu_o - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0 \quad \left(j = 1 \cdots n, j \neq o \right),$$

$$\sum_{r=1}^{s} \mu_r y_{ro} = 1$$

$$where\ \nu_i, \mu_r \geq 0, \nu_o \ \ free$$

Potential problems of SE

- **Each unit is evaluated according to different weights.**
  - **Proportion of the efficiency score that each unit o attained with its chosen weights in relation to a virtual unit closest to it on the frontier.**
- **“Specialized’’ DMUs may obtain an excessively high ranking.**
  - **To avoid this biased problem, Sueyoshi (1999) introduced specific bounds on the weights**
- **Sometimes the super-efficiency model is infeasible for some efficient DMUs.**

Virtual Super-Efficiency Method

(Bazargan and Vasigh, 2003).

- **A virtual super efficient airport is introduced and included with the rest of existing airports**
- **The efficient frontier, based on this model, therefore consists of only this virtual super-efficient airport.**
- **This approach serves to rank all the airports**

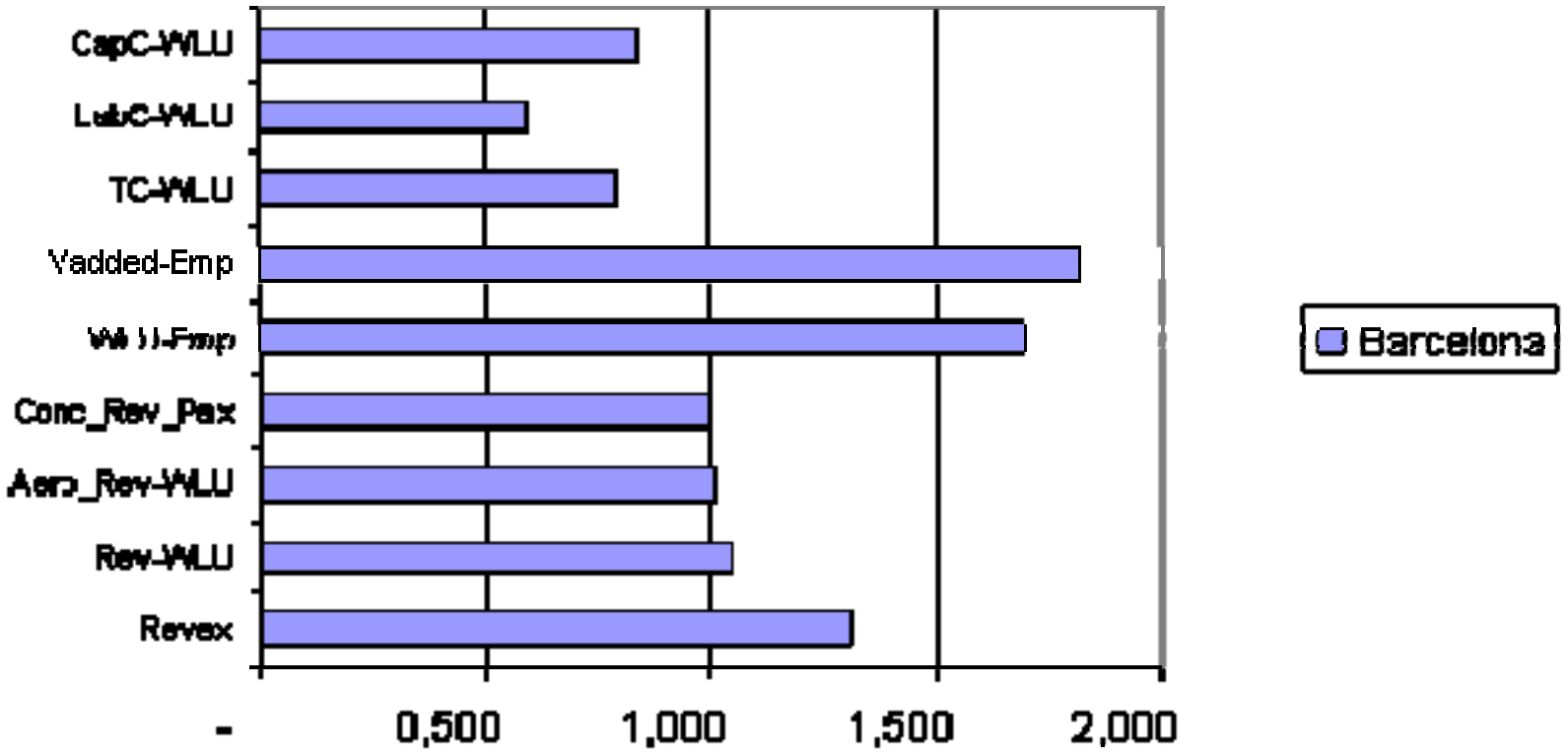
A partial approach of performance indicators

- Doganis and Graham (1995)
  - 21 different partial indicators. However, they only consider a set of nine indicators to study the profile of each individual airport.

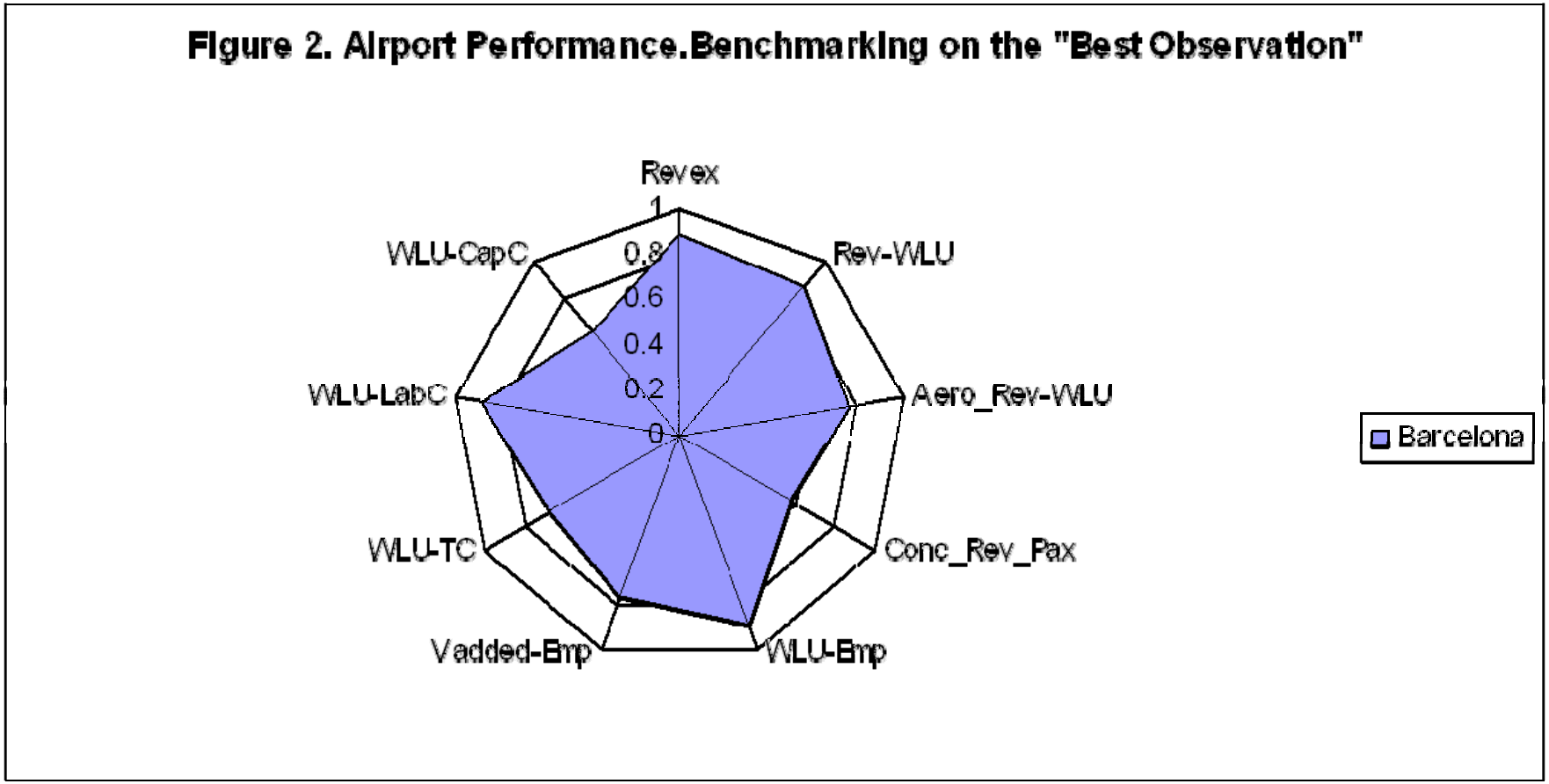
Profitability	Revenue-expenditure ratio
Revenue generation	Total revenues per WLU
	Aeronautical Revenue per WLU
	Concession and rental income per passenger
Labor productivity	WLU per employee
	Value added per employee
Costs	Total unit costs
	Unit labor costs
	Unit capital costs

The profile of each airport

Figure 1. Strength and weaknesses of an airport



SMOP. Radar Chart



DEA ranking results

- Cross-efficiency: Lanzarote, Barcelona, Madrid, Tenerife Norte, Ibiza, Gran Canaria and Tenerife Sur are the most efficient airports in the Spanish System.
- Super-efficiency: The two approaches to measure do not show significant differences.
  - In fact, the differences are only observed in the area of increasing returns to scale
  - There is only one airport, Valladolid, which presents the unfeasibility problem
  - Madrid, Lanzarote, Melilla, Vitoria, Barcelona and Mallorca are the most efficient airports.
    - The performance of Vitoria changes dramatically
- Virtual efficiency: Madrid, Barcelona, Mallorca, Gran Canaria, Tenerife sur and Malaga seem to be the good performers. So the classification of the good performers is quite similar looking at virtual-efficiency or cross-efficiency values.

A comparison between all the methods

- Is there any evidence that the ranking of airport performance is affected by the selection of the ranking method?
  - If the evidence shows that all the methods present robust results, is there any value in having multiple methods to rank the performance of airports?
- If the results may be affected by the selection of the method, which methods are more or less consistent?
- In that case, would it be possible to select a method to rank the performance of the airports? In which situations could this method be considered more appropriate?

The grade of concordance

- To answer these questions, we use the Spearman rank correlation test statistic according to:

$$r_s = 1 - \frac{6\sum_{j=1}^{n} d_j^2}{n^3 - n}$$

The results

Table 4. Spearman rank correlation test statistics of ranking DEA and SMOP methods.

	SE-NIRS	SE-VRS	V	SM-B	SM-A
Cross-Efficiency	1602 $3.11\ 10^{-6}$ 0.732	1780 $9.51\ 10^{-6}$ 0.702	822 $1.52\ 10^{-7}$ 0.862	1606 $3.19\ 10^{-6}$ 0.731	1220 $6.21\ 10^{-7}$ 0.796
Super-Efficiency NIRS		92 $2.2\ 10^{-16}$ 0.984	1386 $1.05\ 10^{-6}$ 0.768	3240 $7.7\ 10^{-3}$ 0.458	3064 $4.3\ 10^{-3}$ 0.487
Super-Efficiency VRS			1630 $3.6\ 10^{-6}$ 0.727	3216 $7.2\ 10^{-3}$ 0.462	3058 $4.2\ 10^{-3}$ 0.488
Virtual Efficiency				1130 $4.86\ 10^{-7}$ 0.811	976 $3.02\ 10^{-7}$ 0.830
SMOP "Best Observation"					70 0 0.988

$\begin{pmatrix} S \\ p \\ r_s \end{pmatrix}$, where S is the squared sum of ranking differences, p is probability associated to r_s and r_s is the Spearman rank correlation statistic.

- It can be seen that all the statistics are significant at a = 0.001 except for the comparison between super-efficiency and SMOP methods; however even in these cases at a level of significance a = 0.05, it can be concluded that all methods produce stable and robust rank orderings.

Conclusions

- Two major empirical contributions
  - Comparison of six benchmarking methods
  - Comparison of DEA ranking performance vs. a partial approach
- There exists a great consistency between the partial productivity indicators (SMOP) and the other sophisticated techniques that are based on linear programming DEA models.

Conclusions (2)

- Doganis and Graham approach synthesize quite well the relevant information of the performance of the airports.
- We have empirically showed that virtual efficiency, in spite of being criticized by lack of realism, ranks airport performance in a consistent way with cross-efficiency methodology.
  - For this reason, it can be used in the future without apology

Conclusions (3)

- We propose the cross-efficiency DEA method as the best alternative that can be used in all the circumstances to rank the airports performance.
- There are at least three main advantages of using cross-efficiency DEA.
  - First, one gets the full rank of the efficient and inefficient airports using a common vector of weights that are computed taking into account the performance of all the airports in the sample.
  - Second, the ranking obtained with this method has been the most consistent with the rankings obtained with the rest of the methods, overcoming the potential problems that may appear if we use super-efficiency or SMOP methodologies.
  - And finally, the ranking results are more robust to the existence of outliers that present some super-specialized airports.

The end

- Thank you for your attention.
  - Questions? Comments?