EFFICIENCY AND PROFITABILITY OF SPANISH AIRPORTS: A COMPOSITE NON-STANDARD PROFIT FUNCTION APPROACH

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ABSTRACT

Using recent financial and traffic data on a large sample of airports worldwide, we develop a composite non-standard profit function approach to estimate cost and revenue efficiencies of Spanish airports. Results show that, while profit margins under cost-efficient conditions are consistent with the existing literature, the important losses experienced by small airports in Spain are largely due to revenue inefficiency. This can be partially explained by a strict regulation of aeronautical revenues and an insufficient promotion of retail activities. Eliminating both cost and revenue inefficiencies would eventually move the threshold of profitability well below the traditional one million passenger mark. This result is expected to improve the prospects of individualized airport management as it is common in most of European and North American countries.

Keywords: airport profitability, translog cost function, non-standard profit function, stochastic frontier.

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1. INTRODUCTION

Several studies have examined cost efficiencies in airport operations, while the revenue side has received much less attention. However, the achievement of revenue efficiency may be also relevant to guarantee the profitability of an airport and to support its competitiveness to attract airline services.

In this paper, we estimate cost and revenue efficiencies of Spanish airports. In Spain, the centralized management of airports have been usually justified on the basis that small airports are not able to exploit scale economies. This situation agrees with the traditional view on airport operations, which regards small airports (i.e. serving less than one million passengers) as unprofitable given their apparent inability to recover costs under increasing returns to scale (Doganis, 1992). However, revenue inefficiencies could also have a strong influence on the financial viability of small airports. In this regard, the traffic threshold that guarantees the profitability of Spanish airports is currently more than 4 million passengers

We want to re-examine the potential profitability of Spanish airports under cost and efficiency conditions, especially considering that the above mentioned "break-even threshold" is mainly based on early airport studies, e.g. Doganis and Thompson (1974). We argue that, since the airport business has radically changed in the last four decades, it is sensible to re-check the validity of these traditional views with more recent data.

In order to achieve these objectives, we use a composite non-standard profit function (CNSPF) approach, adapted from the banking literature, to estimate cost and revenue efficiencies for the 42 main commercial airports in Spain during 2010. An unbalanced pooled database of 240 airports worldwide will be used in the estimation to increase degrees of freedom and also provide a stricter, international benchmark to assess the potential profitability of Spain's regional airports.

This is the first parametric study to use recent financial data on Spanish Airports since the Ministry of Public Works released it in early 2010. The latest cost efficiency estimates for Spanish airports, published in 2009, used very old data from 1997, as no new disaggregated figures had been published since. Additionally, we want to stress that this paper provides the first econometric approach to estimate revenue efficiency in the airport industry. Given the high level of representativeness of the worldwide airport sample, our estimates can also be expected to serve as the first reference values for this important indicator.

The rest of this paper is organized as follows: Section 2 provides a literature survey on airport profitability and cost efficiency in the airport industry. Section 3 describes the Spanish airport system. Section 4 introduces the composite non-standard profit function estimation methodology. Section 5 describes the airport sample and data sources. This is followed by Section 6 which analyzes the profitability of Spanish airports under the assumptions of cost efficiency, revenue efficiency and then full profit efficiency. Several policy implications are discussed. Finally, Section 7 summarizes the main findings.

2. LITERATURE SURVEY

To date, there have been no previous attempts to estimate either profit or revenue efficiencies for Spanish airports. In other countries, only a limited number of studies have tried estimate these indicators using unsophisticated methods. Note that almost all existing academic contributions in the field of airport efficiency have focused on technical/cost efficiencies[1] and no significant attention has been paid to the revenue side[2]. Furthermore, the few cost function studies for Spanish airports used the same old database, which makes difficult to extrapolate their results to the current situation.

Early papers on Spanish airport efficiency are Salazar de la Cruz (1999) and Martín and Román (2001), which used Data Envelopment Analysis (DEA) methods to measure technical/cost efficiency based on data provided by AENA for different airport subsets between 1993 and 1997. More recent papers, e.g. Rendeiro (2005), and Martín et al. (2009), employ parametric methodologies such as adjusted least squares and stochastic frontier analysis, respectively, over cost function specifications. The second study found evidence of significant cost inefficiencies in the Spanish airport system, which the authors associate with the existence of cross-subsidies and other behavioural distortions that can be traced back to the centralized network management. Even though this scenario has not changed since the paper was published in 2009, it is worth noting that the above mentioned results are still based on data from 1997, which was the last year AENA made network-wide airport-specific financial data available to researchers until early 2010. More recently, Tovar and Rendeiro (2010) and Lozano and Gutiérrez (2011) have employed alternative methodologies, such as input distance function and the non-

[1] A comprehensive list of airport efficiency studies can be found in Tovar and Rendeiro (2010).

[2] This could be explained by the highly regulated environment faced by airport companies around the world, which effectively hinders their ability to maximize revenues. This scenario is changing, however, with the rapid expansion of non-aeronautical activities.

parametric slacks-based approach to study different performance aspects of Spanish airports. However, to the best of our knowledge, only Bel and Fageda (2011a) make use of the recent financial data (2009-2010) for a descriptive analysis.

The present paper is uncommon in that it uses a worldwide estimating sample to analyze efficiency of Spanish airports. In the past, there have been a few studies employing worldwide airport databases to estimate cost efficiency, such as e.g. Oum et al. (2008), Martín and Voltes-Dorta (2011), and recently Martín et al. (2012). These papers are the closest methodological references in regards to the implementation of stochastic frontier techniques to a multi-output cost frontier specification (i.e. Stochastic Cost Frontiers - SCF). Taking into account that both cost and revenue equations (the components of the profit function) share the same basic specification, the applicability of the SCF methodology to our case study is straightforward. Crucial points taken from these papers are: i) the preference for a second-order translog specification, ii) the use of Bayesian estimation techniques, iii) the marginal productivity approach to calculate input prices, and iv) hedonic adjustments to the output vector. Regarding average long-run cost efficiency in the airport industry, Martín and Voltes-Dorta (2011) suggests it is around 80% in 2008, though estimates vary widely across different countries. Using a similar database, Martín et al. (2012) found an average drop of 5.85% in short-run cost efficiency between 2007 and 2009 due to the economic recession. These estimates can be used as reference to evaluate our cost efficiency results for 2010.

In comparison, the concepts of revenue and profit efficiency in the airport industry have received much less attention in the literature. Some few studies have examined the determinants of revenues but they do not estimate revenue frontiers or any indicator of revenue efficiency. In a study for US airports, Van Dender (2007) finds that aeronautical revenues per passenger are negatively related with traffic and the number of nearby airports. Results for the variable of airline concentration are mixed. Bel and Fageda (2010b) and Bilotkach et al. (2012) undertake an empirical analysis of airport charges for European airports. Bel and Fageda (2010b) find that airport charges are positively related with traffic, while they are negatively related with the share of low-carriers, airline concentration and the number of nearby airports. In those airports, the market power of the airport in relation to airlines could be lower. Furthermore, Bilotkach et al. (2012) find that airport charges are higher in hub airports that usually are characterized by a low share of low-cost carriers. Concerning commercial revenues, the most comprehensive study is that of Fuerst et al. (2011) for a sample of European airports. They find that commercial revenues per passenger are positively related with the size of the airport, the income of the country and the share of domestic passengers. Other interesting studies on commercial revenues have been done by Appold and Kasarda (2006) for US and Castillo-Manzano et al. (2010) for Spain.

Paradoxically, the most sophisticated analysis of airport profitability is perhaps the earliest. Doganis and Thompson (1974) used a cross-section of 18 UK airports in 1968 to estimate both cost and revenue functions. One of their main conclusions is that cost recovery, and thus profitability, of airports serving less than one million annual passengers was compromised by high average costs (linked to the presence of significant scale economies). Besides that, no efficiency estimates were reported, which is only reasonable since Stochastic Frontier Analysis was not developed until Aigner at al. (1977). To date, no stochastic profit/revenue frontiers have been estimated for the airport industry and the same applies to non-parametric literature. In that regard, an alternative approach consists in specifying "total revenue" along with other physical outputs and inputs in a DEA-production function (e.g. Sarkis and Talluri, 2004). While this effectively incorporates a price effect into the mix, there is no practical way to separate revenue- from technical efficiency afterwards.

Using a small balanced pool of German airports observed between 1998 and 2007, Ülkü (2009) simply uses the ratio of total revenues to total costs as a measurement of revenue efficiency and then concludes that there is a strong positive correlation between cost efficiency (estimated with DEA) and revenue efficiency. Slightly more developed partial factor productivity ratios based on airports' financial performance are found in other publications such as Oum et al. (2003) or TRL (2000), where the latter pays more attention to comparability issues such as accounting standards, government subsidies, or the degree of outsourcing. These studies employ large, international samples but, unfortunately, there is no simple way to translate their results to revenue or profit efficiencies as defined in this paper.

Other approaches to airport profitability include Pagliari and Lei (ref), which found a positive relationship between passenger traffic and profitability at UK airports. Their results also support the existence of some "break-even" threshold under the observed conditions. We aim to check if this result is still valid after correcting for cost and revenue inefficiencies. Graham and Dennis (2007) also examine the impact of low-cost operations on airport costs and revenues, but it concludes that there is no obvious link between low-cost traffic and airport profitability. Finally, a descriptive study of the European Union (2002) analyzes the relationship between the revenue-expenditure ratio and traffic levels for airports in France, Sweden and United Kingdom. Overall, results of this analysis indicate that the profitability threshold is in the range 500.000 to 700.000 workload units.

3. THE SPANISH AIRPORT INDUSTRY

Aeropuertos Españoles y Navegación Aérea (AENA), a public firm dependent on the Ministry of Transports, has managed on a centralized basis 47 commercial airports in Spain. Until December 2010, AENA was responsible of both the management of airports and air traffic control. The law 13/2010 set a new firm, AENA aeropuertos, which is just responsible of the management of airports (the settlement of Aena aeropuertos was made effective in June 2011). The privatization of AENA aeropuertos is currently been discussed but the maintaining of the centralized management has not been put into question by the central government.

AENA aeropuertos is the owner of all the facilities available at these airports and it has the control of all financial resources generated by them. AENA and the Ministry of Transport take all the relevant decisions regarding airports, including investments, prices, development of retail activities and the allocation of slots, check-in counters and gates to airlines.

The centralized management implies that Spanish airports are not able to compete to attract airline services. Furthermore, any financial losses are compensated through a cross-subsidy system. Although it is generally claim that the cross-subsidies go from large to small airports, Bel and Fageda (2009) showed that large airports specialized in tourism have been supporting investments of the rest of airports, including Madrid. With the lack of competition and the cross-subsidy system, it is clear that airports in Spain do not have strong incentives to be efficient in costs.

Along with the weak incentives that Spanish airports have to be efficient in costs, there have been a dramatically increase of investments of AENA in the latter years. The capacity expansions of Madrid and Barcelona airports have implied an expenditure of more than six thousand and three thousand millions of euros, respectively. Furthermore, at least ten of the airports managed by AENA aeropuertos do not offer flights in most (or even all) days of the year. Just an example may provide arguments for arguing that the number of airport devoted to commercial traffic is excessive in Spain. The airport of Vitoria is surrounded by other five airports located in a distance of less than 120 kilometers

Concerning revenues, the Law 25/1998 set the initial values of current aeronautical charges (landing and aircraft parking fees, taxes for the use of terminals and so on) and other charges including car parking and retail activities developed by AENA. There have been traditionally three categories of airports according to their levels of traffic to set aeronautical charges. Within the same category, price differences were minimal. This means that charges of Madrid and Barcelona, which are in the top ten raking of European airports in terms of traffic, were almost identical to some airports with less than five million passengers like Seville, Bilbao or Lanzarote. In June 2011, a re-arrangement of the categories for fixing charges was made effective. The new classification of airports in terms of charges includes four categories. Madrid and Barcelona are in the first category, the biggest tourist airports are in the second, and the other two categories has to do with the levels of traffic.

The update of these charges is proposed by AENA, but the final decision rests with the Spanish Parliament in the accompaniment laws of the General Budget Law. In theory, airport charges are based on the total costs of all airports managed by AENA. However, in practice these charges are approved by Parliament, so they have been adjusted annually in line with charges for other public services (except in 2011 and 2012 were charges in Madrid and Barcelona airports have been increased substantially in relation to the rest of airports). Thus, charges do not necessarily meet costs. Note also that regulation of charges in Spain seem to follow a single-till so that both aeronautical and commercial revenues are regulated. Under a single-till, increases in commercial revenues will be compensated with lower aeronautical revenues. Lower aeronautical charges will push airline traffic, but the single-till regulation may still have some influence on the incentives of Spanish airports to develop retail activities in their facilities.

Within this context, it is important to stress that AENA has recorded financial losses since 2007, making it the airport operator reporting the largest deficit in the world (Bel and Fageda, 2011). The current debt of AENA aeropuertos is more than fourteen thousand millions of euros. Regarding individual airports, figure 1 shows a positive relationship between the levels of traffic and profitability of Spanish airports. Some large airports like Madrid (MAD), Barcelona (BCN) or Málaga (AGP) incur in financial loses but this is due to the high amortization expenses of recent capacity expansions. Overall, only ten airports are profitable in Spain. All of them move more than four million passengers per year with the exception of Bilbao with 3.9 million passengers. This is in contrast of what have been found in studies for other European airports where the profitability threshold may be even lower than one million passengers (Doganis and Thomson, 1974; European Commission, 2002). As we mention above, possible explanations of the poor financial performance of Spanish airports are over-investment, the weak incentives to save costs and the pricing system were charges are not necessarily related with cost or demand conditions.

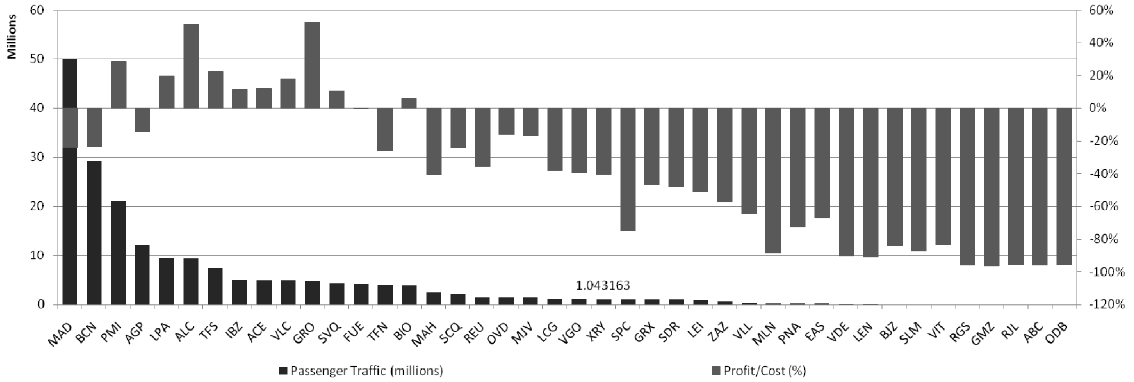

Figure 1. Passenger traffic vs profitability at Spanish airports (2010)

Source: AENA (2010), Own elaboration

Table 1 provides additional indicators of traffic, revenues and costs of Spanish airports. First of all, it is clear from this table that the variability in costs per passenger is much higher than in terms of revenues per passenger. For example, the airport with the lowest cost per passenger is Girona (4.86) while the airport with the highest cost per passenger is Cordova (732). Regarding revenues, El Hierro is the airport with less revenue per passenger (3.39) while Vitoria is the airport with more revenues per passenger (64.65). If we make the same comparison just with airports with more than one million passengers, then we have in costs Girona (4.86) and Jerez (17.13), while in revenues we have Tenerife Norte (5.98) and Madrid (12.23). It seems that the current pricing system does not allow an enough differentiation of charges given the strong heterogeneity in costs of Spanish airports. Note also that the importance of aeronautical revenues is generally much higher than that of commercial revenues.

We could distinguish different types of airports according to the volume and type of traffic. Two airports are ranked between the ten largest airports in Europe; Madrid and Barcelona with 49 and 29 million passengers respectively. The proportion of traffic channelled by network airlines is high in both airports, although the concentration of traffic in fewer airlines is remarkably higher in Madrid due to the fact that is the hub of Iberia. Both airports have high costs per passenger in relation to the revenues that they are able to generate. With new terminals and runways, the passengers per square meter are relatively low in these two big airports.

Second, we can find airports specialized in tourism with traffic levels higher than 4 million passengers; Alicante, Gran Canaria, Málaga, Palma de Mallorca, Tenerife Sur, Fuerteventura, Ibiza, Lanzarote, Girona. In these airports, the proportion of traffic channelled by low-cost or charter airlines is very high although in airports of Canaries intra-island traffic of regional carriers is also relevant. Furthermore, they show a strong diversification of traffic between a high number of airlines (as it shows the low concentration index) with the exception of Girona which is an operating base of Ryanair. Most of these airports show very low costs per passenger in relation to the revenues that they are able to generate.

Then, we have several airports located in relatively large cities or smaller tourist destinations that generally move between 1 and 4 million passengers per year. These airports have generally a higher proportion of traffic moved by network airlines (or their regional subsidiaries) and higher concentration levels. Here there is more variability in the costs per passenger in relation to the revenues, but still we can find several airports with cost per passenger than more than double revenues.

Finally, 14 airports move much less than 500.000 passengers per year. Some of these airports do not offer currently any flight. In most of these airports, the total costs per passenger are extraordinarily high in relation to revenues. However, here we should distinguish between airports like Logroño which have other airports very close and fast access by train and road to the two biggest cities, and airports located in peripheral regions like El Hierro, La Gomera or Melilla. In the latter case, social considerations could be more relevant than concerns regarding financial performance.

Data for Spanish airports in table 1 and that used in the empirical analysis developed in next sections come from AENA. However, our analysis of cost inefficiencies in Spanish airports is going to be conservative because regional and local governments (out of AENA) have spent a lot of public resources to subsidize air traffic in the latter years. A report of the Spanish competition Commission (2011) indicate that regional and local administrations have spent 250 million euros in the period 2007-2011 to subsidize airlines to operate in Spanish airports. The amount of euros per passenger spent in subsidies is in some cases surprisingly high. For example, Burgos (226), Albacete (90), Salamanca (82), León (45), Badajoz (25) or Logroño (20).

Table 1. Traffic, revenues and costs at Spanish airports (2010)

airport	*Pax (million)*	*Share lcc*	*Share charter*	*hhi*	*cargo (kt)*	*Pax per square meter*	*Landing charge per tone (EUR)*	*Total costs per pax (EUR)*	*Aeronautical revenues per pax (EUR)*	*Commercial revenues per pax (EUR)*
ALBACETE (ABC)	0.01	0.00	0.43	0.62	0.00	5.13	4.36	293.10	11.51	0.89
ALICANTE (ALC)	9.38	0.59	0.04	0.15	3.11	175.04	6.07	6.19	5.95	3.40
ALMERIA (LEI)	0.79	0.12	0.31	0.46	0.01	31.60	5.37	20.33	5.80	4.14
ASTURIAS (OVD)	1.36	0.12	0.12	0.28	0.11	77.89	5.44	10.71	6.50	2.47
BADAJOZ (BJZ)	0.06	0.00	0.43	1.00	0.00	13.90	4.39	44.79	6.37	0.82
BARCELONA (BCN)	29.21	0.35	0.03	0.11	104.28	41.53	6.07	14.81	7.44	3.90
BILBAO (BIO)	3.88	0.18	0.05	0.18	2.55	76.92	6.04	10.00	7.20	3.34
BURGOS (RGS)	0.03	0.00	0.76	1.00	0.00	14.44	4.38	172.34	6.25	0.60
CORDOBA (ODB)	0.01	0.00	1.00	0.00	0.00	6.83	4.04	732.30	21.65	10.19
FUERTEVENTURA (FUE)	4.17	0.16	0.26	0.17	1.71	44.88	6.04	7.99	5.14	2.85
GIRONA (GRO)	4.86	0.78	0.20	0.92	0.06	162.13	5.19	4.98	5.07	2.53
GRAN CANARIA (LPA)	9.49	0.13	0.15	0.18	24.53	86.55	6.02	6.59	5.17	2.71
GRANADA (GRX)	0.98	0.23	0.35	0.28	0.04	115.52	5.45	14.93	5.82	2.15
HIERRO (VDE)	0.17	0.00	0.08	1.00	0.15	66.68	1.31	36.50	1.75	1.64
IBIZA (IBZ)	5.04	0.28	0.25	0.14	3.00	138.10	5.93	6.47	4.96	2.25
JEREZ (XRY)	1.04	0.09	0.76	0.25	0.13	64.79	5.46	17.13	5.87	4.31
LA CORUÑA (LCG)	1.10	0.14	0.35	0.32	0.25	84.31	5.45	13.85	6.52	2.06
LA GOMERA (GMZ)	0.03	0.00	0.18	1.00	0.01	10.68	1.31	170.21	3.08	3.39
LA PALMA (SPC)	0.99	0.01	0.16	0.49	0.94	93.09	5.31	20.16	3.13	1.95
LANZAROTE (ACE)	4.94	0.17	0.26	0.18	3.79	84.27	6.05	6.83	5.00	2.66
LEON (LEN)	0.09	0.03	0.41	0.84	0.00	10.49	4.42	89.10	6.32	1.71
LOGROÑO (RJL)	0.02	0.00	0.85	1.00	0.00	6.13	4.38	224.64	8.15	2.45
MADRID (MAD)	49.87	0.17	0.00	0.28	373.91	50.31	6.09	16.06	8.97	3.26
MALAGA (AGP)	12.06	0.40	0.17	0.07	3.06	30.34	6.07	11.91	6.49	3.72
MELILLA (MLN)	0.29	0.00	0.16	1.00	0.34	159.29	3.06	41.59	4.27	0.44
MENORCA (MAH)	2.51	0.18	0.19	0.22	2.40	125.18	5.92	13.03	5.32	2.41
MURCIA (MJV)	1.35	0.61	0.17	0.22	0.00	105.83	4.54	9.76	5.08	3.03
PALMA (PMI)	21.12	0.24	0.16	0.14	17.29	95.99	6.07	6.13	5.76	2.12
PAMPLONA (PNA)	0.29	0.00	0.37	0.86	0.04	23.51	4.45	31.14	6.17	2.40
REUS (REU)	1.42	0.28	0.66	0.72	0.25	109.90	5.20	11.61	5.32	2.10
SALAMANCA (SLM)	0.04	0.00	0.91	0.89	0.00	10.80	4.41	95.65	10.88	1.16
SAN SEBASTIAN (EAS)	0.29	0.00	0.26	0.86	0.02	104.26	4.44	27.48	5.94	3.04
SANTANDER (SDR)	0.92	0.29	0.24	0.53	0.00	45.09	4.51	14.13	5.37	1.96
SANTIAGO (SCQ)	2.17	0.34	0.20	0.24	1.96	115.86	5.45	11.09	5.91	2.49
SEVILLA (SVQ)	4.22	0.36	0.28	0.22	5.47	68.14	6.06	8.72	6.45	3.19
TENERIFE NORTE (TFN)	4.05	0.04	0.00	0.29	15.94	75.53	5.99	8.14	4.12	1.86
TENERIFE SUR (TFS)	7.36	0.24	0.34	0.07	4.29	86.17	6.09	7.86	5.96	3.62

VALENCIA (VLC)	4.93	0.23	0.26	0.26	11.43	132.46	6.04	8.70	6.87	3.37
VALLADOLID (VLL)	0.39	0.17	0.47	0.55	0.03	87.26	4.49	21.70	5.65	2.11
VIGO (VGO)	1.09	0.07	0.15	0.28	0.90	139.99	5.43	14.62	6.63	2.19
VITORIA (VIT)	0.04	0.00	0.85	0.50	27.96	7.24	4.56	388.44	48.49	16.16
ZARAGOZA (ZAZ)	0.61	0.25	0.49	0.32	42.54	37.29	4.56	25.60	8.93	2.00

Note: pton indicates average landing charge per ton MTOW. Source: AENA (2011), Own elaboration

4. ESTIMATION METHODOLOGY

4.1 The composite non-standard profit function approach

The econometric estimation of a standard profit function $\pi(p, \omega)$, where p and ω represent output and input prices, respectively, was considered *a priori* the suitable method to evaluate profit efficiencies in the airport industry. However, note that the standard profit maximization problem (See e.g. Kumbhakar, 2006) assumes that firms adjust output quantities (y) and input demands (x) while taking all prices as given (i.e. fixed by competitive markets). This scenario does not fit well with the reality of airports, which have limited control over their output level (i.e. traffic), while also being traditionally considered natural monopolies that face limited competition in their catchment areas (Doganis, 1992). These considerations led us to the search for an alternative method to estimate profit efficiency that allows for output quantities to be fixed and leaves output prices as a decision variable based on actual market conditions.

The solution was found by reviewing the large body of literature on profit efficiency in the banking sector. The studies by Berger et al. (1996) and Humphrey and Pulley (1997) introduced the alternative profit function $\pi(y, \omega)$, later referred by Kumbhakar (2006) as non-standard profit function (NSPF). Under this approach, firms maximize profits (i.e. revenue minus cost) subject to the technological constraint $y=f(x)$ and a pricing opportunity set $p=(y, \omega)$. The latter incorporates pricing heuristics, market position, and demand conditions in transforming exogenous y and ω into endogenous p (Lozano-Vivas, 1997). Besides allowing for i) fixed outputs and ii) the possibility of market power, Berger et al. (1996) also notes that the NSPF may provide useful when iii) there are unmeasured differences in service quality across the sample, and iv) prices cannot be accurately measured. These four characteristics fit our airport case study perfectly[3].

Despite all advantages, only recently have Restrepo-Tobón and Kumbhakar (2011) fully studied the duality properties of $p=(y,\omega)$, thus finally validating the microeconomic foundations of the apparently ad-hoc formulation of the NSPF. However, they also found that the econometric estimation of profit inefficiencies in e.g. a stochastic frontier setting will lead to biased estimates unless revenue and cost inefficiencies are included separately in the model. This fact, in combination with the difficulties in accommodating negative profits in a translogarithmic specification[4], led the authors to develop the composite non-standard profit function (CNSPF) approach, in which the cost frontier $C(y,\omega)$ and the revenue frontier $R(y,\omega)$, with their corresponding inefficiencies, are estimated separately. This is the method we apply in this paper.

4.2 Model specification

At the very minimum, the econometric estimation of a CNSPF requires data on total costs (TC), total revenues (R), outputs (Y), and input prices (ω) of airports equally

[3] The wide range of discounts offered by the airports to signatory airlines, often negotiated in a case-by-case basis, invalidates the used of published charges as price indicators for this type of empirical research.
[4] Slightly over half of our sample airports recorded negative profits during the sample period.

focused on (long-run) cost minimization and revenue maximization. The preferred functional form for both *C(y,ω)* and *R(y,ω)* is the transcendental logarithmic-translog (Christensen et al., 1973), which is the most commonly used in this kind of empirical studies. A second-order translog expansion on *(y,ω)* presents the following structure:

(1) $$lnQ = \alpha_0 + \sum_j \alpha_j \, lny_j + \sum_i \beta_i \, ln\omega_i + \sum_i \sum_j \gamma_{ij} ln\, \omega_i lny_j + \frac{1}{2}\left[\sum_j \sum_k \rho_{jk} lny_j lny_k + ih\rho ihln\omega iln\omega h+\varepsilon i,\right.$$

where Q represents either total costs or revenues, and ε denotes statistical disturbance. The translog cost function is typically estimated jointly with its cost-minimizing input shares (*s*) by means of a Seemingly Unrelated Equations Regression – SURE (Zellner, 1962). Input share equations can be easily obtained by differentiating and applying Shephard's Lemma[5]:

(2) $$s_i = \frac{\omega_i x_i}{TC} = \frac{\partial TC}{\partial \omega_i}\frac{\omega_i}{VC} = \frac{\partial lnTC}{\partial ln\omega_i} = \beta_i + \sum_j \gamma_{ij} \, lny_j + \sum_m \rho_{ih} \, ln\omega_h$$

If panel data is available, the model can be completed with the time variable (*t*) in order to account for technological change in the industry (Stevenson, 1980).

Previous studies (e.g. Martín and Voltes-Dorta, 2011) have specified up to five outputs in the airports' cost function: aircraft movements (*ATMs*), domestic/Schengen passengers (*dom*), international/transborder passengers (*int*), metric tons of cargo (*cgo*), and commercial revenues (*rev*). In this paper, however, commercial revenues will be removed from the output vector as they become part of the dependent variable in the revenue equation. Given the very high correlation between said variable and the other physical outputs, the remaining four-dimensional output vector is expected to still provide an accurate characterisation of the overall airport business. Furthermore, ATMs will be hedonically adjusted using the airport's average landed Maximum Take-Off Weight (*MTOW*) as a quality variable (Spady and Friedlaender, 1978):

(3) $$\ln ATM_i^{MTOW} = \ln ATM_i + \psi(\ln MTOW_i)$$

This equation is expected to capture the differences in marginal costs imposed by different aircraft models. In order to keep a fixed output reference between the cost and revenue frontiers, the hedonic coefficient will be estimated only in the cost function model (due to its strong cost motivation). The estimated value of ψ will then be imposed in the revenue model.

The profit system also features three input prices: capital (ω_c) materials (ω_m), and labor/personnel (ω_p). The price of labor is obtained by dividing labor costs by the full-time equivalent employees (*fte*) of the airport authority. The calculation of the prices of capital and materials is more complex: the respective costs are divided by a quantity index based on marginal productivity ratios, calculated for a predefined set of physical inputs assumed to represent the airport's overall demand for these factors. Marginal productivities are estimated from the only multi-output ray production frontier provided in the literature[6]. For the capital price, the reference inputs were terminal surface and runway length. For materials, we used check-in desks and boarding gates. As prices are related to the observed costs, they reflect each airport's specific circumstances (i.e., labor policies, scope of outsourcing, etc...). This reduces the need for data

[5] Differentiating costs with respect to a price leads to the input demand function (Shephard, 1953) $\frac{\partial C}{\partial \omega} = x$

[6] See Appendix B in Martín and Voltes-Dorta (2011a).

homogenization and, if there are enough sample airports with the same characteristics, it allows for fair efficiency comparisons between airports from different regions[7].

At one point, the specification of a service quality indicator (e.g. terminal surface per passenger) was considered. However, it was later removed from the cost function because "excessive" service quality is actually one of the main problems of regional airports in Spain, many of them with blatantly oversized terminal buildings for their present and (foreseeable) future traffic levels (e.g. Albacete, Leon, Salamanca, etc…). Removing this variable is crucial for the cost frontier to reallocate all these extra costs into the inefficiency component. On the revenue side, the airports' ability to translate higher service quality into higher prices is implicit in the pricing opportunity set. Additional descriptors of traffic mix and market conditions (Z) are exclusive of the revenue equation[8]. These are the share of low-cost flights, the share of charter (non-scheduled) flights, and the Hirschmann-Herfindahl index of airline traffic shares as a proxy for airline dominance. According to Bel and Fageda (2010b), these variables are crucial in determining the airport's degree of market power. Furthermore, two geographical dummies (Europe and Asia-Pacific) are also included in order to account for different passenger expenditure patterns (Martel, 2009).

The full specification of the profit system is shown in Appendix A. Note that additional parametric restrictions are included in order to impose linear homogeneity in ω[9].

4.3 Stochastic frontier analysis and Bayesian estimation

It is likely that sample airports may have incurred in cost/revenue inefficiencies during the sample period. An airport is said to be inefficient if it fails to generate the maximum possible revenue while also incurring in the minimum feasible cost given a set of exogenous variables (outputs, input prices, market conditions, etc..). An additional one-sided disturbance term can be introduced in both cost and revenue frontiers in order to account for these inefficiencies, leading to a stochastic frontier specification (Aigner et al., 1977). Given the non-linear complexities of the proposed models, they will be estimated using Bayesian inference (Van der Broeck et al., 1994). WinBUGS (Lunn et al., 2000) is the preferred statistical package, as it allows us to adapt the codification proposed in Griffin and Steel (2007). This assumes that the dependent variable (i.e. logged costs/revenues) is normally distributed, with the above described translog equation as the mean and σ_v^2 as the white noise variance:

$$lnTC_{it}^{a} \sim N(lnTC_{it}\,(\omega, Y, \psi, t) + u_{it}^{C}, \sigma_v^{-2}) \quad (4)$$

$$lnR_{it}^{a} \sim N(lnTC_{it}\,(\omega, Y, \psi, Z, t) - u_{it}^{R}, \sigma_v^{-2}) \quad (5)$$

TC^a and R^a represent actual costs/revenues, TC^0 and R^0 are the minimum cost/maximum revenue frontiers, and u^C, u^R are both a positively-valued error terms measuring cost and revenue inefficiencies, respectively. These parameters are allowed to vary over time without imposing any firm-specific constraints. Given the long temporal dimension of

[7]German airports tend to cover a wider range of core activities in-house, which leads to higher operating costs/revenues than similar airports in other countries. However, since they have also higher input prices, their frontier costs will be also higher (according to Kumbhakar and Lowell (2003) the revenue function can also be expected to be non-decreasing in input prices). Thus, each airport will face a cost/revenue frontier adequate to its internal structure.

[8] We prefer a more strict specification for the cost function. One may argue that the construction of cheaper terminal spaces to accommodate low-cost traffic may lead to reduced operating costs for the airport. This impact, however, is likely to be captured by the capital input price.

[9] The revenue equation is not necessarily linearly homogenous in ω, but this property was imposed in order to keep the functional forms equivalent (Restrepo-Tobón and Kumbhakar, 2011).

the estimating dataset (1985-2010), which covers recession periods and other demand shocks, it cannot be expected that firms' efficiencies vary systematically over time (as in the Battese and Coelli, 1995 and Cuesta, 2000 models). Thus, the inefficiency of airport *i* at period *t* (u_{it}) is simply assumed to be exponentially distributed with mean λ^{-1}:

(6) $$u_{it}^{C} \sim \exp(\lambda^{C});\ u_{it}^{R} \sim \exp(\lambda^{R})$$

Prior distributions must be assigned to the parameters. The cost/revenue frontier coefficients (β) follow a non-informative normal distribution with zero mean and infinite variance[10]. In the same spirit, a gamma distribution (0.01, 0.001) is assigned to the models' inverse-variance (white noise). The distributional structure the λ parameters (Griffin and Steel, 2007), allows us to impose prior ideas about mean cost/revenue efficiency (r^*) in the airport industry. Regarding cost efficiency, r^* is set at 0.854 as indicated in Martín and Voltes-Dorta (2011). Given the absence of previous evidence on the subject of airports' revenue efficiency, a non-informative uniform prior was set in the revenue equation. Similarly, the ψ coefficient of the hedonic ATM function was also assigned a uniform distribution $U(0,2)$.

(8) $$\beta \sim N(0,0),\ \sigma_v^{-2} \sim G(0.01,0.001),\ \lambda \sim \exp(-logr^*),\ \psi \sim U(0,2)$$

After both equations have been estimated, cost and revenue efficiency of airport *i* at period *t* ($Ceff_{it}$, $Reff_{it}$) can be easily calculated from the corresponding u_{it}:

(9) $$Ceff_{it} = \exp(-u_{it}^{C});\quad Reff_{it} = \exp(-u_{it}^{R})$$

5. DATABASE AND DATA SOURCES

Even though this paper aims at investigating airport profitability in Spain, an international database will be used in the estimation of both cost and revenue frontiers. Besides increasing degrees of freedom, using international data allows us to measure the profit efficiency of Spanish airports against a representative industry-wide frontier, not a Spanish one. This is expected to improve the analysis by helping to identify the impact on productivity and profitability of AENA's unique consolidated network management, in comparison to other large samples of small regional airports from e.g. the UK, US, or France. This impact cannot be captured by using only Spanish data.

Data collection was completed for the following variables: i) total costs (tc): labor (lab), materials (mat), and capital (cap); ii) Revenues: aeronautical (aero) and non-aeronautical (rev); iii) Outputs: Domestic-Schengen (dom) and international-transborder passengers (int), air transport movements (atm), average landed Maximum Take-off Weight (mtow), and metric tons of cargo (cgo); iv) Infrastructure: gross floor area in m^2 of passenger terminal buildings (ter), runway length in m (run), number of boarding gates (gat), and check-in desks (chk); v) Other: time (t), full-time employees (fte), Hirschmann-Herfindhal index of airline traffic shares (hhi), share of charter flights (scha), share of low-cost flights (slcc). In order to integrate this data with the worldwide estimating sample (described below), all monetary variables were converted to 2010 Purchasing Power Parity (PPP) USD using OECD's exchange rates.

We employ the well-known airport cost categories defined by Doganis (1992). Labor costs include salaries and wages, retirement, and health benefits. "Materials" costs include maintenance, utilities, external services and other administrative costs. Finally,

[10] Normal distributions in Equation 7 follow WinBUGS' notation: N(mean, inverse-variance)

capital costs comprise depreciation of fixed assets and interest paid. Note that these costs only take into account the activities performed in-house by the reporting company, (typically the airport operator). These tend to vary widely across airports. Section 3 discussed how the calculated input prices take this heterogeneity into account.

On the revenue side, we can distinguish between aeronautical and non-aeronautical sources. The first are those collected mainly through airport charges (landing, terminal, security, etc...) levied on the users (airlines, passengers, etc...) to (partially) cover the costs of aeronautical infrastructure. Note that Air Navigation Services are excluded from our data. Non-aeronautical activities are those indirectly related to the transport activity and typically cover retail, parking, catering, etc..., which the airport company either operates directly (through a subsidiary) or receives a rent from a concessionaire. For the purposes of this paper, aeronautical and non-aeronautical revenues are aggregated and a single "total revenue" equation will be estimated. The separation of both revenue streams is left for future research since it requires a deeper investigation of the actual concepts included in each category across the worldwide sample.

Disaggregated financial data on Spanish airports has been very difficult to obtain in recent times as the strong investments dragged down AENA's profitability, which led to increased opacity. Only recently were these figures released to the public by the Ministry of Public Works (*Ministerio de Fomento - MFOM*) in the midst of an intense debate over the management of the public airport system. We had access to the final figures audited by the National Accounting Office – *Tribunal de Cuentas* (TDC, 2012). This publicly available report provides financial data on 42 out of the 48 public airports in Spain for 2009 and 2010 (See Table 4). Traffic data on aircraft movements, passengers and cargo was compiled from AENA's statistics portal. Very detailed information on capacity and infrastructure for the individual airports is provided in their Master Plans, which are also publicly available in the MFOM's website. Airline traffic shares, used to calculate the variables *hhi*, *slcc*, and *scha*, were obtained from the Official Airline Guide's iNet Schedules Tool.

As mentioned before, the Spanish data is merged with a large, supplementary worldwide sample obtained from Martín et al. (2012). This database includes 108 airports from Europe (France, UK, Austria, Germany, Italy, Russia, Turkey, and others), 72 from North America (US and Canada) and 11 from Asia-Pacific (mainly China, Australia, and New Zealand). A wide variety of airport sizes and output mixes is present, and the sample includes almost every major passenger and cargo hub in all featured countries[11]. After merging the Spanish data, the estimating sample is an unbalanced pooled database of 240 airports, observed between 1985 and 2010 (for grand total of 2250 observations). In 2009, the combined sample airports served 2.64 billion passengers and 47 million metric tons of cargo, which represent 51% and 58% of worldwide traffic, respectively (ACI, 2010).

Table 2. Overview of the Spanish airport sample (2010)

	tc (PPP'000)	*atm*	*dom*	*int*	*cgo (t)*	*aero (PPP'000)*	*rev (PPP'000)*	*mtow (t)*	*ter (m2)*
mean	71,780	47,281	3,444,491	1,143,684	15,536	41,361	18,631	54	77,180
max	1,054,039	433,706	34,959,586	14,906,527	373,911	588,763	213,632	94	991,256
min	3,605	1,243	7,839	1	1	132	13	6	1,150
std	179,965	79,914	6,752,239	2,607,595	59,374	100,740	40,447	24	190,274

Source: AENA (2011), TDC (2012), Airports' Master Plans

[11] Given the instrumental nature of this data, and since it has been used in the past (See also Martín and Voltes-Dorta, 2011a; and Martín and Voltes-Dorta, 2011b), readers are referred to the above-mentioned studies for the complete list of sample airports and data sources.

The existence of significant profit inefficiencies in the Spanish network can be easily inferred from Tables 2 and 3, which provide some descriptive statistics for both the Spanish sample (2010) and the combined worldwide estimating sample (1985-2010). In Spain, the scale of production ranges from 1,200 annual ATMs in Albacete up to 433 thousand ATMs in Madrid-Barajas. This range is contained in the worldwide sample (Table 3), where the scale of production ranges between 100 and 980,000 ATMs at Córdoba (1991) and Atlanta (2007), respectively. As expected, this large variability can also be observed in total costs and the infrastructure indicators. The average Spanish airport serves around 4.5 million annual passengers (3.4 domestic and 1.1 international), it has operating costs of 15.95 PPP USD per passenger, while only collecting 13.35 PPP USD per passenger in operating revenues (9.25 and 4.1 PPP USD from aeronautical and non-aeronautical sources, respectively). This estimate compares poorly with the international average of 16.10 PPP USD (9.99 aeronautical and 6.11 non-aeronautical).

Table 3. Overview of the estimating sample: Worldwide airports (1985-2010).

	tc (PPP'000)	*atm*	*dom*	*int*	*cgo (t)*	*aero (PPP'000)*	*rev (PPP'000)*	*mtow (t)*	*ter (m2)*
mean	146,430	136,170	7,335,177	3,573,776	208,179	109,021	66,669	60	101,431
max	2,991,697	981,402	80,858,789	63,323,180	3,840,941	1,576,708	1,128,305	397	1,382,000
min	707	100	1	1	1	10	1	6	500
geom[12]	-	62,161	1,653,629	354,877	17,853	-	-	-	-
std	236,328	158,309	11,110,015	7,270,590	484,282	194,308	114,829	34	142,256

Source: Martín et al. (2012), Own elaboration

Bel and Fageda (2010a) also mention excess capacity as one of the main reasons for the lack of profitability of Spanish airports. In order to illustrate that, we now calculate the average ratio of passengers to terminal surface from the Tables above. Spanish airports serve, on average, 58 passengers per square meter (ppsm) of terminal, while the industry average is 108 ppsm, much closer to well-established 100 ppsm benchmark typically used for airport design (and explicitly acknowledged in most Spanish airports' Master Plans). With this simple evidence, and further to the information shown in Figure 1, it can be concluded that the Spanish airport system is, on average, clearly not profitable under the existing conditions.

6. RESULTS AND DISCUSSION

Two parallel chains of the profit system were run 300,000 times with a burn-in of 100,000 draws to reduce the impact of initial values. Convergence of all parameters was checked with the Gelman-Rubin statistic implemented in WinBUGS. The estimated coefficients of both cost and revenue frontiers are shown in Table 4. Note that the vast majority of parameters are significant at 95% confidence level. The cost model provides very interesting conclusions about airport technology. The inverse of the sum of the first-order output coefficients yields the (geometric) average airport's scale elasticity. This results in a value of 1.65, indicating that airports operating around 2 million passengers (See Table 3) enjoy increasing returns to scale (IRS) and hence, average operating costs can be assumed to decrease with the scale of production. The positive squared output interactions indicate that these significant IRS will inevitably become exhausted at some undetermined point. The negative *dom*int* interaction, however, indicates that airports are benefiting from cost complementarities between domestic and international passenger movements in order to expand their IRS range.

These results are very similar to Martín and Voltes-Dorta (2011). On the contrary, our positive and significant time-related interactions are in sharp contrast to those obtained

[12] Geometric means represent the approximation point for the translog frontiers.

in previous literature. These indicate technical regress during the sample period, which, in other words, means that e.g. passenger traffic has become more expensive over the years. The explanation is quite simple: other studies featured non-aviation revenues as an exogenous output in the cost function, thus allowing for a clear separation between passenger-aeronautical and passenger-commercial production processes. Removing this variable from our cost function eliminates this distinction and hence, the strong development of commercial activities, with all their increased operating costs, appears as technical regress. Finally, the hedonic coefficient indicates that marginal ATM costs increase more than proportionally with aircraft weight.

Regarding the revenue frontier, the positive signs of the Asia-Pacific and European dummies suggest that average passenger expenditure is higher in these regions than in the reference North American airports. A possible explanation for this result is the specific management model of airports in US which account for a high proportion of North American airports in our sample. In this country, airports act like a landlord and airlines are usually involved in the construction and management of terminals. The coefficients for the other traffic descriptors have negative signs. Hence, revenues are lower in airports with higher airline concentration and a higher share of low-cost and charter airlines. Note that the values of aeronautical revenues are usually much higher than those of commercial revenues so that the explanation of results for these variables is strongly influenced by aeronautical revenues. In this regard, we find similar results as in Bel and Fageda (2010b); the market power of airports in relation to airlines should be lower when airline concentration is higher, and the share of low-cost and charter carriers is higher. The negotiation power of an airline with a high share in an airport should be relatively high and both low-cost and charter airlines have less difficulties to move their planes to other airports (network airlines must built a complex structure of routes to develop efficiently their hub-and spoke operations).

Table 4. CNSPF estimation results

	Cost Frontier				*Revenue Frontier*			
node	***mean***	***sd***	***2.50%***	***97.50%***	***mean***	***sd***	***2.50%***	***97.50%***
constant	10.31000	0.01381	10.29000	10.34000	11.10000	0.04098	11.02000	11.18000
atmh	0.31160	0.01798	0.27680	0.34700	0.29790	0.02839	0.24260	0.35430
dom	0.19090	0.01059	0.17000	0.21120	0.15310	0.01763	0.11890	0.18780
int	0.12240	0.00511	0.11240	0.13230	0.19520	0.00884	0.17840	0.21250
cgo	0.04108	0.00583	0.02967	0.05244	0.08069	0.00862	0.06394	0.09788
wc	0.33420	0.00163	0.33100	0.33740	0.11690	0.01557	0.08596	0.14720
wm	0.36250	0.00148	0.35960	0.36540	0.39460	0.01741	0.36100	0.42830
wp	0.30330	0.00165	0.30010	0.30650	0.48850	0.01979	0.44940	0.52670
atmh*wc	0.04380	0.00197	0.03995	0.04764	0.06240	0.01846	0.02617	0.09859
atmh*wm	-0.01106	0.00182	-0.01460	-0.00742	-0.07650	0.01642	-0.10890	-0.04470
atmh*wp	-0.03274	0.00202	-0.03672	-0.02885	0.01410	0.01915	-0.02326	0.05204
dom*wc	0.00094	0.00090	-0.00081	0.00273	0.04150	0.00942	0.02337	0.06020
dom*wm	0.00444	0.00080	0.00287	0.00598	-0.00555	0.00934	-0.02390	0.01264
dom*wp	-0.00252	0.00093	-0.00433	-0.00071	-0.01389	0.00884	-0.03135	0.00312
int*wc	-0.00480	0.00069	-0.00614	-0.00345	0.02248	0.00617	0.01043	0.03451
int*wm	0.00266	0.00059	0.00149	0.00383	0.01738	0.00566	0.00608	0.02824
int*wp	0.00078	0.00072	-0.00063	0.00220	-0.08835	0.01471	-0.11800	-0.05966
cgo*wc	-0.00073	0.00105	-0.00278	0.00135	-0.00923	0.00748	-0.02379	0.00548
cgo*wm	-0.00067	0.00091	-0.00248	0.00110	-0.02055	0.00709	-0.03438	-0.00664
cgo*wp	0.00093	0.00111	-0.00125	0.00310	-0.01985	0.01393	-0.04752	0.00693
0.5*wc2	0.10090	0.00289	0.09536	0.10650	0.06129	0.02915	0.00525	0.11760
wc*wm	-0.09894	0.00195	-0.10270	-0.09504	-0.12900	0.02288	-0.17380	-0.08467
wc*wp	-0.01584	0.00267	-0.02106	-0.01057	-0.08558	0.03572	-0.15500	-0.01460
0.5*wm2	0.13220	0.00250	0.12740	0.13710	0.00341	0.02921	-0.05379	0.06140
wm*wp	-0.00240	0.00247	-0.00726	0.00241	0.03785	0.03192	-0.02493	0.09992
0.5*wp2	-0.00501	0.00490	-0.01471	0.00437	0.14330	0.05111	0.04651	0.24670
0.5*atmh2	0.05256	0.00463	0.04349	0.06162	0.06214	0.00755	0.04762	0.07748
0.5*dom2	0.02706	0.00146	0.02417	0.02987	0.01912	0.00233	0.01454	0.02367
dom*int	-0.00336	0.00119	-0.00568	-0.00099	-0.00928	0.00249	-0.01424	-0.00448

0.5*int2	0.01419	0.00093	0.01238	0.01601	0.02256	0.00147	0.01967	0.02543
0.5*cgo2	-0.00165	0.00144	-0.00449	0.00116	0.00664	0.00196	0.00283	0.01050
time	0.01000	0.00146	0.00712	0.01283	-0.00066	0.00230	-0.00518	0.00380
time*atmh	0.00596	0.00199	0.00201	0.00990	0.00837	0.00302	0.00244	0.01421
time*dom	0.00176	0.00095	-0.00011	0.00364	0.00197	0.00180	-0.00153	0.00556
time*int	-0.00271	0.00050	-0.00370	-0.00174	-0.00623	0.00079	-0.00782	-0.00468
time*cgo	0.00106	0.00089	-0.00071	0.00279	0.00120	0.00128	-0.00131	0.00370
time*wc	0.00155	0.00041	0.00074	0.00236	-0.01037	0.00318	-0.01675	-0.00414
time*wm	0.00093	0.00037	0.00020	0.00167	-0.00792	0.00281	-0.01342	-0.00247
time*wp	-0.00451	0.00045	-0.00542	-0.00365	-0.05600	0.00573	-0.06734	-0.04488
EUR	-	-	-	-	0.26190	0.03690	0.18900	0.33410
AP	-	-	-	-	0.28680	0.05409	0.18060	0.39170
slcc	-	-	-	-	-0.16700	0.05712	-0.27740	-0.05217
scha	-	-	-	-	-0.42630	0.06025	-0.54440	-0.30710
hhi	-	-	-	-	-0.37020	0.04949	-0.46610	-0.27110
psi (hedonic)	1.10326	0.11727	0.91112	1.36256	-	-	-	-
lambda	4.42200	0.18100	4.08600	4.79700	1.82700	0.05220	1.72600	1.93100

Cost and revenue inefficiencies for the average sample airport can be calculated as the inverse of the respective lambda coefficients, these are 22.62% and 54.7%, respectively. The latter indicates that airports, on average, should be able to generate slightly over twice their actual revenue. This estimate may appear, at first, to be excessive, but note that the estimated profit system is not restricted by any fixed factors or external restrictions. Therefore, airports lacking commercial orientation, appropriate retail facilities, facing draconian price regulations, or having subsidized airport charges will incur in significant revenue inefficiencies as they may be compared against best-practice airports (probably) from other regions. Having Spanish airports subjected to these strict benchmarks is necessary in order to find out if they could possibly stand on their own in the event of being managed individually. Cost and revenue efficiencies for Spanish airports, along with other traffic, financial, and infrastructure indicators for 2010, are summarized in Table 5. Traffic-weighted inefficiency averages for Spanish airports are 31% and 34% for cost and revenue inefficiencies, respectively. If only small airports (those serving less than 1 mppa) are considered, the same figures are 23% and 58%. These sharp differences can be explained by the disproportionate impact of the minority of large airports in the calculations, with the small-airport values being closer to the aforementioned worldwide average (around 2 mppa) in terms of airport size.

Cost inefficiencies are mainly determined by the scale of traffic and the utilisation of the capacity. The utilization of the capacity is dependent on traffic and indivisibilities related with recent investments. In a centralized network management, cost inefficiencies may also come from weak incentives due to the lack of competition and the cross-subsidiation system.

Revenue inefficiencies are also associated with traffic levels but also with the type of airlines that are operating there (low-cost, charter, network) and the share of dominant airlines. Furthermore, an insufficient commercial orientation of the airport and aeronautical charges that does not reflect neither costs nor demand conditions could also explain revenue inefficiencies.

Looking at data in table 5, it seems that revenue inefficiencies are more important than cost inefficiencies for almost all airports. The cost efficiency of 14 airports is clearly lower than the mean sample values. With the exception of Valencia and Tenerife Sur, all these airports are characterized by a low utilisation of the capacity (low passengers per square meter). These include large airports like Madrid, Barcelona and Málaga with recent capacity expansions and airports with very low traffic volumes like for example Albacete, Burgos or la Gomera.

From table 5, we can also see that the revenue efficiency of 14 airports is clearly lower than the mean sample values. All these airports are characterized by low traffic volumes. Along with this information, it is also interesting to stress that the airports with the best revenue efficiency performance are large airports specialized in tourism. Generally, these airports show a high diversification of airlines operating there and a high share of low-cost and/or charter carriers. Among the most revenue efficient airports, the only exception is the airport of Barcelona which has a higher proportion of network carriers offering flights.

The largest Spanish airport, Madrid, has a revenue efficiency indicator just slightly higher than the mean sample values and two airports with more than 4 million passengers, Valencia and Tenerife Norte, show a poor revenue efficiency performance as well. In all these three airports, the proportion of network carriers is relatively high. It is likely that airport charges in these airports, particularly Madrid airport, are too low.

Airport profitability under efficient conditions is also explored in Table 5. Both profit-over-revenues and profit-over-cost indicators are calculated under different assumptions: i) using the actual values, ii) correcting for cost efficiency[13] (-*Ceff*), iii) correcting for revenue efficiency[14] (-*Reff*), and iv) correcting for both (-*C&Reff*). The profit-over-cost values for Spanish airports are shown in Figures 2 to 4.

Under the assumption of cost efficiency, five airports with financial loses using actual values would become profitable; Madrid, Barcelona, Málaga, Oviedo and Murcia. The first three are big airports that have expanded capacity recently, while the other two have traffic levels of about 1.3 million passengers so they are operating under increasing returns to scale. In this regard, it is clear that just few airports are not profitable because they are not able to fully exploit scale economies. Likely, the utilisation of the capacity will increase in the coming years in the three large unprofitable airports.

In contrast, a much higher number of airports would be profitable under the assumption of just revenue efficiency. Under such assumption, 14 airports would become profitable: Madrid, Málaga, Tenerife Norte, Menorca, Santiago de Compostela, Reus, Oviedo, Murcia, La Coruña, Vigo, Jerez, La Palma, Granada, Zaragoza. Another two, Barcelona and El Hierro, would be very close to profitability. In fact, most of airports with more than 500.000 passengers per year would become profitable under the assumption of revenue efficiency. This is within the traffic threshold in which the European Commission (2002) set the profitability of airports in France, Sweden and United Kingdom.

Finally, under the assumptions of cost and revenue efficiency only ten airports would be unprofitable; Valladolid, Melilla, San Sebastián, Salamanca, Vitoria, Burgos, La Gomera, Córdova, Logroño and Albacete. These airports have low traffic levels and most of places where they are located are well connected though trains and roads. Recall that regional and local governments have spent a great amount of public resources in subsiding private airlines to operate in these facilities. This additional source of inefficiency is not considered in our analysis because it is out of the responsibility of the airport operator. Only the functioning of La Gomera and Melilla, which are located in peripheral places, could be justified on social grounds.

[13] This is achieved by just multiplying the actual cost by the cost efficiency estimate.
[14] Efficient revenues are calculated by dividing the actual figures by the corresponding efficiency.

Table 5. Traffic, efficiency, and profitability indicators at Spanish airports (2010)

Airport	*tc/pax (EUR)*	*trev/pax (EUR)*	*Ceff*	*Reff*	*Profit/ Revenue*	*-Ceff*	*-Reff*	*-C&Reff*	*Profit/ Cost*	*-Ceff*	*-Reff*	*-C&Reff*
ALBACETE (ABC)	293.10	12.4	0.643	0.096	-2264%	-1420%	-126%	-45%	-96%	-93%	-56%	-31%
ALICANTE (ALC)	6.19	9.35	0.914	0.664	34%	40%	56%	60%	51%	65%	128%	149%
ALMERIA (LEI)	20.33	9.94	0.598	0.555	-105%	-22%	-13%	32%	-51%	-18%	-12%	47%
ASTURIAS (OVD)	10.71	8.97	0.760	0.684	-19%	9%	18%	38%	-16%	10%	22%	61%
BADAJOZ (BJZ)	44.79	7.19	0.728	0.210	-523%	-354%	-31%	5%	-84%	-78%	-23%	5%
BARCELONA (BCN)	14.81	11.34	0.525	0.799	-31%	31%	-4%	45%	-23%	46%	-4%	82%
BILBAO (BIO)	10.00	10.54	0.796	0.739	5%	25%	30%	44%	5%	33%	43%	79%
BURGOS (RGS)	172.34	6.85	0.744	0.189	-2417%	-1773%	-377%	-255%	-96%	-95%	-79%	-72%
CORDOBA (ODB)	732.30	31.84	0.674	0.184	-2200%	-1449%	-323%	-185%	-96%	-94%	-76%	-65%
FUERTEVENTURA (FUE)	7.99	7.99	0.672	0.779	0%	33%	22%	48%	0%	49%	28%	91%
GIRONA (GRO)	4.98	7.6	0.928	0.613	34%	39%	60%	63%	52%	64%	149%	168%
GRAN CANARIA (LPA)	6.59	7.88	0.754	0.764	16%	37%	36%	52%	20%	59%	57%	108%
GRANADA (GRX)	14.93	7.97	0.862	0.482	-88%	-62%	10%	22%	-47%	-38%	11%	28%
HIERRO (VDE)	36.50	3.39	0.892	0.099	-976%	-859%	-7%	5%	-91%	-90%	-6%	5%
IBIZA (IBZ)	6.47	7.21	0.843	0.673	10%	24%	40%	49%	12%	32%	66%	96%
JEREZ (XRY)	17.13	10.18	0.894	0.462	-68%	-50%	22%	30%	-41%	-34%	29%	44%
LA CORUÑA (LCG)	13.85	8.58	0.875	0.433	-61%	-41%	30%	39%	-38%	-29%	43%	64%
LA GOMERA (GMZ)	170.21	6.47	0.726	0.063	-2533%	-1812%	-65%	-20%	-96%	-95%	-39%	-17%
LA PALMA (SPC)	20.16	5.08	0.872	0.240	-296%	-246%	5%	17%	-75%	-71%	5%	21%
LANZAROTE (ACE)	6.83	7.66	0.858	0.574	11%	23%	49%	56%	12%	31%	95%	128%
LEON (LEN)	89.10	8.03	0.533	0.162	-1009%	-491%	-80%	4%	-91%	-83%	-44%	4%
LOGROÑO (RJL)	224.64	10.06	0.660	0.086	-2019%	-1299%	-83%	-21%	-95%	-93%	-45%	-17%
MADRID (MAD)	16.06	12.23	0.662	0.489	-31%	13%	36%	57%	-24%	15%	56%	135%
MALAGA (AGP)	11.91	10.21	0.539	0.817	-17%	37%	5%	49%	-14%	59%	5%	94%
MELILLA (MLN)	41.59	4.71	0.923	0.385	-782%	-714%	-240%	-213%	-89%	-88%	-71%	-68%
MENORCA (MAH)	13.03	7.73	0.806	0.571	-69%	-36%	4%	22%	-41%	-26%	4%	29%
MURCIA (MJV)	9.76	8.11	0.781	0.580	-20%	6%	30%	46%	-17%	6%	43%	84%
PALMA (PMI)	6.13	7.88	0.777	0.806	22%	40%	37%	51%	29%	66%	60%	105%
PAMPLONA (PNA)	31.14	8.57	0.664	0.333	-263%	-141%	-21%	20%	-72%	-59%	-17%	25%
REUS (REU)	11.61	7.42	0.918	0.478	-56%	-43%	25%	31%	-36%	-30%	34%	46%
SALAMANCA (SLM)	95.65	12.42	0.806	0.158	-694%	-540%	-25%	-1%	-87%	-84%	-20%	-1%
SAN SEBASTIAN EAS)	27.48	8.98	0.881	0.480	-206%	-169%	-47%	-29%	-67%	-63%	-32%	-23%
SANTANDER (SDR)	14.13	7.33	0.602	0.640	-93%	-16%	-24%	26%	-48%	-14%	-19%	34%
SANTIAGO (SCQ)	11.09	8.4	0.801	0.715	-32%	-6%	6%	24%	-24%	-5%	6%	32%
SEVILLA (SVQ)	8.72	9.64	0.819	0.717	9%	26%	35%	47%	10%	35%	54%	88%
TENERIFE NORTE (TFN)	8.14	5.98	0.768	0.492	-36%	-4%	33%	49%	-26%	-4%	49%	94%
TENERIFE SUR (TFS)	7.86	9.58	0.717	0.845	18%	41%	31%	50%	22%	70%	44%	101%
VALENCIA (VLC)	8.70	10.24	0.700	0.508	15%	41%	57%	70%	18%	68%	132%	231%
VALLADOLID (VLL)	21.70	7.76	0.841	0.498	-179%	-135%	-39%	-17%	-64%	-57%	-28%	-15%
VIGO (VGO)	14.62	8.82	0.926	0.396	-66%	-54%	34%	39%	-40%	-35%	52%	64%
VITORIA (VIT)	388.44	64.65	0.676	0.480	-501%	-306%	-189%	-95%	-83%	-75%	-65%	-49%
ZARAGOZA (ZAZ)	25.60	10.93	0.861	0.355	-134%	-102%	17%	28%	-57%	-50%	20%	40%

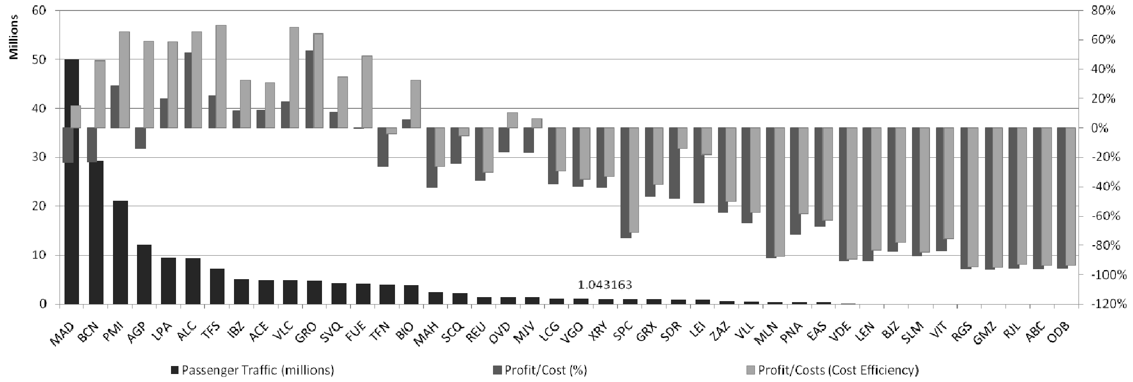

Figure 2 Impact of cost efficiency on profitability of Spanish Airports (2010)
Source: AENA (2011), Own elaboration

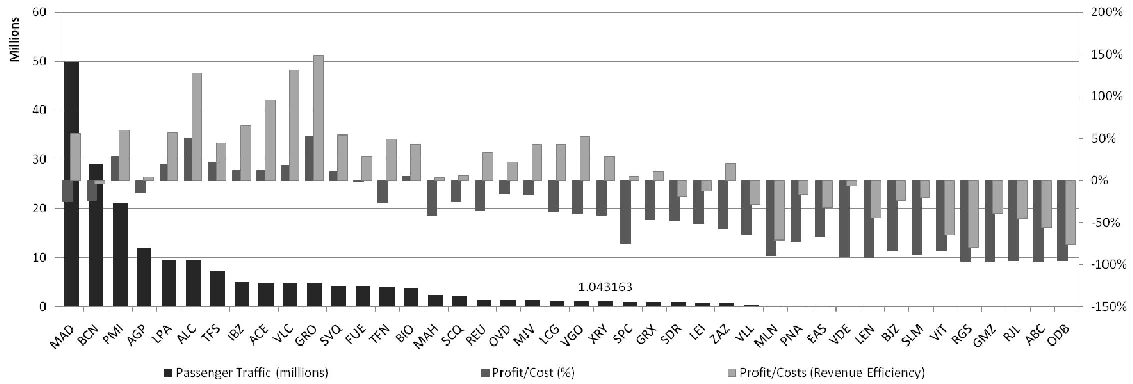

Figure 3 Impact of revenue efficiency on profitability of Spanish Airports (2010)
Source: AENA (2011), Own elaboration

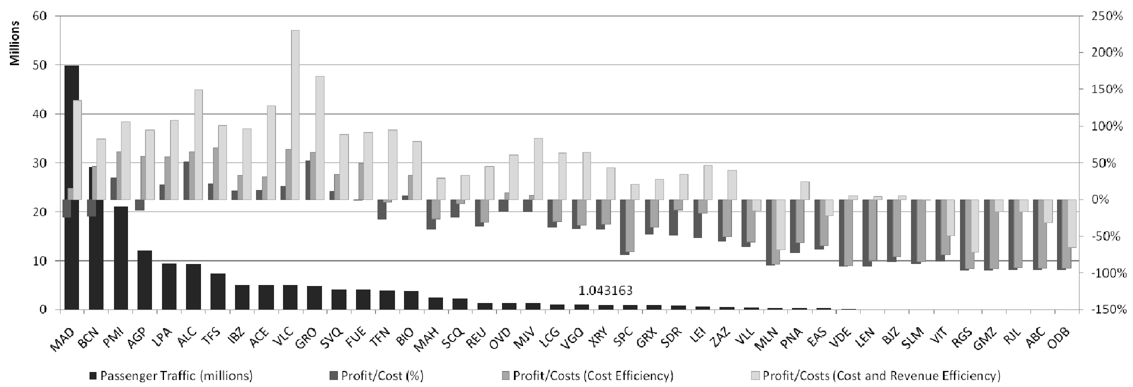

Figure 4 Impact of cost and revenue efficiencies on profitability of Spanish Airports (2010)
Source: AENA (2011), Own elaboration

7. SUMMARY

In Spain, the centralized management has been traditionally justified on the basis that small airports are not able to exploit scale economies. From our analysis, revenue inefficiencies are even more influential for the profitability of small airports. Within a context of revenue efficiency, few airports would be clearly unprofitable. In fact, just those airports with less than 500.000 passengers would likely incur in financial loses. This suggests the viability of an individualized management as it is common in most of European and North American countries. In such a context, it would be advisable that airport charges were set according to the specific costs and demand conditions of each airport. Furthermore, the financial viability of small airports could be guaranteed with an adequate promotion of commercial activities in their facilities.

Our analysis suggests that the revenue side in airport operations should deserve more attention. In fact, the Spanish case illustrate that revenue inefficiencies are crucial to understand difficulties of some airports to be profitable. Note also that airport managers may have restrictions to afford cost inefficiencies related with the use of the capacity. Indeed, there are indivisibilities associated with new investments and the amount of traffic than an airport may generate is usually dependent upon local demand. However, they may have more flexibility in promoting commercial activities in their sites. And a strict regulation of aeronautical revenues should be just clearly justified in those cases where the market power of the airport in front of the airlines is strong.

As a final remark, future research should look into the disaggregation of aeronautical and non-aeronautical revenues, perhaps with the estimation of a three-equation profit system. This separation will allow for a better characterization of the impact of managerial factors such as ownership or price regulation on aeronautical revenue efficiency.

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APPENDIX A. Model specification

A.1 Long-run cost frontier

$$lnTC_{it} = g(y,\omega,t) + u_{it} + v_{it} = \alpha_1 + \alpha_2 atmh + \alpha_3 dom + \alpha_4 int + \alpha_5 cgo + \beta_6\omega_c + \beta_7\omega_m + \beta_8\omega_p + \gamma_9 atmh\cdot\omega_c + \gamma_{10} atmh\cdot\omega_m + \gamma_{11} atmh\cdot\omega_p + \gamma_{12} dom\cdot\omega_c + \gamma_{13} dom\cdot\omega_m + \gamma_{14} dom\cdot\omega_p + \gamma_{15} int\cdot\omega_c + \gamma_{16} int\cdot\omega_m + \gamma_{17} int\cdot\omega_p + \gamma_{18} cgo\cdot\omega_c + \gamma_{19} cgo\cdot\omega_m + \gamma_{20} cgo\cdot\omega_p + \delta_{21} 0.5\cdot\omega_c\cdot\omega_c + \delta_{22}\omega_c\cdot\omega_m + \delta_{23}\omega_c\cdot\omega_p + \delta_{24} 0.5\cdot\omega_m\cdot\omega_m + \delta_{25}\omega_m\cdot\omega_p + \delta_{26} 0.5\cdot\omega_p\cdot\omega_p + \rho_{27} 0.5\cdot atmh\cdot atmh + \rho_{28} 0.5\cdot dom\cdot dom + \rho_{29} dom\cdot int + \rho_{30} 0.5\cdot int\cdot int + \rho_{31} 0.5\cdot cgo\cdot cgo + \tau_{32} t + \tau_{33} t\cdot atmh + \tau_{34} t\cdot dom + \tau_{35} t\cdot int + \tau_{36} t\cdot cgo + \tau_{37} t\cdot\omega_c + \tau_{38} t\cdot\omega_m + \tau_{39} t\cdot\omega_p + u_{it} + v_{it}$$

$$S_c = \beta_6 + \gamma_9 atmh + \gamma_{12} dom + \gamma_{15} int + \gamma_{18} cgo + \gamma_{21}\omega_c + \delta_{22}\omega_m + \delta_{23}\omega_p + \tau_{37} t$$

$$S_m = \beta_7 + \gamma_{10} atmh + \gamma_{13} dom + \gamma_{16} int + \gamma_{19} cgo + \gamma_{22}\omega_c + \delta_{24}\omega_m + \delta_{25}\omega_p + \tau_{38} t$$

$$S_p = \beta_8 + \gamma_{11} atmh + \gamma_{14} dom + \gamma_{17} int + \gamma_{20} cgo + \gamma_{23}\omega_c + \delta_{25}\omega_m + \delta_{26}\omega_p + \tau_{39} t$$

A.2 Revenue frontier

$$lnTR_{it} = g(y,\omega,t) + \pi_{40} EUR + \pi_{41} AP + \pi_{42} slcc + \pi_{43} scha + \pi_{44} hhi + u_{it} + v_{it}$$

A.3 Equations/restrictions common to both models

$$atmh = atm + \psi_1 mtow$$

$$\beta_6 + \beta_7 + \beta_8 = 1; \quad \gamma_9 + \gamma_{10} + \gamma_{11} = 0; \; \gamma_{12} + \gamma_{13} + \gamma_{14} = 0; \; \gamma_{15} + \gamma_{16} + \gamma_{17} = 0;$$

$$\gamma_{18} + \gamma_{19} + \gamma_{20} = 0; \; \gamma_{21} + \gamma_{22} + \gamma_{23} = 0; \delta_{22} + \delta_{24} + \delta_{25} = 0; \; \delta_{23} + \delta_{25} + \delta_{26} = 0;$$

$$\tau_{45} + \tau_{46} + \tau_{47} = 0$$

(all variables in g(.), except time, are logged and deviated from their sample averages)