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Measuring Airports' Technical Efficiency: Evidence from Italy

Doctoral Dissertation

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Abstract

Airports are an essential part of the air transport system. This system shows a great complexity, mainly linked to the dimensional and commercial fragmentation between a number of players. Only few contribution in the literature (Button, 2005 and Button and Mc Dougall, 2006) deal with the issue of the air transport value chain. However, a comprehension of the dynamics at the system level allows a contextualization of the activities operated by airports which play a crucial role not only within the air transportation sector, but also in the process of increasing the quality of life of regional and local communities, directly participating in wealth creation.

Precisely for these reasons, the topic of airport performance has gained increasing attention from researchers, especially after that the liberalization process implemented so far in the air transport sector has brought a strong growth of demand in the aviation market and this in turn has determined an increase in the level of competition between both airlines and airports. Of course, performance evaluation and improvement studies of airport operations have important implications for a number of airport stakeholders: (i) for airlines in identifying and selecting the more efficient airports at which to base their operations, (ii) for municipalities because of the benefits coming from efficient airports in terms of attracting business and passengers, (iii) for policy makers in making effective decisions on optimal allocation of resources to airport improvement programs, and in evaluating the efficacy of such programs. Finally, benchmarking their own airports against comparable airports is one way for operations managers to ensure competitiveness.

The research carried out in this thesis contributes both to the literature regarding the

air transportation system in general and the topic of airport efficiency. Concerning the first one, by pointing out the degree of market power in each stage of air transport vertical channel in order to individuate the existence of bottlenecks or other factors explaining the asymmetric distribution of revenues and allowing a detailed evaluation of the sustainability and stability problem of the air transport market.

The first article (Chapter 2) analyzes the air transport vertical channel to identify some of the factors that can explain the frequent financial difficulties (and also closure) of airlines. The analysis shows that carriers obtain a minimal percentage of the total profit created by the vertical channel. In the last years the average profit margins of airlines are a little lower than 2%. These economic performances seem not to be sufficient to cover airline longterm costs, especially in presence of significant shocks external to the sector. On the contrary, there are stages of the vertical channel, where profit margins are so high, that they could even be classified as excessive (the highest average margins are higher than 20%). Leasing companies and GDSs are in particular sectors with a great market power. The first ones have a high buyer power towards aircraft manufacturers and a high seller power towards airlines. The second ones have the advantage to be the platform of a two sided market in the final distribution segment.

This highly asymmetric distribution of the vertical channel value added is particularly due to two factors; first the lack of balance in the market power on the buyer side (buyer power) and on the seller side (seller power) observed in some stages of the vertical channel. The second factor is instead connected to the liberalization policy implemented so far in the air transport sector. In fact this has concerned only some compartments of the vertical channel (the stage of airlines and handling companies). Airlines are trying to contrast this disequilibrium by moving in two directions: on one side, through offer aggregation policies (as alliances and concentrations); on the other side, through a reducing costs policy (vertical integration and differentiation in the distribution, greater consumption efficiency). It's particularly evident that in the entire sector there is a process of global concentration that constitutes in all respects an evolution of the big alliances among carriers. In fact, if on one side these alliances are precious from the commercial point of view for the synergies created, on the other side, the necessity to restructure big companies and to create scale economies based on significant cost cuttings (including costs related to the staff) are making mergers among airlines inevitable.

Two policy implications can be drawn from this analysis. First, it is necessary to evaluate carefully the mergers among carriers in order not to hinder those aimed at balancing the market power within the vertical channel. These should in fact produce social benefits because the increased countervailing power of carriers should ensure better supply conditions (and reduced margins for the companies upstream). This, in turn, due to the current competition level among airlines, should be translated into a reduction of prices for final consumers. Second, disintegration processes are required in the upstream compartments because of there are monopolistic practices realized by vertical relations. A careful evaluation of the share-holdings within the vertical channel is in particular requested to identify those able to influence the market.

As far as the topic of airport efficiency is concerned, the research interests are the investigation of the determinants of efficiency (with a particular interest in the relationship between airport efficiency and airport competition) and the possibility to include in airport production function of the negative externalities connected to airport activities (local air pollution is considered as negative by-product).

The second paper (Chapter 3) has investigated the impact of airport competition on the efficiency of 38 Italian airports by applying a stochastic distance function model (Coelli and Perelman, 2000) with time-dependent inefficiency components to a panel data set regarding the period 2005-2008 and covering 99.97% of total passenger movements. Airport competition has been computed using a potential demand model, taking into account passengers traveling times to reach an airport as an exogenous factor affecting demand. Efficiency scores are obtained by maximum likelihood estimation (Battese and Coelli, 1995).

Airports technical efficiency are estimated by maximum likelihood (Battese and Coelli, 1995) in terms of efficient inputs utilization (both for physical infrastructures and variable factors such as labour), an approach largely applied in the existing literature on airport efficiency (e.g., Gillen and Lall, 1997, 2001; Pels *et al.*, 2001, 2003) and Lozano and Gutiérrez, 2009).

The results show that airports with higher intensity of competition are less efficient than those which benefit from local monopoly power. Furthermore, public airports result more efficient, while private airports are even less efficient than those with mixed ownership: this can be explained by some reasons. First, investments in indivisible inputs may have been greater in private airports and, given the difficulties involved in reaching in the short run the volume of traffic required for an efficient utilization of the indivisible input, private airports have lower technical efficiency than the other airports types. Second, since private airport maximize profit, they could pay more attention to cost efficiency and commercial revenues: in this sense, they may not be willing to increase traffic, in order to achieve an efficient assets utilization, especially when reaching this target implies adopting unprofitable strategies.

These results yield the following policy recommendations. First, in order to recover efficiency, one possibility is to induce airport specialization within the same territorial system (e.g., one airport may focus on LCCs and another on cargo). Moreover, since passengers living in these areas can choose among alternative airports, an extreme possibility is to close down airports that are at the same time highly inefficient and unprofitable, especially when they cover their losses by public local taxation. Second, regulation should monitor the efficient assets utilization especially after that new investments have been implemented. Many assets suffer from indivisibility in the shortrun and our analysis has proved that their utilization could be inefficient also in presence of private investors.

In the third paper (Chapter 4) a hyperbolic distance function model (proposed by Cuesta *et al.*, 2009), both parametric and stochastic, has been applied for airport efficiency assessment considering local air pollution as undesirable output. Using information on the produced local air pollution, the approach has been applied to a panel data of 33 Italian airports for the period 2005-2008. Airports' efficiency scores have been obtained by maximum likelihood estimation (Battese and Coelli, 1992). In order to include the negative externalities connected to local air pollution, we created an index describing the total amounts of pollutants produced for each Italian airport included in our data set. Each pollutant has been weighted for the cost of damage it imposes. Only few contributions (Yu, 2004, Yu *et al.*, 2008, Patomshiri *et al.*, 2008 and Lozano and Gutiérrez, 2010) have considered undesirable outputs in airport efficiency analysis. To the best of our knowledge, this is the first attempt to consider local air pollution as a bad outputs in airport efficiency assessment. Furthermore, it is also the first attempt to measure airport environmental efficiency using a multi-output stochastic frontier analysis.

The results show that the efficiency assessment of the airports when their undesirable outputs are ignored is totally different and can therefore be misleading. Specifically, airports tend to be more efficient, on average, when negative externalities are included in the analysis. This can be due to the fact that inefficient airports (in terms of passengers and flights) close the gap because their low volumes of desirable outputs mean that the negative externalities produced are lower. However, this contribution provides a first clue about the importance of a characteristic of airports not much considered in the literature so far: the operating fleet. In fact airports managements improve their efficiency scores if they promote carriers to use modern fleets (e.g., increasing airport charges). Given the importance of this consideration in terms of environmental efficiency, it would be interesting in terms of future research to deepen its impact and to understand what kind of tools airports can use to incentive these renewals.

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I assume all responsibility for the eventual errors, inaccuracies or oversights that unfortunately could be still in the dissertation.

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CHAPTER 1

Introduction

Air transport is a rapidly growing sector in many economies, with growth in the number of passengers and the volume of air–freight typically outstripping GDP growth by a factor of 3:1 (EU–25, 1994–2003; Cooper and Smith, 2005). Only the recent global financial economic crisis has temporarily halted this trend. The increase in the provision of air transport services is a contributor to the growth in economic activity more generally. Besides a direct impacts on employment and output in the aviation industry itself, air transport activities also produce (i) indirect impacts on employment and output in the supply chain to the aviation industry, and (ii) catalytic impacts in terms of development of local economies. These capture the extent to which the growth in air transport boosts the performance of other industries (e.g., through tourism, trade, investment and productivity).

Airports are an essential part of the air transport system. They play a crucial role not only within the air transportation sector, but also in the process of increasing the quality of life of regional and local communities, directly participating in wealth creation. In this sense, airport activity can be considered as a key factor in promoting economic, productive, tourist and commercial upgrades of a territory, thanks to the "multiplier effect" in the number of potential business transactions it may stimulate (Jarach, 2005).

However, besides numerous and sizeable benefits to citizens and companies, airports also brings undesired and damaging side–effects to people living nearby and to the local and global environment especially in terms of air quality, noise and congestion. In particular, the continuously increasing passenger traffic and a rise in public awareness have made aircraft noise and emissions two of the most pressing issues hampering commercial aviation growth today.

In this context, the issue of an efficient management of airports has become a central theme in terms of both single airport and airport system. This is even truer in the light of the recent phenomena of deregulation and airport privatization that have characterized the air transport sector over the past years.

Before addressing in detail the topic of airport efficiency, which is the main focus of this dissertation, it is certainly useful to contextualize the role of airports within the air transport sector, identifying the existing boundaries and the peculiarities of the air transport value chain. This is the main goal of the first paper presented in this work (Chapter 2). In fact air transport value chain shows a great complexity, mainly linked to the dimensional and commercial fragmentation between a number of players. The quality level and the price of the final output—i.e., a passenger/customer's travel experience— is related to the intricate set of all individual actions performed by a host of entities: airlines, airports, manufacturers, leasing companies, operators of the distribution phase, etc. Obviously, a crucial role is performed by public policies acting as "regulator" of all industry practices.

As mentioned before, the other two papers included in this dissertation deal with the issue of airport efficiency. During the last two decades there has been a growing interest in measuring airports' performances. On one hand, the process of introducing private participation in the management and operation of airports and the birth of regulatory agencies in charge of setting tariffs for the sector brought along the need to assess the way in which airports are being operated. On the other hand, with the liberalization of competition among airlines, airports started competing with each other for connecting traffic which prompted them to increase their efficiency.

Previous studies on airport efficiency and productivity can be classified according to some critical parameters: (1) the estimation method that was applied; (2) the choice of output and input variables to be used in the efficiency analysis; (3) the geographical scope.

As far as the estimation method is concerned, there are two fundamental groups, one using Stochastic Frontier Analysis (SFA), that is a parametric method, and the other using Data Envelopment Analysis (DEA), that is a non–parametric method.

The most common approach is DEA. Since DEA is an extreme point technique, noise such as measurement error can cause significant problems; at the same time, statistical issues as inference and hypothesis testing are difficult. However they are actually possible even if, for general case with p inputs and q outputs, bootstrap methods remain the only useful approach for inference (Simar and Wilson, 2007). Otherwise SFA is able to manage random shocks and measurement errors and it can be used to conduct conventional test of hypotheses; moreover it allows easily the utilization of panel data and the incorporation of exogenous variables, which are neither inputs of the production process nor output of it, but which nonetheless exert an influence on producer's performance (Kumbhakar and Lovell, 2000). However, SFA presents some disadvantages connected with the need to specify (potentially erroneous) functional relationship between inputs and outputs and distributional assumptions for the one–side error term associated with technical efficiency.

Concerning the variables considered by different researchers, both parametric and non–parametric studies are very various, but the most common outputs are definitely those related to passengers, aircraft movements and cargo. Monetary outputs are also used in performance studies. Furthermore some recent studies consider undesirable outputs such as delays (e.g., Pathomsiri *et al.* 2008) or aircraft noise (e.g., Yu 2004 and Yu *et al.* 2008). On the input side, there are two common approaches: some studies consider factors such as capital, capital stock, labour and other operational costs and others consider physical infrastructure such as airport surface, runways, terminal building area, aircraft parking positions, check–in desks, boarding gates and baggage claims.

Looking carefully at the studies in which DEA was applied, different common approaches should be noted related to (1) the Returns to Scale (RTS), (2) the choice of the orientation and (3) the metrics used to measure the distance to the efficient frontier. In fact there is no consensus on the use of Constant Returns to Scale (CRS) rather than Variable Returns to Scale (VRS). As far as the orientation is concerned, some studies use an input orientation, others an output orientation and the rest a mixed orientation. Finally the two metrics commonly used to measure the distance to the efficient frontier are the Farrell efficiency measure and the directional distance function. Furthermore some studies often use different extensions of the DEA model (as cross efficiency and super efficiency models) in order to better discriminate among efficient units. Other studies, however, use panel data and compute total factor productivity using either Malmquist productivity indexes or Luenberger productivity indicators. In a recent contribution Lozano and Gutiérrez (2009) make an exhaustive review of these kind of studies.

The studies that deal with the estimation of a parametric frontier function are much less common in the literature regarding airports efficiency. The main aspect that differentiates them is the estimation of a production function rather than a cost function. Concerning this, the estimation of a production function deals mainly with the concept of technical efficiency, whereas the estimation of a cost function refers to a concept of cost efficiency. However several further differences should be noted between the estimation of technical and cost efficiency. Firstly the estimation of technical efficiency requires information on input use and output provision, whereas the estimation of cost efficiency requires information on input prices, output quantities and total expenditure. Furthermore the estimation of a stochastic production frontier, unlike the cost frontier, provides an output oriented efficiency measurement and so no distinction is usually made between variable inputs and quasi–fixed inputs (Kumbhakar and Lovell, 2000). Finally technical efficiency cannot be decomposed, whereas cost efficiency has two potential sources: technical efficiency and allocative efficiency. Note that most of the studies about technical efficiency and production function ignore the multi output nature of airport activity: the first recent attempts at using a stochastic distance function to measure airports technical efficiency considering multiple outputs were done by Chow and Fung (2009) and Martín–Cejas and Tovar (2009). Another interesting aspect is the approach to inference by which the estimation of the stochastic frontier model is done: the two alternatives are maximum likelihood estimation, that is the most common technique, and the more recent Bayesian approach applied in the estimation of a cost frontier by Oum *et al.* (2008) and Martín *et al.* (2009).

In term of geographical scope the literature regarding efficiency studies is very heterogeneous. Most of the contributions concern a single country (US, but also Brazil, Taiwan, Japan, Australia, Italy, Portugal, Spain and UK). There are also some studies at a European level and a few that benchmark airports from different countries.

In the light of these considerations, the paper presented in Chapter 3 analyzes the impact of airport competition and airport ownership structure on technical efficiency of Italian airports. The paper presented in Chapter 4 deals with the inclusion in airports' production function of an undesirable output, i.e., local air pollution. Chapter 5 summarizes and concludes this dissertation.

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CHAPTER 2

Market Power and Profits Distribution in the Air Transportation Vertical Channel

Abstract

We analyze the air transportation vertical channel and show the existence of an asymmetric distribution of profit margins between airlines and the firms operating in upstream stages. Higher margins are observed for leasing companies, engine manufacturers and GDSs, while airlines exhibit a very low profitability. Two factors may explain this asymmetry: (1) in some stages of the value chain some firms (e.g., airlines and handling companies) have a low countervailing power both when acting as a buyer and as a seller, and (2) the liberalization policy implemented in the air transport sector so far is incomplete. The latter has increased the intensity of competition in some stages (e.g., airlines and handling companies), but has not faced and reduced the market power in other ones. We can draw some policy implications from this analysis. First, horizontal mergers between airlines should be positively evaluated by competition authorities, since they increase the airlines countervailing power in the vertical channel and this may, in turn, bring about a price reduction for consumers. Second, the degree of vertical integration in some stages should be reduced, because it is likely to be an instrument for increasing the market power in upstream stages and not to reach a higher efficiency.

JEL classification: L93, L42
Keywords: air transportation, vertical channel, profits distribution.

2.1 Introduction

The air transport sector has been characterized in the last years by a strong development in terms of both passengers and cargo. Since 2003 up to 2007, for example, the passengers traffic in Europe grew steadily with rates ranging from 4% to 7.6%. The cargo traffic recorded a similar growth from 2.3% in 2003 to 7.6% in 2004 (Malighetti *et al.*, 2008). Only the recent global financial economic crisis has temporarily halted this growth, influencing strongly the results of late 2008 and early 2009.[1]

Furthermore, the air transport sector has also known in these years numerous turbulences with consequent bankruptcy cases (or calls in the receivers) of the companies belonging to the last stage of the vertical channel, i.e., the airlines.[2] These phenomena are not only caused by bad management, but are often due to the different strength relationships among the players operating in the different compartments inside the air transport vertical channel. Our aim is to show how the value added created along the whole vertical channel is distributed among the different stages and thus to understand why the operators of one or more stages of the vertical channel periodically suffer in terms of profitability.

A vertical channel analysis allows to point out the degree of market power in each stage, from both the buyers and the sellers standpoint, and to individuate the existence of bottlenecks or other factors enabling companies of some compartments to obtain extra–profits. A vertical channel analysis also allows to point out relevant factors for the airlines dynamics that are often not seriously considered, and also allows to evaluate in details the sustainability and stability problem of the air transport market.

The economic literature has paid low attention to the issue of the air transport vertical channel with exception of some studies made by Button (2005) and by Button and Mc Dougall (2006): they underline the presence of a relevant asymmetry in the value appropriation inside the vertical channel. This asymmetry is connected to the fact that the liberalization process of the air transport sector has concerned almost exclusively the final stage, which is the stage of airlines. This has notably reduced the market power of the old national carrier (which operated exploiting rents coming from their incumbent position in the domestic market), but has not contextually fought against elements of either institutional or natural monopoly, which enable players operating in other stages of the air transport supply chain not only to recover all costs, but also to obtain good operating

[1]The economic slowdown led to a sudden drop in the demand. According to the *International Air Transport Association* (*IATA*) forecasts (www.iata.org), the sector profits should decrease by 12% during this year. Forecast for 2009 is a drastic drop in demand with a decline in passenger traffic of 5.7%. The demand for freight should drop by 13%. These data represent a significant worsening compared to the forecasts of December 2008 (decrease of 3% and 5% of passengers and cargo respectively).

[2]According to *IATA* (www.iata.org), in the last one year and a half there were no less than 30 bankruptcies: 18 in 2008 and 12 in 2009. In the last ten years, besides the well known *Alitalia* matters, there have been "renowned" financial difficulties of the Belgian and Suisse flag carriers *SABENA* and *SWISSAIR* (both in 2001). Two big American airlines, i.e., *US Airways* and *United Airlines*, had similar problems in 2002.

margins.[3]

Most of the studies have analyzed single stages of the vertical channel. For example, Mason (2007) studies the compartment of aircraft production, analyses the strategies of the two major large aircraft manufacturers, Airbus and Boeing, and concludes that they are adopting substitute strategies. About the same sector, Irwin and Pavcnik (2004) declare that, despite the low number of operators, the competition has intensified, because of the entry of new aircraft varieties. This is even truer if we consider the whole market, including regional jets.[4]

Dussart–Lefret and Federlin (1994) and Soames (1997) have analyzed the segment of ground handling services[5], while Alamdari and Mason (2006) have studied the final distribution sector, showing an overview of changes taking place and pointing out the impact that these, in the next future, will have on airlines, travel agencies, the so called Global Distribution System (GDS) providers and consumers.

However, in the literature the most studied compartments are those of airports and airlines. Concerning the latter, studies point out the existence of an offer excess (Oum *et al.*, 2005), they analyse the welfare effects of mergers between carriers (Brueckner and Pels, 2005), they try to find out factors affecting passengers preferences (Pels *et al.*, 2008). Other analyses concern the low cost airlines (Piga and Polo, 2003) and the effects of the liberalization of the air transport sector in Europe (Arrigo and Giuricin, 2006).

Concerning the airport compartment, many studies regard the efficiency (Gillen and Lall, 1997; Pels *et al.*, 2001 and 2003) and the privatization effects (Oum *et al.*, 2008).[6]

Even the literature regarding the air transport sector in Italy dwelt upon the effects of the liberalization process on the airports (Nicoletti, 1998; Colombo, 2001; Sebastiani, 2002, 2004; Pettinato, 2004; Barone and Bentivogli, 2006; Macchiati and Piacentino, 2006) and on the airlines (Rampini, 2000; Arrigo, 2005; Minervini, 2006; Buccirossi and Cambini,

[3]Authors point out that in the final distribution sector there are only few companies with a high market power, while the big aircraft manufacturing sector has a duopolistic structure. Furthermore, three companies have control over the worldwide market of aircraft engines manufacturing. Last, most airports are still working as local monopolists.

[4]As indicated by Brueckner and Pai (2009), regional jets combine a relatively small passenger capacity (up to 70–90 seats) with a relatively long range (1,500 miles), a high cruising speed and a level of passenger comfort comparable to that of mainline jets. Turboprop aircraft, while providing a similar small capacity, have a shorter range, lower cruising speed (350 mph), and less comfort, mainly because of higher noise levels.

[5]These studies analyze the effects of the liberalization process in the European market and point out how policy interventions have tried to obtain a compromise among the different players involved (airlines, airports and handlers).

[6]For an in–depth analysis regarding airports please refer to Malighetti *et al.* (2007).

2006; Barone and Bentivogli, 2006; Macchiati and Piacentino, 2006; Boitani and Cambini, 2007; Gitto *et al.*, 2008).

The airport and airline compartments, whose salient features from the industrial point of view are well known in literature (i.e., for airports, local monopoly and lack of competition to obtain the temporary management of the whole structure and/or of a particular service performed within it; for airlines, the different business models currently available and the agglomeration phenomena), are not analyzed here. If necessary to give an overview of the vertical channel, we will indicate some data that characterize them, in order to offer a comparison.[7]

The vertical channel analysis has allowed to point out two relevant criticalities: (1) the presence of a strong market power in the stage of engines manufacturers, leasing companies and GDSs; (2) the incompleteness of the sector liberalization process. The latter has concentrated only on two stages of the supply chain (those where airlines and handling companies operate), without pointing out significant guidelines for the activity of the antitrust authorities in the other stages of the vertical channel, such as the necessary limitations of the shareholdings between companies operating in the upstream sectors.

It's important to highlight, that these criticalities correspond, at least in part, to the considerations, which in 2001 pushed the European Commission (EC) to hinder an important merger (predominantly a vertical merger) among companies belonging to the air transport vertical channel.[8] The Commission's thesis was based on the asymmetry observed in the market power within the vertical channel, in favour of an engine manufacturing company, with controlling interests even in the field of the leasing companies. Our work, as it will be outlined later, closely examines and extends this intuition bound to the application of the antitrust policy.

The work is structured as following: in the second paragraph there is a brief description of the air transport vertical channel, while paragraphs 3–7 are respectively about the aircraft manufacturers, the engine manufacturers, the leasing companies, the handling companies and, finally, about companies operating in the final distributing stage. Synthesis considerations are reported in paragraph 8, which concludes this work.

[7] Since we couldn't analyze in–depth all compartments connected more or less directly to the air transport service, we have made a choice according to the following criteria: 1) importance of the compartment within the vertical channel relations 2) less emphasis given by the literature (most of the studies are in fact relative to the airport and airline compartments).

[8] We refer to the antitrust case *General Electric/Honeywell* (COMP/M 2220). For further information about this case please refer to Fox (2002) and Motta (2004).

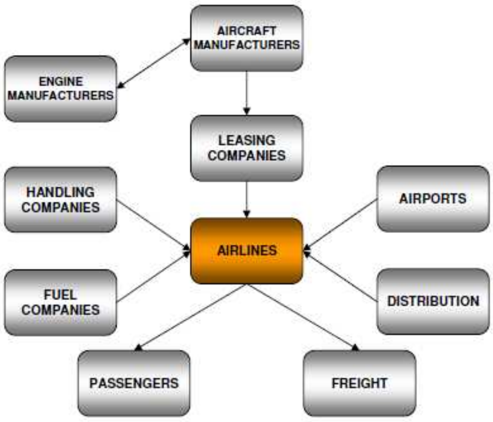

Figure 2.1: The air transport vertical channel

2.2 Air transport vertical channel

The air transport sector includes numerous production stages operating between the upstream phase of the aircraft manufacturing and the downstream phase of the sale of flight tickets to the end consumers (Button, 2005). The air transport vertical channel is represented in Figure 2.1. For the main compartments we have also reported the average sales (Table 2.1 for the period 2005–2008).[9]

Aircraft manufacturers operate in the upstream stage, supplying the necessary mean to perform the air transport of passengers and cargo. Strategic suppliers for this compartment are engine manufacturers, which, because of the high R&D costs, are vertically separated from the previous ones. Going on along the vertical channel we find the leasing companies, which purchase aircrafts from the manufacturers by means of long–term financing, and then lease these aircrafts to the airlines. Airlines are located downstream and provide services directly to the end consumers, playing a central role in the sector. Their centrality is confirmed by the fact that carriers are the only actors of the vertical channel having more

[9]Sales values are an average of the turnovers from 2005–2008 (for data sources please refer to Appendix A). For Airlines the data is relative to all carriers members of *IATA* (www.iata.org/economics). For aircraft manufacturers the data was obtained by considering *Boeing* and *EADS* revenues plus 6% (both companies have, as explained in paragraph 2.3, 94% of the orders in value. Airports value has been estimated by Airport Council International (www.airports.org). For engine manufacturers the value was obtained by *GE*, *Pratt&Whitney* and *Rolls Royce* revenues plus 7%, considering that the three companies reach (as explained in paragraph 2.4) 93% of the orders in value. For the leasing companies the data is related to *GECAS* and *ILFC* incomes plus 30%, considering that both companies have (as explained in paragraph 5.3) 70% of the orders in value. For GDSs, we have considered the sum of the revenues of *Amadeus*, *Sabre* and *Travelport*.

or less direct relationship with the operators of all the other stages.

Table 2.1: Average level of sales for the different stages (2005–2008)

Ranking	Stage	Sales (mln $)
1	*Airlines*	480,000
2	*Aircraft manufacturers*	122,000
3	*Airports*	80,000
4	*Engine manufacturers*	43,000
5	*Leasing companies*	12,000
6	*GDS*	9,000

Two are the major elements that differentiate companies operating in the different stages of the vertical channel: the geographical market where they have to compete[10] and, above all, the economic performances achieved. Concerning this last aspect, two data provide a first indication about the power relationship among the different compartments: the level of sales (reported in Table 2.1) and the average operating margins realized (Figure 2.2).[11]

It is evident the asymmetric distribution of revenues, and in particular, of margins among the different stages, and the consistent variation of these last ones within the periods taken into consideration. We want to emphasize the datum relative to airlines, especially if we consider the fact that, as mentioned before and well highlighted in Figure 2.1, they play a central role within the vertical channel. They obtain the highest revenues (that have to be divided among the 230 *IATA* member airlines), but they extract a small percentage of the value added created (the operating margin is one of the lowest within the vertical channel, a little less than 2%). Moreover, it seems that cyclically they cannot cover their own long–terms costs. This tendency is confirmed by recent cases of bankruptcy or financial difficulties for many carriers.

On the other hand, there are stages within the vertical channel characterized by lower level of sales (but split up a very limited number of operators) and, in particular, by profits that seem to be "excessive". Aircraft manufacturers are at the second place in terms of

[10]Some compartments (for example aircraft and engine manufacturers, leasing companies, GDSs and online travel agencies) have a real worldwide market, while other compartments are purely local (for example handling companies, airports and offline travel agencies).

[11]The data reported in Figure 2.2 represent the average of the margins realized from 2005–2008 by the companies analyzed in each compartment of the channel (for the sources please refer to Appendix A). Operating margin means here the ratio between operating income and revenues. In particular, the data regarding the airlines refer to all the carriers members of *IATA* (www.iata.org/economics). Whereas we have taken into consideration *Boeing* and *EADS* for the aircraft manufacturers compartments; *GE*, *Pratt&Whitney* and *Rolls Royce* for the engine manufacturers sector; *SEA*, *AdR*, *SAVE*, *GESAC* and *SACBO* for airports stage; *Amadeus*, *Sabre* and *Travelport* for the GDSs; *Expedia*, *Opodo* and *Priceline* for online travel agencies. Concerning handling companies, we have taken into account the most important handlers operating in the Italian airports (for an in–depth information please refer to Table 2.5).

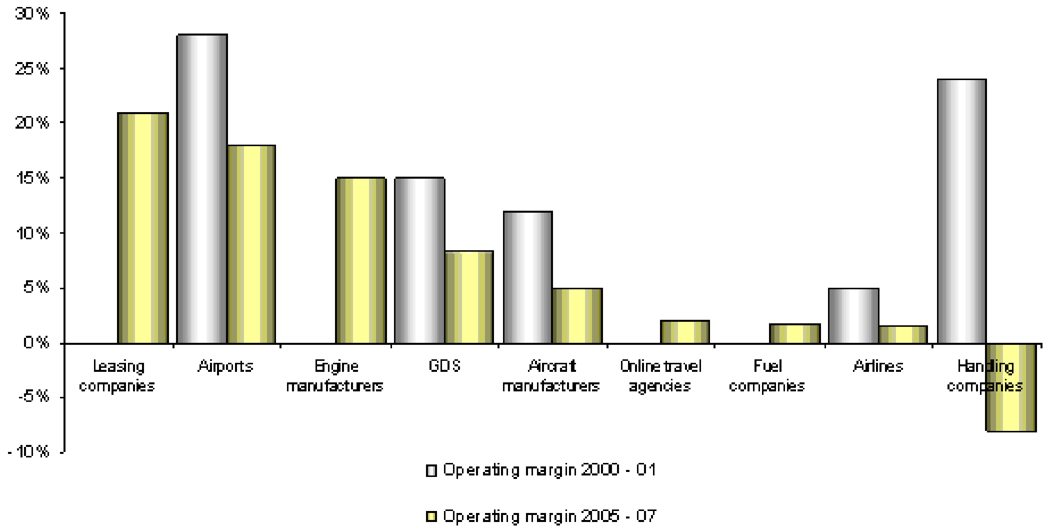

Figure 2.2: Average operating margin for the different stages of the vertical channel

revenues (122 billion dollars) and at the fifth place in terms of value extraction (5%). While engine manufacturers achieve considerably high margins (around 16%) compared to a lower total level of sales (43 billion dollars).

Particularly significant are the economic performances of leasing companies: they show relatively low revenues for the sector (13 billion dollars), but they achieve higher margins than any other compartment of the vertical channel (over 20%). Also GDSs seem to have good margins (5,5%), while companies dealing with airport handling in Italian airports are in considerable difficulties.[12]

There are two main reasons for this strong heterogeneity in the distribution of the total value added, and in particular of the reduced percentage of appropriation by airlines.[13] On one hand, the deep asymmetry existing between buyer and seller power in the different stages of the vertical channel, as we will later elucidate; and on the other hand, as already explained, the fact that policy interventions relative to the progressive liberalization of the air transport sector have mostly been addressed to limit the market power of big incumbent

[12]In confirmation of what reported in the introduction regarding the airports' market power, we stress the importance of the profit margins (around 20%) obtained in this compartment of the vertical channel.

[13]Another possible explanation for these different economic performances is connected to their operative flexibility. For example, a negative shock of the demand has a strong impact on airlines, handlers, companies of the distribution and also on airport operators but with a lighter impact. Contrariwise, the effects are lower for aircraft and engine manufacturers and leasing companies which can in part protect themselves from this kind of risk with long–term contracts. We thank an anonymous referee for the latter consideration.

carriers (the former flag carriers), without stimulating, at the same time, the competition in the other stages. As a result, this has led to serious vertical distortions in the overall air transport market (Button, 2005).

Finally, concerning the dynamic aspects of the profit margins, Figure 2.2 shows that the more recent period (years 2005-2008) has recorded lower values (if not even negative) compared to the less recent period (years 2000-2001). This confirms that the air transport vertical channel largely depends both on the business cycle and on the external shocks (like for example terrorist attacks or spread of diseases among the population of a certain part of the globe), that lead to the already mentioned periodically suffering of airlines.

2.3 Aircraft manufacturers

The stage of aircraft manufacturers can be considered the upstream sector within the air transport vertical channel. In particular the compartment of large aircraft manufacturers is a symmetric duopoly (*Airbus* and *Boeing*); including all–sized aircrafts, the market becomes a concentrated oligopoly.[14]

Aircraft manufacturers are system integrators, in the sense that they deal with the planning and assembly of finished products and trade with a high number of suppliers of first, second and third level operating in all world markets.[15] In particular, system integrators have to conceive and coordinate the development of new products and the aircraft assembly, dealing with the complex network of suppliers that enable the realization of the end product. These can be classified in prime contractors, suppliers of second level and subcontractors.

Prime contractors are medium–large companies that are the main interlocutors of the system integrators, and partially assume the risk of the project sharing predetermined parts of non–recurring costs (for example the R&D expenses). Suppliers of second level are companies that have developed next to the prime contractors: they are characterized by a good level of specialization in the production of parts, components or entire groups, which are functional for the aeronautics and space sector.

[14]In terms of market definition, it's possible to consider only big aircraft manufacturers rather than medium–large sized aircraft manufacturers (including regional jets and turboprop aircrafts) or all aircraft producers, even those of smaller size for sport flying or business.

[15]From the technical point of view, the value chain in the manufacturing of an aircraft is divided into three macro components of the product: aerostructure (or cell), propulsion and avionics (included the equipments). The second and third component have a more intensive and frequent innovative cycle, and thus a higher strategic and economic value.

Subcontractors are represented by a large number of small companies that dispose of technologies and production processes which are compatible with the technical standards required by the sector (quality, precision, ability in treating particular materials, etc.). These companies usually produce parts according to drawings or specifications of the buyers, or execute particular manufacturing. In other words, these are companies with a low know–how, and they survive thanks to their production capacity which is able to support the prime contractors at a low cost.

The aircraft production sector is a complex system of both collaborative and competitive relationships, that cuts across the segment of aircraft producers horizontally and vertically. In fact it's possible to represent this production phase as a pyramid characterized on the top by very high levels of concentration and technology which decrease as you move down towards the base.

In terms of quantity, the market of aircrafts for commercial aviation in 2007 was characterized by a growing demand. In particular, the demand by low cost airlines and by airlines based in emerging markets contributed to the growth of the order books for airframe (e.g., Asiatic airlines actually ensure about 24% of the orders of new aircrafts). 3,743 new widebody aircrafts were ordered in 2007.[16] The market shares can be gathered from data in Table 2.2.

Table 2.2: Cargo and passenger gross aircraft orders by manufacturer, 2007

Manufacturer	N. aircrafts ordered	Value (mln of $)	% orders	% value
Airbus	1,555	180,723	42%	49%
Boeing	1,398	168,549	37%	45%
Bombardier	250	7,567	6.7%	2.00%
Embraer	179	6,586	4.8%	1.80%
ACAC	100	3,000	2.7%	0.80%
ATR	105	1,845	2.8%	0.50%
Ilyushin	43	793	1.1%	0.20%
Viking Air	26	83	0.7%	0.02%
Xian	22	132	0.6%	0.04%
Tupolev	19	836	0.5%	0.20%
Antonov	18	244	0.5%	0.10%
Sukhoi	12	300	0.3%	0.10%
Utility Aerospace Industries	10	68	0.30%	0.02%
Aircraft Industries Let	3	3	0.10%	0.00%
Yunshuji	3	12	0,10%	0.00%
Totale	**3.743**	**370.741**	**100%**	**100%**

SOURCE: Analyses of the European air transport market, Annual Report 2007, EC

About 42% of the orders were received by *Airbus*, a company controlled by *EADS* (*European Aeronautic Defence and Space Company*), and 37% by *Boeing*. These two

[16]A widebody aircraft is a large airliner with two passenger aisles. Its typical fuselage diameter is from 5 to 6 meters and passengers are seated seven to ten abreast. The total capacity is from 200 to 600 passengers. By comparison, a traditional narrowbody airliner has a diameter of 3 to 4 meters , with a single aisle, and seats between two and six people abreast. Narrowbodies usually transport less than 200 passengers.

operators share almost on equal parts the market of the so–called large jets, which are aircrafts with more than 100 seats and a range longer than 1,000 km. This compartment can be analyzed at least in part separately from the rest. It's a duopoly where in 2007 *Airbus* had the 53% of the orders and the 52% of their value. These data are slightly different year by year and show the predominance of *Boeing* in a certain period and of *Airbus* in another one, but they remain basically stable around 50% for each producer.

The other operators listed in Table 2.2 are mostly specialized in the production of regional jets or turbo–props.[17] However, we want to point out that due to the fuel price increase, in 2007 the market for widebody planes saw a demand increase for models with two engines, which ensure a substantial fuel saving. In particular *Airbus 330* and *Boeing 777* registered a big increase of orders.[18]

Furthermore, there is the market of aircrafts used in the so–called General Aviation that differ for the number of producers and for the size of aircrafts available. We are talking about aircrafts ranging from very light jets[19] to the *Boeing 747–8BBJ*.[20] *Cessna* is the leader in this segment with a market share of 34%, followed by *Eclipse Aviation* and *Embraer*, each of them with a share of 16%.

The above evidence shows the great importance of *Airbus* and *Boeing*. It's interesting to analyze the reasons of this symmetric duopoly and also to observe the source of such strategic advantage and, in turn, of their good economic results.

This high market concentration is due to a strong push to centralize the activities within a single firm because of the presence of considerable integration advantages coming from the criticality of the R&D processes, the homogeneity of demand, the presence of strong scale economies and the high value of the reputational effect. These are not collusive or predatory reasons, but reasons of technological and financial nature. In fact in the low–tech segments the market becomes wider and the competition extends to a larger number of companies.[21]

[17] As mentioned before, regional jets are aircrafts with less than 90 passengers and a range shorter than 1,200 kilometers. Turboprop aircrafts have similar capacity and range, but they differ from the previous ones for the turbo–propeller propulsion.

[18] The use of only two engines instead of four gives an operative advantage of about 8–9% in terms of fuel consumption.

[19] Aircrafts with a maximum takeoff weight of less than 4,000 kg for 4–6 passengers.

[20] *Boeing 747–8BBJ* is a particular configuration of the large–sized aircraft produced by *Boeing*, which is usually conceived to transport important people (presidents of republics, monarchies, etc.) with a maximum takeoff weight of 440,000 kg and an inner space that could host more than 500 passengers in the configuration of a commercial airplane.

[21] Despite the limited number of companies, the competition raised between the end of the 60s and the end of the 90s, with an increase of the average demand elasticity and a drop of the margins, also thanks to the

The high market concentration and the presence of a symmetric duopoly don't necessarily involve a strong bargaining power towards their own customers, i.e., airlines, and leasing companies. In particular leasing companies are more and more involved in funding for R&D of new models thanks to their financing capability. As mentioned before, the high costs and risks of these investments push aircraft manufacturers to diversify their funding sources in order not to limit innovation. By exploiting this situation, leasing companies obtain better prices for the purchase of aircrafts and sometimes they may influence the decisions of manufacturers, especially since these last ones, before starting the realization of a new aircraft, need a portfolio of potential orders whose cancellation may gravely affect their destiny.

Furthermore, the presence of a symmetric oligopoly between *Airbus* and *Boeing* leads to a tough competition between these two manufacturers, also because their product range—at the moment—does not differ considerably.[22] It's an exception the current competition between Airbus and Boeing in the development of new aircrafts: they are indeed following two alternative ways due to a different vision about the future of aviation. In fact, according to the forecast estimating an annual growth in the number of passengers of about 5% for the period 2005–2024, Airbus is concentrated on the development of the A380[23], with 550 seats, 73 m long and 21.4 m high. It's the largest aircraft in the world that enables to transport 20% more passengers compared to the *Boeing 747*. The *A380* has been conceived to solve congestion problems of big hubs due to the scarcity of slots through passengers transport on large–sized planes, with the possibility to obtain savings also in terms of operating cost per passenger. On the other side, *Boeing* has concentrated its efforts mainly in the development of the *B787*, an aircraft with 210–330 seats, that thanks to new technologies, materials and engines, offers very low operating costs, a reduced environmental impact and a very high–speed cruise (of around 930 Km/h). Hence, it seems that *Boeing* is expecting a fragmentation of the air traffic, with the multiplication of the connections point–to–point to a disadvantage of the hub–and–spoke model.[24]

range of aircraft models introduced during the years (Irwin and Pavcnik, 2004).

[22]The two duopolistic manufacturers seem to propose, considering their global offer of aircrafts, close substitute aircraft models, like for example *Airbus 319*, *320*, *321* and *Boeing 737*, which are the most common models for medium–haul flights, and *Airbus 330*, *340* and *Boeing 777*, *787* for long–haul flights. At the moment there are no close substitutes for *Boeing 747*, but *Airbus* is going to remedy this situation by producing *A380*.

[23]European Government funds to the *EADS* Consortium for the development of the superjumbo *A380* have caused a dispute between the USA and EU (for further details please refer to Pavcnik, 2002).

[24]As stressed by Mason (2007), the development by *Airbus* of *A350* and by *Boeing* of *B747–8 Intercontinental*, demonstrate that none of the two manufacturers intends giving up unilaterally part of the widebody

One of the most controversial issues regarding aircraft manufacturers is connected to the state subsidies received by *Airbus* and *Boeing*, the first one often helped by the governments of France, Germany, Spain and Great Britain, the second one mostly subsidized thanks to the military investments of the American government.[25] The high costs requested by the development and the construction of commercial aircrafts are one of the reasons that have often made the government participation, directly or indirectly, necessary to support the risk levels that are involved. But it's difficult to provide an assessment of how much these supports (subsidies, loans and advantageous conditions, tax relieves) have drawn in terms of economic performances: it seems that these subsidies didn't really turn into higher margins for the compartment, but rather into price reduction focused on enhancing the market share of a company to the detriment of the rival, in the light of the strong competition between the two colossus. Irwin and Pavcnik (2004) have shown empirical evidence of the fact that reduced subventions to *Airbus* and *Boeing* after the bilateral agreement in 1992 made the prices grow of 3.7%.

Finally, if we analyze the potential competition, the greatest possibilities of entrance in this segment of the vertical air transport channel are connected, in the long run, to the Asian aviation industry and to niche manufacturers that try to exploit the boom of low cost airlines, developing new aircraft models for point–to–point short–haul connections.[26] In conclusion, as shown in Figure 2.2, it's possible to state that the actors operating in this stage of the air transportation supply chain has a reasonable degree of market power (especially the duopolists active in the large jets market), but they are also characterized by factors (especially the necessity of funding sources for R&D) that don't allow them to obtain the highest profit margins within the vertical channel: in the period 2005–2008 they are only at the fifth position in terms of operating margin among the companies belonging

market to its competitor.

[25]*Airbus* has indeed always received subsidies, so that the complete launch costs of the models *A300* and *A320* have been supported by State subsidies (Newhouse, 2007), partially paid back with favourable interest rates and in part never rewarded. Subsidies to the European colossus have continued till the very recent launch of the model A380, partially financed through loans that should be paid back (Contrada, 2004). Concerning *Boeing*, the empirical evidence available suggests, on one side, that profits coming from the military activity have granted to the American colossus the necessary liquidity in the most difficult economic periods; on the other side, many results coming from R&D in military applications have been particularly precious to obtain competitive advantages in the civil aircraft sector (Newhouse, 2007).

[26]The economic situation of both companies seems rather stable despite the recent crisis. Two reasons can explain this: on one side, both companies have full order books (it will take many years to fill them), around 3,500 aircrafts (The Economist, 18th June 2009); on the other side, the demand by carriers of new aircrafts models more efficient in terms of fuel consumption is at the moment very strong (the air transport industry aims at reducing by 50% fuel consumptions within 2020, with the purpose to halve CO_2 emissions), and this should grant in the future a high turnover of commercial fleet.

to the different compartments of the vertical channel.

2.4 Engine manufacturers

Engineering knowledge points out that technological changes in the construction of more aerodynamic aircrafts and their utilization in a more efficient way (for example by reducing delays due to the air traffic control processes) can lead to two third of the requested saving in terms of fuel (the air transport sector has foreseen a target of lowering consumption of 50% by 2020): the remaining part depends on the technological development in the engine manufacturing. The sector of engine manufacturers is particularly interesting, because, as we will see later, for widebody aircrafts there are only three manufacturing companies (also in this case we can talk about a highly concentrated oligopoly). These companies have an exclusive competence, and this ensures them a strong bargaining power towards aircraft manufacturers. As a result, as you can see in Figure 2.2, they tend to extract a considerable share of the value added created by the vertical chain. Their margins are lower than the ones achieved—in the period 2005–2008—by leasing companies and airports, but much higher than the ones obtained by aircraft manufacturers (15% against 5%). Also the stage of engines production in its broadest sense, and thus not limited only to widebody aircrafts, is characterized by a pyramid of highly specialized companies, that at various levels of manufacturing complexity, interact with the main operators of the sector.

Table 2.3 shows the number of engines ordered and the relative market share for each manufacturer (spare engines are not considered) in 2007. Note that *CFM*[27] and *IAE* (*International Aero Engines*)[28] are consortia where *General Electric* (*CFM*), *Rolls Royce* and *Pratt&Whitney* (*IAE*) are relevant members. Furthermore, *General Electric*, *Pratt&Whitney* and *Rolls Royce* receive individual orders, as shown in Table 2.3. Considering both consortium orders and individual orders, their market share is around 93% and this is a strong collective dominant position.

The *CFM* consortium is the leader company with a market share equal to 36.4%, because it has indirectly profited from the strong demand for *Boeing 737* and *A320*, which are the most successful aircraft models in the segment of medium–haul flights.[29]

The main airframe types to be equipped with engines from *General Electric* are regional

[27]The acronym *CFM International* comes from the names of the commercial engines of the two parent companies: *CF6* for *GE* and *M56* for *Snecma*.

[28]In the *International Aero Engines* consortium cooperate *Rolls Royce*, *Pratt&Whitney*, *MTU* and *JAEC*.

[29]*CFM* is exclusive supplier of *Boeing 737*.

jets from *Embraer* and *Bombardier*. Rolls Royce, third producer with a market share of about 15%, is the exclusive engine provider for *Airbus A350XWB*. Engine manufacturers make good operating margins: in the period 2005–2008 *General Electric* (*Aviation* segment of the *Infrastructure* division) has achieved a margin of around 20%, *Rolls Royce* of around 10% and *Pratt&Whitney* of around 16%.

Table 2.3: Engines orders by manufacturer, 2007

Engines Manufacturer	Engines ordered	Market share
CFM International	2,350	36.4%
General Electric	1,558	24.1%
Rolls Royce	950	14.7%
IAE	632	9.8%
Pratt&Whitney	540	8.4%
Klimov	196	3.0%
Aviadvigatel	132	2.0%
Engine Alliance	68	1.1%
PowerJet	24	0.4%
Walter	6	0.1%
Tot. engines ordered	**6,456**	**100.00%**
OTHERS	1,038	-
Tot. engines on the aircrafts ordered	**7,494**	-

SOURCE: Analyses of the European air transport market, Annual Report 2007, EC

From the technological point of view the development of new engine models requires considerable investments in R&D. For this reason, usually consortia form and share the risks of development. The research activity in areas such us new materials and rotor blades design, has produced incremental improvements so far, which then are usually copied by imitators in the space of two years. In the last forty years none of the most important competitor, after having achieved the technological leadership, has managed to keep it for more than ten years (Bonaccorsi and Giuri 2001 and Bonaccorsi *et al.*, 2005). Besides, these recent improvements seem not to be sufficient to provide the expected results in terms of consumption reductions. As a consequence, there is a strong competition in the realization of a new typology of engines (the so called green jet engines).

With regards to this, the main producers are following so different strategies, that in the future the choice of a particular kind of engine could also involve the choice of a particular aircraft typology.[30] Thus, while airlines or leasing companies are at the moment choosing aircraft and propeller, and aircraft manufacturers are able to assembly different kinds of engines on the same aircraft, in the future this could not be possible anymore. This lower interchangeability between engine and aircraft typologies could significantly reduce the market power (both as buyer, and as seller) of aircraft manufacturers.

[30]For example *Pratt&Whitney* is developing an engine with gearbox called geared turbo fan (classified as *PW1000G*). Compared to a classic turbofan engine, it uses a gearbox instead of a simple shaft between the turbine and the fan. *Rolls Royce* and *General Electric* are, on the contrary, developing an engine based on the open rotor, a solution that will enable to bypass the turbine.

Besides the development of new engines, the competition in this stage of the vertical channel takes place also in the so called aftersales engine market. The market for repair and maintenance services has a so relevant role, that it is estimated that some manufacturers gain from these activities seven times more than what they earn from the selling of the product *ex novo*.[31] It is also possible that it is a widespread practice in this sector to sell engines below cost, to recover in a further moment, by means of the incomes coming from spare parts and customer services. Obviously, this kind of strategy may involve a certain level of risk: the rich margins of the aftersales market attract a lot of independent companies specialized in this kind of services and able to supply certified spare parts with definitely lower prices compared to the original engine manufacturers.[32] For this reason, the main operators of the sector have convinced their own customers to pay a fee for each operative hour of their engines, ensuring maintenance and replacement in case of breaking.[33]

The engines manufacturing sector, as already mentioned before, was object of the popular *General Electric/Honeywell* antitrust case. This case concerns the merger between General Electric and Honeywell, a company specialized in airborne avionics and auxiliary systems (non avionics, for example auxiliary power generators, sidelights, etc.). The competitive issues connected to this concentration, which were highlighted by the European Commission, concerned *General Electric*s vertical integration into aircraft purchasing, financing and leasing activities, and so they will be analyzed in the following paragraph.

2.5 Leasing companies

As already mentioned before, leasing companies are a strategically very important stage within the air transport vertical channel. These companies exploit the financial leverage to assist airlines during the purchase of aircrafts. International regulations in force in the aviation sector foresee the possibility for carriers to use, in addition to their own aircraft, aircrafts available through a leasing contract, usually signed with a financial company.[34]

[31]Estimated gross margins coming from reparation and replacement of spare parts are around 35% (The Economist, 10th January 2009).

[32]Spare parts can be also sold to one third of the price requested by the original engine manufacturer (The Economist, 10th January 2009).

[33]*Rolls Royce*, for example, offers this kind of service for over 10 years; *IAE* offers for its props *V2500* used for *Airbus A319/320/321* a program called *Select*, structured in order to facilitate maintenance and to improve consumption efficiency.

[34]Leasing has a function similar to financing because it allows, by paying a periodic fee, to have at disposal instrumental goods in order to perform the activity, with the possibility to purchase the goods at an agreed

In the air transport sector there are two kinds of leasing contracts regulated under article 83 bis of the Chicago Convention (ICAO), as well as the national standards: the "dry lease", usually used for a long period of leasing and the "wet lease", usually used for shorter periods of leasing, for example during the peak stages or for the launch of new routes. With dry lease we mean airlines that, within their operating licence, don't use their own aircrafts. While for wet lease we mean airlines that lease the flight: not only the aircraft, but also the crew, who is placed at disposal by the leasing company owner of the aircraft.[35]

The decision to have recourse to a leasing instead of a direct purchase of an aircraft is certainly one of the most strategically complex decisions for an airline.[36] It is based on an optimal balance between advantages (financial and operative flexibility) and disadvantages (high costs, non–capitalization, rigidity in the aircraft configuration) of the leasing compared to the direct purchase.

The leasing companies compartment (that has a relevant global geographic market) is the one able to achieve the main share of the value added created in the vertical channel, as reported in Figure 2.2. This shows that leasing company manage to obtain better economical results, even if they are not perceived by end consumers as main protagonists of the aviation industry (many consumers even ignore their existence), and even if they don't have a technological know–how (aircraft and engine manufacturers) or a managerial know–how (companies in charge of distributing flight tickets). In our opinion, this is due to the exploitation of competitive advantages in the relationships with companies operating downstream and upstream (as we will discuss later in details).

In the last ten years the number of aircrafts owned or managed by leasing companies has raised of 13% and in 2006 it represented one third of the world air fleet (about 17.000 units). According to forecasts, this sector will grow from 129 billion dollars turnover in 2006 to about 170 billion dollars in 2011.[37] We also estimate that companies belonging to this compartment will keep on obtaining much higher profits compared to the ones obtained by airlines (included low cost carriers). This is mainly due to the fact that carriers are more and more oriented in having recourse to leasing in order to reduce financial risks.

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price lower than the market value of the goods.

[35]There are also combinations of these two leasing contracts, for example the wet leasing can become later dry leasing.

[36]According to an empirical analysis made by Oum *et al.* (2000) based on the data of 23 of the biggest airlines in the world (from 1986 to 1993), the optimal mix for a carrier includes a 40%–60% of leased aircrafts in its fleet.

[37]A.T. Kearney–Global Management Consultants.

Leasing companies are mostly banks and finance institutes, the so called Commercial Aircraft Sales and Leasing (CASL). Among these the two biggest and most famous ones are *General Electric Commercial Aviation Services* (*GECAS*) and *International Lease Finance Corporation* (*ILFC*), which every year obtain profits around billions of dollars and hold jointly a market share higher than 50%. The first ten worldwide operators are listed in Table 2.4, according to their fleet dimension.

Table 2.4: Leasing companies ranking by fleet size, 2007

Rank	Leasing companies	N. of aircrafts	Value (mln $)	% orders	% value
1	*GECAS*	1721	38,514.90	40%	35%
2	*ILFC*	962	38,821.80	23%	35%
3	*AerCap*	241	4,241.95	6%	4%
4	*Boeing Capital Corporation*	267	4,058.72	6%	4%
5	*CIT Aerospace*	214	5,992.05	5%	5%
6	*Aviation Capital Group*	213	4,647.45	5%	4%
7	*Babcock&Brown*	203	4,869.27	5%	4%
8	*Pegasus Aviation Inc.*	183	4,089.10	4%	4%
9	*AWAS*	138	2,263.05	3%	2%
10	*Maquire Aviation Leasing Ltd*	129	2,798.95	3%	3%

SOURCE: Airline Fleet&Network Management, May/June 2007

GECAS owns the widest aircraft fleet and is controlled by *General Electric*; *ILFC* is part of the financial insurance group *American International Group* (*AIG*) and manages a fleet composed of more than 900 aircrafts.[38]

General Electric is active, as already seen before, also in another segment of the vertical channel (engines manufacturing). It is a partial vertical integration that enables *GECAS* to have a relevant strategic role inside the *General Electric Group*. In fact, it applies a market strategy oriented in promoting aircrafts with *General Electric* engines, by exploiting its market power as buyer (for example by ordering big quantities of aircrafts) with the purpose of damaging the main competitors in the engines manufacturing stage (i.e., *Pratt&Whitney*, and *Rolls Royce*). If we compare the market position of *General Electric* "pre–*GECAS*" (from 1988 to 1995) with the "post–*GECAS*" (from 1996 to 2000) we deduce that while the selling of *General Electric* engines to leasing companies, included *GECAS*, increased more than 20%, the direct purchase of *General Electric* engines by airlines decreased of only 5% (data from the European Commission). These data show, as highlighted in the antitrust case previous mentioned, that the other leasing companies and airlines have not been able to "compensate" the *GECAS* effect and this led to a net transfer of market

[38]In 2007 *GECAS* had a turnover coming from leasing fees of 4,605 million dollars, 10% more with respect to the previous year. The operating income in 2007 grew up to 1,115 million dollars (compared to 1,108 million dollars of 2006). In the same period *ILFC* had a turnover of 4,694 million dollars, 15% more compared to the previous year. The operating income in 2007 was 873 million dollars (578 million dollars in 2006).

shares in favour of *General Electric*. These are the main reasons which have pushed the European Commission to avoid the merger between *General Electric* and *Honeywell*. This concentration would have led to the strengthening of *General Electric*'s dominant position in the market of aircraft engine manufacturing. The Commission has highlighted how *General Electric*, thanks to the combination of the financial strength coming from the economical disposability of *GECAS*, has been able to achieve a dominant position in the market for large commercial and regional aircraft engines, increasing the distance from its competitors and ensuring exclusive positions to the detriment of competitors. The merger would have promoted a further extension of the already high market power, also by exploiting the position of Honeywell in the avionics and non–avionics compartments. In fact *General Electric* could have used the bundling strategy, i.e., the combined sales at one price of *General Electric*'s engines and *Honeywell*'s avionics and non–avionics products. These evaluations confirm the previous considerations: in the vertical channel upstream stages, and in particular in the stage of aircraft engine manufacturers and of leasing companies, there are competitive advantages and rent positions that considerably increase the buyer power and the seller power of the companies belonging to these compartments. This market power is used to obtain high profit margins, reducing at the same time the profitability of the companies operating in other compartments.

2.6 Handling companies

With the expression "airport handling" we usually mean all the services within the airport assistance. The airport infrastructure is generally divided into two parts: the airside includes the equipment and services for aircraft handling and the landside includes the equipment, facilities and services connected with passengers and freight. Dussart–Lefret and Federlin (1994) point out that even if these services aren't an homogeneous block and could be divided into more and more restricted markets, the sector is usually divided into three submarkets relatively separated: passengers services, aircrafts services, and cargo services.

The stage of handling activities has been object of an intense process of liberalization within the European Union, similarly to what happened in the airline segment.[39] Handling

[39] The European legislation considers as groundhandling services under the liberalization system (please refer to EC Directive 96/97) all activities related to the following categories: ground administration and supervision, passengers handling (including checking tickets and travel documents, registering baggage and carrying it to the sorting area), baggage handling, freight and mail handling, ramp handling, aircraft services, fuel and oil handling, aircraft maintenance, flight operations and crew administration, surface transport and catering services.

activities, to be performed, require the access to different centralized airport infrastructures, such as baggage handling and claim, piers for boarding and disembarkation of passengers, de–icing systems for aircrafts, centralized information systems, static facilities for fuel supply, catering, ... Of course, some of these infrastructures, for complexity, cost or environmental impact, cannot be duplicated and often cannot even be used simultaneously by several operators. In this case the rules provide for a possibility of limitation in the number of authorized operators[40] and the selection of these operators is made through a tender. Whereas for all the other kinds of infrastructures there is the possibility to have several operators for the same service.

Also in Italy the liberalization process started several years ago with the approval of Legislative Decree (L.D.) 18/99. Free access to the market for groundhandling services has been recognized to service providers with certain requirements[41] in airports with yearly traffic of at least 3 million passengers or 75,000 tons of freight.

However the Italian antitrust authority (*AGCM*) pointed out in the notification of 16th February 2004[42] that the liberalization process met relevant obstacles connected in particular with the practices of airport operators which were interested in extending their dominant position into adjacent markets (similar considerations were formulated by Piacentino (2006) too, but with a view of implementing regulatory policies). *AGCM* highlights in particular how:

- there was a late and inadequate use of selection procedures;[43]

- companies managing airports adopted some obstructive practices, both by exploiting their role of managers of local infrastructures[44] and by having recourse to their settled experience in the market for groundhandling services in order to deter carriers from using new operators;

[40]The European legislation states that the State members may limit the number of suppliers authorized to provide the following categories of groundhandling services: baggage handling, ramp handling, fuel and oil handling, freight and mail handling. They may not, however, limit this number to fewer than two for each category of groundhandling service.

[41]These requirements, under the control of ENAC, the national authority with regulation functions in Italy, are for example the existence of a corporate capital of at least one fourth of the foreseen turnover coming from the activities to perform, the availability of instrumental resources and proper organization abilities in connection with the requested service categories and the subscription to an insurance appropriate for the risks related to the activities to be done.

[42]*AGCM* report n. 5 dated 16th February 2004.

[43]In some important Italian airports such as *Rome Fiumicino*, *Milan Malpensa* and *Catania Fontanarossa*, *ENAC* has limited the access to new operators for specific handling services. In these circumstances, the selection of suppliers should be made through a tender invited by the airport operator.

[44]Please refer to Soames (1997).

- the application of the transitional clause in Article 14 of L. D. 18/99[45] has introduced elements of rigidity for new entrants and opportunities to adopt obstructionist practices by incumbent operators.

However, the groundhandling market liberalization has introduced even in Italy several specialized operators that operate in many airports and have the capacity to offer to the market different complete packages oriented to carriers requirements or to focalize on specific customers needs.

Handling activities can be considered as one of the most interesting compartments of the air transport vertical channel because it represents a stage that before the liberalization process was completely integrated in the airport management companies. In this way they were able to further increase their market power thanks to the exclusive supply of essential services for airlines. The liberalization has (at least partially) destroyed this monopoly and has introduced a certain competition level among firms to obtain the supply contract (usually multiannual, but repeated at regular intervals) of some handling services in a specific airport.

The impact of the higher competition resulting from the market opening is well elucidated by the data on the margins obtained in Italy in this compartment of the air transport vertical channel (Figure 2.2), that even show negative values. Therefore this is the compartment of the vertical channel with the lowest value added. These considerations reinforce the idea, which has already been partially exposed in the literature (Button, 2005 and Button a McDougall, 2006), that the liberalization of the air transport sector is currently incomplete because in some stages, those where the liberalization process was more intense the margins are low, while in other stages, not touched by the market opening processes, there are monopolistic rents with far wider profit margins.

Some data relative to the handling companies operating in Italian airports can be useful to appreciate in more details the main features of this compartment. As mentioned before, these companies of the sector seem to be subject to a constant pressure on margins[46] (Table

[45]The first paragraph of the article states: “When guaranteeing free access to the groundhandling market, it is necessary, for 30 months after this decree enters into force, to ensure that existing employment levels are maintained and that labour relations with staff under the previous management arrangements are continued”. The second paragraph states: “except where a branch of an undertaking is transferred, any transfer of activity in one or more categories of groundhandling, as set out in Annexes A and B, shall include the transfer of staff, named by those concerned, and in agreement with trade unions, from the previous supplier to the subsequent supplier, in proportion to the volume of traffic or to the scale of the activities being taken over by the subsequent supplier”.

[46]Notice that for many handlers the credit exposure towards certain carriers (e.g., *Alitalia*) has a significant impact on their economic results.

2.5, for each company it is also reported the parent company).[47]

Table 2.5: Parent company, revenues and operating margins (EBIT/Revenues) by handler

Company	Reference shareholder	Turnover (mln euro)			Margin		
		2005	2006	2007	2005	2006	2007
SEA Handling	SEA (Municipality of Milan)	179.705	180.27	175.692	-20.3%	-23.5%	-34.2%
Alitalia Airport	*Alitalia*	181.673	146.881	166.058	1.3%	-2.2%	-1.3%
Flightcare Italia	*FCC S.A.*	86.848	82.48	72.741	6.9%	-1.3%	-6.8%
Ata Handling	*Acqua Marcia*	24.248	30.257	33.866	1.7%	4.2%	-0.8%
Alisud	*Alisud*	13.71	14.102	14.438	4.6%	5.6%	5.1%
Sagat Handling	Sagat (Municipality of Tourin)	13.638	14.004	14.542	-4.7%	-1.4%	1.3%
SAV	*Acqua Marcia*	13.191	13.012	13.576	-21.9%	-21.8%	-20.5%
Aviapartner	3i Group PLC	14.073	12.095	11.771	-19.6%	-28.6%	-12.8%

SOURCE: balance data Amadeus.

As highlighted in Table 2.6, the main Italian airports have a fair number of operators competing among each other. The choices of location made by the handlers are particularly clear. *SEA handling* is located only in *Malpensa* (*MXP*) and *Linate* (*LIN*) airports in Milan (the ones managed by SEA); likewise *Flightcare* (at the moment independent, but born as *Adr* handling company) operates only in the *Fiumicino* (*FCO*) and *Ciampino* (*CIA*) airports in Rome.

Table 2.6: Main handling companies in the first six Italian airports

Airport	Handlers				
FCO	*Flightcare Italia*	*Globe Ground*	*Aviapartner*	*Alitalia airport*	*EAS Handling*
MXP	*SEA Handling*	*Aviapartner*	*ATA Handling*	*SKY Service*	*Globe Ground*
LIN	*SEA Handling*	*ATA Handling*	*EAS Handling*	*SKY Service*	*Globe Ground*
VCE	*Aviapartner*	*GH Venezia*	*SAV*	*SKY Service*	
CTA	*Alitalia airport*	*SAC*	*ATA Handling*		
BGY	*SACBO*	*AGS Handling*			

SOURCE: our elaborations from Internet sites of airports and handling companies.

On the other hand, *Alitalia Airport* is active in more airports, probably because it could exploit the presence of the flights of its parent company *Alitalia*. Nevertheless *Alitalia Airport* is not the only player of the sector that operates in airports which don't belong to the same catchment aerea; in fact, there are smaller independent operators like *Aqua Marcia*, *Alisud* and *Aviapartner*, which operate through their partners in several airports.

2.7 The distribution system

The distribution stage of the air transport sector includes all activities connected with the information relative to the flights connections (prices, timetable, connections etc.) and with

[47] As evident in Table 2.5, there is a variety of different types of subjects controlling Italian handling companies, some of them independent from airports and airlines (handlers or financial operators), other highly integrated. This heterogeneity has certainly an influence on the quality of competition.

the purchase and emission of flight tickets. The distribution system operates thus on two different types of network:

- the network of connections available, composed by the offer formulated by different carriers independently one from the other;[48]

- networks of reservation and ticket sales.

The choices related to the first one are part of the "product" decisions made by airlines, because connected to the decision to enter or not into a new market (i.e., a new connection point–to–point); while the ones related to the reservation and ticket sales are part of the distribution policy, which concerns in particular the choice between two not mutually exclusive options: vertical separation and vertical integration.[49] With the first option, the distribution is made by companies independent from airlines (for example travel agencies); with the second option, airlines directly take care of tickets purchase and emission.

The evaluation between these two alternative is usually based on three criteria: economic (preference for fix costs of the direct or for variable costs of the indirect network), of control over the intermediaries behavior, and of adaptability, that is the ability of the distribution channel to adapt to the quantitative and qualitative changes of the demand. In this sense, the option of vertical integration has recently become more attractive to carriers thanks to one of the most important innovations of recent years: the introduction of the electronic ticket that has promoted the spread of online sales.[50]

Now we are going to analyze in details the main features of the operators active in the air transport sector in case of vertical separation. Then we will repeat the analysis for the vertical integration. Finally, the last part of the paragraph is about companies operating as GDS, because of their importance compared to the sector value added (Figure 2.2), and because they represent the platform able to configure the distribution segments as a typical two sided market, according to the meaning of Rochet and Tirole (2003) and Armstrong (2006).

[48] A certain level of collaboration in establishing the network of connections exists among airlines belonging to the same alliance system, i.e., *Sky Team*, *One World* and *Star*.

[49] Airlines usually adopt "mixed" distributive strategies with sales channels vertically integrated (as purchase online) and channels vertically separated (as purchase through GDSs or travel agencies).

[50] However, electronic ticket is also used by other companies operating in the distribution stage, such as GDSs and travel agencies. In fact in June 2004 *IATA* imposed the target of achieving 100% of electronic tickets in four years. This goal was achieved on the 1st June 2008 by the 230 airlines members of *IATA*: carriers, travel agencies, airports, suppliers of systems and GDSs translated an entire industrial sector from paper to digital tickets. The 230 airlines members of *IATA* represent 93% of the world air traffic.

2.7.1 Vertical separation

In the indirect sales channel we have travel agencies, tour organizers, GDSs, consolidators, tour operators and, in the last years, online travel agencies.

Travel agencies are traditional tourism intermediary organizations that sell products supplied by third parties. They act more like retailers, realizing the matching between airlines and customers. Tourism services that are sold have particular features: they are intangible, they cannot be shown before their fruition, they cannot be stocked, the production and consumption stages correspond.

GDSs are computerized reservation systems created by the big American airlines aiming at linking up a wide sales network to a headquarter that collected all reservations, optimizing the available seats on aircrafts and in the meantime providing an immediate feedback to the customer on the actual availability. The segment represents a worldwide oligopoly with only three active big companies: *Sabre*, *Amadeus* and *Travelport*.[51]

The consolidator is an intermediary which takes care of placing on the market the seats that, a few days before the take–off (usually one or two days before), are still unsold and so it represents an efficient channel to spread the last minute rates among customers.

Tour operators are companies which offer trips to consumers through travel agencies. They are important for airlines that serve the tourist market, but absolutely irrelevant for the distribution of business connections. Tour operators enter into agreements with airlines to book a certain number of seats (block seat) which are later sold to their customers with the addition of other services (e.g., accommodation, car rental, etc.).

Online travel agencies are able to benefit from all Internet advantages. In this sense, they reach directly final customers, overcoming traditional distribution channels. Web agencies and off–line agencies are often in competition with each other, but they can also enter into collaboration agreements oriented in carrying out a multichannel strategy.

2.7.2 Vertical integration

The direct sales channels include airline ticket offices, call–centers, the online distribution and the so called smart cards.

The call–centers are centralized offices used by airlines for the purpose of receiving reservations by phone. Passengers can pick up the ticket directly at the airport or in a specific travel agency.

[51] *Travelport* has recently acquired GDSs *Galileo* and *Worldspan*. This acquisition had interesting repercussions on antitrust policies, as we will explain later.

Online distribution services enable consumer to book a flight using his own computer. Basically, today all companies have a web site that permits to book tickets on–line.

The smart card[52] is a magnetic card containing identification information of the passenger, credit card and passport details, and if necessary, also information required by immigration regulations in force in some countries of the world. The owner of the smart card can immediately get his boarding pass using specific automatic machines (Automated Ticket and Boarding Pass, ATB) placed at the airports or in the city centers; as alternative it's possible to book by phone by communicating to the operator the number of the card and go directly to the boarding gate.

2.7.3 GDS segment: the platform of a two–sided market

The main operators in the GDS segment are *Travelport*[53] with a 45% market share, *Amadeus* with a 30% and *Sabre*[54] with a 25% (data of 2007).[55] At European Union level *Amadeus*[56] is the leader with a market share of about 55%. In North America the leader is *Sabre* with a market share between 40 and 50%.

GDSs had, up to the first years of the 90s, a dominant role in the air transport sector. First created by some airlines to connect the different travel agencies among each other, GDSs managed about 95% of the flight tickets sales. The carriers gave a fee to GDSs, while travel agencies always required from airlines the payment of a commission for the work done. In this scenario the computerized connection provided by GDSs was an essential facility, that enabled them to obtain a strong market power and thus the faculty to increase prices. This led to an increase of distribution costs for airlines.[57]

The reaction of these last ones, also due to the higher competitive pressure caused by

[52] *ATA–IATA* Passenger Conference has taken a package of decisions about standards and procedures to use in order to spread easily this tool. This package entered into force in June 1997.

[53] *Travelport* GDS comprises GDSs *Galileo by Travelport* and *Worldspan by Travelport*; *Shepherd Systems*, a company specialized in providing business and marketing intelligence to the travel industry; *aiRES*, a server–based internal airline IT product suite; and *THOR*, a provider of distribution and marketing services to travel–related companies. *Travelport* is controlled by *The Blackstone Group*, *One Equity Partners* and *Technology Crossover Ventures*.

[54] Headquartered in Southlake, Texas, the company employs approximately 9,000 employees in 59 countries and is controlled by private equity founds of *Silver Lake Partners* and *TPG*.

[55] *Travelport*'s market share was obtained by the sum of the shares of *Galileo* and *Worldspan*.

[56] The controlling shareholder of *Amadeus* is *WAM Acquisition*, whose stockholders are *BC Partners*, *Cinven*, *Air France*, *Iberia* and *Lufthansa*.

[57] As pointed out by Alamdari and Mason (2006), in 10 years from 1989 to 1998 British Airways' cost of sales rose by 50%, accounting for some 18% of their total costs. The increase in these costs can be mainly attributed to rises in travel agency payments and GDS fees.

the progressive air transport liberalization, led in part to decrease the commissions paid to the travel agencies, reducing them to almost zero (Alamdari and Mason, 2006); on the other side it led to a fervent competitive comparison with GDSs (Lavere, 2001), also due to the evident gap between the profit margins of these two compartments of the air transport value chain.[58] The framework of the vertical relationships has been deeply modified by two important "external" factors, which have reduced, at least partially, the market power of GDSs: (i) the already mentioned spread of Internet as tool for flight reservation and ticket distribution and (ii) the fall of some regulatory barriers.[59]

In particular, the spread of Internet has permitted to airlines to reduce distribution costs both by creating portals alternative to GDSs[60], and by direct sales from their own web sites.[61] GDSs have reacted to these dynamics through an expansion into the OTA segment.[62] However, it is possible to state that GDSs actually represent the main component of the distribution costs (between 8% and 11% of the flight ticket rate).[63]

The reason of this competitive advantage is given by the fact that they are the typical platform of a "two–sided market". These companies in fact perform their activities between two distinct groups of users: airlines and travel agencies (see Figure 2.3).[64] On the one side of the platform (upstream market), airlines provide travel content (namely prices and availabilities) to be included in the GDS offer to agents. Through the platform, airlines

[58]According to Horth (2004), in 2003 the profits margins of Amadeus and Sabre, the two most important GDSs, were respectively 16,6% and 8,1% compared to the average profits margins of European and USA airlines respectively of 1,9% and -2,8%.

[59]GDSs were regulated in the US and Europe in the 1980s. The key principles of the regulation were that GDSs should treat all airlines fairly and offer equal functionality, airlines owning a GDS should participate equally in other systems, and that GDSs should provide an un–biased display of airline information. With the advances in the Internet and the gradual disinvestment in GDSs by Airlines, US regulation became less necessary and disappeared in July 2004. The effect of this decision was that Airlines could choose freely the GDSs where they could offer their flights and negotiate with them the fees for the service provided. This situation was slightly different in Europe (Alamdari and Mason, 2006) due to a lower spread of the Internet and because some European carriers still have participations in GDSs.

[60]*Orbitz* in the US, *Opodo* in Europe and *Zuji* in Asia were created by airlines with the aim to put pressure on GDSs. However, GDSs have reacted by purchasing shares of these companies.

[61]According to data of the report 2006 of the EU regarding the air transport industry, in 2006 37% of the flights tickets in the USA have been sold through the online travel market. Europe follows with more than 10% less, even if the differences among European countries are rather strong (in the UK online sales were 34% of the total, in Germany and France were respectively 20% and 14% , while in Italy and other countries the percentage is still modest).

[62]*Travelport* controls *Orbitz* and *CheapTickets*; *Sabre Holding* owns *Travelocity* and *Lastminute.com*; while *Amadeus* has a shareholding in *Opodo*.

[63]UATP (Universal Air Travel Program), Airline Business, July 2006.

[64]For an in–depth analysis of the features of the two-sided market in the air transport distribution sector please refer to Vannini (2008) and Rosati (2008).

obtain access to a distribution channel, namely the network of agents using that GDS. On the other side of the platform (downstream market), each travel agency subscribing to a GDS provides its customer base to airlines via the GDS. Through the platform, agents obtain efficient access to travel content, with facilities for price and content comparisons as well as an interface for centralized bookings from different sources.

Moreover, airlines tend to subscribe to all GDSs (multi–homing): in fact, the number of "reachable" agents (and the related customer base) is extremely important for airlines, because indirect network externalities generated on the agent side (e.g., in terms of booking volumes) depend on it.

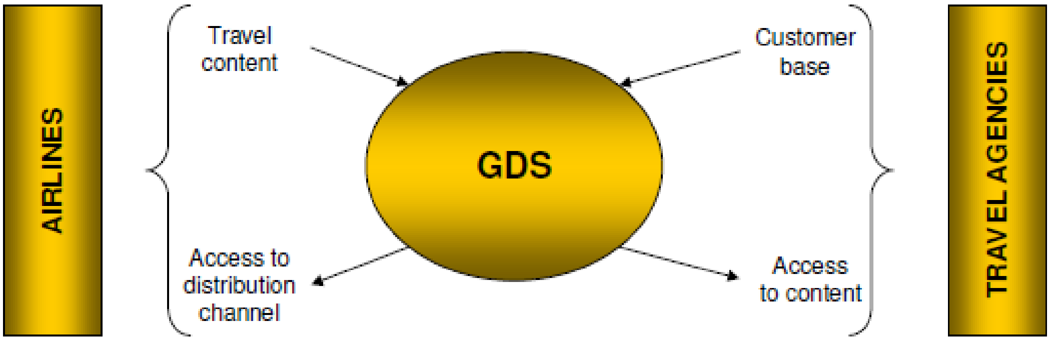

Figure 2.3: The two–sided GDS market.

All this reduces the indirect network externality generated on the side of the airlines and the relative value added for travel agencies resulting from the subscription to more than one GDS. As a consequence, travel agencies usually use only one GDS (single–homing). This asymmetry at the level of network effects, together with the limited product differentiation, involves a different pricing policy applied by GDS providers to the users of the two sides of the platform[65], as well as an unbalanced distribution of the profits.

There are therefore all elements typical of a market configuration that in literature are known as single–homing/multi–homing configuration or competitive bottleneck (Armstrong, 2006). There is a sort of competitive bottleneck, in the sense that a specific GDS has to compete only to attract a sufficient number of agencies, while it can loose interest in the market segment where airlines operate. In fact these latter will look for an access to the

[65]There are two types of financial flows between airlines, GDSs and travel agencies. The first concerns the fees paid by the airline to the GDS for the distribution of its travel content and the net payments by the GDSs to the travel agencies for their use of that particular GDS (e.g., incentive payments or minor subscription fees). The second financial flow concerns payments made directly by travel agencies to the airlines for the travel service being purchased (e.g., the flight, the hotel accommodation or the rental car).

GDS platform in any case, because the multi–homing is their dominant strategy. For this reason GDS providers manage to receive from carriers high premiums in form of fees paid to use the platform, while they practice low prices or even incentives to travel agencies, for which a specific GDS is in strong competition with the other providers.

The recent antitrust case *Travelport/Worldspan* (COMP/M.4523), concluded with the European Commissions authorization for the acquisition of *Worldspan Galileo* by Travelport, has shown that the context above described is changing rapidly. In fact, firstly airlines have started to introduce some diversifications in their offer among the different GDSs. This happened for example offering lower prices only for some platforms and not for all of them. This decision forces also travel agencies to the multi–homing. Furthermore, airlines are using more and more alternative sales channels (for example the direct sales through their own web site), which permit to bypass GDSs and to reach directly travel agencies or consumers. This sector evolution is modifying the balances of the market power among airlines, GDSs and travel agencies, reducing the competitive advantage of GDSs in the distribution stage.

2.8 Conclusions and policy implications

We have analyzed the air transport vertical channel to identify some of the factors that can explain the frequent financial difficulties (and also closures) of airlines. This analysis has in fact enabled to understand how the market power is distributed among the different stages and which companies are able to extract a relevant part of the total value added generated by the entire sector.

The analysis has shown that carriers obtain a minimal percentage of the total profit created by the vertical channel. In the last years the average profit margins of airlines (taking into consideration also low cost carriers) are a little lower than 2%. These economic performances seem not to be sufficient to cover airline long–term costs, especially in presence of significant shocks external to the sector. On the contrary, we have identified stages of the vertical channel, where profit margins are so high, that they could even be classified as "excessive" (the highest average margins are higher than 20%): especially the compartments of leasing companies, which rent aircrafts to airlines, of engine manufacturers and of GDSs providers.

This highly asymmetric distribution of the vertical channel value added is particularly due to two factors; first the lack of balance in the market power on the buyer side (buyer power) and on the seller side (seller power) observed in some stages of the vertical channel.

Leasing companies and GDSs are in particular sectors with a great market power. The first ones have a high buyer power towards aircraft manufacturers and a high seller power towards airlines. The second ones have the advantage to be the platform of a two–sided market in the final distribution segment.

The second factor is contrariwise connected to the liberalization policy implemented so far in the air transport sector. In fact this has concerned only some compartments of the vertical channel (the stage of airlines and handling companies).

Airlines are trying to contrast this disequilibrium by moving in two directions: on one side, through offer aggregation policies (as alliances and concentrations); on the other side, through a reducing costs policy (vertical integration and differentiation in the distribution, greater consumption efficiency). It's particularly evident that in the entire sector there is a process of global concentration that represents an evolution of the big alliances among carriers. In fact, if on one side these alliances are precious from the commercial point of view for the synergies created, on the other side, the necessity to restructure big companies and to create scale economies based on significant cost cuttings (including costs related to the staff) are making mergers among airlines inevitable.[66]

We can essentially draw two policy implications. The first one is related to horizontal mergers among airlines; the second one concerns the necessity of vertical disintegration operations in the upstream sectors of the air transport vertical channel.

Concerning the mergers among carriers, we suggest valuating them carefully in order not to hinder those aimed at balancing the market power within the vertical channel. These should in fact produce social benefits because the increased countervailing power of carriers should ensure better supply conditions (and reduced margins for the companies upstream). This, in turn, given the current competition level among airlines, should be translated into a reduction of prices for final consumers.

Whereas the necessity of vertical disintegration processes in the upstream compartments is caused by monopolistic practices realized by vertical relations (for example a leasing company can use the financial leverage to orient the purchase of engines, as highlighted by the popular antitrust case *General Electric/Honeywell*; a GDS can exploit the existence of a competitive bottleneck in the two–sided market to take advantage towards airlines—refer

[66]A confirmation of this sector evolution can be seen in the merger between the American *Delta Air Lines* and *Northwest* (2008), which created the biggest airline in the world. At the same time, the market is getting more and more concentrated in Europe too. In fact, after the merger between *Air France* and *KLM* (2004), the European market has seen *Lufthansa* incorporating several carriers (*Austrian* and *BMI* are the most recent ones) belonging to *Star* alliance. Furthermore, *British Airways* and *Iberia*, the main airlines of *One World* alliance, announced their merger (2009).

to the antitrust case *Travelport/Worldspan*). A careful evaluation of the shareholdings within the vertical channel is in particular requested to identify those able to influence the market.

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2.10 Appendix – Budget data sources

Stage	Company	Sources
Aircraft manufacturers	*Boeing*	A.R./R. *Boeing* (www.boeing.com)
	EADS	A.R. *EADS*
Engine manufacturers	*General Electric*	A.R. *General Electric*
	Pratt&Whitney	A.R. *United Technologies Corporation*
	Rolls Royce	A.R. *Rolls Royce*
Leasing companies	*GECAS*	A.R. *General Electric*
	ILFC	A.R. *American International Group*
Airlines	*IATA* airlines	www.iata.org/economics
Companies managing airports	*SEA*	A.R. *SEA*
	AdR	A.R. *AdR*
	SAVE	A.R. *SAVE*
	GESAC	A.R. *GESAC*
	SACBO	A.R. *SACBO*
Distribution	*Amadeus*	A.R./C.I. (www.amadeus.com)
	Sabre	A.R./E.R. (www.sabre–holdings.com)
	Travelport	A.R./E.R. (www.travelports.com)
	Expedia	A.R./Q.R./F.Y.R. *Expedia Inc.*
	Priceline	Financial Data Supplement
	Opodo	*BvD Amadeus* B.S.D.
Handling companies	*SEA Handling*	*BvD Amadeus* B.S.D.
	Alitalia Airport	*BvD Amadeus* B.S.D.
	Flightcare Italia	*BvD Amadeus* B.S.D.
	Ata Handling	*BvD Amadeus* B.S.D.
	Alisud	*BvD Amadeus* B.S.D.
	Sagat Handling	*BvD Amadeus* B.S.D.
	SAVE	*BvD Amadeus* B.S.D.
	Aviapartner	*BvD Amadeus* B.S.D.

A.R. = Annual Report
B.S.D. = Balance Sheet Data
C.I. = Company Information
E.R. = Earning Report
F.Y.R. =Fully Year Report
Q.R. = Quarterly Report
R. = Report

CHAPTER 3

The Impact of Airport Competition on Technical Efficiency: A Stochastic Frontier Analysis Applied to Italian Airports

Abstract

We investigate how the intensity of competition among airports affects their technical efficiency by computing airports' markets on the basis of a potential demand approach. We find that the intensity of competition has a negative impact on airports' efficiency in Italy during the 2005–2008 period. This implies that airports belonging to a local air transportation system where competition is strong exploit their inputs less intensively than do airports with local monopoly power. Furthermore, we find that public airports are more efficient than private and mixed ones. Hence, policy makers should provide incentives to implement airports' specialization in local systems where competition is strong and monitor investment plans even when private investors are involved.

JEL classification: L930, L590, L110
Keywords: Airport efficiency, stochastic distance function, airport competition.

3.1 Introduction

An important effect of the liberalization process implemented in the EU air transportation market has been the exponential growth in the European network. Today every European airline can provide new European connections (i.e., flights having origin and destination in airports belonging to the EU 25) without any further restrictions than that regarding slot availability.[1] As a consequence, if we consider all 460 airports of the 18 countries belonging to the European Common Aviation Area (ECAA) in 1997 (i.e., the 15 EU members plus Iceland, Norway, and Switzerland), the total number of airport pairs connections has signed an impressive 35% increase, from 3,410 in 1997 to 4,612 in 2008, with a Compound Annual Growth Rate (CAGR) equal to 2.78%.[2] Furthermore, the total number of connecting flights has increased from 4,102,484 in 1997 to 5,228,688 in 2008, with a CAGR for the period equal to 2.23%.

The network expansion has increased the intensity of competition between airports, since they compete, on the one hand, directly for airlines and, on the other hand, indirectly for passengers and freights (Graham, 2008). New airlines entered the EU market (especially low cost carries (LCC)) while existing carriers opened new routes at different airports. Airports' managers started to compete directly both for attracting new airlines and new air services. Furthermore, travelers may now choose the final destinations using alternative options that may be available starting from the same airport (the competition among airlines is *within* the airport) or at different nearby ones. In the latter case the (indirect) competition is *between* airports.

Our main aim is to investigate the impact of competition between airports on their technical efficiency, which is an important factor in air transportation: airport efficiency is linked both with airport charges and with the services provided to airlines and passengers (e.g., shorter aircraft turnaround times, quicker passenger transfer, faster baggage claim times, etc.). Hence, we want to analyze whether airports with a higher intensity of competition are more technically efficient.

A further interesting consequence of the EU liberalization process is the privatization of several airports. Even if the large majority of European airports is still controlled by central or local governments (e.g., municipalities, regional governments, etc.), there is a growing number of airports controlled by private agents. Furthermore, some airports have a mixed ownership, for the simultaneous presence of local governments and private agents

[1]The EU liberalization process started in 1987 and, through the sequential implementation of several packages, has now formed a uniquely large internal market. The set of measures adopted in December 1987 led to the approval of the "first package" of the integrated European rules on air transportation. Two other packages (1990 and 1992) led up to the creation of the European common market. However, the complete liberalization entered into force in April 1997, 15 years after the start of the process.

[2]Data where extracted from the Official Airline Guide (OAG) database; information regarding the total number of operating flights connecting airports belonging to the European Common Aviation Area (ECAA) during a year. Operating flights means that co–sharing connections are considered as a single flight, to avoid useless replications.

in their capital stock (ACI Europe Report, 2010). Hence, our second aim is to test whether a specific ownership type leads to greater efficiency.

This paper deals with these issues by developing a potential demand approach to compute an airport competition index and a multi–output stochastic frontier econometric model to estimate technical efficiency. These techniques are applied to a sample of 38 Italian airports for the period 2005–2008.

We find a statistically significant negative relation between airport competition and technical efficiency. This implies that an airport that is closer to the local monopoly model has a more efficient utilization of its inputs and assets, probably because airports with strong competition easily lose passengers and flights (which move toward nearby facilities) keeping the same assets.[3] As a result, the benefits induced by the EU liberalization have been greater in those airports with local monopoly power.

Second, we find that Italian public airports are the most efficient ones, while private facilities are even less efficient than mixed airports, a result similar to that obtained by Curi *et al.* (2009). The role of different investment levels and of the potential divergence between technical efficiency and profit maximization are two possible explanation discussed in the second part of this contribution.

The above results suggest that policy makers should provide incentives to implement airports' specialization in local systems where competition is strong and monitor investment plans even when private investors are involved.

To the best of our knowledge, few previous contributions have attempted to model airport competition. Malighetti *et al.* (2007) estimate an airport's potential demand by adopting a fixed radius technique, whereby an airport's competitors are all the other airports located within a fixed distance around the airport. Oum *et al.* (2008) assume that airports are in competition if they belong to the same metropolitan area. Chi–Lok and Zhang (2008) adopt as a proxy for airport competition the logarithmic distance between close by airports. These arbitrary approaches may overstate the true size of some markets and understate others, especially in Europe, where urbanization is different than in the U.S. (many towns and airports are relatively close). Furthermore, they do not take into account the determinants of the demand for airport services in a geographic area. Our model instead considers travelers' costs as exogenous factors affecting demand and builds an airport geographic market (i.e., its Catchment Area, CA) based on this variable.

[3]Many airports cannot be easily modified. For instance, the estimated utilization period of a runway is about 50 years.

Many papers have instead investigated airports' technical efficiency, but mostly they do not consider the impact of airport competition on it. The majority has adopted a non parametric approach (i.e., Data Envelopment Analysis—DEA).[4] The latter presents some drawbacks. First, it does not take into account the impact of random shocks on production (e.g., weather conditions, epidemic diseases, volcanic eruptions, etc.). Second, as shown by Simar and Wilson (2007), this approach can lead to biased estimates of the effects of some exogenous variables on the inefficiency scores.[5]

We compute airport efficiency using instead a parametric approach; in doing so, we have links with a limited number of previous contributions. Pels *et al.* (2001, 2003) adopt a stochastic frontier model without taking into account the multi–output features of airports' activities (i.e., aircraft, passenger, and cargo movements); Barros (2008), Oum *et al.* (2008) and Martín *et al.* (2009) estimate a cost stochastic frontier using accounting data, a choice that involves some problems in computing input prices.[6] Finally, Chow and Fung (2009) and Tovar and Martín–Cejas (2009), which adopt a multi–output approach, did not investigate the determinants of airports' estimated inefficiency scores. Hence, our contribution is the first one adopting a multi–output distance function and investigating also some possible determinants of airports' inefficiency. In doing so, we estimate airports' technical efficiency in terms of efficient inputs utilization (both for physical infrastructures and variable factors such as labour), an approach largely applied in the existing literature on airport efficiency (e.g., Gillen and Lall, 1997, 2001; Pels *et al.*, 2001, 2003; Lozano and Gutiérrez, 2009).

The paper proceeds as follows. Section 3.2 describes the Italian airport system. In Section 3.3, we present the multi–output stochastic distance function adopted to estimate the airports' technical efficiency and the model of potential demand developed to compute the airport competition index. The data set is described in Section 3.4, while empirical results are reported in Section 3.5. Concluding comments are highlighted in Section 3.6.

[4]See Gillen and Lall's seminal contribution (1997), and the comprehensive survey provided by Lozano and Gutiérrez (2009). These studies usually deal with a single country (e.g., the U.S., Brazil, Taiwan, Japan, Australia, Italy, and Spain), but there are also some studies at a European level and a few that benchmark airports from different countries.

[5]This analysis is usually performed with a two–stage approach, DEA in the first stage and a Tobit or truncated regression in the second stage. Simar and Wilson (2007) show that the inefficiency scores are serially correlated since they depend on all input and output observations; consequently the error terms in the second stage regression are also serially correlated. Furthermore, the latter correlation does not disappear quickly enough for standard inference approaches.

[6]Cost efficiency analysis require information on unit labor costs or unit capital costs obtained from balance sheet data. The latter may lead to biased estimates, since, for instance, the assets values are not updated (e.g., the historical value of a runway is registered in the balance sheet and not its substitution value).

3.2 The Italian airport system

Before 1990 Italian airports were controlled by the national government, as in many other European countries. There were only few exceptions in which the management of an airport was delegated by the central government to a public agency.[7] The first important change was the Act n. 537/93. This law introduced several changes in Italian airports' ownership. First, it established that airports will no longer be under the control of the national government. Second, the management of airports was delegated to companies open to private agents, local governments (Regions and Counties), municipalities and chambers of commerce. Third, the stake of shares of the company managing the airport not in the hand of private agents had to be at least equal to 20%. As a consequence, many local governments entered in the airports' ownership, taking the control in the vast majority of cases. In 1997 a new Act (n. 521/97) eliminated the 20% minimum stake for local public governments and created a national public authority—ENAC—in charge of the sector's regulation.[8]

These reforms have created the conditions for the gradual entry of private capitals into airports ownership. The first privatization took place in 1995 in Naples, where the British Airports Authority (BAA) got the majority of share of the company managing the airport. Privatization occurred also in 2000 for ADR (that controls Rome Fiumicino and Rome Ciampino). Other airports with private ownership are Florence (2003), Venice (2005), Treviso (2007), Parma (2008) and Olbia (since the beginning–1974). Hence, the majority of Italian airports is still under the control of local public authorities (with public or mixed ownership).

The Italian system consists of 45 airports open to commercial aviation. Rome Fiumicino (more than 30 million passengers in 2008) and Milan Malpensa (more than 20 million of passengers) are the two most important intercontinental airports. Long haul flights, European and domestic connections are provided also by 12 regional medium sized airports, ranging from about 3 million (Verona) to about 10 million (Milan Linate). The remaining 31 airports can be classified as regional small size ones (less than 3 million of passengers

[7]Olbia airport, in Sardinia, is the unique exception. It was built in 1974 by a private company, and so it may be regarded as the first Italian airport with private for–profit ownership.

[8]ENAC authorizes both that an airport may be open to commercial flights and that an airline can operate in the Italian skies. Furthermore, ENAC set up the airport charges and performs the safety checks on aircrafts, on airlines and their flight personnel and the security checks on groud operations. Last, ENAC controls two airports located in two small Mediterranean islands, Lampedusa and Pantelleria, where air transportation is the main way to ensure people and merchandise mobility.

per year), with a limited number of European and domestic connections. The system is composed by a relatively large number of airports, with a rather high territorial density.

All these airports have benefited from the EU liberalization of air transportation. As a result, the average number of destinations has risen from 20 (1997) to 37 (2008). This factor and the relative geographical proximity of many Italian airports have led to an increase in the inter–airports intensity of competition, whose effects on airports' efficiency will be estimated.

3.3 Methodology

This section is split into two parts: first we introduce the stochastic distance function econometric model. Second we develop a model of an airport's potential demand.

3.3.1 The stochastic distance function econometric model

In order to analyze the determinants of airports efficiency, a crucial step is the estimation of a production frontier for an airport system.

We implement a Stochastic Frontier Analysis (SFA), by which it is possible to disentangle random shocks from technical inefficiency, as shown by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977) in their seminal contributions.[9] Furthermore, SFA may involve "the incorporation of exogenous variables, which are neither inputs to the production process nor outputs of it, but which nonetheless exert an influence on producers' performance" (Kumbhakar and Lovell, 2000).

Other important issues need to be addressed when an airport's efficiency is investigated. First, our aim is to measure technical efficiency—i.e., an airport management's ability to achieve efficient input utilization. This means that we do not identify the input combination yielding the minimum cost.[10] Second, since airports are typically multi–product firms, an appropriate multi–output framework for estimating technical efficiency is required. As shown by Coelli and Perelman (1999, 2000) and Kumbhakar and Lovell (2000), this implies the estimation of a stochastic distance function. Third, we need to choose between input and output orientation. The former (the latter) identifies the inputs' reduction (the

[9] They were the first to develop SFA, where the error term of the usual regression model is equal to the sum of two components. The first one is typically assumed to be normally distributed and represents the usual statistical noise (i.e., the random shocks). The second component is non negative and represents technical inefficiency.

[10] This is due to the features of our data set that do not include monetary variables—e.g., input prices, airports' different revenues, etc.—but only physical inputs and outputs.

output improvements) required to reach the efficient frontier. Given that in airport operation many inputs are indivisible (at least in the short run), an output oriented stochastic distance function seems to be more appropriate, especially in a context where airports are in competition.[11]

In this framework we define $P(x)$ as the airports' production possibility set—i.e., the output vector $y \in R_+^M$ that can be obtained using the input vector $x \in R_+^K$. That is: $P(x) = \{y \in R_+^M : x \; can \; produce \; y\}$. By assuming that $P(x)$ satisfies the axioms listed in Fare *et al.* (1994), we introduce Shepard's (1970) output oriented distance function:

$$D_O(x, y) = min\{\theta : (y/\theta) \in P(x)\}, \tag{3.1}$$

where $\theta \leq 1$. Lovell *et al.* (1994) show that the distance function (3.1) is nondecreasing, positively linearly homogeneous, and convex in y, and decreasing in x. $D_O(x, y) = 1$ means that y is located on the outer boundary of the production possibility set—i.e., $D_O(x, y) = 1$ if $y \in IsoqP(x) = \{y : y \in P(x), \; \omega y \notin P(x), \; \omega > 1\}$. If instead $D_O(x, y) < 1$, y is located below the frontier; in this case, the distance represents the gap between the observed output and the maximum feasible output. This gap may be due both to random shocks and to inefficiency, as will be shown later.

We adopt a translog distance function for its nice properties: (i) it is flexible, (ii) it is easy to calculate, and (iii) it allows the imposition of homogeneity.[12]

If we assume that there are M outputs and K inputs, the translog distance function is defined as follows:

$$\begin{aligned} lnD_{Oit} = \alpha_0 &+ \sum_{m=1}^{M} \alpha_m \, ln \, y_{mit} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \, ln \, y_{mit} \, ln \, y_{nit} \\ &+ \sum_{k=1}^{K} \beta_k \, ln \, x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \, ln \, x_{kit} \, ln \, x_{lit} \\ &+ \frac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{M} \zeta_{km} \, ln \, x_{kit} \, ln \, y_{mit} \\ & i = 1, 2, ..., N \;\; t = 1, 2, ..., T, \end{aligned} \tag{3.2}$$

[11] Our approach is different from Tovar and Martín–Cejas (2009), who assume that "demand is beyond the airports' control and it has to be met", p. 254. We believe instead that airports' managers have the capacity to improve traffic movements, for instance by attracting new carriers.

[12] Notice that a Cobb–Douglas distance function requires a constant elasticity of substitution, which is unlikely to be fulfilled.

where N is the total number of airports in the sample and T represents the total periods (years) of observation. Hence, lnD_{Oit} is the distance from the frontier of airport i in year t. Notice that being on the frontier yields $D_{Oit} = 1$, so that the left–hand side of Eq. (3.2) is equal to zero.

As shown by Coelli and Perelman (2000, the restrictions required for homogeneity of degree 1 in outputs are the following ones:

$$\sum_{m=1}^{M} \alpha_m = 1; \ \sum_{n=1}^{M} \alpha_{mn} = 0, \ m = 1, 2, \dots , M; \ \sum_{m=1}^{M} \zeta_{km} = 0, \ k = 1, 2, \dots , K.$$

Furthermore, the restrictions required for symmetry of the interaction terms are: $\alpha_{mn} = \alpha_{nm}$ $(m, n = 1, 2, ..., M)$, $\beta_{kl} = \beta_{lk}$ $(k, l = 1, 2, ..., K)$. The homogeneity condition upon Eq. (3.2) implies that $D_O(x, \omega y) = \omega D_O(x, y)$. Hence, it is possible to choose arbitrarily one of the outputs (e.g., output M), so that we define $\omega = 1/y_M$ and obtain the following expression:

$$D_O(x, y/y_M) = D_O(x, y)/y_M. \tag{3.3}$$

Given Eq. (3.3), the translog distance function becomes:

$$\begin{aligned} ln(D_{Oit}/y_{Mit}) = \alpha_0 &+ \sum_{m=1}^{M-1} \alpha_m \, ln \, y^*_{mit} + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{n=1}^{M-1} \alpha_{mn} \, ln \, y^*_{mit} \, ln \, y^*_{nit} \\ &+ \sum_{k=1}^{K} \beta_k \, ln \, x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \, ln \, x_{kit} \, ln \, x_{lit} \\ &+ \frac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{M-1} \zeta_{km} \, ln \, x_{kit} \, ln \, y^*_{mit}, \end{aligned} \tag{3.4}$$

where $y^*_{mit} = y_{mit}/y_{Mit}$. Equation (3.4) can be written as $ln(D_{Oit}/y_{Mit}) = TL(x_{it}, y_{it}/y_{Mit}, \alpha, \beta, \zeta)$, where TL stands for the translog function. Hence, we can write:

$$-ln(y_{Mit}) = TL(x_{it}, y_{it}/y_{Mit}, \alpha, \beta, \zeta) - ln(D_{Oit}). \tag{3.5}$$

In Eq. (3.5), the term $-ln(D_{Oit})$ is non–observable and can be interpreted as an error term in the regression model. If we replace it with $(v_{it} - u_{it})$, we get the typical SFA composed error term: v_{it} are random variables that are assumed to be iid as $N(0, \sigma_v^2)$ and independent of the u_{it}; the latter are non–negative random variables distributed as $N(m_{it}, \sigma_u^2)$. v_{it} represent the random shocks, while the inefficiency scores are given by u_{it}. Hence, we can now write the translog output–oriented stochastic distance function that we are going to regress later:

$$\begin{aligned}
-ln(y_{Mit}) = \alpha_0 &+ \sum_{m=1}^{M-1} \alpha_m \, ln \, y^*_{mit} + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{n=1}^{M-1} \alpha_{mn} \, ln \, y^*_{mit} \, ln \, y^*_{nit} \\
&+ \sum_{k=1}^{K} \beta_k \, ln \, x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \, ln \, x_{kit} \, ln \, x_{lit} \\
&+ \frac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{M-1} \zeta_{km} \, ln \, x_{kit} \, ln \, y^*_{mit} + v_{it} - u_{it}.
\end{aligned} \tag{3.6}$$

In order to investigate the determinants of inefficiency, we apply a single–stage estimation procedure following Coelli (1996).[13] The technical inefficiency effect, u_{it} in Eq. (3.6) can be specified as follows:

$$u_{it} = \delta z_{it} + w_{it},$$

where the random variable w_{it} is defined by the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is -δz_{it}; i.e., $w_{it} \geq -\delta z_{it}$. Furthermore, z_{it} is a $p \times 1$ vector of exogenous variables that may influence the efficiency of a firm, and δ is a $1 \times p$ column vector of parameters to be estimated. Battese and Coelli (1995) propose a method of maximum likelihood that is equivalent to the Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991) specification, but applied to panel data.[14]

According to this time–varying specification of airports' inefficiency, the technical efficiency of airport i at period t is defined as follows:

[13]This issue was addressed by Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991) who propose stochastic frontier models in which the inefficiency effects are expressed as an explicit function of a vector of firm–specific variables and a random error.

[14]The model proposed by Battese and Coelli (1995) differs from that of Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991) in that the w_{it} random variables are not identically distributed, nor are they required to be non–negative. Furthermore, the mean, δz_{it}, of the normal distribution, which is truncated at zero to obtain the distribution of u_{it}, is not required to be positive for each observation, as in Reifschneider and Stevenson (1991). The likelihood function is expressed in terms of the variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$.

$$TE_{it} = e^{-u_{it}}.$$

3.3.2 The airport Competition Index

The common approach to defining markets for airports assumes that an airport's relevant geographic market consists roughly of a circular area around its geographic location. A fixed–radius technique is usually implemented in order to define the airport's competitors. The latter are all the other airports located within a fixed distance around the airport. The fixed–radius technique presents some drawbacks, however. First, it is arbitrary. Second, it overstates the true size of some markets and understates others—especially, as mentioned before, in Europe. Finally, it does not depend on the determinants of the demand for airport services in a geographic area (Gosling, 2003).

In dealing with these issues, we have to take into account that any measure based on the determinants of demand cannot be implemented using actual realized airport choices taken by passengers (or by firms shipping freights). Observed choices may be influenced by unobservable airport heterogeneity regarding the quality and the cheapness of their available supply (Kessler and McClellan, 2000). This, in turn, is likely to produce biased estimates of demand determinants. For this reason, it is necessary to compute predicted travelers choices based on exogenous factors. We consider traveling costs as exogenous factors affecting demand and build an airport geographic market (i.e., CA) based on this variable. The proxy we adopt is given by passenger traveling time to reach airports. Hence, we assume that individuals are potential passengers of any airport that they can reach in a reasonable time.[15]

Our technique is composed of several steps.[16] First, we draw a boundary around airport i that defines all the zip codes within T minutes drive from that airport. We will consider the following specifications of the maximum traveling time: $T = \{60, 75, 90, 105, 120\}$.[17] We compute the traveling time from zip code j to airport i driving a car on three different

[15] As shown by Graham (2008), passengers' demand for flights is function of their preferences regarding (1) the destination, (2) the type of flight (e.g., long/short haul, LCC/traditional, direct/connection flight, etc.) and (3) her/his "type" (e.g., business *versus* leisure). In this contribution we focus on a representative passenger, i.e., a passenger having an average of all the previous characteristics.

[16] A similar technique has been implemented by Propper *et al.* (2004, 2008) for hospitals.

[17] The analyses performed by many airports and national aviation authorities (for instance the British CAA) show that almost all passengers choosing a given airport leave in an area where it is possible to reach the airport within 90 minutes.

road types: urban roads, extra–urban roads, and motorways.[18] All the zip codes falling within the T–minutes defined boundary are included in the catchment area of airport i; i.e., CA_i.

Second, we define η_i as the set of population living in airport i's catchment area. The latter is the population living in all zip code towns belonging to CA_i. Similarly, η_j is the set of population living in airport j's catchment area, CA_j.[19]

Third, since in air transportation each O–D route defines a separate market, airport i is subject to competition coming from airport j only if the same route is available at both airports. This means that airport i and airport j must have either the same airport destination, or a destination in different airports but located at a reasonable distance. We assume that different flights have the same destination if the arrival airports are located at a maximum distance equal to 100 kilometers.[20] The application of different methodologies to estimating the potential demand at the origin and destination airports is due to the different exogenous factors affecting them. Traveling costs are the main determinant of the origin airport's potential demand, while the region where the travel is directed is instead the main factor influencing the destination airport's potential demand. The intuition is the following: a traveler, when choosing a flight, considers first the region that needs to be reached (not necessarily the town but also the surrounding region), then she or he verifies whether, at a reasonable traveling distance, this region can be reached leaving from different origin airports.

Hence, if we consider all airports where route r is available, we define the following expression:

$$\begin{aligned}
&\eta_{ij,r} = \{(\eta_i \cap \eta_j) \setminus \eta_k,\ \forall k \neq i, j\} \\
&\eta_{ijk,r} = \{(\eta_i \cap \eta_j \cap \eta_k) \setminus \eta_h,\ \forall h \neq i, j, k\} \\
&\ldots,
\end{aligned}$$

where $\eta_{ij,r}$ is the subset of population leaving in CA_i, which has only the possibility to reach also airport j within T minutes traveling time for the route r; $\eta_{ijk,r}$ is the subset of

[18]The driving times, influenced by the different road types, are computed using $GoogleMaps$.

[19]Hence, we assume that the value of time is the same for the entire population living a given area. Clearly, people traveling for business may have a different value of time in comparison to leisure passengers. This means that the maximum traveling distance should be lower for people with high value of time. We did not consider this issue for simplicity. Hence the share of population that may choose among alternative airports is greater in our approach, which means that we overestimate the degree of airport competition. However, the share of business travelers is small, and so this effect is rather negligible.

[20]Fuellhart (2003) shows that airports are subject to strategic interaction if they are located within a circle with 95 kilometer–150 kilometer rays.

η_i, which has only the possibility to reach also airport j and airport k within T minutes traveling time, always for the route r. Fourth, if we denote $\hat{\eta}_{i,r}$ as the potential demand of airport i on the route r, this is given by:

$$\hat{\eta}_{i,r} = \eta_i - \sum_j \frac{1}{2}\eta_{ij,r} - \sum_k \frac{1}{3}\eta_{ijk,r} - \sum_h \frac{1}{4}\eta_{ijkh,r} + \ldots . \tag{3.7}$$

Fifth, the Competition Index for airport i on route r ($CI_{i,r}$) is:

$$CI_{i,r} = 1 - \frac{\hat{\eta}_{i,r}}{\eta_i},\ 0 \leq CI_{i,r} \leq 1. \tag{3.8}$$

We need an aggregate index of competition for airport i—i.e., a measure that takes into account all of the routes available in that airport and also their relative importance. The latter is given, for route r, by the ratio between the number of Available Seats for route r in airport i ($AS_{i,r}$) and the total number of Available Seats (AS_i) in the same airport.[21]

Hence, the aggregate index of competition for airport i is defined as follows:

$$CI_i = \sum_{r=1}^{R} \frac{AS_{i,r}}{AS_i} \times CI_{i,r}, \tag{3.9}$$

where $0 \leq CI_i \leq 1$ and R is the total number of routes available in airport i. This implies that the higher is CI_i, the more airport i is subject to competition. Figure 3.1 provides an example of the methodology.

Suppose we want to compute CI_A by applying Eq. (3.9). After having fixed a given level of T, the procedure draws the boundary of its catchment area, given by the grey area. Suppose that airport B is the unique nearby airport, and that people living in the dashed area represent the population that may, within $\overline{T}$ minutes, also reach airport B.

The next step is to consider the available routes at the two airports. Airport A has two routes: A–C and A–D. Airport B has only route B–E. Routes A–D and B–E belong to the same market for the population η_{AB} since airport D is located at less than 100 kilometers distance from airport E. Clearly, on route A–C, airport A is not subject to any competition coming from airport B. Hence, $\eta_{AB,A-C} = 0$, while $\eta_{AB,A-D} = \eta_{AB}$. Consequently, from Eq. (3.7) we get that $\hat{\eta}_{A,A-C} = \eta_A$, while $\hat{\eta}_{A,A-D} = \eta_A - \frac{1}{2}\eta_{AB}$. Then, from Eq. (3.8) we get: $CI_{A,A-C} = 0$, while $CI_{A,A-D} = 1 - \frac{\eta_A - \frac{1}{2}\eta_{AB}}{\eta_A} = \frac{\eta_{AB}}{2\eta_A}$. Now, suppose that $AS_{A,A-D} = 50$ (i.e., during a year the total number of available seats for

[21] $AS_{i,r}$ and AS_i are taken from the OAG database. The available seats is the variable adopted in air trasportation to measure the flight capacity.

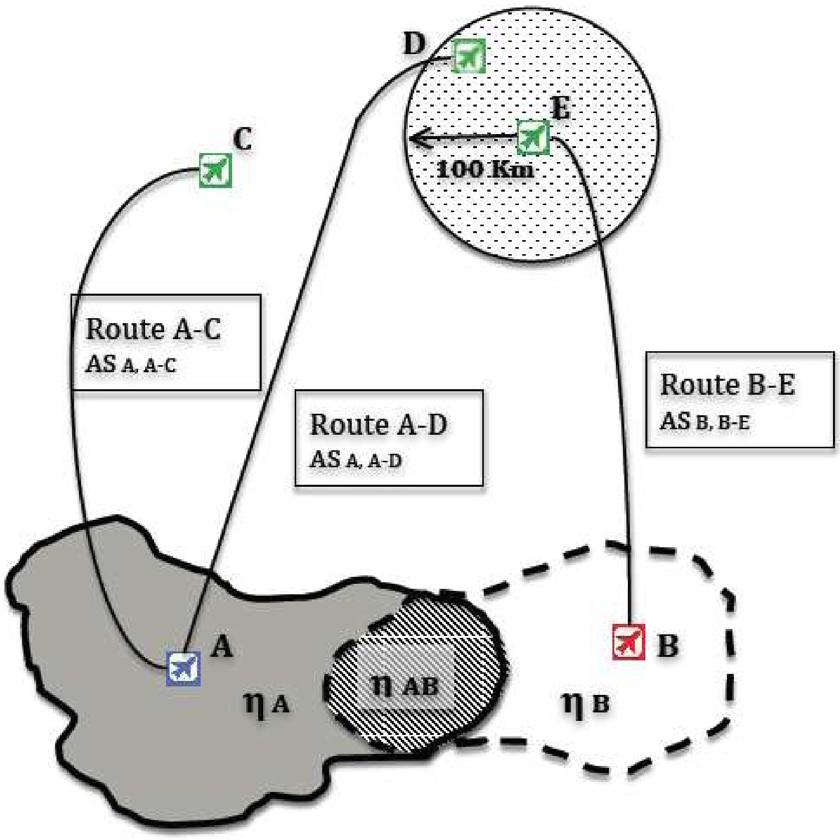

Figure 3.1: An example of competition between airports

the route A–D is equal to 50) and that $AS_A = 100$. Hence, from Eq. (3.9) we obtain $CI_A = 0 + \frac{50}{100} \times \frac{\eta_{AB}}{\eta_A} = \frac{\eta_{AB}}{4\eta_A}$, which is airport A's competition index.

3.4 Data

The multi–output/multi–input production frontier for Italian airports is estimated using annual data on 38 airports over the period 2005–2008. Our data set covers 84% of Italian airports and 99.97% of passenger movements.The data sources are ENAC for outputs (i.e., aircraft, passenger, and freight movements) and the technical information provided by the airports' official documents for inputs. The latter have been integrated by a direct investigation with the managing boards of the airports. Information regarding exogenous variables have been collected from the Italian national institute for statistics (ISTAT) and from the airports' balance sheets.

As the vast majority of previous contribution we consider three output variables: the yearly number of aircraft movements (ATM), of passengers movements (APM) and of freights (FRE). Regarding inputs, following again all previous contributions investigating the efficient inputs utilization, we include in our data set a mixture of physical infrastructures (the runway capacity (CAP) measured as the maximum number of authorized flights per hour,[22] the total number of aircraft parking positions ($PARK$), the terminal surface area ($TERM$), the number of check–in desks ($CHECK$), the number of baggage claims (BAG)) and the number of employees measured in terms of Full–Time Equivalent units (FTE). The descriptive statistics regarding outputs and inputs are presented in Table 3.1.[23]

Table 3.1: Descriptive Statistics of Input (I) and Output (O) Variables

	Average	**Median**	**Std. Dev.**	**Max**	**Min**
ATM (O) (number)	43,024	18,919	63,881	346,65	1,748
APM (O) (number)	3,347,933	1,300,206	6,048,541	35,226,351	7,709
FRE (O) (tons)	25,261	3,569	74,169	486,666	0
TERM (I) (sqm)	33,326	11,600	69,630	350,000	256
CHECK (I) (number)	37	17	62	358	3
FTE (I) (number)	208	74	387	2,186	1
PARK (I) (number)	24	16	25	142	2
CAP (I) (flights per hour)	17	12	17	90	2
BAG (I) (number)	4	3	3	15	1

It is possible to check the validity of the chosen inputs and outputs by testing for their isotonicity—i.e., outputs should be significantly and positively correlated with inputs (Charnes *et al.*, 1985). Pearson correlation coefficients are shown in Table 3.2. The correlation between all the inputs and the outputs is significant (at a 1% level) and positive. Moreover, the input correlation is positive, significant, and very high, as a confirmation that in managing airports, inputs are jointly dimensioned to avoid bottlenecks (Lozano and Gutiérrez, 2009).

Table 3.2: Pearson Correlations of Input (I) and Output (O) Variables

	TERM (I)	CHECK (I)	FTE (I)	PARK (I)	CAP (I)	BAG (I)
ATM (O)	0.936	0.969	0.958	0.890	0.944	0.878
APM (O)	0.968	0.958	0.856	0.874	0.946	0.936
FRE (O)	0.808	0.642	0.695	0.802	0.738	0.860
TERM (I)	1	0.979	0.895	0.927	0.920	0.875
CHECK (I)	0.979	1	0.928	0.923	0.943	0.903
FTE (I)	0.895	0.928	1	0.859	0.932	0.836
PARK (I)	0.927	0.923	0.859	1	0.904	0.858
CAP (I)	0.920	0.943	0.932	0.904	1	0.875
BAG (I)	0.875	0.903	0.836	0.858	0.875	1

Furthermore, we consider two types of exogenous variables. The first type influences

[22]This variable takes into account both the runway length and the airport's aviation technology level—e.g., some aviation infrastructure such as ground–control radars and runway lighting systems.

[23]Notice that we have not included in our inputs the total surface area because this may lead to biased estimation, since in many Italian airports a relevant portion of the surface is dedicated to military activities.

the production frontier, while the second one has an impact on the airports' inefficiency scores. Hub (HUB) and Seasonality ($SEASON$) are the two variables influencing the frontier. HUB is a dummy variable equal to 1 if the airport is an hub: airport with hub and spoke system employs different technologies (e.g., different BHS). $SEASON$ is a dummy variable equal to 1 if the airport belongs to a region whose monthly tourist flows are strongly seasonal and correlated with airports' monthly passenger flows: tourist flows may have a high traffic variation across the different months and this has an impact on airports' production levels and not on their efficiency.[24]

Four variables are instead considered as determinants of airports' inefficiency scores: the airport competition index (CI_i), two dummies regarding ownership ($PRIV$ for private ownership and MIX for mixed public–private ownership), and the degree of dominance of the main airline in a specific airport (DOM), which is a proxy of airline competition within the airport.

The airport competition index (CI_i) is computed from Eq. (3.9). Table 3.3 and Figure 3.2 show the distribution of the airport competition index as function of T. For instance, the first row in Table 3.3 shows that if $T = 60$, then 10 Italian airports have no competition at all. Furthermore, for the same maximum traveling time, the degree of competition is rather small (i.e., $CI \leq 20\%$) in 16 airports, while only 4 airports have a competition index between 40% and 60%. No airports have a degree of competition higher than 60%. If instead $T = 90$, row 3 in Table 3.3 shows that only 4 airports have no competition, 8 airports have a rather high competition index (between 40% and 60%), while competition is very high in 3 airports (60%$\leq CI_i \leq$ 80%).

Table 3.3: Distribution of Airport Competition Index as Function of T

	0	**(0, 20] %**	**(20, 40] %**	**(40, 60] %**	**(60, 80] %**	**(80, 100] %**
CI(T=60)	10	16	8	4	0	0
CI(T=75)	5	13	11	8	1	0
CI(T=90)	4	7	16	8	3	0
CI(T=105)	4	5	8	14	7	0
CI(T=120)	3	3	6	13	11	2

Figure 3.2 confirms the positive correlation between the competition index and T, as well as the increase in its variance as the maximum traveling time grows. The latter implies that an enlargement of the airport's catchment area does not have the same effect on all

[24]We first compute the Gini index of monthly regional tourist flows (measured by the recorded hotel bookings reported by ISTAT). Then, we classify a region as strongly influenced by tourist flows if the Gini coefficient is greater than the national average. Finally, we assume that the tourist flow is strongly correlated with passenger movements if the Pearson Correlation index is greater than 0.9.

Italian airports. For some of them, this implies an increase in the competition index, while this is rather small for other airports.[25]

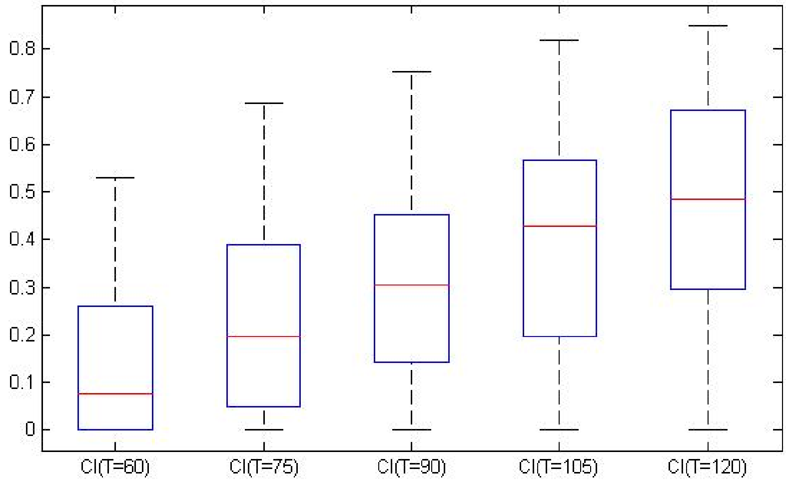

Figure 3.2: The dispersion of airport competition as function of T.

As mentioned before, we consider two ownership dummies: $PRIV$ is equal to 1 if the stake of private agents is higher than 50% of the capital stock. MIX is equal to 1 when the stake of private agents is greater than 25% but lower than 50% of the capital stock. Hence, public airports are those where private agents have less than 25% of the shares.

The distribution of airports' ownership during the period 2005–2008 is characterized by a majority of public airports: 28 out of 38 (74%) both in 2005 and in 2008. Private airports have slightly increased during the observed period, from 5 in 2005 (13%) to 7 in 2008 (18%). Mixed–ownership airports were 13% in 2005 and 8% in 2008.

Finally, the variable DOM is given by the percentage of AS offered by the airline with the largest market share in the airport. The higher is this percentage, the lower is the competition among airlines in airport i. In terms of airports' efficiency, this variable may also show the impact of incumbent carriers' strategy to block entrance, which may limit the possibility to attract new airlines. This, in turn, may reduce the airport's efficiency of asset utilization.

[25]We have compared our measure of airport competition index with the common approaches previously adopted in the literature and we have found that they underestimate the degree of competition. For instance, the fixed–radius technique provides, on average, a measure of airport competition which is 70% lower than our index. Hence these measures reduce the impact of airport competition on technical efficiency.

3.5 Econometric results

The multi–output stochastic distance function regressed is the following:

$$
\begin{aligned}
-ln(APM_{it}) = TL(&ATM_{it}/APM_{it},\ FRE_{it}/APM_{it},\ TERM_{it},\ CHECK_{it}, \\
&BAG_{it},\ FTE_{it}, PARK_{it},\ CAP_{it},\ \alpha,\ \beta,\ \zeta) + \lambda_1 HUB \\
&+\lambda_2 SEASON + v_{it} - u_{it},
\end{aligned} \tag{3.10}
$$

where APM_{it} is the normalizing output (i.e., ATM_{it} and FRE_{it} are expressed in APM_{it} terms), α is a vector of coefficients for ATM_{it}/APM_{it} and FRE_{it}/APM_{it}, β is a vector of coefficients regarding inputs, and ζ is a vector of coefficients related to output–input interactions. The equation describing the impact of the exogenous variables on the inefficiency scores u_{it} is the following:

$$
m_{it} = \delta_0 + \delta_C C_{it} + \delta_{Priv} Priv_{it} + \delta_{Mix} Mix_{it} + \delta_{Dom} Dom_{it}, \tag{3.11}
$$

where m_{it} represents the mean of u_{it}.[26] Table 3.4 presents the econometric results.[27]

First–order coefficients are all statistically significant with the exception of the number parking positions ($PARK$). Concerning second–order coefficients, terminal area ($TERM$), the number of check–in desks ($CHECK$) and the runway capacity (CAP) are statistically significant.

Furthermore, many interaction effects are statistically significant as a confirmation of the multi–output features of airport activity, with the exception of those coefficients regarding the interaction between freight movements and other inputs (this may be due to the fact that many regional airports have a value of FRE equal to 0).

Both the hub and seasonality dummies are not statistically significant. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. Table 3.4 shows that they are statistically significant at the 1% level, with the estimated γ equal to 0.56. Hence, the relatively high value of γ shows that a relevant part of the distance between the observed output levels and the maximum feasible ones is due to technical inefficiency.[28] The hypothesis of normal error distribution is confirmed by the

[26] Notice that not including an intercept parameter, δ_0, in Eq. (3.11) may imply the fact that the δ–parameters associated with the z variables are biased and that the shape of the inefficiency effects' distributions are unnecessarily restricted (Battese and Coelli, 1995).

[27] The estimation has been performed using the package FRONTIER 4.1 (Coelli, 1996).

[28] The significance of γ is also confirmed by the generalized likelihood–ratio (LR) test. In our case, the

Table 3.4: Estimation Results

Parameter	Estimate	Std. Error	Parameter	Estimate	Std. Error
$Constant$	-5.1365 (*)	2.7865	$TERM^2$	0.023637 (**)	0.10568
ATM^*	-2.0280 (***)	0.63279	$TERM \times CHECK$	0.3697 (**)	0.15369
FRE^*	0.33862 (***)	0.12989	$TERM \times FTE$	0.51484 (***)	0.095031
$TERM$	-1.7487 (**)	0.72764	$TERM \times PARK$	0.23401 (*)	0.13845
$CHECK$	-2.3936 (**)	1.0223	$TERM \times CAP$	-0.93400 (***)	0.12368
FTE	-3.7216 (***)	0.71368	$TERM \times BAG$	-0.95908 (***)	0.14089
$PARK$	-0.97477	0.69863	$CHECK2$	-1.9252 (***)	0.35751
CAP	7.6914 (***)	0.95905	$CHECK \times FTE$	-0.48801 (***)	0.10187
BAG	5.7138 (***)	0.94732	$CHECK \times PARK$	0.084751	0.19140
ATM^{*2}	0.2396 (***)	0.08544	$CHECK \times CAP$	1.4290 (***)	0.22045
$ATM \times FRE$	0.0002427	0.0088612	$CHECK \times BAG$	1.7186 (***)	0.24799
$ATM \times TERM$	0.33511 (***)	0.094901	FTE^2	0.082515	0.059360
$ATM \times CHECK$	-0.13411	0.13767	$FTE \times PARK$	0.21308 (*)	0.11777
$ATM \times FTE$	-0.11917 (**)	0.055346	$FTE \times CAP$	-0.57416 (***)	0.11592
$ATM \times PARK$	0.32043 (**)	0.14246	$FTE \times BAG$	0.0092822	0.11778
$ATM \times CAP$	0.45349 (***)	0.16125	$PARK2$	-0.04388	0.19622
$ATM \times BAG$	0.012968	0.17012	$PARK \times CAP$	-0.18354	0.18421
FRE^{*2}	0.000088248	0.0047334	$PARK \times BAG$	-0.44925 (***)	0.17098
$FRE \times TERM$	-0.037878 (**)	0.01691	CAP^2	0.68349 (***)	0.24611
$FRE \times CHECK$	0.017914	0.021973	$CAP \times BAG$	-0.23321	0.20143
$FRE \times FTE$	-0.010258	0.01072	BAG^2	0.077724	0.31679
$FRE \times PARK$	-0.0029147	0.016879	$SEASON$	0.059776	0.062863
$FRE \times CAP$	-0.035539	0.024086	HUB	0.085058	0.20665
$FRE \times BAG$	0.037596	0.024339			
$Constant_Z$	-2.2851 (***)	0.49749			
$CI(T = 90)$	3.4519 (***)	0.67646			
$PRIV$	1.0176 (***)	0.18341			
MIX	0.81339 (***)	0.17025			
DOM	0.63825 (***)	0.21635			
σ^2	0.030876 (***)	0.010543			
γ	0.55941 (***)	0.19027			
LR	68.283				
$log\ likelihood\ value$	92.37796				

Note that *,**,*** denote significance at 10%, 5% and 1% respectively.

Shapiro–Wilk normality test (W=0.9935, p–value=0.733).

We can now look at the determinants of efficiency. Concerning the impact of airport competition on technical efficiency, since CI_i is a function of T, Table 3.5 shows the estimated coefficients for different specifications of the maximum traveling time. They are always positive and statistically significant. Moreover, their magnitude is the largest among the determinants. This implies that airports with higher competitive pressure are less efficient. In contrast, in the Italian system, an airport that is closer to the local monopoly model (i.e., those airports with a competition index lower than 20%—see Table 3.4) has an efficient utilization of its inputs.

We provide the following explanation for this result: airports with higher levels of competition have low technical efficiency levels because they still suffer from overcapacity. The EU liberalization benefits coming from the traffic growth have been distributed among many airports if they belong to areas with strong competition. On the contrary, airports with

LR statistic is greater than 60, and this confirms that most of the variance of the estimated residual is then attributed to variations in the degree of efficiency, rather than to a stochastic disturbance.

Table 3.5: Airport Competition Index Sensitivity

Parameter	Estimate	Std. Error
CI(T=60)	2.1422 (***)	0.16521
CI(T=75)	5.4519 (***)	0.73176
CI(T=90)	3.4519 (***)	0.67646
CI(T=105)	3.2369 (***)	0.88771
CI(T=120)	0.4136 (**)	0.17224

local monopoly power did improve their performances thanks to liberalization, because they could fully exploit these benefits. This, in turn, has led to a more efficient assets' utilization, reducing their spare capacity. Inefficient airports subject to intense competition may recover efficiency by attracting more passengers. They may achieve this target by enlarging the number of routes available at their airports, i.e., they need to stimulate new demand (e.g., by attracting a new LCC or by offering a new point–to–point connection not provided by nearby airports) or to divert the existing demand from other airports. However, in a competitive environment, this does not seem to be an easy task for the following reasons. First, active carriers incur relevant switching costs when changing airports (e.g., different accessibility systems among airports, transaction costs when signing a new contract with different handlers, etc.). Second, the current general crisis facing airlines worldwide limits the frequency of entry (when it does not also reduce the number of existing carriers).[29]

The coefficients of $PRIV$ and MIX are both statistically significant and positive, and among them the coefficient of $PRIV$ is the highest. This implies that public airports are more efficient than those with mixed ownership, whereas private airports have the lowest efficiency. This evidence confirms Curi *et al.*'s (2009) contribution for Italian airports, while it is different from the results obtained by Oum *et al.* (2008), who investigated the efficiency of the largest airports in the world and by Chi–Lok and Zhang (2008), who studied the effects of privatization on Chinese airports.[30]

We provide the following explanation for this result. First, investments in indivisible inputs may have been greater in private airports. Indeed many local governments have decided to privatize their airports also taking into account the investment plans proposed by the new airports' owners. As a consequence of this, in the vast majority of cases privatization implied an increased in the investments, especially in indivisible inputs. Given the difficulties involved in reaching in the short–run the volume of traffic required

[29]Note that, between 2008 and 2009, the Italian authority suspended the license to fly to several airlines: $Air\ Vallee$, $Airbee$, $Alpi\ Eagles$, $Clubair$, $Italian\ Tour\ Airlines$, $Myair.com$ and $Ocean\ Airlines$.

[30]We rule out the possible endogeneity problem arising between inefficiency and privatization, since the anecdotal evidence we collected (mainly from newspapers) shows that the decision to privatize an airport has not been usually taken on the basis of efficiency reasons (e.g., it has been mainly based on political issues).

for an efficient utilization of the indivisible input, private airports have lower technical efficiency than the other airport's types. Second, private airport maximize profit. This means that if we had estimated a cost frontier rather than a production function, private airports could turn out to be the most efficient ownership type. Moreover, they may give more weight to commercial revenues; last, they may not be willing to increase traffic, in order to achieve an efficient assets' utilization, if reaching this target implies adopting unprofitable strategies. For instance, many public regional airports, controlled by local governments, increase their traffic by attracting new airlines (especially LCCs) through subsidization.[31] As a result, public airports have a higher attractive power, and so they obtain higher utilization rates of their assets. For the same reason, mixed airports are more efficient than private ones.

The coefficient of the variable DOM is statistically significant and positive. This means that airport efficiency is positively related to airline competition: when the latter is strong, the airport has a high efficiency. This negative dominance effect may be explained in terms of entry deterrence adopted by incumbent airlines. As a consequence, the airport's capacity to attract new routes is limited, and, in turn, its utilization of assets.[32]

To sum up, in the Italian airport system technical efficiency is higher in airports with low inter–airport competition, public ownership, and high airline competition.

Concerning the dynamics of efficiency, our aim is to identify which airports exhibit substantial (positive or negative) variation in their efficiency rather than small changes, exploiting the time–variant stochastic frontier model that we have implemented. Table 3.6 shows the airports' annual efficiency scores. The annual mean of the Italian system was equal to 89.7% in 2005 (see the last row of Table 3.6) and to 90.7% (+1.09%) in 2008. Hence, the whole Italian system has raised its technical efficiency during the period 2005–2008.

The last column of Table 3.6 shows that the CAGR of technical efficiency is positive for 20 airports (53%). A large improvement has taken place in 3 airports (CAGR greater than +5%; i.e., a 1,25% annual productivity increase), while 2 airports exhibit a substantial efficiency growth (CAGR between +2.5% and +5%).

[31]The recent case of Ryanair and Alghero (a regional airport in Sardinia) is a clear example. In 2009, Ryanair received subsidies of 6.4 million Euro (this is called "co–marketing"), while the public company managing the airport incurred about 12 million Euro of losses. The local government of the Sardinian region, which is on the board of the company managing the airport, has covered this loss. For further evidence of this kind of subsidies, see also the well known *Charleroi airport–Ryanair* case.

[32]This factor is particularly important when the main carrier is *Alitalia*, which has frequently implemented actions to prevent new carriers' entry (Boitani and Cambini, 2007).

Table 3.6: Airports' Technical Efficiency Scores

	Airport	IATA	2005	2006	2007	2008	CAGR
1	Alghero	AHO	0.9916263	0.9916508	0.9900854	0.9894926	-0.05%
2	Ancona	AOI	0.9789876	0.9801658	0.9860817	0.9831161	0.11%
3	Bari	BRI	0.9920014	0.9901703	0.9882672	0.9876648	-0.11%
4	Bergamo	BGY	0.9535409	0.9639889	0.9241105	0.89809	-1.49%
5	Bologna	BLQ	0.9814023	0.9789476	0.9714875	0.9701399	-0.29%
6	Bolzano	BZO	0.9920942	0.9650263	0.9598382	0.9707327	-0.54%
7	Brescia	VBS	0.422112	0.5129745	0.4807263	0.5515363	6.91%
8	Brindisi	BDS	0.98704	0.9865149	0.9878908	0.9873603	0.01%
9	Cagliari	CAG	0.9906068	0.9916903	0.9905852	0.9903494	-0.01%
10	Catania	CAT	0.9912252	0.9912866	0.9909291	0.9912537	0.00%
11	Crotone	CRV	0.9330256	0.7668822	0.8935151	0.9345646	0.04%
12	Cuneo	CUF	0.9750859	0.9918241	0.9711049	0.9439398	-0.81%
13	Florence	FLR	0.5334409	0.6454671	0.5714794	0.6238201	3.99%
14	Foggia	FOG	0.9924914	0.9918196	0.9921186	0.9917261	-0.02%
15	Forl	FRL	0.8920345	0.8503685	0.8041961	0.9701447	2.12%
16	Genoa	GOA	0.984181	0.9842489	0.9813073	0.9831483	-0.03%
17	Lamezia	SUF	0.9868458	0.990097	0.9889069	0.989265	0.06%
18	Lampedusa	LMP	0.9913451	0.9909779	0.9908206	0.9898437	-0.04%
19	Milan Linate	LIN	0.8490341	0.8451649	0.8274307	0.716069	-4.17%
20	Milan Malpensa	MXP	0.9813868	0.9789565	0.972274	0.9793153	-0.05%
21	Naples	NAP	0.9827084	0.9787345	0.9797691	0.9842881	0.04%
22	Olbia	OLB	0.9795703	0.979435	0.8813891	0.9812243	0.04%
23	Palermo	PMO	0.9904311	0.9877705	0.9837758	0.9870098	-0.09%
24	Pantelleria	PNL	0.9907673	0.9919699	0.9898001	0.9898001	-0.02%
25	Parma	PMF	0.2648153	0.4063978	0.2851199	0.222219	-4.29%
26	Perugia	PEG	0.9862724	0.9867029	0.9808133	0.9836295	-0.07%
27	Pescara	PSR	0.9880302	0.9885017	0.9887526	0.9893561	0.03%
28	Pisa	PSA	0.9331822	0.923296	0.7671704	0.7538619	-5.19%
29	Reggio Calabria	REG	0.9865357	0.9841762	0.9857244	0.9873995	0.02%
30	Rimini	RMI	0.9856242	0.9838765	0.9828345	0.9870263	0.04%
31	Rome Ciampino	CIA	0.4820843	0.4759245	0.6215589	0.5948844	5.40%
32	Rome Fiumicino	FCO	0.9565278	0.9596029	0.9517886	0.9668774	0.27%
33	Turin	TRN	0.9003624	0.9673553	0.9727949	0.9767103	2.06%
34	Trapani	TPS	0.9609811	0.9530352	0.9445934	0.9700457	0.23%
35	Treviso	TSF	0.7319935	0.9272504	0.8415282	0.8289349	3.16%
36	Trieste	TRS	0.950216	0.9580929	0.9668805	0.9646108	0.38%
37	Venice	VCE	0.9122712	0.9380202	0.8340658	0.9056087	-0.18%
38	Verona	VRN	0.7202178	0.9298975	0.9577055	0.9554569	7.32%
	Mean		0.8974237	0.9133753	0.8994532	0.9071188	0.27%

Note that only 3 airports shows a large negative variation in technical efficiency (CAGR less than -4%).

3.6 Conclusion

This paper has investigated the impact of airport competition on the efficiency of 38 Italian airports by applying a stochastic distance function model with time–dependent inefficiency components to a panel data set regarding the period 2005–2008. The sample covers 84% of the commercial Italian airports and 99.97% of total passenger movements. Airport competition has been computed using a potential demand model, taking into account passengers' traveling times to reach an airport as an exogenous factor affecting demand.

We find that airports with higher intensity of competition are less efficient than those which benefit from local monopoly power. Furthermore, we show that public airports are more efficient, while private airports are even less efficient than those with mixed ownership.

These results yield the following policy recommendations. First, there are two ways to deal with technical inefficiency: one possibility is to induce airport specialization within the same territorial system (e.g., one airport may focus on LCCs and another on cargo). Since passengers living in these areas can choose among alternative airports, an extreme possibility is to close down highly inefficient airports, because there is no economic justification for covering their losses (especially when the coverage is carried out by public local taxation).

Second, regulation should monitor the efficient assets' utilization especially after that new investments have been implemented. Many assets suffer from indivisibility in the short–run and our analysis has proved that their utilization could be inefficient also in presence of private investors.

This contribution has not considered airport cost efficiency, which may lead to different ownership rankings. Furthermore, we did not take into account some negative effects in airport activities, such as noise and pollution produced in the surrounding area, which may overturn our results. These issues are left for future research.

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CHAPTER 4

The Impact of Local Air Pollution on Airport Efficiency: Evidence from Italy

Abstract

We estimate technical efficiency of 33 Italian airports for the period 2005–2008. In addition to the conventional outputs (aircraft, passenger and cargo movements), an airport byproduct producing negative externalities has been considered: local air pollution. We apply a hyperbolic distance function that is both parametric and stochastic. Such approach allows to treat the outputs' vector asymmetrically by allowing equiproportional desirable outputs expansion and undesirable outputs contraction. Airports' efficiency scores (obtained by maximum likelihood estimation) show to be greater and closer when local air pollution is included as undesirable output of the production function. Hence, we find that not taking into account the airport undesirable outputs may provide misleading efficiency assessments.

JEL classification: L930, L590, L110
Keywords: Airport efficiency, stochastic distance function, undesirable outputs.

4.1 Introduction

Airport efficiency has been the subject of a great number of research studies. Usually, the inputs considered represent either the production factors (labor and capital) or the physical infrastructure of the airports, while the outputs consist of the volumes of aircraft operations, passengers, and cargo. Efficient airports are those that maximize their outputs with their given inputs. Hence, the pursuit of efficiency aims at increasing the number of aircraft movements as well as the number of passengers transported and cargo handled. In other words, in most efficiency studies in the literature, these outputs are increased as much as possible within the production possibility set derived from the existing data.

However, even though airports that increase passengers, cargo and flights (i.e., "efficient airports") bring significant economic and social benefits to the local communities, there are some environmental externalities (such as noise pollution and emissions) associated to airport activities, that should be considered in airport performance evaluations. However, this does not affect the concept of efficiency, once that it has been avoided the misspecification error of not including undesirable outcomes in airport production process.

In this regard, the aim of the present study is to reassess airports technical efficiency by a proper perspective, taking into account that airports exploit their physical assets (e.g., runways, terminal area, etc.) to produce, at the same time, the conventional good outputs (e.g., air traffic movements, passenger movements, and cargo handled) and some undesirable outputs.

In particular, this contribution focuses on the production of Local Air Pollution (LAP).[1]

Since we are dealing with technical efficiency, the inputs considered refer to airports physical infrastructure. Following the approach of Cuesta *et al.* (2009), we estimate technical efficiency scores for a panel of Italian airports for the period 2005–2008, developing a hyperbolic distance function model that is both parametric and stochastic. In this way, we are able to represent the proportion by which desirable outputs can be expanded and undesirable outputs and inputs can be reduced in a multiplicative manner. Furthermore, this methodology allows us to apply a conventional econometric technique based on maximum likelihood estimation (Battese and Coelli, 1992).

To the best of our knowledge, no previous study regarding airport efficiency has considered local air pollution as undesirable outputs. Moreover, there are no parametric studies about airport efficiency that take into account the simultaneous production of desirable and undesirable outputs. The structure of this paper is as follows. A review of previous related airport efficiency studies is presented in Section 4.2. In Section 4.3, the hyperbolic distance function model is formulated and the methodology by which the index

[1]Other categories of negative externality related to air transportation are noise and climate change. The first one is not considered in this contribution because of the difficulties connected to both the non–linear properties and the subjectivity characterizing noise annoyance. The second one is mainly associated with emissions of aircrafts during the cruise stage, regardless of departure and arrival airports. In fact, as pointed out by Givoni and Rietveld (2010), to account for aircraft operation impact on climate change the whole flight must be accounted.

for LAP has been constructed. Section 4.4 reports the results of the proposed approach. Finally, Section 4.5 summarizes and concludes.

4.2 Literature review

Technical efficiency refers to the ability to maximize outputs from a given input vector or minimize inputs utilization in the production process of a given output vector (Coelli *et al.*, 2005). Thus, it is necessary to employ information on the quantities of inputs and outputs to describe the structure of production technology (Kumbhakar and Lovell, 2000). In the frontier approach a best practice production frontier, by which each firm is evaluated, has to be estimated: this estimation could be done using parametric or non–parametric techniques.

Parametric studies about airport technical efficiency are a limited number. Among these, we mention Pels *et al.* (2001, 2003).[2] However, most of them ignore the multiple nature of airports' activities: since airports are multiple outputs firms, it is necessary to replace the production function with a distance function for a proper analysis of producer performance. Input and output oriented distance functions have been introduced by Debreu (1951), Malmquist (1953) and Shepard (1953). To the best of our knowledge, Chow and Fung (2009), Tovar and Martín-Cejas (2009) and Scotti *et al.* (2010) are the only contributions which adopt a multi-output parametric approach to study airport technical efficiency.

Non–parametric distance functions have been introduced by Charnes *et al.* (1978) and dominate empirical analysis of airport performance: Lozano and Gutiérrez (2009) present a recent and detailed review of this branch of the literature.

However, the most relevant papers directly related to this contribution are those that consider undesirable outputs produced by airports. As far as the parametric approach is concerned, Cuesta *et al.* (2009) introduce new specifications of traditional distance functions that allow the inclusion of undesirable outputs in the production function. However, to the best of our knowledge, there are no studies regarding airports that takes into account the production of bads adopting a parametric technique. With regard to non–parametric analysis, there are different possibilities for dealing with undesirable factors. The first possibility is to treat the undesirable outputs as inputs and the undesirable inputs as outputs. However, this does not reflect the true production process. The second is to treat the

[2]Some contributions, Barros (2008), Oum et al. (2008) and Martín *et al.* (2009), estimate a cost stochastic frontier using accounting data. This choice involves some problems in computing input prices.

undesirable outputs in the non–linear DEA model (Fare *et al.*, 1989). The third is to apply a monotone decreasing transformation to the undesirable outputs and to use the adapted variable as outputs. Unfortunately, this does not preserve the convexity relations that are necessary to apply a traditional DEA model. Another possibility is to apply a monotone linear transformation to the undesirable outputs and to use the adapted variable as outputs (Seiford and Zhu, 2002). Some papers applied a Directional Distance Function (DDF) approach (Fare and Grosskopf, 2004) which allows to explicitly model a joint environmental technology and gauge performance in terms of increased good output and decreased undesirable output. Lozano and Gutiérrez (2010) recently introduced a Slack Based Model (SBM) that consider inputs, outputs, and undesirable outputs.

To the best of our knowledge, only four papers have considered undesirable outputs in airport efficiency analysis using a non–parametric approach. Yu (2004) uses a DDF DEA approach with aircraft traffic movement as desirable output and aircraft noise as undesirable output. The data used correspond to 14 Taiwanese airports described by the following inputs: runway area, terminal area, apron area, number of routes connections with other domestic airports, and city population. It turns out that including undesirables in the efficiency analysis can more reflect efficiency compared to a conventional measure that considers positive outputs only. Yu *et al.* (2008) apply a DDF DEA approach to compute Malmquist-Luenberger Productivity Indexes of a panel data from 4 Taiwanese airports. Desirable output is represented by airport revenues, whereas aircraft noise is the undesirable output. Passengers and aircraft movements are considered non–discretionary inputs, while the other inputs considered are labor costs, capital stock and operating expenditures. Their results show that the annual productivity growth of Taiwans airports is as high as 8.0% between 1995 and 1999 and that traditional productivity analysis may seriously bias such upward growth. Pathomsiri *et al.* (2008) also use DDF to compute Malmquist-Luenberger Productivity Indexes for a panel of 56 US airports considering passenger movements, cargo, and non–delayed flights as desirable outputs and time delays and number of delayed flights as undesirable outputs. Inputs considered are land area, number of runways and total runway area. The results show that if delayed flights are excluded from the model, many large but congested airports are found to be efficient. Lozano and Gutiérrez (2010) propose a slacks–based measure (SBM) approach that assumes variable returns to scale and joint weak disposability of the desirable and undesirable outputs. They analyze the efficiency of 39 Spanish airports for years 2006 and 2007, considering two undesirable outputs, i.e., the percentage of delayed flights, and the average conditional delay of delayed flights. The inputs (i.e., runways area, aircraft parking positions, baggage belts, check–in desks and boarding gates) are considered non–discretionary (i.e., fixed). They find that the inclusion in the analysis of the undesirable outputs leads to more valid results. Moreover, their results show that more than half of the airports are technical efficient.

Summarizing, considering all the previous studies closely connected to this paper, no one present a parametric distance function model; three papers use a DDF approach and one proposes a SBM of efficiency.

4.3 Methodology

4.3.1 Hyperbolic distance functions and environmental efficiency

To define the hyperbolic distance function, we begin by defining a production technology that transforms input vectors $x_i = (x_{1i}, \ldots, x_{Ki}) \in R^K_+$ into output vectors $o_i = (o_{1i}, \ldots, o_{Vi}) \in R^P_+$, consisting of desirable and undesirable output subvectors $y_i = (y_{1i}, \ldots, y_{Mi}) \in R^M_+$ and $w_i = (w_{1i}, \ldots, w_{Ri}) \in R^R_+$, and where the subscript $i = (1, 2, \ldots, N)$ refers to a set of observed airports. The production possibility set representing the technology is $T = \{(x, y, w) : x \in R^K_+, (y, w) \in R^P_+, x \; can \; produce \; (y, w)\}$, which is assumed to satisfy the axioms found in Färe and Primont (1995).

The hyperbolic distance function represents, for a given amount of inputs, the maximum expansion of the desirable output vector and equiproportionate reduction of the undesirable output vector that places a producer on the boundary of the technology T. Following Cuesta *et al.* (2009), we can represent it by the following expression:

$$D_H(x; y; w) = inf\{\theta > 0 : (x; y/\theta; w \times \theta) \in T\}.$$

This function has the virtue of treating desirable and undesirable outputs asymmetrically, thus providing an environmentally friendly characterization of the production technology. The range of the hyperbolic distance function is $0 < D_H(x, y, w) \leq 1$. If the technology satisfies the customary axioms, then the hyperbolic distance function satisfies the property of almost homogeneity (degrees 0, 1, -1, 1):[3]

$$D_H(x, \mu y, \mu^{-1} w) = \mu D_H(x, y, w), \; \mu > 0. \tag{4.1}$$

Furthermore, D_H is also (i) non–decreasing in desirable outputs, (ii) non–increasing in

[3]For more information, see Aczél (1966) and Lau (1972).

undesirable outputs, and (iii) non–increasing in inputs.

Since Eq. (4.1) fully characterizes the technology assuming weak disposability, if $D_H(x, y, w) < 1$, the producer is inefficient and could improve environmental performance by expanding production of marketed outputs and reducing undesirable pollutants.

Another possible representation of technology can be obtained by an enhanced hyperbolic distance function. Unlike its hyperbolic counterparts, the enhanced hyperbolic distance function calls also for further proportional reduction on the input side. The enhanced hyperbolic distance function is defined by

$$D_E(x, y, w) = inf\{\phi > 0 : (x \times \phi; y/\phi; w \times \phi) \in T\}. \tag{4.2}$$

As D_H, D_E assumes values between 0 and 1, and satisfies (i), (ii), (iii) and a more inclusive degree of almost homogeneity:

$$D_E(\mu^{-1}x, \mu v, \mu^{-1}w) = \mu D_E(x, v, w),\ \mu > 0. \tag{4.3}$$

As shown in Cuesta *et al.* (2009) and Cuesta and Zofio (2005) D_H and D_E not only provide a flexible approximation to the unknown production technology, but also prove to be quite amenable to the imposition of almost homogeneity restrictions. The translog specification of a general function $F(x, y, w)$ is

$$\begin{aligned}
lnF = {} & \alpha_0 + \sum_{k=1}^{K} \alpha_k \, ln\, x_{ki} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \alpha_{kl} \, ln\, x_{ki} \, ln\, x_{li} \\
& + \sum_{m=1}^{M} \beta_m \, ln\, y_{mi} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \beta_{mn} \, ln\, y_{mi} \, ln\, y_{ni} \\
& + \sum_{r=1}^{R} \chi_r \, ln\, w_{ri} + \frac{1}{2}\sum_{r=1}^{R}\sum_{s=1}^{R} \chi_{rs} \, ln\, w_{ri} \, ln\, w_{si} \\
& + \frac{1}{2}\sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{mr} \, ln\, x_{ki} \, ln\, y_{mi} + \frac{1}{2}\sum_{k=1}^{K}\sum_{r=1}^{R} \xi_{kr} \, ln\, x_{ki} \, ln\, w_{ri} \\
& + \frac{1}{2}\sum_{m=1}^{M}\sum_{r=1}^{R} \upsilon_{mr} \, ln\, y_{mi} \, ln\, w_{ri} \\
& i = 1, 2, ..., N \;\; t = 1, 2, ..., T,
\end{aligned} \tag{4.4}$$

As explained in Cuesta *et al.* (2009), the necessary $(1 + M + K + R)$ restrictions that ensure almost homogeneity of degrees 0, 1, -1, 1 for D_H are satisfied choosing the Mth desirable output for normalizing purposes and obtaining

$$D_H(x, \frac{y}{y_M}, w \times y_M) = \frac{D_H(x,y,w)}{y_M}.$$

Hence, replacing F in Eq. (4.4) with D_H, we obtain

$$\begin{aligned}
ln(D_{Hi}/y_{Mi}) = {} & \alpha_0 + \sum_{k=1}^{K} \alpha_k \, ln\, x_{ki} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \alpha_{kl} \, ln\, x_{ki} \, ln\, x_{li} \\
& + \sum_{m=1}^{M} \beta_m \, ln\, y^*_{mi} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \beta_{mn} \, ln\, y^*_{mi} \, ln\, y^*_{ni} \\
& + \sum_{r=1}^{R} \chi_r \, ln\, w^*_{ri} + \frac{1}{2} \sum_{r=1}^{R} \sum_{s=1}^{R} \chi_{rs} \, ln\, w^*_{ri} \, ln\, w^*_{si} \\
& + \frac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{mr} \, ln\, x_{ki} \, ln\, y^*_{mi} + \frac{1}{2} \sum_{k=1}^{K} \sum_{r=1}^{R} \xi_{kr} \, ln\, x_{ki} \, ln\, w^*_{ri} \\
& + \frac{1}{2} \sum_{m=1}^{M} \sum_{r=1}^{R} \upsilon_{mr} \, ln\, y^*_{mi} \, ln\, w^*_{ri} \\
& i = 1, 2, ..., N \;\; t = 1, 2, ..., T,
\end{aligned} \tag{4.5}$$

where $y^*_{mi} = y_{mi}/y_{Mi}$ and $w^*_{ri} = w_{ri} \times y_{Mi}$.

Following the same procedure with regard to the almost homogeneity restrictions and specific conditions that must be satisfied in case of enhanced hyperbolic distance functions, we obtain

$$
\begin{aligned}
ln(D_{Ei}/v_{Mi}) = \alpha_0 &+ \sum_{k=1}^{K} \alpha_k \, ln \, x^*_{ki} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \alpha_{kl} \, ln \, x^*_{ki} \, ln \, x^*_{li} \\
&+ \sum_{m=1}^{M} \beta_m \, ln \, v^*_{mi} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \beta_{mn} \, ln \, y^*_{mi} \, ln \, y^*_{ni} \\
&+ \sum_{r=1}^{R} \chi_r \, ln \, w^*_{ri} + \frac{1}{2} \sum_{r=1}^{R} \sum_{s=1}^{R} \chi_{rs} \, ln \, w^*_{ri} \, ln \, w^*_{si} \\
&+ \frac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{mr} \, ln \, x^*_{ki} \, ln \, y^*_{mi} + \frac{1}{2} \sum_{k=1}^{K} \sum_{r=1}^{R} \xi_{kr} \, ln \, x^*_{ki} \, ln \, w^*_{ri} \\
&+ \frac{1}{2} \sum_{m=1}^{M} \sum_{r=1}^{R} \upsilon_{mr} \, ln \, y^*_{mi} \, ln \, w^*_{ri} \\
& i = 1, 2, ..., N \;\; t = 1, 2, ..., T,
\end{aligned}
\tag{4.6}
$$

where $y^*_{mi} = y_{mi}/y_{Mi}$, $w^*_{ri} = w_{ri} \times y_{Mi}$ and $x^*_{ki} = x_{ki} \times y_{Mi}$.

In a stochastic framework one may think of the distance that separates a producer from the production frontier as the combined result of inefficiency and random noise reflecting events beyond producers' control. Enhancing our model to allow for a multi–period framework, Eq. (4.5) becomes $-ln(y_{Mit}) = TL(x_{it}, y^*_{it}, w^*_{it}, \alpha, \beta, \chi, \delta, \xi, \upsilon) - ln(D_{Hit})$, where TL stands for the translog function. Following Coelli and Perelman (2000), the term $-ln(D_{Hit})$ is non–observable and can be interpreted as an error term in the regression model. If we replace it with $(v_{it} - u_{it})$, we get the typical Stochastic Frontier Analysis (SFA) composed error term: v_{it} are random variables that are assumed to be iid as $N(0, \sigma^2_v)$ and independent of the u_{it}; u_{it} are non–negative random variables distributed as $N(m_{it}, \sigma^2_u)$. v_{it} represent the random shocks, while the inefficiency scores are given by u_{it}. Hence, we can now write the translog hyperbolic stochastic distance function that we are going to estimate later:

$$
-ln(y_{Mit}) = TL(x_{it}, y^*_{it}, w^*_{Mit}, \alpha, \beta, \chi, \delta, \xi, \upsilon) - u_{it} + v_{it}. \tag{4.7}
$$

Similarly, the translog enhanced hyperbolic stochastic distance function becomes

$$
-ln(y_{Mit}) = TL(x^*_{it}, y^*_{it}, w^*_{Mit}, \alpha, \beta, \chi, \delta, \xi, \upsilon) - u_{it} + v_{it}. \tag{4.8}
$$

We estimate Eq. (4.7) and Eq. (4.8) using standard maximum–likelihood techniques by Battese and Coelli (1992) to obtain the individual conditional distribution of the one sided errors, $\epsilon(u_{it}, vit)$. In this way, time variant hyperbolic efficiency estimates can be calculated for each airport substituting these values into the following expressions:

$$TE_{it} = e^{-u_{it}}.$$

4.3.2 Local Air Pollution

Local air quality at airports is an increasingly important issue for airports operators, particularly in European Union, where national and international air quality directives and strategies are requiring detailed assessments of impacts. At the local level, airports are working alongside regional partners and stakeholders to assess the contribution of airport emissions on local air quality and developing management strategies and plans. For an individual airport this will require a detailed understanding of emission sources.

Aircrafts are considered to impact local air pollution (LAP) only when operating inside the Landing Take–Off (LTO) cycle. LTO cycle, following ICAO standards, is divided in four stages: take–off, climb (up to 3,000 ft), approach (from 3,000 ft to landing), and idle (when the aircraft is taxiing or standing on the ground with engines–on).[4]

In this work, emissions of each aircraft type are computed on the basis of the emission factors for the aircrafts specific engines and the time spent in each phase of the LTO cycle. To this purpose, we decided to quantify the impacts of air operations through the values of aircraft certification, established in accordance with the criteria set out on the basis of Annex 16 of the ICAO Convention (Volume 2), dealing with the protection of the environment from the effect of aircraft engine emissions.

The study considers the operations of aircraft with a maximum take–off weight (MTOW) greater than 5,700 kg with turbine engines, i.e., turboprop and turbojet. Therefore, aircrafts with internal combustion piston engine (necessarily helical), used only in the light aviation, are ignored.

In order to compute the emissions produced by each airport in our data set we matched five databases: the OAG, the EASA, the IRCA, the FOI and the ICAO Engine Emissions Databank databases.[5] The first one allows us to compute the number of landing and

[4]The 3,000 ft (approximately 915 m) boundary is the standard set by the ICAO for the average height of the mixing zone, the layer of the earth atmosphere where chemical reactions of pollutants can ultimately affect ground level pollutant concentrations (US Environmental Protection Agency, 1999).

[5]OAG is the database provided by Official Airlines Guide; IRCA is the International Register of Civil

take–off operations for the different model of aircraft in each Italian airport. The second and the third ones allow us to link each model of aircraft both to its engine type and to the number of engines installed.[6] By the fourth and the fifth database, we can determine the emissions of each engine model. ICAO and FOI provide the Emission Factor (i.e., the quantity in grams emitted per kilogram of fuel consumed) for the four phases and for each engine model. The pollutant analyzed in this study are: hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x).[7]

In order to compute the total emissions for the LTO cycle (Q_{ip}) for the engine i and the pollutant p, we sum the specific engine emission factor (E_{ipf}) of pollutant p (kg) for each phase f multiplied by the duration of the phase (d_f) and by the indicated specific engine fuel consumption (F_{fi}) in kg/sec.

$$Q_{ip} = \sum_{f=1}^{4} E_{ipf} \times d_f \times F_{fi}$$

Since the calculated emissions refer to the single engine, we had to match each aircraft with its engine (considering the number of engines) in order to get aircrafts emissions (HC, CO, NO_x) for the LTO cycle. The sum of the emissions (kg) produced by each aircraft in a particular airport (from OAG) gives the total amount of HC, CO and NO_x produced by the airport. Table 4.1 shows the total kilograms per pollutant for each airport in the period 2005–2008.[8]

To aggregate these data into a single index, representig the LAP produced by each airport, we consider the cost of damage they impose. Such estimates are provided by Dings *et al.* (2003) and are applied to the emission levels computed to each airport. The index Weighted Local Pollution (WLP) is obtained as the sum of kg produced of each pollutant

Aircraft for engines; EASA is the European Aviation Safety Agency, FAA is the Federal Aviation Administration for engines noise certification; ICAO Engine Emission Databank is provided by the International Civil Aviation Organization and FOI Database (for engines pollutant emissions) is provided by the Swedish Defence Research Agency.

[6]The matching is realized on the basis of both the aircraft model and the MTOW. In case of not identical weight, we estimate the level of emissions considering only the combinations between the OAG data and the EASA with similar MTOW, i.e., with differences lower than $\pm 3\%$.

[7]Notice that also SO_2 emission and Particulate Matter (PM) emission are contributors to LAP (US Environmental Protection Agency, 1999), but they are (still) not part of the engine certification process. Emission of these pollutants is directly related to fuel consumption and therefore can be incorporated in the analysis. However, results of previous studies (Givoni and Rietveld, 2005, and Dings *et al.*, 2003) show that the cost of LAP from aircraft operation during the LTO cycle strictly depends on the volume of NO_x emission.

[8]Notice that non–aircraft emissions from airport and airport–related activities such as fleet vehicles and ground access vehicles are not considered in this contribution.

Table 4.1: Average yearly values of pollutants produced by airport (kg)

Airport	HC	CO	NO_x	Airport	HC	CO	NO_x
AHO	3,892	45,247	55,139	OLB	6,798	62,401	74,743
AOI	877	11,949	14,095	PMF	441	4,888	5,875
BDS	3,327	34,453	43,561	PMO	15,467	164,305	197,459
BGY	15,959	165,091	232,956	PNL	210	5,712	5,567
BLQ	18,948	183,283	165,914	PSA	10,288	112,269	132,920
BRI	8,975	96,925	101,426	PSR	1,701	16,858	16,114
CAG	9,770	96,469	120,726	REG	2,303	22,596	27,539
CIA	13,169	131,270	187,176	RMI	523	5,738	5,884
CTA	18,223	192,436	240,694	SUF	4,482	46,064	55,574
FCO	145,583	1,350,748	1,844,126	TPS	1,321	18,656	20,079
FLR	13,325	109,064	79,231	TRN	16,921	175,923	165,520
FRL	1,787	18,643	29,117	TRS	2,338	26,957	32,209
GOA	3,831	49,672	53,733	TSF	3,967	38,467	58,366
LIN	36,867	385,550	498,737	VBS	4,612	24,336	22,541
LMP	293	5,833	5,897	VCE	33,009	314,971	311,884
MXP	112,569	944,858	1,250,709	VRN	10,426	100,409	94,540
NAP	21,141	223,346	229,965				

weighted for the relative cost of damage.[9]

$$WLP = \sum_p q_p \times c_p$$

Table 4.2 shows the value of the WLP index divided by the number of movements for each airport of our dataset (for the year 2008). The different values show clearly that the different fleet characterizing airports have a significant impact on the LAP produced. For example, in Brescia airports a lot of flights have been done by MD–80, an old and very polluting aircraft introduced into commercial service in 1980, while in Ancona by ATR 42, a twin–turboprop that is much more environmentally friendly than the MD–80: as a result, Brescia airport presents a WLP per movement equal to 79.72 and Ancona airports equal to 16.69.

4.4 Results

In this section, we present and discuss the results of the application of the proposed model to 33 Italian airports for the period 2005–2008.

The inputs considered are related to the existing infrastructure at the airports, namely runway capacity (CAP)[10], number of aircraft parking positions ($PARK$), terminal area

[9]The cost of LAP from the operation of different aircraft is based on Dings *et al.* (2003) and it is equal to 4 Euro/kg for HC and 9 Euro/kg for NO_x. Carbon monoxide (CO) emissions from aircraft operation do not appear to result in substantial health effects and therefore a cost estimate for emission of this gas is assumed equal to 0 Euro/kg (Dings *et al.*, 2003; Givoni and Rietveld, 2010).

[10]This variable takes into account both the runway length and the airport's aviation technology level—e.g., some aviation infrastructure such as ground–control radars and runway lighting systems.

Table 4.2: WLP on aircraft movements by airport (year 2008).

Airport	WLP/Movements	Airport	WLP/Movements
Alghero	49.27	Olbia	45.31
Ancona	16.49	Palermo	43.74
Bari	41.61	Pantelleria	18.01
Bergamo	52.13	Parma	34.41
Bologna	33.49	Pescara	27.60
Brescia	79.72	Pisa	42.36
Brindisi	43.02	Reggio C.	40.03
Cagliari	42.35	Rimini	36.75
Catania	46.32	Rome Ciampino	50.91
Florence	27.09	Rome Fiumicino	57.20
Forlì	51.95	Turin	34.02
Genoa	31.25	Trapani	32.49
Lamezia	47.00	Treviso	52.69
Lampedusa	24.38	Trieste	25.13
Milan Linate	49.25	Venice	42.50
Milan Malpensa	55.00	Verona	36.32
Naples	39.38		

($TERM$) and number of check–in desks ($CHECK$). Furthermore, we have included in the production function also the number of employees measured in terms of Full–Time Equivalent units (FTE). These inputs have been obtained by direct investigation.

The desirable outputs considered include annual passenger movements (APM), available on the website of the Italian authority Ente Nazionale Aviazione Civile (ENAC), and annual aircraft traffic movements (ATM) obtained by the OAG database.

The undesirable output included is the WLP index presented in section 4.3.[11]

The descriptive statistics regarding outputs and inputs are presented in Table 4.3.

Table 4.3: Descriptive Statistics of Inputs (I), Desirable (D) and Undesirable (U) Outputs

	Average	Median	Std. Dev.	Max	Min
ATM (D)	38,782	16,932	62,876	337,986	434
WLU (D)	4,136,556	1,732,196	6,949,506	36,758,411	69,059
WLAP(U)	1,805,864	667,303	3,451,583	19,333,542	22,675
TERM (I)	38,102	13,505	73,578	350,000	256
CHECK (I)	42	19	65	358	3
FTE (I)	237	110	408	2,186	2
CAP (I)	19	15	18	90	2
PARK (I)	26	18	26	142	2

In order to show the differences of the inefficiency scores obtained taking into account undesirable outputs, we run three different multi–output stochastic distance functions: (i) an output distance function D_O (Equation (4.9)) including only desirable outputs, (ii) a hyperbolic distance function D_H (Equation (4.10)), and (iii) an enhanced hyperbolic

[11]Notice that we check the validity of the chosen inputs and outputs by testing for their isotonicity—i.e., outputs should be significantly and positively correlated with inputs (Charnes *et al.*, 1985). Pearson correlation coefficients between all the inputs and the outputs is significant (at a 1% level) and positive. Moreover, the input correlation is positive, significant, and very high, as a confirmation that in managing airports, inputs are jointly dimensioned to avoid bottlenecks (Lozano and Gutiérrez, 2009).

distance function D_E (Equation (4.11)). Both D_H and D_E include WLP as undesirable output.

$$\begin{aligned}-ln(ATM_{it}) = TL(&WLU_{it}/ATM_{it}, TERM_{it}, CHECK_{it},\\ &FTE_{it},\ CAP_{it},\ PARK_{it}, \alpha, \beta, \chi, \delta, \upsilon)\\ &+\lambda_1 HUB + v_{it} - u_{it},\end{aligned} \tag{4.9}$$

$$\begin{aligned}-ln(ATM_{it}) = TL(&WLU_{it}/ATM_{it}, WLP_{it} \times ATM_{it}, TERM_{it}, CHECK_{it},\\ &FTE_{it},\ CAP_{it},\ PARK_{it}, \alpha, \beta, \chi, \delta, \upsilon)\\ &+\lambda_1 HUB + v_{it} - u_{it},\end{aligned} \tag{4.10}$$

$$\begin{aligned}-ln(ATM_{it}) = TL(&WLU_{it}/ATM_{it}, WLP_{it} \times ATM_{it}, TERM_{it} \times ATM_{it},\\ &CHECK_{it} \times ATM_{it}, FTE_{it} \times ATM_{it},\ CAP_{it} \times ATM_{it},\\ &PARK_{it} \times ATM_{it}, \alpha, \beta, \chi, \delta, \upsilon) + \lambda_1 HUB + v_{it} - u_{it},\end{aligned} \tag{4.11}$$

where ATM_{it} is the normalizing output and HUB is a dummy variable equal to 1 if the airport is an hub: in fact airports with hub and spoke system employ different technologies (e.g., different BHS). In this sense, HUB could be considered as a variable that is not an input, but that, in a certain sense, exert an influence on the production function.

Prior to estimation, all the output and input variables have been divided by their respective geometric means. Consequently, the first–order coefficients of the estimated production functions can be regarded as (partial) distance elasticities when evaluated at the variable means of the empirical sample.

Table 4.4 presents the obtained maximum likelihood estimates of the alternative stochastic models (4.9),(4.10) and(4.11).

These MLE parameters for the output, hyperbolic and enhanced hyperbolic distance functions' specifications, and their associated standard errors allow us to determine (i) the effect that the undesirable output and the inputs have on the distance functions, and (ii) whether the magnitude corresponding to each direct partial elasticity is statistically significant or not.

Table 4.4: Estimation results

	Model 1: D_O		Model 2: D_H		Model 3: D_E	
Variable	Coefficient	Std.Error	Coefficient	Std.Error	Coefficient	Std.Error
$Cost.$	0.787 (***)	0.107	0.120 (***)	0.019	0.060 (***)	0.016
WLU	0.565 (***)	0.165	0.312 (***)	0.040	0.276 (***)	0.027
$WLAP$	-	-	-0.464 (***)	0.009	-0.397 (***)	0.015
$TERM$	0.122	0.090	-0.060 (***)	0.017	-0.025 (*)	0.013
$CHECK$	-0.149 (*)	0.084	-0.061 (**)	0.024	-0.058 (***)	0.018
FTE	-0.504 (***)	0.079	-0.021	0.017	-0.005	0.014
CAP	-0.384 (**)	0.167	0.112 (***)	0.033	-0.020	0.023
$PARK$	-0.064	0.092	0.025	0.027	-0.019	0.022
$WLU \times WLU$	0.388 (**)	0.186	-0.037	0.065	-0.035	0.038
$WLU \times WLAP$	-	-	-0.060 (***)	0.017	0.004	0.023
$WLU \times TERM$	-0.136	0.125	-0.002	0.044	-0.068 (**)	0.029
$WLU \times CHECK$	0.045	0.199	0.090	0.056	0.079 (**)	0.040
$WLU \times FTE$	0.106	0.089	0.065 (**)	0.031	0.038 (*)	0.022
$WLU \times CAP$	0.377	0.311	0.001	0.073	-0.003	0.058
$WLU \times PARK$	-0.709 (***)	0.202	-0.151 (**)	0.059	-0.094 (**)	0.044
$WLAP \times WLAP$	-	-	-0.048 (***)	0.008	0.015	0.031
$WLAP \times TERM$	-	-	0.053 (***)	0.015	0.036	0.026
$WLAP \times CHECK$	-	-	0.007	0.022	0.001	0.035
$WLAP \times FTE$	-	-	0.019 (.*)	0.010	-0.027 (*)	0.016
$WLAP \times CAP$	-	-	-0.060 (***)	0.023	0.020	0.037
$WLAP \times PARK$	-	-	0.012	0.021	-0.108 (***)	0.036
$TERM \times TERM$	0.361 (**)	0.154	-0.110 (***)	0.037	-0.027	0.032
$TERM \times CHECK$	0.080	0.181	-0.007	0.045	0.024	0.039
$TERM \times FTE$	0.050	0.088	0.064 (**)	0.031	0.089 (***)	0.024
$TERM \times CAP$	-0.437 (**)	0.181	-0.065	0.047	-0.110 (***)	0.038
$TERM \times PARK$	0.310 (**)	0.156	-0.043	0.041	-0.024	0.038
$CHECK \times ba$	-0.416	0.544	0.012	0.121	-0.089	0.100
$CHECK \times fte$	0.234 (**)	0.107	0.045	0.042	0.025	0.033
$CHECK \times CAP$	0.172	0.334	-0.113	0.073	-0.031	0.060
$CHECK \times PARK$	-0.363	0.222	0.086	0.073	0.093	0.059
$FTE \times FTE$	-0.126	0.084	-0.093 (***)	0.024	-0.108 (***)	0.019
$FTE \times CAP$	0.039	0.196	0.103 (***)	0.037	0.033	0.031
$FTE \times PARK$	-0.221	0.169	-0.105 (**)	0.050	0.036	0.037
$CAP \times CAP$	-0.524	0.475	0.220 (**)	0.098	0.079	0.071
$CAP \times PARK$	0.694 (**)	0.286	0.047	0.074	0.002	0.057
$PARK \times PARK$	-0.153	0.222	0.088	0.059	0.040	0.049
hub	-2.345 (***)	0.556	0.068	0.084	-0.046	0.067
σ^2	1.112 (***)	0.364	0.009 (***)	0.003	0.004 (***)	0.002
γ	0.992 (***)	0.003	0.907 (***)	0.039	0.856 (***)	0.068
$time$	-0.031 (***)	0.010	0.069 (**)	0.031	0.075	0.045
$logl$	45.89		237.20		265.17	

Note that *,**,*** denote significance at 10%, 5% and 1% respectively.

As far as the positive output is concerned, in all the models it presents the expected positive sign. This indicates that any increase in the amount of WLU produced *ceteris paribus* would mean a smaller distance to the frontier. Hence the estimated translog D_O, D_H and D_E meet the monotonicity condition of being non–decreasing in desirable outputs (at the sample mean). From Table 4.4, it can be seen that the relative sizes of the output elasticities (respectively +0.56, +0.31 and +0.28) show WLU to be considerably relevant in airport production process.

The estimated undesirable output coefficient, which is significantly different from zero both for D_H and D_E, also has the expected negative sign. This finding indicates that the estimated translog functions are non–increasing in the WLP at the sample mean, as required by the already mentioned monotonicity condition. When compared to the sizes of the input elasticity values, the WLP elasticity values (respectively -0,46 and -0,39) are considerably higher indicating that pollution has relatively more importance in the distance function characterization.

Concerning the inputs, first–order coefficients indicate the magnitude of the respective partial input elasticities at the sample mean. Table 4.4 shows that all the significant coefficient have the expected negative sign with the exception of the variable CAP in the second model. The negative signs found are expected as any increase in the amount of inputs used *ceteris paribus* would mean a greater distance to the frontier. Thus the finding indicates that the estimated translog D_O, D_H (with one exception) and D_E satisfy the monotonicity property of being non–increasing in inputs (at the geometric mean of the data). Moreover, in case of non–significance of the first–order coefficient, in all the model either second–order coefficients or interactions terms result significant. This is a further confirmation of the relevance, for airport production process of the variables chosen for this analysis.

The likelihood function is expressed in terms of the variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. Table 4.4 also shows that the variance parameters are statistically significant at the 1% level, with the estimated γ equal respectively to 0.99, 0.91 and 0.86. Hence, a relevant part of the distance between the observed output levels and the maximum feasible ones is due to technical inefficiency in all the three specifications.

Table (4.5) puts in comparison the average efficiency scores of the three models described by equations (4.9), (4.10) and (4.11). As you can see, the average efficiency increases introducing local air pollution (i.e., the undesirable output) in airport production function and the differences among airports become thinner in terms of efficiency scores. This result is interesting because, on the one hand, it could be surprising that most of airports are highly efficient in model (ii) and (iii). However, also Lozano and Gutiérrez (2010) found similar results (applying a non–parametric technique and considering congestion as undesirable). Notice that an efficient airport is one that, with its current inputs utilization, carries out as many aircraft and passenger movements as possible at the same time that pollution and noise are minimized as much as possible. Airport inefficiency can, thus, come from two main sources: low utilization (much less traffic than the nominal capacity) or high production of undesirable outputs. In this sense, it is undeniable that airports with more passengers and flights also produce more pollutants. Similarly, inefficient airports (in terms of passengers and flights) close the gap because their low volumes of output mean that the negative externalities produced are lower.

This could partially explain the flattening of the differences in the efficiency scores observed in the second and the third models, but it is not the unique explanation of our results. Since the level of pollution produced depend on the model of engine and aircraft used, another explanatory factor is the fleet mix used at the airport. This means that airports' managements could promote carriers to use modern fleets, improving in this way their efficiency score, especially since the airlines fleet renewal already take into account the need for lower emission levels. In this sense, the real question becomes what power airports actually have to incentive these renewals. Increasing airport charges could be a solution as long as this does not compromise the presence of some airlines that may choose an alternative airport nearby. The same could be said for the introduction of systems of penalties in order to encourage much stricter compliance with regulations by airlines. Another solution could be the introduction of a regulation providing incentives for airlines to improve their fleets in terms of emissions production or rewarding for airports environmentally efficient. These premiums could then be shared between airlines and airports in case of close cooperation aimed at reducing the environmental impacts of the airport activities.

Furthermore, we have grouped the airports in 4 categories based on the average annual number of aircraft movements: the first category includes airports with less than 10,000 movements per year; at the second one belong airports whose annual movements are between 10,000 and 40,000; airports in the third category present movements higher than 40,000 but lower than 80,000; airports with annual movements over 80,000 belong to the fourth category. According to our results, airports in the first group show the lowest efficiency improvement (equal to 90%) in the transition from model D_O to D_H. On the contrary, those that show the highest increase in terms of efficiency scores are medium–large airports, namely those belonging to group 3 (+244% on average). This result may suggest that, on average, this kind of airports has a better ratio between good outputs and bad outputs.

However, we would like to highlight, as already shown in previous contributions and with different methodologies, that not taking into account the undesirable outputs (when these exist) can give misleading efficiency assessments.

4.5 Conclusion

In this paper, a hyperbolic distance function model, both parametric and stochastic, has been applied for airport efficiency assessment considering undesirable outputs. Using

Table 4.5: Technical efficiency scores by model

Airport	D_O	D_H	D_E	Airport	D_O	D_H	D_E
AHO	0.490	0.977	0.970	OLB	0.953	0.984	0.989
AOI	0.390	0.855	0.915	PMO	0.355	0.950	0.977
BRI	0.182	0.979	0.981	PNL	0.385	0.921	0.848
BGY	0.271	0.948	0.973	PMF	0.934	0.861	0.875
BLQ	0.355	0.850	0.885	PSR	0.780	0.898	0.962
VBS	0.512	0.990	0.993	PSA	0.267	0.891	0.907
BDS	0.351	0.980	0.966	REG	0.752	0.988	0.994
CAG	0.235	0.969	0.934	RMI	0.942	0.836	0.967
CTA	0.176	0.972	0.972	CIA	0.233	0.919	0.947
FLR	0.376	0.872	0.910	FCO	0.898	0.968	0.980
FRL	0.345	0.933	0.906	TRN	0.309	0.947	0.979
GOA	0.587	0.866	0.936	TPS	0.240	0.975	0.964
SUF	0.779	0.769	0.937	TSF	0.554	0.935	0.968
LMP	0.922	0.975	0.976	TRS	0.284	0.976	0.983
LIN	0.272	0.983	0.986	VCE	0.196	0.938	0.950
MXP	0.612	0.979	0.983	VRN	0.707	0.862	0.888
NAP	0.415	0.893	0.969	**Mean**	**0.487**	**0.928**	**0.951**

information on the produced local air pollution, the approach has been applied to a panel data of 33 Italian airports for the period 2005–2008.

In order to include the negative externalities connected to local air pollution, we created an index describing the total amounts of pollutants produced for each Italian airport included in our data set. Each pollutant has been weighted for the cost of damage it imposes. To the best of our knowledge, this is the first attempt to consider local air pollution as a bad outputs in airport efficiency assessment. Furthermore, it is also the first attempt to measure airport environmental efficiency using a multi–output stochastic frontier analysis.

The results show that the efficiency assessment of the airports when their undesirable outputs are ignored is totally different and can therefore be misleading. Specifically, the results indicate that airports tend to be more efficient, on average, when negative externalities production is included in the analysis. Furthermore, this contribution provides a first clue about the importance of a characteristic of airports not much considered in the literature so far: the operating fleet. Given the importance that takes the fleet for environmental efficiency, it would be interesting to deepen its impact, such as creating some variables able to describe the fleet in terms of environmental impact and including these in a model as explanatory variables of the obtained efficiency scores.

About further possible continuations of this research, one is, of course, the inclusion of noise in the production function to obtain a more complete environmental efficiency assessment. However, noise is difficult to treat because of both (i) its non–linear characteristic and (ii) the subjectivity characterizing the noise annoyance.

Another interesting development of this work could be a comparison between parametric and non–parametric technique (e.g., Directional Distance Function DEA model or DEA slack based model). Furthermore, it could be interesting enlarging the data set with observations from other airports outside Italy so that a more ambitious benchmarking could be carried out.

All these issues are left for future research.

4.6 References

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CHAPTER 5

Conclusion

Over recent years the topic of airport performance has gained increasing attention from researchers, since the liberalization has brought a strong growth of demand in aviation markets and this in turn has determined an increase in competition between both airlines and airports.

Performance evaluation and improvement studies of airport operations have important implications for a number of airport stakeholders: (i) for airlines in identifying and selecting the more efficient airports at which to base their operations, (ii) for municipalities because of the benefits coming from efficient airports in terms of attracting business and passengers, (iii) for policy makers in making effective decisions on optimal allocation of resources to airport improvement programs, and in evaluating the efficacy of such programs on the bottom line of airports' efficiency. Finally, benchmarking their own airports against comparable airports is one way for operations managers to ensure competitiveness.

The research carried out in this thesis contributes to the literature about airport efficiency by (i) investigating the determinants of efficiency and (ii) by considering undesirable externalities produced by airports in the production function. The dissertation includes an introduction (Chapter 1) and three essays (chapters 2, 3 and 4).

The Introduction gives a brief overview of the topic of airport efficiency, highlighting the main characteristics of previous studies in terms of (i) the applied estimation method, (ii) the choice of output and input variables, and (iii) the geographical scope of the analysis.

The first paper analyzes the air transportation vertical channel and shows the existence of an asymmetric distribution of profit margins between airlines and the firms operating in upstream stages. Higher margins are observed for leasing companies, engine manufacturers and GDSs, while airlines exhibit a very low profitability. Two factors may explain this asymmetry: (i) in some stages of the value chain some firms (e.g., airlines and handling companies) have a low countervailing power both when acting as a buyer and as a seller, and (ii) the liberalization policy implemented in the air transport sector so far is incomplete. The latter has increased the intensity of competition in some stages (e.g., airlines and handling companies), but has not faced and reduced the market power in other ones.

Some policy implications are drawn from this analysis. First, horizontal mergers between airlines should be positively evaluated by competition authorities, since they increase the airlines countervailing power in the vertical channel and this may, in turn, bring about a price reduction for consumers. Second, the degree of vertical integration in some stages should be reduced, because it is likely to be an instrument for increasing the market power in upstream stages and not to reach a higher efficiency.

The second contribution investigates how the intensity of competition among airports affects their technical efficiency by computing airports' markets on the basis of a potential demand approach. Airport technical efficiency is estimated by a multi–output stochastic frontier. The main findings are that the intensity of competition has a negative impact on airports' efficiency in Italy during the 2005–2008 period. This implies that airports belonging to a local air transportation system where competition is strong exploit their inputs less intensively than do airports with local monopoly power. As a consequence, policy makers should provide incentives to implement airports' specialization in local systems where competition is strong.

Furthermore, we find that public airports are more efficient than private and mixed ones: this can be explained by some reasons. First, investments in indivisible inputs may have been greater in private airports and, given the difficulties involved in reaching in the shortrun the volume of traffic required for an efficient utilization of the indivisible input, private airports have lower technical efficiency than the other airports types. In this sense, regulation should monitor the efficient assets utilization especially after that new investments have been implemented. Many assets suffer from indivisibility in the short-run and our analysis has proved that their utilization could be inefficient also in presence of private investors.

However a second explanation for these results could be considered. Since private airport maximize profit, they could pay more attention to cost efficiency and commercial revenues: in this sense, they may not be willing to increase traffic, in order to achieve an efficient assets utilization, especially when reaching this target implies adopting unprofitable strategies. On the contrary, public airports, mainly controlled by local municipalities, aims to develop airports' connections as much as possible in order to foster local economy: this explains the reason why some public airports subsidize airlines even if they are at a loss.

In the third paper technical efficiency of 36 Italian airports for the period 2005–2008 is estimated. In addition to the conventional outputs (aircraft and passenger movements), an airport byproduct has been considered: local air pollution. It is applied a hyperbolic distance function that is both parametric and stochastic. Such approach allows to treat the outputs' vector asymmetrically by allowing equiproportional desirable outputs expansion and undesirable outputs contraction. Efficiency scores are obtained by maximum likelihood estimation. The results show that the efficiency assessment of the airports when their undesirable outputs are ignored is totally different and can therefore be misleading. Specifically, the results indicate that (i) the average efficiency increases introducing an undesirable output in airport production function and (ii) the differences among airports become thinner in terms of efficiency scores.

This can be due to the fact that *ceteris paribus* airports with more passengers and flights also produce more pollutants and so inefficient airports (in terms of passengers and flights) close the gap because their lower volumes of pollution. However, since pollution produced depend on the model of engine and aircraft used, airports' managements have a potential lever for increasing their technical efficiency: promoting carriers to use modern fleets.