Final Report of the

CARE Innovative Action Project

STUDY OF THE IMPACT OF INNOVATIVE ROUTE CHARGE SCHEMES CONSIDERING ATC AND AIRLINES NEW PERSPECTIVES

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Executive Summary

This proposed preliminary study aims at identifying the basic steps of a possible further and longer project to be performed subsequently, in strict collaboration with EUROCONTROL. The final purpose of the overall project is to define and study the impact of alternative route charge pricing schemes that might include a factor related to the level of service supplied by the ATC providers, with the objective of increasing their performance as well as airline efficiency, and stimulating a more efficient use of ATC capacity. Accordingly, the main target of this preliminary study is to identify a general framework that will subsequently allow for evaluating different scenarios and different alternatives. To this aim, the investigation and definition of feasible methodologies and proper techniques can be considered as the expected results of this project.

In this context, our study moves in two directions, relative respectively to the "demand side" and the "supply side" of the air navigation services. On the "demand side" we define general methodologies to assess the indirect impact on air travel demand and the direct impact on ATC service demand of the route charges. On the "supply side" we investigate the application of economic methodologies to promote status and ways of operation positively affecting the behaviour of the system, both from the point of view of ATS suppliers and of the customers. In this framework, the project considers three main lines:

Air travel demand: An econometric model for air travel demand is produced together with a detailed analysis of the involved factors. The model is applied to some historical data from a regional carrier (Air Dolomiti) and shows a good performance in terms of explanatory power, with respect to results available in the literature. Accordingly, elasticity values are derived and discussed for the considered data. These results suggest to extend the use of the proposed model to other airlines, with different characteristics.

ATC service demand: We propose an indirect approach to assess the different impact of variations of the route charges on airspace users. The basic idea is to consider route charges as a cost for airlines, and to study how a change in cost factors can affect carrier behaviours, and, as a consequence, the demand for ATC services. For this purpose, econometric and time series based techniques are individuated. As a first step of this analysis airspace users are classified in different categories, for which different mechanisms can be expected. Then an ABC analysis is performed in order to concentrate on airlines providing a major part of revenues from route charges. Then, a first version of total route costs shares assessment among the different categories individuated is provided for years 1999 and 2000.

Supply side of ATC services: An extensive review of several forms of incentive regulation is carried out. As they normally rely upon the evaluated performance of the considered units, some performance evaluation techniques are suggested, such as Data Envelopment Analysis. Then the problem of assessing the performance in the management of a single flight is considered, as a possible basis upon which to analyse airline attitudes and behaviour. Finally, the specific question of equity is addressed, in view of devising new schemes for ATC complying with such a requirement. A possible approach to model equity is also outlined.

Finally, a concise scheme of the directions and the guidelines for a possible further and longer project to be subsequently performed is presented.

Chapter 1

Introduction

Following the liberalization of the European airline market, the number of airspace users involved in the ATC system is increasing year by year and their behaviours and needs are continuously evolving. In a parallel process, there is a trend towards the corporatization of the Authorities providing the ATC services (ANSPs), which remain statutory monopolies. Demand for air traffic control has continuously increased in the last years (5-6% annual traffic growth on average) and a larger number of flights have to be controlled by ATC centres even if considering the recent downturn in traffic following the economic growth evolution and the situation caused by 11 September 2001 attacks (see [29]). The current mismatch between demand and capacity results in a large amount of delays for airlines, and, therefore, in a poor quality of service.

1.1 Aim of the preliminary study

This proposed preliminary study aims at identifying the basic steps of a possible further and longer project to be performed subsequently, in strict collaboration with EUROCONTROL. The final purpose of the overall project is to define and study the impact of alternative route charge pricing schemes that might include a factor related to the level of service supplied by the ATC providers, with the objective of increasing their performance as well as airline efficiency, and stimulating a more efficient use of ATC capacity. Accordingly, the main target of this preliminary study is to identify a general framework that will subsequently allow for evaluating different scenarios and different alternatives.

1.2 Motivations

At present time, the costs incurred by states to provide en-route services and the costs incurred by EUROCONTROL are recovered through route charges levied for each flight performed under Instrumental Flight Rules in the Flight Information Regions falling within the competence of the Member States. The formula adopted for the total charge per flight (*R*) collected by EUROCONTROL is:

$$R = \sum_n r_i$$

where r_i is the charge generated in the FIRs of State *i*, and is calculated as:

$$r_i = d_i \times \sqrt{\frac{MTOW}{50}} \times t_i$$

where d_i is the great circle distance flown, expressed in hundreds of kilometres, *MTOW* is the Maximum Take Off Weight, expressed in metric tons, and t_i is the unit rate, whose value is set at the appropriate level to recover the costs incurred by State i to provide en-route services and a proportional part of the costs incurred by EUROCONTROL for the collection of charges (see [20]). Each State may also levy route charges on any flight conduced in accordance with Visual Flight Rules. The same unit rate may, where appropriate, be applicable both to VFR and IFR flights.

In this framework, airspace users have no economic alternative to using those services ([26]). Moreover, no direct link exists between the level of service provided to flights (in terms of imposed delay or deviations from the optimal route chosen) and route charges to be paid by carriers. This situation provides to airlines little incentives to manage their operations in a way to allow the best use of the system capacity. On the other hand, the charging system based on a full cost recovery mechanism does not seem to give the necessary signals for ATC providers to supply the optimal amount of capacity at the right time and at the right location.

Hence the investigation of innovative route charge pricing schemes considering the level of service supplied by the ATC providers becomes a necessary task. To this aim, there is a need to carefully understand airline and passenger behaviours with respect to the current ATC charging mechanism, and to assess its impact on the level of demand (airline demand for aircraft movements and final passenger demand) given the new competitive market conditions. Since airspace users have different characteristics in terms of, e.g., fleet, size, passenger types, network structure, degree of competitive environment, and business strategy, the impact of ATC charges might be quite different for each category of users. Military users might also have different characteristics. Passengers (and shippers), that represent the final demand for air transportation, might also have different reactions to changes in airfare levels, for instance according to their travel purpose (business or leisure travellers). As a consequence, ATC providers face a broad range of different needs and complex requirements.

1.3 Structure of the work

In the current analysis, the different actors involved in the complex system of Air Traffic Management have been grouped in two parts:

- the "demand side" that refers to the direct and indirect users of air navigation services, i.e. airlines and passengers (or shippers);
- the "supply side" that refers to the suppliers of ANS, i.e., ATC units and EUROCONTROL.

For the "demand side", our purpose is to define general methodologies and models to:

- assess the different *direct* impact of the route charges on the different airspace users, by characterizing the main categories of such users and model their behaviour induced by a variation in route charges;
- evaluate the different *indirect* impact of route charges on the final passenger (or shipper) demand, by assessing the price elasticity of demand for air transportation for the different groups of airspace users.

For the "supply side", our objective is to investigate the application of economic measures to promote status and ways of operation positively affecting the behaviour of the system, both from the point of view of ATS suppliers and of the customers. In such sense, our study will follow two directions:

- *Incentives for ANS providers*: investigation on the applicability of performance based regulation techniques for the ATC centres, starting from the analysis of their use in different economic systems (e.g. utilities). Accordingly, performance analysis and benchmarking techniques applicable in this context, will be studied, with particular emphasis to potentials of Data Envelopment Analysis.
- *Incentives for airspace users*: investigation on the demand management techniques and tools. This includes defining methodologies to study decision preferences and mechanisms of the different types of carriers, by utilization of flight performance metrics. Relying on these data, economic incentive schemes for airspace users to reduce airspace congestion and to smooth demand for ATC services will be studied.

Chapter 2

Price elasticity of demand for passenger air transportation

The heterogeneous market of air transportation involves, as customers of air traffic services, several types of users, with very different behaviours and characteristics (see, e.g., [29], [36] and [34]). In the context of air traffic management, a policy that involves a change in prices for air traffic services might have different effects for the different airspace users. In particular, different core business and different markets make air carriers more or less sensitive to a change in prices for ATS. For example, if we put a price on an externality to reduce its negative effect (e.g. a «peak factor» in the route charges formula), but the passengers would not be very sensitive to changes in fares, this policy will probably have little effect: the airlines simply pass the surplus charge to the passengers. Conversely, if the final customers of an airline are very sensitive to changes in fares, the pricing policy may yield its effect. Therefore, the price sensitivity of passengers for the various kinds of airlines is a key factor in order to estimate the effects of a price policy.

Airfare elasticity of passengers varies essentially because they fly for different reasons; a broad distinction is generally made between business travellers and leisure travellers. Leisure travellers aim to maximize the utility derived from air travel and from the associated holiday experiences, subject to a given budget constraint. Business travellers use air travel as an input to final production and are generally interested in minimizing their expenditures for achieving a given level of output (see [38]). In general, demand for business travel tends to be less sensitive to changes in airfare than demand for leisure travel (see [9]).

In this chapter, we propose a statistical methodology to investigate the airfare elasticity of air travel demand for an airline. Evaluating the price elasticity of transportation demand for a single airline gives important information both on characteristics of its passengers and on its possible strategies following a variation in route charges. After a detailed analysis of factors affecting demand for air transportation, we perform a case-study to assess elasticity of passenger air travel demand for a regional carrier (Air Dolomiti) which supported us in this preliminary study. For sake of clarity and to share a common notation, the main statistical concepts used here are briefly introduced in Appendix A.

2.1 Methodological approach

In the aviation industry various methods are used for representing and studying the air travel demand, ranging from time series techniques to econometric modelling. In particular, time series approaches are commonly used to forecast the traffic demand (see [1]). Unfortunately, this approach is not useful for our purpose because, despite its common use to capture the trend of the market, it is not able to capture the relative impact of the many relevant variables affecting air transportation demand.

For our purposes, we decided to develop a statistical econometric model of the air travel demand for an airline, and analyse it by regression analysis techniques. This allows us to express the influence and the interaction of all the relevant variables affecting demand and therefore to obtain, from the «big picture», the effect of fares on the passengers demand for air travel.

2.2 Determinants of air travel demand

The demand for a commodity depends on various parameters, as, for example, the number of close substitutes within the market, the percentage of income spent for it or whether the goods or the services under study are luxuries or necessities. In particular, air transport is a service that, for its peculiar characteristics, is subject to multiple possibilities of substitution at different levels (see

[9]). First, we have intra-modal possibility of substitution when different carriers compete with each other on the same route. Next, on certain market segment and routes, and particularly in the European context where the majority of flights are short - haul with an average of 795 Kilometers per flight (source PRC [26]), there is the possibility of inter-modal competition by alternative transport modes. Finally, especially for the leisure market, substitution may be made between different destinations with similar characteristics. Thus, for a particular market a relatively large number of substitutes leads to a high price elasticity, whereas a small number of possible substitutes implies lower price elasticities for the passenger air travel demand.

In general, the literature has defined the demand for air transport as being dependent on two main groups of drivers (see [32] or [42]). The first one is composed of the geo-economic variables, determined by the economic activities and geographical or locational characteristics of the two cities between which transportation takes place. The second group is composed of the service-related factors, determined by the quality and price characteristics of the air transport system (airline) connecting them. A general model for D ij , demand for air transport between cities *i* and *j*, is:

$$D_{ij} = D(GE_i, GE_j, SR_{ij})$$

where GE_i and GE_j are city-specific vectors that include the socioeconomic characteristics of the passengers and some variables pertaining to city *i* and *j* respectively, and SR_{ij} is a vector of variables related to the characteristics of service provided by the airline supplying the transport between cities *i* and *j*. In most demand-analysis studies, it is assumed that the two vectors GE_i and GE_j which represent the socioeconomic characteristics of the area of departure and destination are invariant with respect to the direction of the flight (from *i* to *j* or from *j* to *i*), and no distinction is made between an origin city and a destination one.

2.2.1 Geo-economic factors

An investigation of the literature on transport-demand analysis suggests that geo-economic factors should be distinguished in two categories: activity factors and locational factors (see [42]). Activity factors depend on the socioeconomic characteristics of the passengers. The two main drivers in this category are population and income, commonly considered proxies for all other activity factors (see [42], [32], [2], [1], [31]). Generally, population of the total metropolitan area served by airports is included in the model, as the product or the sum of the populations served by the two airports. Also income is generally included in the model as the sum or the product of the per-capita income of the two areas.

Locational factors are related to the relative characteristics of the two cities. They explain the geographical and environmental drivers of air travel demand between the two cities. The most common factor is distance, which affects demand in two opposite directions (see [42]). First, there is a positive effect, due to the travel time-savings provided by air transportation with respect to other modes. The negative effect is due to less social and economical interactions as distance increases. Other locational factors found in literature are the cost of travelling by other transportation modes, like car or train (as in [38], [2] and [31]). Dummy variables are also used to indicate if origin or destination are holiday resorts (as in [32] and [42]) or if the route flies over sea water.

2.2.2 Service - related factors

This group contains the factors related to the airline network structure, quality-of-service characteristics and applied prices. The analysis of the literature reveals as relevant factors the frequency of flights on the route (as in [2], [32] and [42]), the load factor and the aircraft size (as in [32] and [42]). The frequency of flights is considered to have a positive impact on demand, since a high frequency reduces the so-called «frequency delay», i.e. the difference between the customer's preferred departure time and the nearest departure time available. Load factor, despite its statistical irrelevance in many studies, seems to have a negative effect on passenger demand. In [32] and [42] its role in driving demand is ambiguous. Aircraft size is considered to have a positive effect on demand (see [32] and [42]). In [32], Ghobrial has gone into greater detail defining two variables for aircraft capacity in peak (6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m.) and in off-peak periods. The cost of travelling, as determined by fares, turns out to be a significant explanatory variable throughout the literature. As the airfare increases, the demand is generally expected to decrease (as in [2], [9], [31], [38], [32] and [42]). Dummy variables are included in [42] to indicate if one or both airports of origin and destinations are hubs for the airline. These variables are expected to have a positive impact on traffic as hub cities handle a disproportionately larger volume of traffic due to their role as connecting points.

2.2.3 Model specification

The functional form selected for the estimating model is log-linear, as suggested by [42], [32] and [31] in similar works. The relationship between demand for air transportation *D* and the explanatory variables is assumed to take the following functional form:

$$D = A \times \prod_i G_i^{b_i} \times \prod_j S_j^{g_j} \qquad (2.2)$$

where *A* is a constant, and G_i and S_j represent respectively the geo-economic and service-related factors. Taking the logarithm on both sides, equation (2.2) becomes linear in the exponents of the factors (i.e., Greek letters). This allows the use of linear regression techniques for their assessment.

Besides, using an exponential functional form for the demand for air transportation (as in our case) implies that the coefficients of the variables included in the logarithmic form (i.e., Greek letters) yield the elasticity of demand with respect to the variable, as explained in deeper detail in Section A.1.1.

2.3 A case-study: Air Dolomiti

2.3.1 General description of the Airline

Air Dolomiti S.p.A.-European Regional Air Lines-is the leading Italian company in the regional air transport sector. Founded in 1989 by the Gruppo Siderurgico Leali (Leali Steel Group), it started operating in 1991. The company, of which Lufthansa has a 26% stake, is part of the Star Alliance.

Currently, Air Dolomiti makes a total of more than 600 weekly flights (summer season 2001). It operates both feeder and point to point flights. Air Dolomiti's feeder routes are basically those towards the hubs of Munich and Frankfurt. The other European destinations of the company are

Amsterdam, Barcelona, Berlin (Tegel), Brussels, Cologne, Paris (Charles De Gaulle) and Vienna. During the summer period, there are connections with Sardinia.

The Air Dolomiti fleet consists of 15 ATR turbo-prop aircrafts (ten ATR 500 46 seaters and five ATR 700 64 seaters), and three CRJ-200 jet aircrafts with a special internal configuration of 48 seats. The delivery of other three additional jet aircrafts is planned for 2002/3.

The company's strategy is oriented to the business traveller market; this choice is highlighted by the close attention paid to the requirements of its customers in terms of quality and services. As an example, the company has developed a special seating configuration for all its aircrafts. This is more spacious than the standard ones and uses of sound-proofing materials and ergonomic seats. In addition, the company has considered marketing as an innovative instrument which enables it to satisfy its passengers' expectations in the best possible way during the flight, through customer service, training staff in contact with the public and direct services using new technologies. In the sphere of global marketing and with the aim of achieving total quality, in 1996 Air Dolomiti created «Settimocielo by Air Dolomiti» (Seventh Heaven by Air Dolomiti), the brand name of hospitality and welcome on board. The innovation and the quality of this philosophy has been recognized at a world level, as several international awards received demonstrate.

2.3.2 Model Specification

Dependent Variable

The dependent variable used is the number of passengers D_{ift} travelling on route i in the fare-class f at time t. For this specification of the dependent variable, the demand considered is the demand for a single flight. In this model a distinction is also made between business and non-business traffic, assuming fare-class (economy and business) as proxy for travel motive. This assumption seems to be commonly accepted in literature (see [9]), although in recent years many studies were addressed to study the growing propensity of business travellers to use low-cost fares and airlines (see, for example, [49]). Thirdly, here we aggregate both origin-destination and transfer traffic. As discussed below, dummy variables were included to explain the extra-traffic expected in hub airports, where the volume of transfer traffic is supposed higher. Finally, the model is supposed non-directional: no distinction is made between origin and destination city. As we discuss in the section concerning the estimation results, this is justified by the set of data used, which revealed no significant difference in the passenger flows between the two directions of the route.

Explanatory Variables

According to the literature, population and regional Gross Domestic Product per capita have been introduced in the model, as a proxy for socioeconomic characteristics of the passengers on the different routes. In our model we considered population of the total metropolitan area served by the airports. Population factor *POP* has been defined as the product of population of the two airport areas. Also for GDP per capita in the two airport areas, their product has been chosen as the explanatory factor *GDP* . As geographical and locational factors of the two cities, many explanatory variables have been tested in the model. According to the literature, distance between the two cities was introduced (*DIST*). Finally, a tourist-market dummy variable TOUR was set to one for routes serving holiday destinations.

Service-related variables were also included in the model. As explanatory of the service quality provided, daily frequency of flights (*FREQ*) and aircraft size used for each flight (*CAPA*) were inserted. A dummy variable *HUB* was introduced to identify «hubbing activity», and was set to one for routes from or to a hub airport for the airline. This variable was expected to have a positive effect on demand as hub airports handle a relevant part of transfer traffic. As regards pricing patterns, a variable *FARE* was included in the model. Since the dependent variable is demand for each fare-class in a specific flight, the corresponding fare introduced in each sample was the lower economy fare in case of economy class and the higher business fare in case of business class. These simplifying assumptions were determined by data availability.

Moreover, a dummy variable *COMP* was introduced to identify direct intramodal competition. The dummy variable was set to 1 for airport-pairs among which other airlines perform direct flights. Finally, a control variable *YEAR* has been included in the model to capture the influence of the year of observation in the demand.

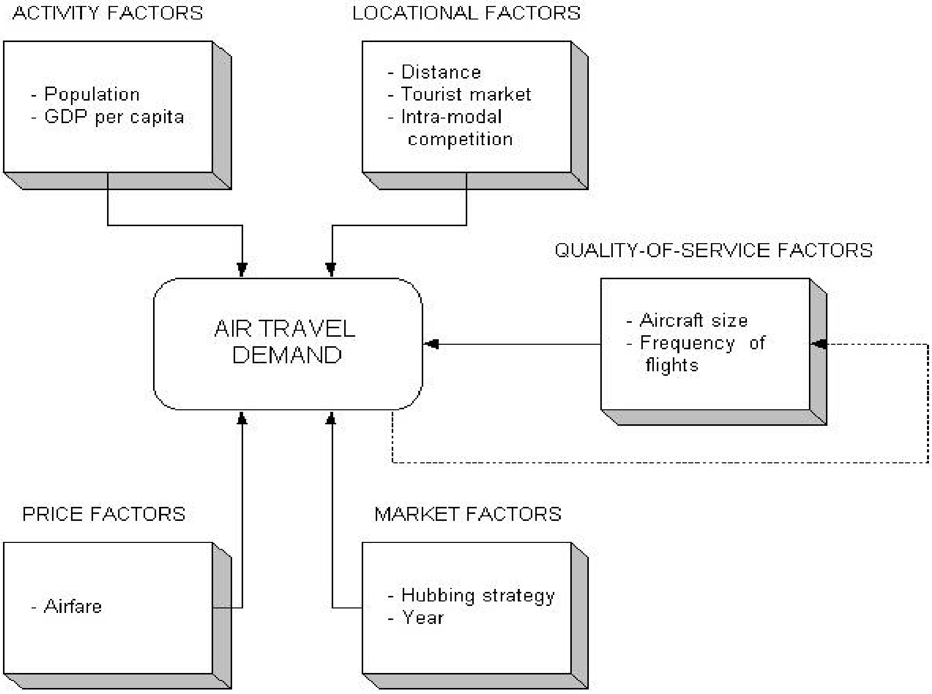

Figure 2.1: Drivers of Air Travel Demand1

Endogeneity of factors issues

An important issue in estimating demand models is the endogeneity problem. The demand for air travel represents only a part of a simultaneous system of market equilibration (see [2]); the equilibrium values of some variables in the system are determined by the interaction of the demand for and supply of airline services. In our model for passenger demand, we could note that some of the independent or explanatory variables adopted are themselves endogenous, that is, they are determined by other variables or by the dependent variable itself. For endogenous variables, the disturbance term of the regression could be correlated with the independent variable. If this happens, model parameter estimations calculated using Ordinary Least Squares could be not consistent and a two-stage methodology is adopted. In the first stage, new variables are created to substitute the problematic endogenous ones, by using instrument exogenous variables. In the second stage, regression is computed in OLS fashion, but using newly created variables; in subsection A.2.1 a deeper description of the methodology is provided.

In the context of air transport demand, a literature analysis reveals that possible endogenous problematic variables could be frequency of flights ([2], [42]), airfares ([32], [42]) and aircraft size ([42]).

In the specific case of Air Dolomiti, some considerations have been done in order to evaluate endogeneity of these three factors. As a matter of fact, the market environment where Air Dolomiti operates gives many constraints to these «degrees of freedom» of the airline. First, Air Dolomiti operates on routes with a relatively high level of both direct and indirect competition (major competitor is Alitalia both on domestic and international routes, and, on routes considered in this study, there is also direct competition with Iberia). Competition has strong effects on airfares settings for airlines (evidence of this in US market is provided by Ghobrial in [32]). This assertion is confirmed by an analysis of Air Dolomiti, whose airfare levels are strongly constrained by the ones of the competitors. Moreover, partnership with Lufthansa provides constraints both for routes and for airfares.

Concerning the aircraft size factor, the available fleet of Air Dolomiti is relatively homogeneous, being composed of aircrafts with capacity of 46 and 64 seats (with an average load factor of 55%). An analysis of the sample data reveals a relatively constant pattern of utilization of the same aircraft on the same route during time.

For these reasons, in this analysis we consider both airfare and aircraft size as exogenous factors affecting demand. Frequency of flights has been considered endogenous. Therefore, exogenous instrument variables have been considered for use in a two-stage least-square procedure.

Since daily frequency of flights is assumed to be an equilibrating mechanism of the airline market, those exogenous factors which influence passenger demand are supposed to affect also frequency of flights. In addition, as factors affecting supply of flights, fuel and crew costs are considered to be included as instrument variables. However, by scarcity of data, the crew costs factor has been dropped. A control dummy variable set to one for flights performed in week-ends or festivities was also included as instrument variable.

Data Sources

The data used in the estimation of the model originate from a variety of sources. First, the time period considered was the month of May in years 1999, 2000 and 2001. This choice has been done for two reasons: the availability of data for the passenger demand in an electronic form and the absence of seasonality. Seasonal variation is a characteristic of passenger demand for Air Dolomiti (and for air transport demand in general, see [26]); this effect is limited by considering a small time period (a month) for each year. Data of passengers flown in each fare-class (business and economy) and fares were provided by Air Dolomiti for 4 routes: Torino-Barcelona, Verona-Barcelona, Trieste-Munchen, Venezia-Munchen. Economic data (GDP per capita in the area served by the airports, fuel costs) and demographic data have been taken from the National Institute of Statistics for each airport. Data relative to frequency of flights, aircraft used, scheduled flight time and hub strategies were provided by Air Dolomiti. Distance between two cities was considered as the length of the shortest segment between pertaining airports. Analysing the correlation matrix of the sample data, we found that a multicollinearity problem would arise in demand estimation. Substantial collinearity was present between distance *DIST* and *HUB*, *GDP* and *FARE*. The analysis of the estimation results proved the redundancy of the *DIST* factor, and therefore it has been dropped.

2.3.3 Estimation Results

The estimated model is displayed in equation 2.3, which has been linearized taking the logarithms on both sides of the equation, as shown in 2.4.

$$D_{ift} = A \times POP_{it}^{b_1} \times GDP_{it}^{b_2} \times FREQ_{it}^{b_3} \times FARE_{ift}^{b_4} \times CAPA_{it}^{b_5} \times \times YEAR_t^{b_6} \times \exp(g_1 HUB_i + g_2 TOUR_i + g_3 COMP_i + e) \quad (2.3)$$

$$\ln D_{ift} = a + b_1 \ln POP_{it} + b_2 \ln GDP_{it} + b_3 \ln FREQ_{it} + b_4 \ln FARE_{ift} + + b_5 \ln CAPA_{it} + b_6 \ln YEAR_t + g_1 HUB_i + g_2 TOUR_i + g_3 COMP_i + e \quad (2.4)$$

where *i* represents route, *f* represents fare-class and *t* is a progressive index for the different flights. Greek letters are the estimated factors. b_n, the coefficients of the *n* quantitative variables, represent the direct elasticity of demand with respect to a change in the corresponding factor. g_m are the coefficients of the *m* qualitative variables; a is the constant term and e is the error term of the estimation.

Initially, values of the daily flight frequency on each route were regressed against the set of exogenous variables, as described in 2.3.2. Passenger demand for each flight in the sample was then regressed against flight frequency and the set of demand-side exogenous variables of equation 2.4.

The results of regression analysis are presented in table 2.3.3.

Explanatory variable	Coefficient	Estimated coefficient	T-statistic
Constant	a	0.122	0.17
Population (POP)	$ß_1$	-0.056	-1.652
GDP per-capita (GDP)	$ß_2$	0.765	11.275
Frequency of flights (FREQ)	$ß_3$	-0.164	-2.034
Airfare (FARE)	$ß_4$	-1.217	-48.012
Aircraft seat capacity (CAPA)	$ß_5$	0.762	5.107
Year (YEAR)	$ß_6$	0.149	3.116
Hub airport (HUB)	$?_1$	0.291	4.896
Tourist market (TOUR)	$?_2$	0.122	1.516
Direct competition (COMP)	$?_3$	-0.266	-4.785
Observations	3793		
R^2_{adj}	0.465		
Fisher Test	367.67		
Durbin-Watson Test	1.817		

Table 2.1: Estimation results

The adjusted multiple determination coefficient R^2_{adj}, that indicates the percentage of variance in passengers demand explained by the selected drivers, for our model is 46.5%. This result, although lower than the ones found by Abrahams and Calderón in their studies ([2] and [42] respectively), is in line with the values found by Ghobrial and Kanafani in [32]. A major reason for this relatively low R^2_{adj} is the small sample of routes considered, that limited the variability of data in the model and the explanatory effect of some, especially macro-economic, demand drivers. The Fisher value F , that indicates the overall significance of the estimated regression line, is 367.67. The F distribution, with 8 *(k - 1)* and 3784 *(n - k)* degrees of freedom allows the rejection of the null hypothesis, i.e., all partial slopes are simultaneously equal to zero or, alternatively $R^2 = 0$. By looking into the results of regression analysis, we found that almost all estimated coefficients are of the expected sign. Population factor, which is expected to have a positive effect on passenger demand, has a negative not statistically significant coefficient. This result is in line with the study of Calderón ([42]) and together with the coefficient of *GDP* factor seems to suggest that demand is more responsive to income than to population, also with respect to other public transport modes (whose demand from passengers is strongly dependent of the population in the area where transport takes place, see for example [6]).

Being Air Dolomiti oriented to business travellers, also the tourist market dummy variable TOUR proves not significant, revealing a scarce effect of tourist extra-traffic on pertaining routes. Another reason, in this latter case, is that the time-period considered for observations, i.e. May, is not a tourism peak-period for Venezia and Barcelona.

The dummy variables for routes from or to the Munchen hub (*HUB*) and indicating direct competition on the route (*COMP*) appear to be statistically significant at the 0.05 level. This indicates the influence of the two factors on passenger demand.

As far as the frequency of flights is concerned, it must be observed that the minus sign of its coefficient is due to the fact that the demand for single flights is considered here: therefore, increasing frequency has the effect of distributing the demand on a larger number of flights, thus reducing the demand for each of them, even possibly in presence of a raised global demand level

With regard to prices, demand is elastic with respect to airfare, with an elasticity of -1.218. This result may seem quite surprising for an airline oriented on business traveller market. In fact, business class travellers have generally been considered an inelastic demand segment and studies focused on this subject on the past years revealed an average price elasticity of-0.8 (see [9]). However, this latter figure refers to the whole business passenger market. Instead, the price elasticity of demand for a single firm, i.e. an airline, is generally higher than the price elasticity of demand for the whole market where it operates in. Moreover, in the last years, faced with an increased choice of airlines, prices and frequency, the behaviour of the business travel market has become more and more price sensitive. For example, there is an increasing tendency for business travellers to travel economic and discounted classes (see [49] and [50] for a detailed analysis of the phenomena) and airlines are developing various economic measures and marketing strategies to maintain their loyalty (frequent flyers programmes, web check-in, etc.). A recent meta-analysis of price elasticities of demand for passenger air travel ([9]), indicates that studies published on the topic reveal a mean price elasticity of-1.146.

2.4 Conclusions and Future Research

Despite the limitations of this initial case-study of passenger air travel demand, some clear patterns have emerged on the responsiveness of demand to prices. The regression analysis suggests that passenger demand for Air Dolomiti is elastic in respect to airfares; a change in 10% in prices will result in a more than proportional change of 12% in traffic demand.

As noted before, this model would only serve as a starting point for future developments. Data relative to more routes will be collected and sub-samples will be tested to better understand the effect of fares on passengers demand. In addition, a refinement of the model would be developed considering other explanatory variables, such as, e.g., aircraft technology (jet vs turbo prop) or variables characterizing trade exchanges between city pairs.

For what concerns the general context of this study, the analysis will be extended to other categories of airlines. This will provide a general framework to predict and study the behaviour of airlines and passengers when new charging formulas are tested.

Chapter 3

Price elasticity of demand for Air Traffic Services

EUROCONTROL and Air Navigation Services providers (ANSPs) provide to airspace users five broad categories of facilities and services, i.e., Air traffic management and communication, navigation and surveillance services (ATM/CNS), meteorological services for air navigation (MET), search and rescue (SAR) and aeronautical information services (AIS). Among these tasks, the primary one is ATM/CNS that comprises ATS, ASM and ATFM. Finally, ATS consists of air traffic control (ATC), flight information and alerting services (see [28]). Costs incurred for their provision are reimbursed to EUROCONTROL and ANS providers of the contracting States by levying a charge for each flight, as highlighted in the Introduction. In year 2000, the total amount of en-route costs was about 4.5 billion Euro.

In this chapter we deal about methodologies to study the impact of the route charges on air traffic services primary users. Demand for ATS is determined by an heterogeneous number of airlines, with different characteristics in terms of service offered, fleet, network size, market strategies and, therefore, with different reactions to route charge changes.

In the previous chapter we identified a general methodology to investigate airfare elasticity of passenger demand for a single airline city-pair flight. Evaluating passenger airfares elasticity of demand for different airlines could give important indications on characteristics of their customers, and a key to interpret and predict their behaviour and their pricing strategies. If we consider an uniform increase in route charges (or another operating cost) across the whole airline industry, reactions of airlines could be very different. Low price elasticities in passenger demand allow airlines to transfer directly to passengers the differential in costs, while high price elasticities in passenger demand do not allow the complete pass-through of the different costs to passengers. In this latter case, other strategies should be taken by airlines, by varying their offer, in terms of network, routes or frequency of flights. In fact, charging the rises in costs to passengers and keeping the same number of movements and frequencies, will probably yield a reduction in load factors and, therefore, a loss of profitability. Other strategies implemented to maintain the level of profitability rely, for example, on dropping the number of movements and frequencies to maintain load factors. This will have a great impact on ANSPs, in terms of revenues collected and in terms of capacity to be offered and, therefore, in the resulting delay/quality of service.

In the analysis of new route charges schemes, on one side price elasticity of passenger demand may provide important insights on the airline behaviour. On the other side, the tracking of the different airline behaviour during the years following the increase of the operational costs in terms of movements, available seat × km, fares, etc. is another relevant aspect to be considered. This latter analysis is the ultimate goal of this chapter.

First, a description of the appropriate methodologies to perform this investigation is provided. Then, the identification of the different categories of ATS users is presented. This is a basic step for dividing in different classes the airlines operating in the European airspace.

3.1 Methodological approach

With the purpose to evaluate the route charges price elasticity of airlines demand for Air Traffic Services, we propose an indirect approach. In last years, route charge levels have not changed significantly, while the European air transport market has seen great changes following the liberalization process. Therefore, the investigation of the direct influence of the small changes of route charges in airline strategies risks to be biased and distorted by the effect of other airline operations affecting factors, whose changes have been more significant.

The proposed methodology is to investigate the behaviour of airlines in consequence of an exogenous change in their operating costs due to another cost driver (i.e., exogenous increase of an input price), for which changes in these years have been more conspicuous than the ones in ATC charges. Moreover, such factor, if compared to route charges, has to represent about the same percentage of total operational costs for the airline and its changes have not to influence directly the airline demand-side. In these conditions, the price elasticity of airlines demand for ATS could be considered quite similar to the price elasticity of airline demand for the factor. To investigate reactions of the airlines, outputs considered could be available seat × kilometres (or available tonne × kilometres), movements or kilometres flown.

A factor meeting the above requirements is represented by fuel costs, which, in the latter years, have seen significant fluctuations: IATA sources (see [46]) indicate that in 2000 fuel and oil costs raised from 15.4% in 1999 to 18.1% of total operating costs. The same study (see figure 3.1) identifies the impact of user charges (i.e., the sum of route charges and terminal charges) at 9.7% of total operating costs. Further refinements will be necessary to these data, which only serve to give a general impression on the share of contribution of the various cost drivers to the total operating costs for an airline. In fact, IATA statistics rely on data from a world-wide sample of airlines and give a world-wide average distribution of costs; a study conducted in the European context for different airlines might give different shares for the various cost drivers.

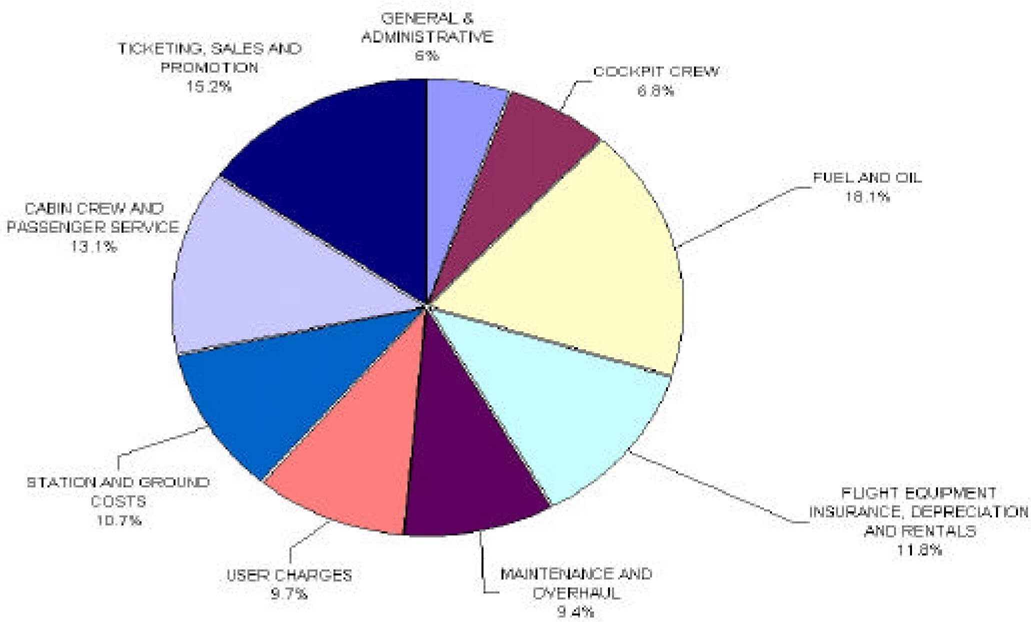

Figure 3.1: Distribution of total operating costs, Year 2000, source IATA

Another important way to understand the different reaction to costs for the different types of airlines is to monitor the current situation. After the September 11 disaster, many of the operational costs, especially those related to insurance and safety, have significantly raised. In addition to this, fear for new attacks has generally lowered the demand for air travel, especially by leisure travellers. Reactions of airlines have been rather different: for example, Alitalia has reduced frequency on routes while in the meantime Air Dolomiti has increased its offer, by introducing new routes.

To identify the elasticity of airlines demand, useful methodologies could be individuated in time series analysis and, as for price elasticity of passengers demand, linear regression analysis.

Time series analysis is relatively simple to perform and could be used when the cost factor under study has a sudden change with respect to the other factors, and the effects in the airline output variables (e.g., movements, kilometres flown, available seat × kilometres, available tonne × kilometres) are reasonably attributable to its changes. As explained in [26], ATS demand series are characterized by seasonality and trends. In this context suitable methods rely on the de-seasonalization of the data and the individuation of the trend (see [51] for a review of the main techniques). The residual data would provide the variations of demand due to external perturbations of the market as, in case of strong gradient in the variation of the factor under test, the effect of the factor itself.

Multiple regression analysis is useful when the changes in the output variables (movements, kilometres flown, available seat × km, available tonne × kilometres) could not be reasonably considered as consequence of the changes only in the cost-driver under test, but are effect of multiple explanatory factors. In our case, if the cost factor considered has slow variations (respect to all the factors affecting the operational decisions of an airline), we have to consider other drivers to detail the regression model, as, for example, competition, peculiar events in the period considered, variation in other costs.

3.2 Analysis of Air Traffic Services Demand

As highlighted in the introduction of this chapter, price elasticity of ATS demand is potentially different for different types of airlines and different markets to which airlines are addressed. Therefore, the first step of the analysis is to identify and define the different categories of users of air traffic services in Europe. In such sense, no literature exists on specific metrics and methodologies on scientific publications; a first attempt to group in categories the air carriers operating in Europe is provided here. This is illustrated in Figure 3.4. Civil aviation comprises the main users of air traffic services, although it should be recognised that military airspace users are also important consumers of air navigation services. Civil aviation can be broken down into Aerial Work, General Aviation, and Commercial Aviation. Furthermore, Commercial Aviation, the main component of Civil Aviation, has been broken down according to the nature of airlines operations (scheduled, charter, cargo). Following an ABC analysis, route charges have then been allocated to the various identified categories. Finally, a first analysis of market influence and characteristics of the various categories has been made.

3.2.1 Categories of civil aviation air carriers

Following the classification made by ICAO and supplemented by IAOPA (International Council of Aircraft Owner and Pilot Association) in [48], civil aviation in Europe is composed by:

- **General Aviation (GA)**, that includes corporate aviation, fractional ownership operations, business travel (flown by the business pilot), personal travel (in an owned or rented aircraft), air tourism, recreational flying and aerial sports. Deeper characterization of this category is provided by IAOPA, that groups many general aviation operators;
- **Aerial Work (AW)**, that include civil flights whose primary goal is not the transportation of persons or goods from one point to another. Examples of aerial work operations are agricultural flights, weather research flights, flight demonstrations, TV-live reporting flights, photography and surveying flights. As for General Aviation, more insights on this category is provided by IAOPA (see for example [47]) that groups many aerial work operators;
- **Commercial Aviation**, which is defined as those activities for which payment is made for the transport of persons or goods from one place to another. This category gathers the larger carriers in Europe and represents about 95% of the total EUROCONTROL route charges revenues. Considering the European context, as reported in figure 3.4, commercial aviation has been subdivided in:
    - *European Scheduled carriers*: European carriers whose core business is to provide scheduled services, i.e. flights scheduled and performed for remuneration according to a published timetable, or so regular or frequent as to constitute a recognisably systematic series, which are open to direct booking by members of the public (see AEA, [5]);

- *European Non-scheduled carriers*: European carriers which mainly perform non-scheduled services, as charter flights and special flights performed for remuneration on an irregular basis;
- *Non-European carriers*: airlines not registered in Europe but flying on European routes, principally flag carriers of non-European states.

With the purpose to assign the various airlines operating in Europe to the pertaining category, further subdivisions have been made for commercial aviation components, as reported in figure 3.4. At present, no metric has been defined in literature to characterize each category. In our case, classification has been developed according to the following definitions:

- European Scheduled Carriers:
  - National Carriers: airlines which have historically represented the flag carrier for their state. Therefore, a common characteristic of flag carriers is to represent the main carrier in their pertaining states in terms of market share. Moreover, they generally have a "global" network, performing both domestic, short-haul and long-haul flights. In this group are present the 10 major scheduled carriers operating in Europe, which pay about 36% of total route charges collected in Europe. Important source of statistics and information about this group is AEA (Association of European Airlines) which many of these airlines belong to.
  - Regional Carriers: airlines that perform essentially scheduled domestic and intra-European flights. Characterization of this group has been derived from the features of airlines members of ERA (European Regions Airline Association). These airlines generally work on national and regional markets, as feeder for the major hubs, although there is an increasing tendency to perform point-to-point flights between outlying regional airports (source ERA). Their fleet is composed of relatively small aircrafts (with capacity of 50/60 seats on average). Load factors for these airlines are 58% on average.
  - Low-cost Carriers: these airlines generally entered the European market after the full liberalization in 1997. Most of them have modelled their operations on the structure of the Southwest Airlines, by offering "no-frills" low-cost point-to-point operations. Another emerging feature, firstly introduced in this category by Ryanair, is to focus their activity on under-utilized secondary airports located close to major hubs. Another characteristic is the use of a homogeneous fleet; routes are generally shorter than 1000 km.
  - Air Cargo Carriers: airlines principally devoted to transportation of freight.

- European Non-scheduled Carriers:
    - Charter Carriers: airlines that perform principally non-scheduled charter flights, generally with passengers travelling for leisure purposes. Common feature of these airlines (see [62]) is the utilization of large-size aircrafts with high load factors (Airtours in 1997 flew with on average 93.6% of their seats occupied). Moreover, charter airlines usually fly relatively long sectors, of over 2000 km.
    - Taxi Carriers: companies that provide air transport on demand, generally for business reasons. Main feature of these airlines is to perform non-scheduled flights. The flight is performed according to a self-determined schedule, determined by the destination of the business traveller. For this group, an important source of data is EBAA (European Business Aviation Association).
- Non-European Carriers: no subdivision has been made for this group, constituted principally by flag carriers of non-European states. In this category there is also a significant component of non-European air cargo carriers and non-scheduled charter traffic.

3.2.2 First analysis on European air market shares

Relying on the civil aviation demand characterization provided in the previous subsection, here a first analysis of the European market shares of the various components is conduced. During year 2000, the number of airspace users who paid EUROCONTROL for air traffic services was 4563. The absence of a common source of information on all of them would have required the necessity of a great amount of time to categorize a such large sample of users. Therefore, an ABC analysis based on the percentage of contribution to the total route charges collected by EUROCONTROL has been performed for the whole group of ATC customers. Using this methodology our analysis has been concentrated on airlines providing a major part of revenues from route charges. The ABC analysis revealed that 7% of total users contribute for 96% of the total charges collected (see figure 3.2).

In appendix B a classification of the sub-sample of airlines considered on the pertaining category (as defined above, in subsection 3.2.1) is presented. Airlines that provide different types of transportation (for example both cargo and passenger activities or both scheduled and non-scheduled operations) are classified in the category pertaining to their main activity. Despite to its advantages in terms of identification and concentration on the main customers of ATS, a major drawback of ABC approach is to exclude from the analysis minor airspace users, that often belong to the same categories (e.g., general aviation, aerial work and air taxi carriers). In such sense, more refinements will be possible using cluster analysis, as done in a recent publication for the airport context by Burghouwt and Hakfoort ([10]). In this case, more data are necessary regarding the airspace users.

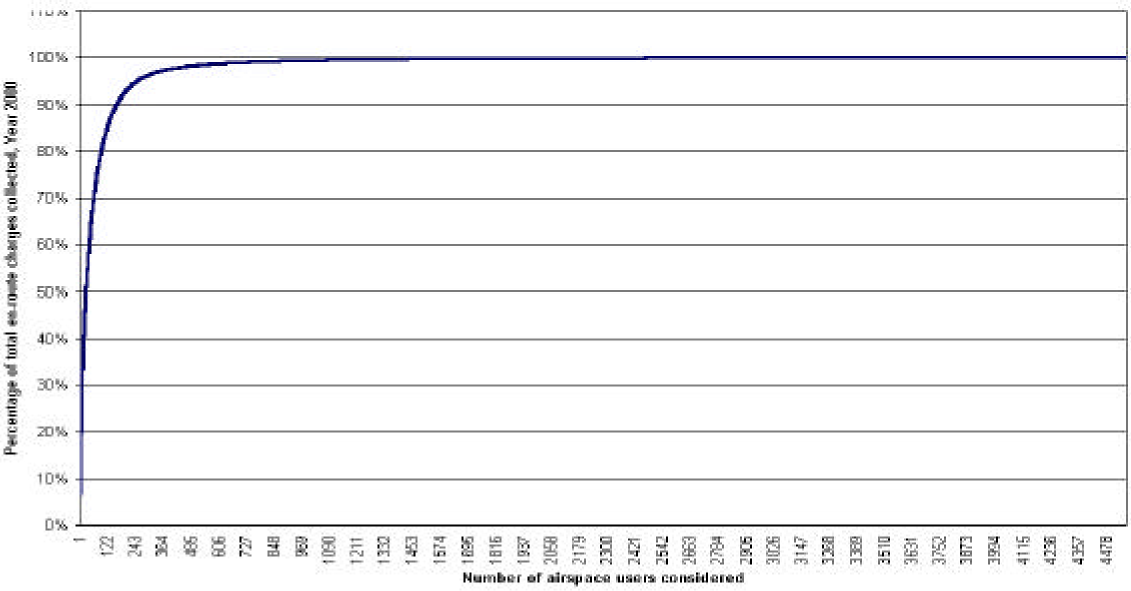

Figure 3.2: ABC analysis of the contribution of airlines to the total route charges, Year 2000

Following the ABC analysis approach, the percentage of route charges paid to EUROCONTROL by the different categories of users on years 1999 and 2000 is presented in Figure 3.3. Airlines pertaining to each group are listed in appendix B.

In Figure 3.4 it is performed the analysis of market shares on Year 2000 for the top 10 users (providing the 36.15% of total route charges collected by EUROCONTROL), for the top 50 users (providing the 67.06% of total route charges collected by EUROCONTROL), for the top 100 users (providing the 82.33% of total route charges collected by EUROCONTROL) and for all users of air traffic services in Europe. The analysis reveals that the main carriers operating in Europe are national airlines. In the top 50 users a significant component of demand of ATS is generated by charter and non-European airlines. The analysis also seems to suggest that the segment of regional airlines is fragmented into many medium/small carriers.

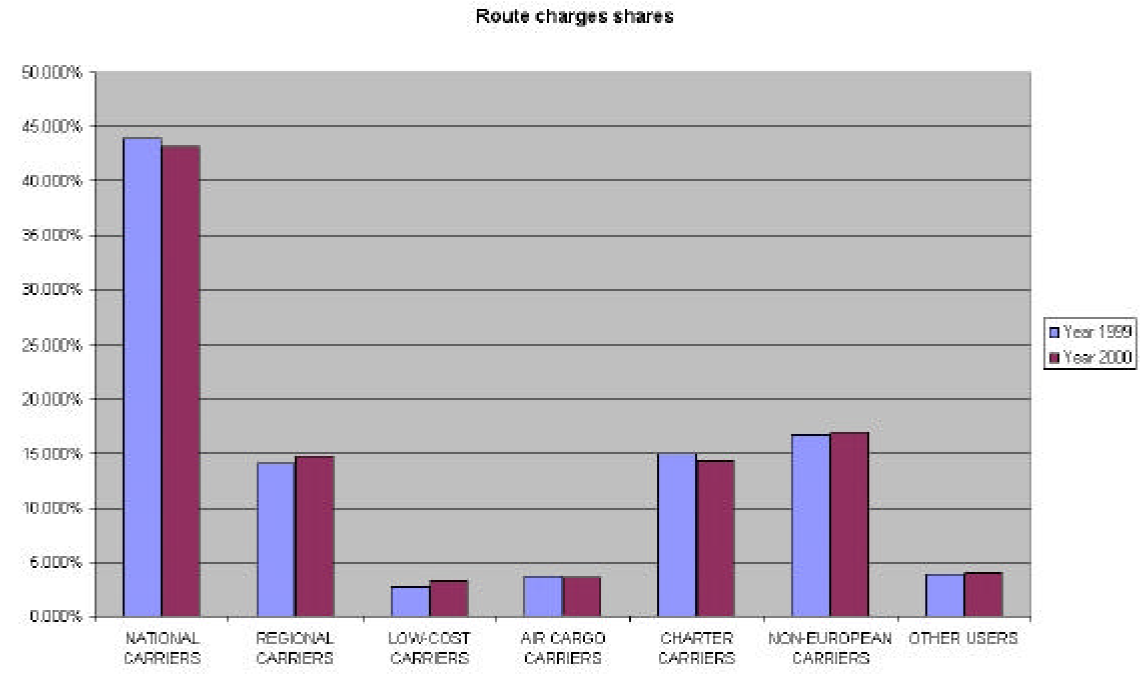

Figure 3.3. Percentage of route charges paid by category of users, Years 1999 and 2000

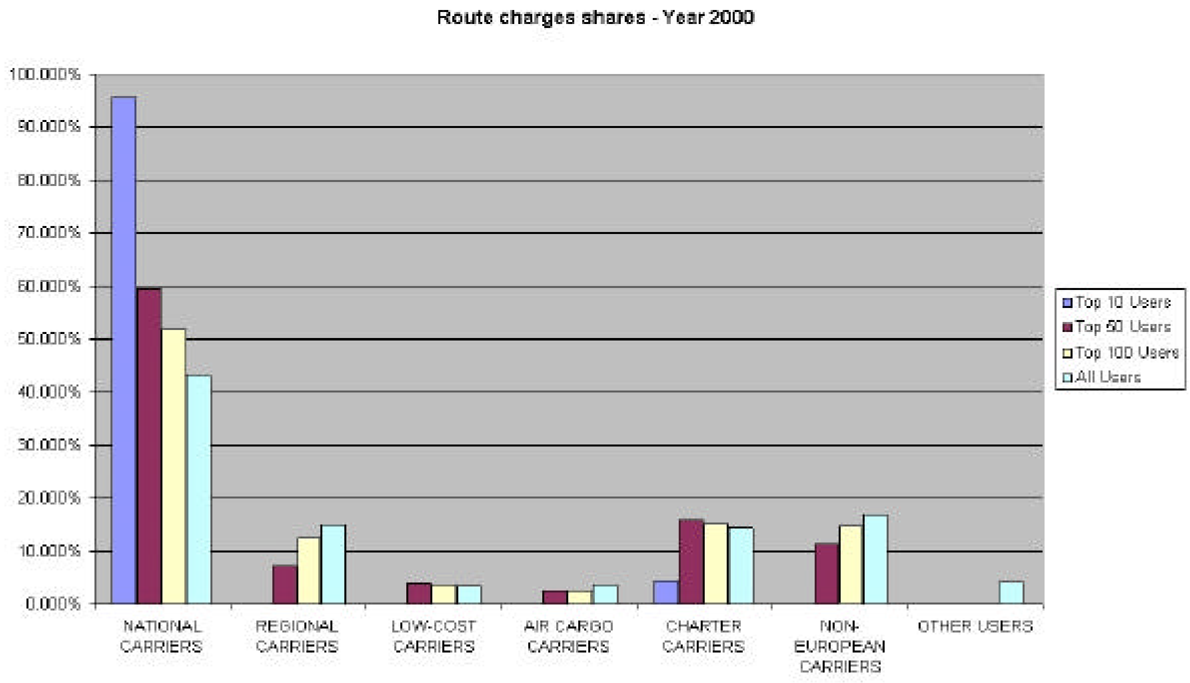

Figure 3.4: Percentage of route charges shares by category: top 10, top 50, top 100 and all users

3.3 Conclusions and Future Research

The investigations presented in this chapter represent only a staring point for future developments. As regards the classification of the ATS demand, a further step of the study could be the adoption of cluster analysis methodologies. This will provide numerical dimensions of the various categories. Important requirement further phases of the analysis is the availability of data on users.

The following step of the study is the analysis of the price elasticity of various categories of airspace users, according to the methodologies individuated above. Also for this phase economic and operational data are required for the various airlines. In such sense, important sources of information are IATA studies and airlines and airspace users associations (AEA, ERA, EBAA, IAOPA). Another investigation methodology is the direct collection of information from a significant sample of airspace users pertaining to the same category. Finally, another important source of operational information on airlines is the CFMU Archive System (ARC), that stores data on each flight performed in EUROCONTROL area in the last 3-5 years.

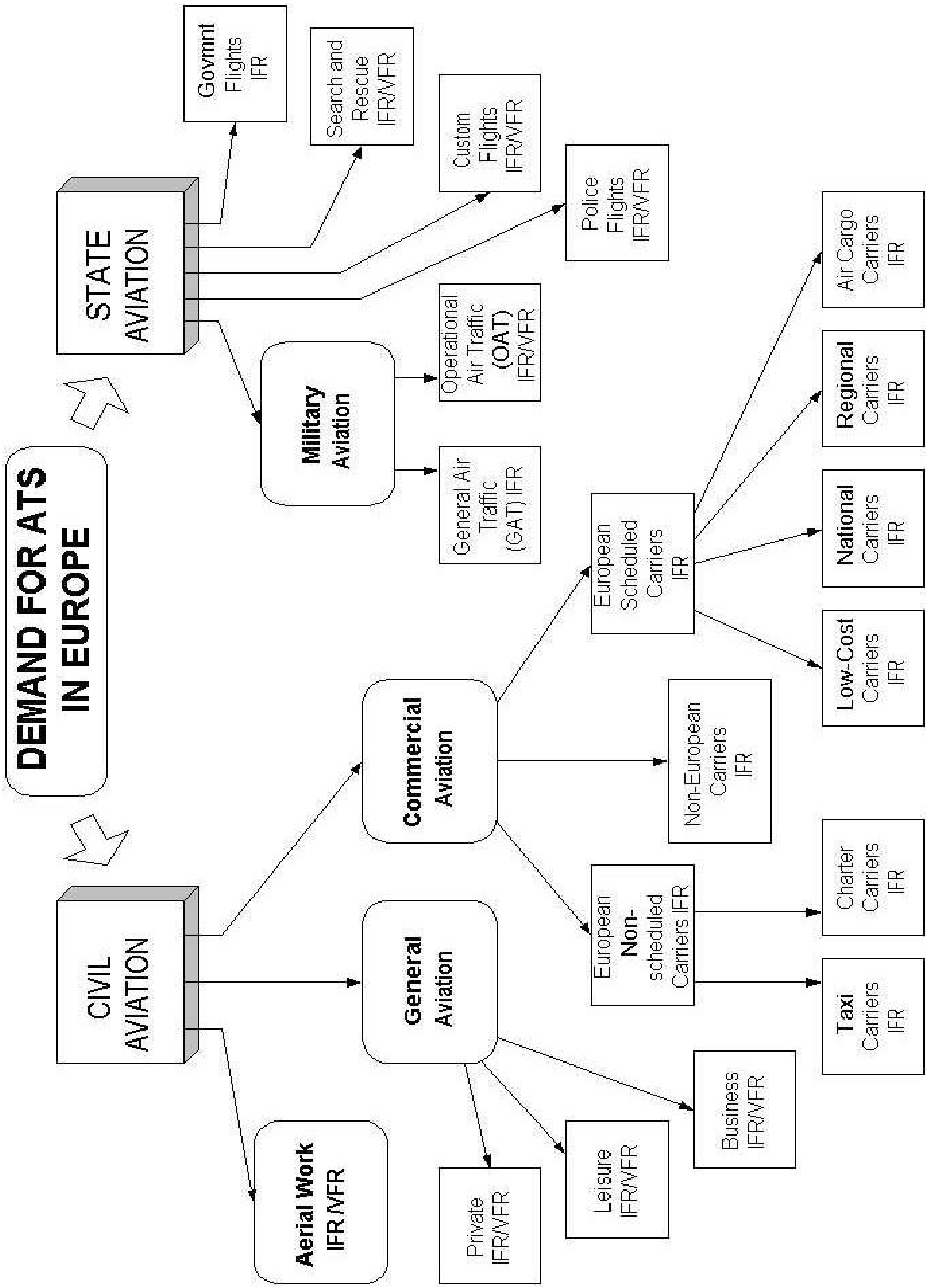

Figure 3.4: Components of Demand for ANS

Chapter 4

Supply side

After having considered, in the previous chapters, different issues concerning the demand side for transportation and ATC service, we deal in this chapter with the supply side of ATS in order to provide a complete framework into which innovative charge schemes could be formulated, analysed and evaluated in their impact on the system.

The general approach we adopt to devise innovative route charges is to promote status and ways of operation positively affecting the behaviour of the system, both from the point of view of ATS suppliers (ATC centres), and of customers (airlines). In such a context, the role of EUROCONTROL is intended to fix the game rules defining feasible alternatives, admissible procedures and pertinent charges.

Since the late 1980s (the first European «Aviation Liberalization Package» was approved in 1987) a wave of reforms has transformed the operating environment of the air traffic management companies. Air transport has benefited from sustained growth as a result of the positive economic climate, helped by the liberalization of aviation at European and at global level (see [41]). The ATM system itself is also undergoing an evolution. Facing a stronger competitive environment in even more congested markets, a key objective for authorities is to improve the efficiency and responsiveness to market needs of the ATM procedures. In such sense, among other measures (as reduction of vertical separation minima), several countries are preparing, or at least considering, the privatisation of their air traffic service providers (see [61]) to achieve the efficiency objective by enhancing access to capital and human resources with a market-oriented approach.

In this scenario, we propose a general scheme to classify innovative charge rules for ATC. First, we distinguish the case of rules that in some way contemplate assessing ATC centre performance and the ones that do not. For the first group, in Section 4.1 we consider several incentive paradigms that have been studied in literature for different economic systems. Then, since incentives necessarily require some form of assessment of the performance of the involved agents, in Section 4.2 we propose some pertinent issues concerning performance analysis methodologies that could be used for the case of interest.

For rules not requiring ATC performance evaluation, we specifically address rules involving economic elements leading each airline to eventually modify its demand either at the strategic level (e.g., charter airlines may prefer to suffer (heavy) delays if they would be allowed to pay less route charges) or at the operational level (i.e., for a given specific flight). In Section 4.3, we briefly introduce this issue.

As an additional, although not exclusive, topic we may consider rules involving operational, or procedural elements. For this type of rules it is important to understand which are the “allowed moves” and the “forbidden” ones, in the sense of modifications of the current operating rules and procedures that can or cannot be proposed. To this end, the concept of equity seems to be crucial. It is discussed in Section 4.4, where a possible approach is outlined to formally state and evaluate the equity concept.

4.1 Incentive Regulation and utilities performance

Incentive regulation, often known as Performance Based Regulation (PBR), is a pricing technique commonly used at present time in telecommunication, water and power sectors, where it has seen its major developments. Objectives of such methodologies are essentially to create financial incentives for cost minimization, promoting efficient capital investment expenditures and also enhancing information revelation in order to mitigate the traditional asymmetry of information between the regulator and the firm.

In the power sector, for example, incentive-based regulation has emerged as an alternative to the traditional rate-of-return (full cost recovery) regulation, enhancing incentive signals and the performance of the regulation (see [39]). Common characteristic of the incentive regulation schemes is the use of a “benchmark factor”, relative to a comparison of some measures of the actual performance of the utility against a reference or benchmark performance.

There are many possible approaches to incentive regulation. In the following part the most widely discussed and adopted methods are presented. The review relies particularly on [40], [35] and [55].

4.1.1 ROR Regulation

Rate-of-Return regulation is a method that allows the utilities to set prices for the service provided in a way to recover their costs and earn a reasonable return on invested capital. The general formula for the calculation of the required revenue *RR* for a generic firm is:

$$RR = OE + D + T + RB \times ROR$$

where *OE* are the operating expenses for the firm, *D* is the depreciation expense for the time period considered (usually year), *T* are the tax expenses, *RB* is the rate base (defined as the difference between the gross valuation and accumulated depreciation of utility's plant investment) and *ROR* is the allowed rate of return.

ROR regulation is a traditional approach to regulation of privately owned monopolies and an alternative to public owned utilities (see [40]). The present Air National Services providers recovery costs mechanism falls into this category, although it has some peculiar characteristics that distinguish it from many other ROR systems (see [18] for a description of the method used for the calculation of the charges and their cost base, and annual reports, as [19], for financial and operational results).

Main characteristic of this regulation method is to allow utilities to recover all relevant costs, since their revenue is a-priori fixed. Nevertheless, practical application of this regulation approach has evidenced as its major drawback to not provide incentives for cost savings and efficiency improvements but rather to reward over-investments.

To address the drawbacks of ROR regulation, many incentive-based regulation methods have been proposed. A common characteristic of these approaches is the use of a benchmarking factor in the pricing function. Within this context (see [39]) benchmarking can be broadly defined as comparison of some measures of actual performance against a reference or benchmark performance.

A description of the main approaches used is provided in the following. Generally, they are not used in the pure form but, according to the complexity and multiple objectives of utilities, combined schemes of many regulatory techniques are adopted.

4.1.2 Price Cap Regulation

Price Cap regulation is a technique that essentially decouples the profits of the regulated utility from its costs by setting a price ceiling. This represents a widely used alternative to ROR regulation and has been implemented for many years in telecommunication industry (see [57]) and in the power sector.

The basic principle of price cap regulation is to remove ROR profit constraints and to fix an upper bound for a firm's prices; in this way strong incentives to cut costs and to improve efficiency will be created, leading to improvements in social welfare. A general formula for the price cap $P_{i.t}$ for utility *i* in time period *t* (usually year) is:

$$P_{i,t} = P_{i,t-1} \times (1 + RPI + X_i) \pm Z_i$$

where $P_{i,t-1}$ is the price cap for the previous time period considered, *RPI* is the Retail Price index, X_i is the efficiency factor for utility i and Z_i is a correction factor to account for the effect of exogenous extraordinary events affecting the utility's costs.

Application of this regulation method (see [55]) reveals that, compared to ROR regulation, incentives created by price caps more closely simulate the dynamics of the competitive market. If successful, with a price cap scheme, consumers will pay reasonable prices and the regulated firm will have strong incentives to institute cost-reducing initiatives. A major drawback of this approach is that price cap shifts the risk of fluctuations in system usages to the regulated firm. In sectors where this could induce important issues for the whole community, a revenue cap approach mitigates this risk.

4.1.3 Revenue Cap Regulation

Revenue cap regulation is a technique that regulates the maximum revenue that a utility can earn. These methodologies are quite similar to price cap mechanisms; regulation shifts to total revenue requirements rather than per unit rates (see [45]). Purpose of revenue cap regulation methods is to provide the utility with incentive to maximize its profits by minimizing the costs and allowing the utility to keep the cost savings achieved during the regulation lag (see [40]). A general formula for the revenue cap R_i for utility *i* in time period *t* (usually year) is:

$$R_{i,t} = (R_{i,t-1} + CGA_i \times \Delta Cust_i) \times (1 + RPI + X_i) \pm Z_i$$

where CGA_i is the custom growth adjustment factor, $\Delta Cust_i$ is the variation in the number of customers, X_i is the efficiency factor for utility *i* and Z_i is an adjustment factor for events beyond management control.

Revenue cap regulation has been applied in the context of electricity transmission in UK and US (see [40]). Although it provides strong incentives for cost minimization, this method has revealed to limit the incentive to increase sales and competition among utilities.

4.1.4 Sliding Scale Regulation

Sliding scale regulation (also called ROR bandwidth regulation) allows utility's revenues to vary in a certain range, and provides for ROR adjustments if utility's gross rate of return is outside this range. The utility's rate of return is benchmarked against a reference ROR that lies within a pre-specified dead-band. The name sliding scale derives from the fact that the ratio of sharing of shortfalls or overshoots between utility stockholders and consumers changes with the level of variation from the benchmark.

An example of sliding scale regulation mechanism for the allowed rate of return R_t in the period *t* considered is the following (see [40]):

$$R_t = R_{t-1} - l \times (R_{t-1} - R^*)$$

where R_{t-1} is the actual rate of return in the previous period, R^* is the benchmark ROR and *?* is the sharing parameter, depending to R_{t-1}. When the R_{t-1} is within the predefined range, *?* is equal to zero, and utility stockholders absorb all shortfalls and enjoy the benefits of all overshoots. For R_{t-1} outside the predefined range the sharing parameter varies, taking values between zero and one.

Sliding scale of return has been used in hybrid schemes, in connection with price caps by constraining the ROR impact of price cap mechanisms to politically and operationally acceptable levels (see [55]).

4.1.5 Yardstick Regulation

Yardstick regulation methodologies were introduced to promote indirect competition among regulated utilities operating in geographically separated markets (see [40]). With yardstick regulation techniques, prices for a regulated utility are directly related with the performance of the other firms. Under this approach, price levels for a firm are not based on its initial performance, but are derived from a "yardstick" or benchmark group of comparable firms, or the industry as a whole. A general formula for the price cap $P_{i,t}$ for utility i in the time period t is (see [40]):

$$P_{i,t} = a_i C_{i,t} + (1 - a_i) \sum_{\substack{j=1 \\ j \neq i}}^{n} (f_j \cdot C_{j,t})$$

where a_i is the share of utility's own cost information ($a_i = 0$ represents pure yardstick regulation), C_i is the unit cost of utility i, f_j are the revenue or quantity weights for peer group utilities j (having the corresponding unit cost $C_{j,t}$) and n is the number of utilities in the peer group.

Yardstick regulation has been applied in the water industry (see [59]) in conjunction with price cap techniques, and in the electricity sector (see [64]).

Practical application has revealed its characteristics to create strong incentives for cost minimization and to promote efficient capital expenditure. By creating a strong linkage between the regulatory rule and differences among utilities, yardstick competition techniques have provided incentives to utilities to reveal information about themselves and about each other to the regulator, mitigating the traditional asymmetry of information between the regulator and the firm (see [64]).

A major concern in applying yardstick regulation is the identification of the comparison group for each firm, because, generally, the regulated utilities vary widely in size and characteristics. To cope with this problem, a way followed has been to select a group of firms with generally similar cost structures or to apply the mechanism only to cost categories that are expected to be relatively homogeneous across firms. However, the result of these mechanisms may be very small samples. Another approach to take into account company heterogeneity is the use of appropriate adjustment tools. For this purpose many techniques are used, ranging from statistical regression to data envelopment analysis (see [64], [59] and [39]).

4.1.6 Menu of contracts

In menu of contract regulation, the regulator offers the utility a menu of incentive plans with constant consumer welfare. Within this menu, the firm will chose the contract that maximizes its profits and this self-selecting processing reveals to regulator utility's welfare-enhancing preferences. For example (see [40]), a menu of incentives can be designed where the utility's share of profits s or some specific reward is a function of the efficiency factor X or the price cap chosen by the utility from a base value:

$$s = f(X)$$

In this case, to higher X-factors chosen correspond higher shares of profits for the utility. The major issue in implementation of this incentive regulation scheme is that the design of menu requires considerable information about the link between efficiency level and rewards.

4.1.7 Target Incentive Regulation

Target incentive regulation is a incentive methodology used to address specific aspects of the operation of the utility, pursuing an objective of “local” performance improvement of a specific outcome. Target incentive regulation is usually used to promote environmental standards, technical efficiency and quality of service objectives (see [40]). Despite to the efficacy of these methods to target their specific objectives, their practical application has highlighted how they could distort efficient allocation of resources, degrading broad performance. In many cases, target incentive methods are used in connection with global incentive regulation techniques (see also [63]).

4.2 Benchmarking techniques and performance analysis

In the previous section many incentive regulation techniques have been presented. In all these methodologies efficiency improvements are driven by rewarding good performance with respect to some benchmarks. The choice of appropriate benchmarks and techniques to measure performance is therefore a key issue for the regulator (see [63]).

Following the approach of Jamasb and Pollitt (see [39]), benchmarking and performance evaluation techniques could be grouped in two categories:

- **Frontier benchmarking methods**: based on the identification of an efficient performance frontier, determined by the "best practice" of the utilities in the sample. The efficient frontier is the benchmark against which relative performance of utilities is measured. Efficient frontier could be found using various methods, ranging from statistical parametric Corrected Ordinary Least Squares and Stochastic Frontier Analysis, to the linear programming-based non-parametric Data Envelopment Analysis;
- Mean and average benchmarking methods: based on the identification of an average production function or cost function for the sample of utilities. Performance of an utility is given by the deviation of the observed production (or cost) from the estimated average production (or cost) function. The common method used to assess the performance function is the statistical parametric Ordinary Least Squares. Other methods based on average performance rely on the use of Total Factor Productivity techniques to define the benchmarks.

In the following part of the section a detailed description of potentials and drawbacks of some of these methods is provided, and great attention is paid to the possible application of such methodologies in the ATC sector. As a general indication (see [39]), from a regulatory policy point of view, the main difference between frontier and average benchmarking is that the former gives greater prominence to performance variation between firms, while the latter focuses on performance differences with respect to an "average behaviour". A frontier benchmarking approach could therefore be useful at initial stages of incentive regulation, where the objective is to reduce performance gap among utilities. Average benchmarking methods may be used to mimic competition among firms with relative homogeneous characteristics. Another important factor is the size of the sample; in general, frontier benchmarking methods require relatively large samples of firms, to obtain robust performance analysis; average benchmarking methods are suitable when there are scarce data and comparators for application of frontier methods.

According to the literature on efficiency measurement and benchmarking techniques, we could individuate a new broad distinction of them into parametric and non-parametric approaches (see, for example, [60] and [33]). This distinction has principally historical reasons; parametric approaches were the first methods used for performance studies and are generally based on estimation of stochastic functions, as Stochastic Frontier Analysis or Ordinary Least Squares-based Regression Analysis, while non-parametric approaches, and in particular Data Envelopment Analysis (DEA), represent relatively new tools to face the problem.

A wide literature exists on efficiency measurements by parametric approaches. Regression Analysis is a common tool to perform stochastic frontier analysis and to assess efficiency (see [43] for a detailed description). An important study wherein these techniques are applied to determine cost effectiveness of ANSPs has been performed by EUROCONTROL PRU-EEC (see [23] and [27]).

While statistical parametric analysis is the classical approach to assess performance of DMUs, non-parametric methods, DEA in particular, represent new and powerful tools to face the problem. Many recent studies in literature deal with differences among parametric and non-parametric methods for efficiency measures. For example, Cubbin and Tzanidakis ([15]) compare the use of Regression Analysis and DEA to assess the efficiency of regulated water industry; in [54] DEA is compared to stochastic frontier analysis to evaluate the relative efficiency of European airports. A comparison between parametric stochastic production frontier based method and non-parametric DEA-based method in agricultural production efficiency assessment has been carried out in [60].

Conclusions reached in previous studies are that many conceptual differences between parametric and non-parametric methods exist. One advantage of the parametric regression approach is that there are a number of well-developed statistical tests to investigate the validity of the model specification, and tests of significance for the inclusion or exclusion of factors. Moreover, statistical methods are less sensitive to outliers and other noise in the data, allowing testing of specific assumptions for the error term. Nevertheless, this has the drawback, especially for regression analysis, to require the specification of a functional form to be fitted. If the true functional form is unknown, a non-parametric method like DEA could be advantageous since it avoids the risk of fitting the wrong functional form. Moreover, DEA can easily handle both multiple inputs and outputs, which is not straightforward for regression analysis. Another advantage of DEA is that it does not require price information. This represents an attractive feature to determine efficiency of firms that consume or produce inputs or outputs which lack natural prices. Another advantage of DEA is that it identifies “peers” for DMUs to be compared with. A general overview of Data Envelopment Analysis is provided in Appendix A.3.

In the following part of the section, we concentrate our analysis on potentials of non-parametric approaches to assess efficiency. Firstly, Total Factor Productivity methodologies are investigated, and a review of their applications in performance measurements is provided. A larger attention is devoted to Data Envelopment Analysis and its potentials of application in ATC context. This methodology has captured great interest among researches, and in recent years there is a growing literature on its application in the air transportation sector.

4.2.1 Total Factor Productivity

Total Factor Productivity is an index number technique that measures the ratio of an index of outputs to an index of inputs, allowing the comparison between the same DMU in different periods, or between different DMUs (see [44]). The weights used in constructing the indexes are respectively the revenue shares and the cost shares of outputs and inputs. A disadvantage of TFP versus DEA is that it requires price information on inputs and outputs (and this is not easy for firms that produce or consume inputs or outputs which lack natural market prices, for example government institutions). Total Factor Productivity techniques have been used to measure efficiency in the US telecommunication sector in regime of price cap regulation (see [57]). In the air transportation sector, TFP measures are used to study productivity performance of the Australian domestic airlines by Forsyth (see [30]). Performance of airports has been investigated using TFP approach by Hooper and Hensher (see [37]).

4.2.2 Data Envelopment Analysis

ATC Units can be regarded as organizations that make decisions about how to use their inputs (e.g. technical and human resources) to produce specific outputs (e.g. traffic density and kilometres controlled). Since it is reasonable to assume that all ATC Units use similar inputs to produce the same outputs (see [23]), we could regard them as homogeneous Decision Making Units. Our objective is to determine the efficiency of the various ATC Units in carrying out these tasks. At present time no DEA applications to this purpose have been found in literature. However, there are many applications of DEA in airport efficiency studies. Airports and ATC Units have many common characteristics in inputs and outputs and, in many cases, in the form of control by the pertaining states. Therefore, the various DEA models developed and the methodological approaches tested in the airport context could be adapted for the case of ATC Units.

A first application of Data Envelopment Analysis to measure airports performance was published by Gillen and Lall in 1997 ([33]). They developed two DEA models based on terminal and airside operations. In his study ([58]), Sarkis tested various DEA models to determine US airports efficiency. In this study, airport efficiency scores are calculated using different DEA models, providing a good insight of DEA methodology and its variants for the air transportation sector. For example, in addition to the basic CCR model (see A.3) with a constant-return-to-scale, a variable-return-to-scale model was considered (the BCC model) to take into account different size of airports (smaller airports are generally penalized by constant-return-to-scale models). In the European context, in [54] Pels, Nijkamp and Rietveld study airports efficiency comparing DEA and stochastic frontier analysis. In [3], Adler and Berechman use DEA to assess airports efficiency relying on airports evaluation data provided by airlines.

4.3 Demand Management

Each airline produces a demand to the ATC system to perform all its flights according to the time and the route indicated in the flight plan. Delays and re-routing may force carriers to operate flights deviating from the «optimal» situation. In this context, acting on the demand drivers, like, e.g., the route charges (see Chapter 3), may lead airlines to consider strategies for evaluating the level of service received taking into account either route charges and ground delay costs either flight efficiency (route lengths and deviation from optimal flight level). This framework may induce carriers to modify their demand in terms of delays and routes provided they would receive some economic benefits. As an ultimate goal, these new trade-off solutions derived from the innovative pricing schemes yield a new pattern of the overall ATC demand enhancing the capacity of the whole system, eventually providing further advantages to airlines.

This investigation is essentially composed of two steps. First, in collaboration with airlines, flight performance metrics such as «flight efficiency» indicators have to be defined. Second, new strategies for demand management have to be envisaged.

4.3.1 Flight performance metrics

In the Tactical phase, the 4D flight plan is known. In fact, the Route Assembly Section of the ATS Environment System (ENV) contains the Standard Routes (CFMU handbook [25]). The flight plan is modified, in the Pre-Tactical and Tactical planning phases and when the flight is in the airspace, by means of horizontal and vertical re-routing operations aiming at reducing the work load on the different sectors (in addition to slot allocation if required). Data on the flight plans of the last 49 months are collected in the Archive System (ARC).

From these data and from the standard routes it might be possible to define indicators of the flight performance in terms of the "distance" of some given parameters from the standard values in ENV. Such indicators could be defined for each single flight or, in a more aggregate way, considering also the different airspace sectors. In fact, congested areas often impose re-routing. Hence we might relate the flight performance indicator to the deviation from the average rather than the per se value.

On that topic, there already exists an EUROCONTROL study (CARE-INTEGRA Project) defining flight performance metrics.

4.3.2 Demand management strategies for air routes

In accordance with the research activity currently performed at the University of Padova, Italy, we propose a market-based approach investigating and developing ([4]) *economic incentives and instruments (such as congestion tolls, peak-period pricing, slot auctions and slot trading) aimed at*

- *limiting in some way the demand for access to busy airfields or to congested airspace and/or*
- *modifying the spatial and temporal distribution of this demand to bring it closer to available capacity.*

In the air transportation field, similar studies have been carried out dealing with airport congestion only (see, e.g., [52]) and not with congestion of the en route airspace ([4]). In this context, we would like to extend, adapt and integrate the framework developed for the airport environment to the air routes scenario collaborating with airlines in defining a proper model of their behaviour.

4.4 Study on equity

The ATC problem is a very complex one, both in terms of its dimensions and of the constraints it must comply with. At present, there are no clear benchmarks for the performance of the involved actors. In this direction, the PRU of EUROCONTROL has developed a hierarchical structure of the “performance areas” (ten areas have been identified: in order of decreasing importance, safety, delay, cost-effectiveness, predictability, access, flexibility, flight efficiency, availability, environment and equity). For them, some relevant performance indicators have been defined (cfr. [21]). It is important to point out that for some areas, such as for instance for safety, the indicators level has an absolute value per se, in the sense that it is inserted in a well defined normative system having precise constraints and a clear and non ambiguous objective. Instead, for other performance areas, such as for instance delay and cost-effectiveness, the value of a single indicator could be quite less meaningful per se, and tradeoffs could be devised among different indicators, thus producing alternative solutions still having the same Pareto - efficiency. Using the latter kind of metrics is in any way useful for comparison purposes, for instance in order to compare the level of the offered service in different years or in different areas.

However, these metrics can be hardly used to devise algorithms, as they are often too subjective and lack formalization. In particular, in order to design new algorithms for a more efficient slot allocation, it is necessary to implement some constraints that are implicit in the different metrics, in such a way that the resulting procedures may produce results that comply with the EUROCONTROL service characteristics. For example, in the literature there are different solutions to the slot allocation problem that are provided by techniques different from the one of the CASA algorithm, and such solutions often yield better performances in terms of mean produced delay and of amount of work required by the ATC centres (see, for example, [53] and [7]). However, such solutions may fail as far as equity is concerned. In fact, the advantage of these algorithms comes from facilitating flights that could expand perturbations to the global system, and from penalizing flights whose delay has narrower consequences. But such an attitude could contrast equity, which is a basic requirement for the EUROCONTROL service. This requirement is implicitly satisfied by the allocation algorithm presently in use, which does not distinguish different flights, but just stipulates that any flight crossing different congested zones must be subject to the most restrictive constraint. In order to overcome this drawback, an explicit equity constraint could be considered, but there are not clear indications from PRU on how to formalize this concept, since its present formulation is purely subjective, and it is difficult to refer it to measurable physical parameters.

A first interesting analysis to be carried out will be devoted to understand the impact of the algorithm presently in use on equity with respect to the different companies. Using historical data, different indicators such as the average or the maximum delay will be considered in order to produce unambiguous equity parameters, to be used to devise new algorithms. In turn, such algorithms could produce feasible solutions to be used as benchmarks for the global ATM service.

Furthermore, the analysis of the equity concept for airlines operating in different market segments could produce a deeper understanding on which are the most critical issues concerning equity for companies of different types (e.g., the average delay, or the maximum delay, or the number of delayed flights, etc.)

Chapter 5

Conclusions

Main target of our preliminary study has been to identify the basic steps for a possible further and longer project to be performed subsequently. Final purpose of the overall project will be the definition and the study of impact of alternative route charge pricing schemes that might include a factor related to the level of service supplied by the ATC providers, with the objective of increasing their performances together with airline efficiency, and stimulating a more efficient use of ATC capacity.

According to the main objective, our study has moved in two directions, relative respectively to the "demand side" and the "supply side" of the air navigation services.

On the "demand side" we have defined general methodologies to assess the indirect impact on air travel demand and the direct impact on ATC service demand of the route charges. On the "supply side" we have investigated the application of economic methodologies to promote status and ways of operation positively affecting the behaviour of the system, both from the point of view of ATS suppliers and of the customers.

In this framework, the project has been developed along three main lines:

- air travel demand
- ATC service demand
- the supply side of ATC services.

5.1 Air travel demand

An econometric model for air travel demand has been produced, with a detailed analysis of the involved factors, showing when, why and how they have to be considered. In particular, it has been devised how to deal with issues of endogeneity of explanatory variables. The model has been applied to some historical data from Air Dolomiti. The results it provides have been analysed, and show a good performance of the model in terms of explanatory power, with respect to results available in the literature. Accordingly, elasticity values have been derived and discussed for the considered data. The results obtained in this section suggest to extend the use of the proposed model to other airlines, with different characteristics. This would require on one hand other data, from different sources, and, on the other, some deeper analysis of the statistical properties of the model. The collaboration of other airlines will be very important to the former goal.

5.2 ATC service demand

We proposed an indirect approach to assess the different impact of variations of the route charges on airspace users. The basic idea has been to consider route charges as a cost for airlines, and to study how a change in cost factors (for instance, fuel, whose incidence is to some extent similar to route fares) can affect carrier behaviours (as expressed, for instance, in terms of passenger × kilometre, or number of flights), and, as a consequence, the demand for ATC services. For this purpose, econometric and time series based techniques have been individuated. As first step of this analysis, in order to better distinguish different mechanisms by which costs affect their behaviours, airspace users have been classified in different categories, for which different mechanisms can be expected. Then an ABC analysis has been performed in order to concentrate on airlines providing a major part of revenues from route charges. It turns out that 7% of companies contribute for 96% of paid route charges. Then, a first version of total route costs shares assessment among the different categories individuated has been provided for years 1999 and 2000.

This line of the project should develop first of all by analysing the relation between costs and productivity (in terms of quantity of provided air transportation service), as it turns out by comparing 1999 and 2000 data. Moreover, the classification of airlines could be refined upon, considering more detailed data. Also the ABC classification, which shows some drawbacks that lead it to exclude minor companies, that often belong to the same categories (e.g., general aviation, aerial work and taxi carriers), could be improved, possibly using, for instance, cluster analysis. Also in this latter case more data are necessary.

5.3 The supply side

An extensive review of several forms of incentive regulation has been carried out, considering different areas. As they normally rely upon the evaluated performance of the considered units, some performance evaluation techniques have also been suggested, such as Data Envelopment Analysis. Then the problem of assessing the performance in the management of a single flight has been considered, as a possible basis upon which to analyse airline attitudes and behaviour. Finally, the specific question of equity has been addressed, in view of devising new schemes for ATC complying with such a requirement. A possible approach to model equity has been also outlined.

Of course, the supply side should be developed most in view of the objectives we propose. In particular, the considered incentive schemes should be considered for application to the airline case. Different scenarios should be analysed, possibly using simulation tools. The single flight case should be used to test different performance metrics on historical data. This will be the basis for studying decision preferences and mechanisms of different types of carriers (according to the classification mentioned in the previous section), considering, in different scenarios, alternatives involving new charging schemes and new operational procedures. For this task in particular, a strict collaboration with the research group of University of Padova, Italy, appears to be very appropriate. Finally, the equity problem could be studied on the base of historical data in order to formally state equity constraints for ATC rules.

Chapter 6

Proposals for further work

In this preliminary study we have defined the guidelines for a further and longer project with the purpose of defining and studying the impact of alternative route charge pricing schemes, that might include factors related to the level of service supplied by the ATC providers, with the objective of increasing their performance, as well as airline efficiency, and of stimulating a more efficient use of ATC capacity.

To this aim, feasible methodologies and proper techniques have been individuated. Moreover, some of them have been implemented: relying on Air Dolomiti data, the econometric model produced to study factors affecting air travel demand has been tested. A first analysis of the various components of ATC demand and their market share in Europe has been carried out. The performed analysis and the first results obtained suggest to structure the following steps as shown in figure 6.1. The direction of unbroken arrows indicates the logical dependence, hence the temporal precedence, of the work packages involved. Dashed arrows identify suggested but not necessary precedences of the phases concerned.

In the following, a concise outline of the directions along which this research can be developed is presented on the base of the diagram of figure 6.1.

As regards the study of passenger demand for transportation, the next step is the refinement of the econometric model proposed, using data from a larger sample of routes and testing other possible explanatory variables, in order to improve its. statistical properties. This phase is expected to be developed in collaboration with Air Dolomiti.

Then, the use of the passenger demand model can be extended to other air carriers, to test, for the various types of airlines, the different passenger reactions to changes in airfares and, in general, in the level of service provided (as defined in the demand model through the service-related factors). A necessary requirement for this phase is the availability of data from other airlines.

Moreover, to better understand the global meaning of the results of the econometric model and to calibrate the choice of the sample of airlines to study, the extension of the analysis of passenger demand to other airlines could be preceded by a cluster analysis of the European airspace users. This would allow to refine the characterization of demand for ATC in Europe and to define homogeneous groups of airspace users, for which similar behaviours are expected. To perform such analysis, operational and economic data for the airspace users are necessary. Primary sources of information are EUROCONTROL, airspace users associations (e.g., AEA, ERA, IAOPA, EBAA) and international organizations (e.g., ICAO, EC, IATA).

As highlighted in figure 6.1, the cluster analysis is also the starting point for studying the impact of the variation of route charges on the homogeneous components of ATC demand. This part of the study is expected to use time series analysis and regression techniques. Also in this case, operational data for the airspace users are necessary. Primary data sources are still individuated in airspace users associations and international organizations. For operational data, an important source is the Eurocontrol CFMU Archive System (ARC).

Another important line of the project is the analysis of airline attitudes and behaviour concerning ATM rules. It involves the definition, in collaboration with air- lines, of “flight efficiency" indicators, based on flight performance metrics identified by EUROCONTROL CARE-INTEGRA Project. A case study is first planned with Air Dolomiti. Then, collaboration of other airlines is necessary.

In parallel, the analysis of ATS demand management by pricing techniques can be carried out. In this phase, the application of mathematical models developed to define economic measures for airlines to avoid airport congestion is extended to the context of route airspace. This analysis requires a strict collaboration with the research group of the University of Padova, Italy.

Models for ATC demand management and the knowledge of airline behaviours and decisional criteria then allow to devise price mechanisms and economic incentives for airspace users, in order to reduce airspace congestion and smooth demand for ATC.

For the "supply side" of ATC, the project contemplates the application of incentive paradigms to ATC units. Relying on the indication provided by the use of these techniques in the context of utilities regulation, their impact on ATC units behaviour is considered. In this framework, simulations may be performed for different scenarios, according to different levels of performance and different decisional criteria for ATC units. Moreover, for the same scenario many techniques for ATC units incentive regulation can be tested. For the development of this phase, EUROCONTROL is certainly an important source of information on ATC units.

Still on the supply side of ATC, another covered by our study is the definition of performance analysis and benchmarking techniques for ATC units. In this direction, a further step is the application of these methodologies to the analysis of ATC units performance. In particular, methodologies and models can be studied for the application of Data Envelopment Analysis in the ATC context. For this purpose, collaboration and data from EUROCONTROL are necessary.

Then, as shown in figure 6.1, the assessment of the impact of the different incentive mechanisms, together with the performance assessment for ATC units constitute the basic elements for a new task, where price mechanisms and economic incentives for ATC providers is considered.

Finally, since new route charge rules may fail to comply with equity requirements, another task of our future work is the implementation of the methodologies identified in our preliminary study to formalize equity constraints. To this purpose, flight management historical data are needed. Therefore, collaboration with EUROCONTROL CFMU is again necessary.

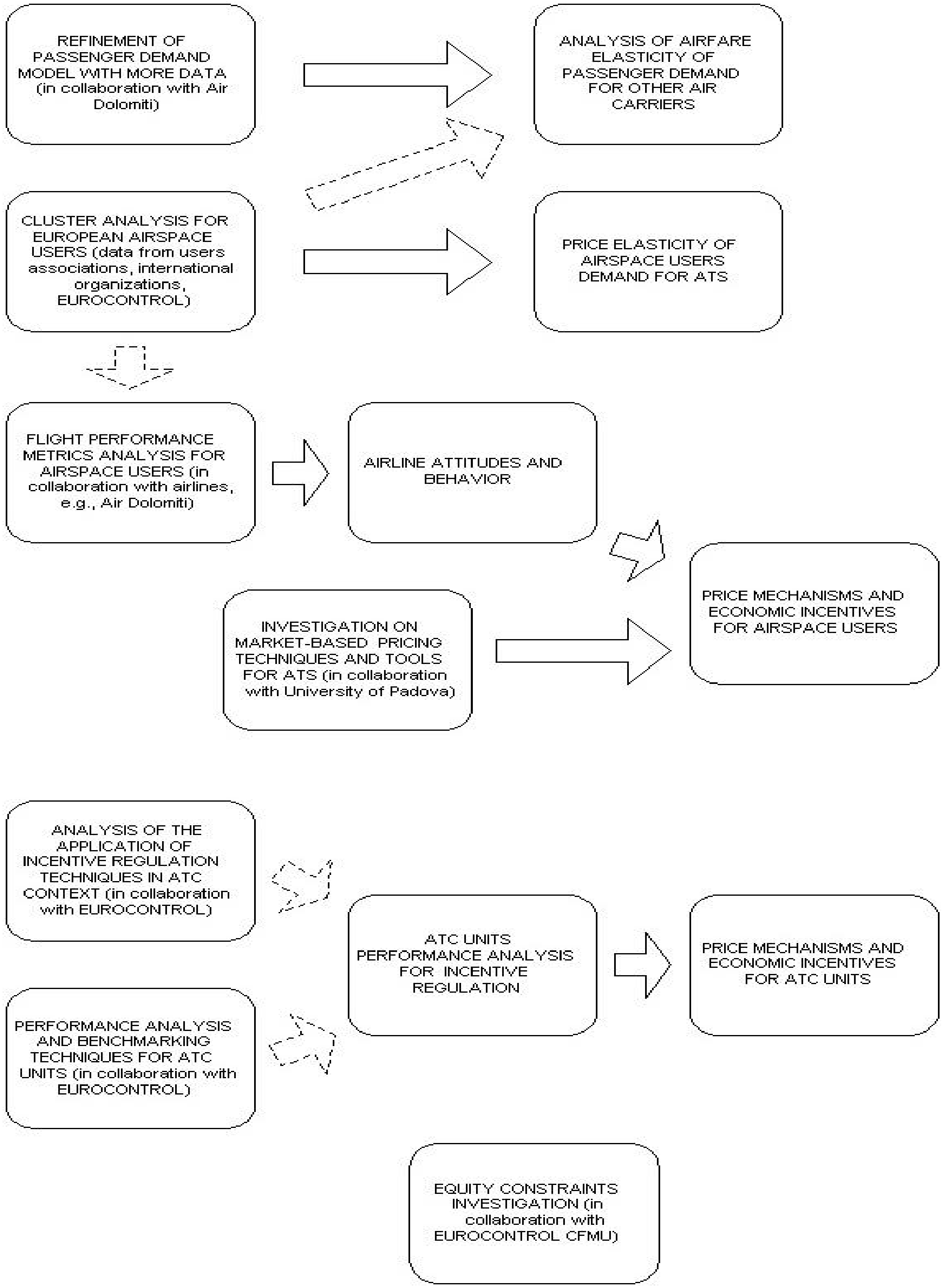

Figure 6.1: Further steps of the project

Appendix A

Mathematical Background

A.1 Concepts of Elasticities of Demand

In general, the demand for a good or a service depends on various characteristics and factors affecting the choice of the consumer. If we want to measure the "reactivity" of the demand level D with respect to a variation in a factor f affecting it, we might evaluate the slope s of the function of demand, that is the ratio between the variation of the demand *D* and the variation of the factor

$$s = \frac{\Delta D}{\Delta f}$$

Actually, the slope of the function is a measure of the reactivity of the demand, but has the drawback to be dependent on the unit of measure of the demand and of the factor. To cope with this problem, the elasticity η is normally considered, which is defined as the ratio between the percentage of change in demand D and the percentage of change in the factor *f*.. In this case, the measure of the "responsiveness" of the demand results independent on the units of measure used: an increase of 10% in the factor, e.g. price, represents the same variation both if price is expressed in Pounds or in Dollars. Formally, elasticity η can be expressed as:

$$h = \frac{\Delta D / D}{\Delta f \,/\, f}$$

Following definition A.2 we can say that:

- if h is greater than one (in absolute value) the good or the service is **elastic** respect to f . Demand is responsive to a change in the factor *f* ;

- if h is less than one (in absolute value) the (demand for the) good or the service is **inelastic** respect to *f*. Demand is not very responsive to changes in the factor *f* ;
- if h is equal to one (in absolute value) the (demand for the) good or the service has **unit elasticity** respect to *f* . The percentage change in quantity demanded is equal to the percentage change in the factor *f*;
- if h is equal to zero, the (demand for the) good or the service is **perfectly inelastic** respect to *f*. A change in the factor *f* will have no influence on the quantity demanded;
- if h is infinity, the (demand for the) good or the service is **perfectly elastic** respect to *f* . Any increase in the factor *f* makes the quantity demanded fall to zero.

In particular, when the factor *f* affecting the demand for a good or a service is its price, we talk about price elasticity of demand.

A.1.1 Exponential demand

In this subsection, we prove that the coefficients of the explanatory variables represent the elasticity of the demand with respect to the pertaining variable when considering an exponential functional form for the demand *D* for a good or a service.

If we assume, without loss of generality, an exponential function for the demand *D* depending to two explanatory variables *G* and *S*:

$$D = a_0 G^{b} S^{g} \qquad (A.3)$$

by definition, elasticity of the demand *D* respect to the factor *G* is defined as (see A.2):

$$h_G = \frac{dD}{dG} \cdot \frac{G}{D} \qquad (A.4)$$

The derivative of the function of *D* respect to the variable *G* is

$$\frac{dD}{dG} = b \cdot \left(a_0 G^{b-1} S^{g} \right) = b \cdot \left(a_0 G^{b} S^{g} \right) G^{-1} = b \cdot \frac{D}{G} \qquad (A.5)$$

Substituting the value of *dD/dG* found in A.5 in A.4 we obtain:

$$h_G = \frac{dD}{dG} \cdot \frac{G}{D} = b \cdot \frac{D}{G} \cdot \frac{G}{D} = b \qquad (A.6)$$

A.2 Linear Regression Analysis

Multiple regression analysis study the relationship between one dependent variable, *y*, and two or more independent variables x_j . In particular, in linear regression models the dependent variable *y* is assumed to be a linear function of the explanatory variables x_j and of the error term ε. In case of *K* independent variables, for the i-th observation, the regression equation takes the form:

$$y_i = b_1 x_{1i} + b_2 x_{2i} + \ldots + e_I \qquad (A.7)$$

The purpose of regression analysis is to obtain estimates of the *K* unknown parameters β_j , which indicate how a change in the respective independent variable affects the change of the dependent one. Many statistical tools and methods exist to estimate coefficients of the regression equation A.7 and assess the validity of the results. Anyway, the validity of results depends on the assumptions made for the data sample. A widely used set of assumptions (known as Gauss-Markov assumptions) is the following:

- The error terms ε_i have normal distribution with expected value of zero: $E[\varepsilon_i] = 0$. This means that on average errors balance out.
- The variance of the error term is constant for each observation: $E[\varepsilon_i^2] = \sigma^2$ for $i = 1, \ldots, n$.
- The error terms of different observations are not correlated: $E[\varepsilon_i \varepsilon_l] = 0$ if $i \neq l$.
- The independent variables have finite variances. As a consequence of this assumption, the independent variables will be independent of the error terms.
- The independent variables are linearly independent, i.e., no independent variable can be expressed as linear combination of the others. For explanatory variables not linearly independent (*multicollinear* variables) the explanatory effect of one could be transferred on the others.

According to the assumptions above, the common method used for estimating the coefficients of equation A.7 is Ordinary Least Squares (OLS). If we denote $\hat{b}_1, \ldots, \hat{b}_K$ the OLS estimates of $b_1, \ldots, b_K$, the predicted value of y_i concerning the i th observation is:

$$\hat{y}_i = \hat{b}_1 x_{1i} + \cdots + \hat{b}_K x_{Ki}$$

The error in the OLS prediction of y_i, called also residual, is:

$$e_i = y_i - \hat{y}_i$$

The basic property of OLS estimation is to choose $\hat{b}_1,\ldots,\hat{b}_K$ in a way to minimize the sum of square residuals $\sum_{i=1}^{n} e_i^2$, where *n* is the number of observations.

It can be shown that:

$$\hat{b} = \left(X^T X\right)^{-1} X^T Y$$

where X is an $n \times K$ matrix with (i, j) th element x_{ij}, Y is an $n \times 1$ vector with typical element y_i, and $\hat{b}$ is a $K \times 1$ vector with typical element $\hat{b}_j$.

In the hypothesis of Gauss-Markov assumptions A.2 for the data sample, the OLS estimator $\hat{b}$ above is the best unbiased estimator. That is, it has the smaller variance than any other unbiased estimator.

A.2.1 Two-Stage Least Squares Regression Analysis

Two-stage least square regression is a methodology that allows to extend regression to cover models where the disturbance term of the dependent variable is correlated with the independent variable. If this happens, Gauss-Markov assumptions A.2, are not satisfied for the model, and parameter estimations calculated using OLS could be not consistent.

To cope with this problem, a two-stage least-square regression analysis is performed. This is a two-step methodology: in the first stage new variables are created to substitute the problematic endogenous ones; in the second stage regression is computed in OLS fashion, but using newly created variables. To create the first-stage new variables to replace the problematic endogenous ones, instruments variables are used. The instruments are exogenous variables with direct causal influence to the endogenous causal variables, but with no direct relation to the error term in the base regression. These variables are used in a model estimated using OLS with the endogenous causal variable as dependent and the instrumental variables as independent. The predicted values of this regression equation are the values of a new causal variable which replaces the endogenous causal one. If we consider a model with multiple problematic endogenous variables, there will be one regression for each one of them. The second step, where OLS are used for the new model estimation, provides non-distorted estimation of the parameters.

A.3 Data Envelopment Analysis: an overview

DEA is a technique that measures the relative efficiency of decision making units with multiple inputs and outputs but with no obvious production function to aggregate the data in their entirety. In contrast to parametric approaches, whose object is to optimise a single regression plane through the data, DEA optimises on each individual observation with an objective of calculating a discrete piecewise frontier determined by the set of Pareto-efficient DMUs. Moreover, in parametric analysis the single optimised regression is assumed to apply to each DMU. DEA, in contrast, optimises the performance measure of each DMU. This results in a revealed understanding about each DMU instead of the depiction of an «average» DMU.

The parametric approach requires the imposition of a specific functional form (e.g., a regression equation, a production function, etc.) relating the independent variables to the dependent variables. The functional form selected also requires specific assumptions about the distribution of error terms (e.g. independently and identically normally distributed) and many other restrictions. In contrast, DEA does not require any assumption about the functional form. DEA calculates a maximal performance measure of each DMU relative to all other DMUs in the observed population with the sole requirement that each DMU lie on or below the extremal frontier. Each DMU not on the frontier is scaled against a convex combination of the DMUs on the frontier facet closest to it (for a comprehensive introduction to DEA see for instance [13]; some recent developments are in [11] and [12]).

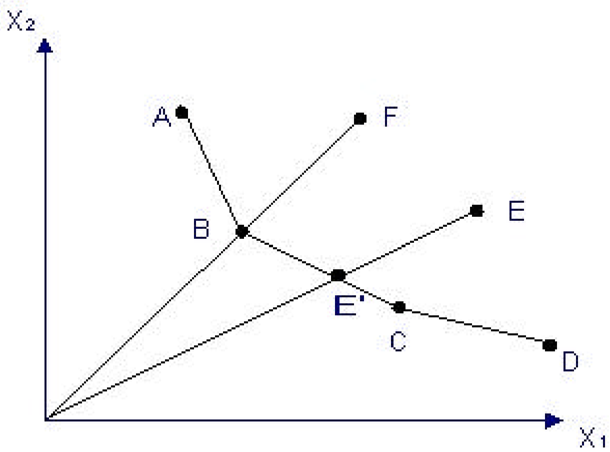

Figure A.1: Efficiency of DMUs with DEA approach

For example, in Figure A.1 there are six companies (A to F), each one producing a unit of single output *y* using two inputs, x_1 and x_2. Analysing the figure, we see that companies A, B, C and D are efficient. For example, C uses more of x_1 and less of x_2 compared with B, while company F is inefficient compared to B since it uses more of both x_1 and x_2. The efficient counterpart of F, i.e. B, is called D's reference group, and could be used as a benchmark to increase the performance for F. In the same way, E' (convex combination of B and C) is a benchmark for the inefficient unit E and the distance EE' is a measure of the efficiency of company E. Formally, we could define efficiency as a generalized ratio:

$$efficiency = \frac{results}{resources}$$

If we represent results (outputs) and resources (inputs) with two vectors:

$$results = Y = (y_1, y_2, ..., y_s)$$

$$resources = X = (x_1, x_2, ..., x_m),$$

then efficiency results to be a ratio between a weighted sum of the outputs and a weighted sum of the inputs:

$$efficiency = J = \frac{\sum_{i=1}^{s}(v_i \cdot y_i)}{\sum_{i=1}^{m}(u_i \cdot x_i)} = \frac{v_1 \cdot y_1 + v_2 \cdot y_2 + \ldots + v_s \cdot y_s}{u_1 \cdot x_1 + u_2 \cdot x_2 + \ldots + u_s \cdot x_m}$$

where vectors

$$V = (v_1, v_2, ..., v_s)$$

$$U = (u_1, u_2, ..., u_s)$$

represent the weights associated to outputs and inputs respectively. In the basic DEA ratio model, known as CCR model (from its authors Charnes, Cooper and Rhodes), the objective is maximizing the efficiency value of the DMU *k*, from among a reference set of *n* DMU, by selecting the optimal weights associated to outputs and inputs. Formally, for each DMU we have to define a virtual input and a virtual output that, considering for example DMU k, are expressed as:

$$virtual\ input = X_{vk} = (u_{1k} \cdot x_{1k} + u_{2k} \cdot x_{2k} + ... + u_{mk} \cdot x_{mk})$$

$$virtual\ output = Y_{vk} = (v_{1k} \cdot y_{1k} + v_{2k} \cdot y_{2k} + ... + v_{sk} \cdot y_{sk}).$$

in the hypothesis of *m* inputs and *s* outputs.

The optimal weights associated to unit *k:*

$$V_k = (v_{1k}, v_{2k}, ..., v_{sk})$$

$$U_k = (u_{1k}, u_{2k}, ..., u_{mk})$$

are the ones that, evaluating the other DMUs with the same weights, put DMU *k* “in the best possible light”, with maximum efficiencies constrained to 1. The mathematical formulation of the problem is:

maximize $$J = \frac{Y_{vk}}{X_{vk}} = \frac{\sum_{i=1}^{s}(v_{ik} \cdot y_{ik})}{\sum_{i=1}^{m}(u_{ik} \cdot x_{ik})} = \frac{v_{1k} \cdot y_{1k} + v_{2k} \cdot y_{2k} + \ldots + v_{sk} \cdot y_{sk}}{u_{1k} \cdot x_{1k} + u_{2k} \cdot x_{2k} + \ldots + u_{sk} \cdot x_{mk}}$$

Subject to:

$$\frac{v_{1k} \cdot y_{1j} + v_{2k} \cdot y_{2j} + \ldots + v_{sk} \cdot y_{sj}}{u_{1k} \cdot x_{1j} + u_{2k} \cdot x_{2j} + \ldots + u_{sk} \cdot x_{mj}} \leq 1 \qquad \forall j \in [1 \ldots n]$$

$$v_{1k}, v_{2k}, ..., v_{sk}\ {}^{3}0$$

$$u_{1k}, u_{2k}, ..., u_{mk}\ {}^{3}0$$

considering *n* DMUs.

This nonlinear programming formulation is equivalent to the following linear programming problem (see for example [14] for proof):

$$max \quad q = \mu_{1k} \cdot y_{1k} + \mu_{2k} \cdot y_{2k} + ... + \mu_{sk} \cdot y_{sk}$$

subject to:

$$n_{1k} \cdot x_{1k} + n_{2k} \cdot x_{2k} + ... + n_{mk} \cdot x_{mk} = 1$$

$$\mu_{1k} \cdot y_{1j} + \mu_{2k} \cdot y_{2j} + ... + \mu_{sk} \cdot y_{sj} £ n_{1k} \cdot x_{1j} + n_{2k} \cdot x_{2j} + ... + n_{mk} \cdot x_{mj} \qquad "j\ Î\ [1..n]$$

$$\mu_{1k}, \mu_{2k}, ..., \mu_{sk}\ {}^{3}\ 0$$

$$n_{1k}, n_{2k}, ..., n_{mk}\ {}^{3}\ 0.$$

The result of this formulation is an optimal simple or technical efficiency value # # that is at most equal to 1. If $q^*= 1$ the DMU is efficient. If $q^*< 1$ the DMU is inefficient, because there is at least one other DMU (or a convex combination of others DMU) that:

- with the same resources produces more outputs;
- produces the same outputs with a less resources.

DEA also could give clear and concise information about the relative efficiency of each DMU and about the policies that inefficient DMUs have to undertake, through comparison with the efficient units.

As highlighted in [14], for each DMU DEA gives:

- the relative efficiency, i.e. the measure of aptness in using resources to produce results, in comparative terms respect to other units,
- the weights (relative to inputs and outputs) that put the unit in the “best possible light”. This allows the individuation of the strong points (inputs and outputs associated to higher weights) and the weak points (inputs and outputs associated to lower weights) of the DMU;
- for inefficient DMUs, the more efficient units that dominate it. This indication could be useful for a «benchmark policy» of the DMU, which could have precise reference models;
- for inefficient DMUs, the values of the flows (inputs and outputs) that, if joined, would make the unit efficient.

Appendix B

Airlines classified by category of users

B.1 National Carriers

AIR FRANCE
ALITALIA
BRITISH AIRWAYS BA
IBERIA
KLM
LUFTHANSA
SABENA
SAS
SWISSAIR
TURKISH AIRLINES THY
AEROFLOT
ADRIA AIRWAYS
AER LINGUS
AIR MALTA
AIR PORTUGAL
AUSTRIAN AIRLINES
BELAVIA AIRLINES
CROATIA AIRLINES
CYPRUS AIRWAYS
CZECH AIRLINES
FINNAIR OY
ICELANDAIR
JAT
LOT
LUXAIR
MALEV
OLYMPIC AIRWAYS
TAROM

B.2 Regional Carriers

AEGEAN AVIATION
AER ARANN
AEROCONDOR PORTUGAL
AIR ALFA
AIR ALPS AVIATION
AIR BALTIC

AIR BELGIUM
AIR BERLIN 2
AIR BOTNIA
AIR DOLOMITI
AIR ENGIADINA 2
AIR GEORGIA
AIR GREECE
AIR JET
AIR LIBERTE 2
AIR LIETUVA
AIR LITTORAL
AIR MOLDOVA
AIR NOSTRUM
AIR ONE ITALIA
AIR OSTRAVA
AIR PROVENCE 3
AIR RHONE ALPES
AIR SICILIA
AIR URGA
ALITALIA EXPRESS
ALPI EAGLES SPA
AMC AVIATION
AOM MINERVE
ARKIA ISRAEL AL
ARMENIAN AIRLINES
ATLANTIC AIRWAYS
AUGSBURG AIRWAYS
AURIGNY AIR
AXON AIRLINES
AZZURRA AIR
BALKAN BULGARIAN
BINTER CANARIAS SA
BRAATHENS SAFE
BRIT REGIONAL AIRL
BRITAIR
BRITISH ANTARTIC
BRITISH MEDITERR
BRITISH MIDLAND
BRITISH WORLD
BRYMON AIRWAYS 2
CHANNEL EXPRESS
CIMBER AIR DENMARK
CITY BIRD
CITYFLY S.P.A.
CITYFLYER EXPRESS
CITYJET
CONTACTAIR
CORSE MEDITERRANEE
CRONUS AIRLINES
CROSSAIR
DELTA AIR TRANSPORT
DENIM AIR
DEUTSCHE BA
EASTERN AIRWAYS UK
EMERALD AIRWAYS
ESTONIAN AIR
EUROPE AIR LINES SA
EUROPE CONTINENTAL
EUROPEAN AIR EXPRESS
EUROPEAN AIR SERVICE
EUROPEAN AVIAT CHART
EUROWINGS FALCON AIR AB

FLANDRE AIR
FLIGHTLINE
FLYING ENTERPRISE
FUTURA INTERNATIONAL
GALAXY AIRWAYS
GANDALF AIRLINES
GB AIRWAYS LTD
GILL AVIATION
HAMBURG INTL
HEMUS AIR
ISTANBUL AIRLINES
JERSEY EUROPEAN AWYS
KIBRIS TURK HAVA YOL
KLM CITYHOPPER KLM EXEL
KLM UK LTD
LAUDA AIR
LAUDA AIR ITALY
LINAIR
LITHUANIAN AIRLINES
LUFTHANSA CITYLINE
MAERSK AIR
MAERSK AIR LTD
MANX AIRLINES
MERIDIANA ITALIA
MINERVA AIRLINES
MONTENEGRO AIRLINES
NEWAIR A/S
NEWAIR AIRSERVICE
ONUR AIR
ORCA AIR

PORTUGALIA
PROTEUS AIRLINES
PULKOVO
REGION AIR
REGIONAL AIR LINES
REGIONAL AIRLINES
REGIONAL LINEAS AER
RHEINTALFLUG
SAT AIR
SATA AZORES
SATA INTERNATIONAL
SCHREINER AIRWAYS
SCORPIO AVTN
SCOTAIRWAYS
SKYTEAM
SKYWAYS AB
SKYWAYS INTL (OE)
SPANAIR S A
SUN EXPRESS
SWIFTAIR ESPANA
TITAN AIRWAYS
TRADE AIR
TRANSTRAVEL AIRLINES
TYROLEAN AIRWAYS
UKRAINE INTL AIRLINE
V L M
VOLARE AIRLINES LI
WEST AIR SWEDEN AB
WIDEROE FLYVESELSKAP

B.3 Low Cost Carriers

EASYJET AIRLINE
GO FLY LTD
MARTINAIR
RYANAIR
VIRGIN BLUE
VIRGIN EXP IRELAND
VIRGIN EXPRESS
VIRGIN ATLANTIC

B.4 Air Cargo Carriers

AEROPOSTALE SEA
AIR CARGO PLUS INC
AIR TRANSPORT INTL
AIRBUS TRANSPORT
AIRFREIGHT EXPRESS
ATLANTIC AIR TRANSP
AVIOIMPEX MACEDONIA
CAL CARGO AIRLINES
CARGOLUX
DAS AIR CARGO
DHL INTERNATIONAL
EAT
EMERY WORLDWIDE ARL
GEMINI AIR CARGO
GUARDAIR
HAPAG LLOYD
HEAVYLIFT CARGO AIRL
LUFTHANSA CARGO
MAKEDONSKI AVIOTRANS
MK AIRCARGO
MNG HAVAYOLLARI
POLAR AIR CARGO
STERLING EUROPEAN
TEA BALE
TMA
TNT AIRWAYS
TNT INTL AVIATION
TOWER AIR
UPS
VEGA AIRLINES
VOLARE UKRAINE
WDL AVIATION

B.5 Charter Carriers

AIR EUROPE ITALIA
AERIS SA

AERO LLOYD REISEN
AEROLYON SA
AIR 2000 LTD
AIR CHARTER COLOGNE
AIR CHARTER ICELAND
AIR CHARTER LTD
AIR CHARTERS EELDE
AIR COMET S.A.
AIR EUROPA
AIR HOLLAND CHARTER
AIR SCANDIC AB
AIR VIA BULGARIAN
AIRCHARTER FLUGSERV.
AIRLONG CHARTER
AIRTOURS INTL
AJT AIR INTL
BALAIR CTA SA
BLUE PANORAMA LI
BRITANNIA AIRWAYS
BRITANNIA AIRWAYS AB
BRITANNIA AWYS GMBH
CHARTER AIR
CHARTER COMMUNICTION
CHARTER SVC HETZLER
CHARTERTECH
CONDOR
CORSE AIR
EDELWEISS SUISSE
EURALAIR INTL
EUROCYPRIA
EUROFLY
EUROPE AIR CHRTR LUX
FISCHER AIR SRO
FLY FTI
FLYING COLOURS
GERMANIA
IBERWORLD S.A.
JMC AIRLINES LTD
LTU LUFTTRANSPORT
MONARCH AIRLINES
PEGASUS TURKEY
PREMIAIR
SABRE AIRWAYS LTD
SOBELAIR
STAR AIR
STAR AIRLINES S.A.
TRANSAER INTL
TRANSAVIA AIRLINES
TRAVEL SERVIS A.S.

B.6 Non European Carriers

AEROLINEAS ARGENTINA
AEROLINEAS MEXICANAS
AEROVIAS DE MEXICO
AIR AFFAIRES GABON

AIR AFRIQUE
AIR ALGERIE
AIR ANATOLIA/ANADOLU
AIR BOTSWANA
AIR CANADA
AIR GABON
AIR GHANA
AIR HONG KONG
AIR INDIA
AIR JAMAICA
AIR KAZAKHSTAN
AIR KUBAN
AIR LUXOR
AIR MADAGASCAR
AIR MALDIVES LTD
AIR MALI
AIR MAURITANIE
AIR MAURITIUS
AIR NAMIBIA
AIR NEW ZEALAND
AIR SEYCHELLES
AIR TAHITI NUI
AIR TOGO
AIR TRANSAT
AIR ZIMBABWE
ALIA ROYAL JORDANIAN
ALL NIPPON AIRWAYS
AMERICAN AIRLINES
AMERICAN TRANS AIR
ASIANA AIRLINES INC
ATLANTA
ATLAS AIR USA
AVIANCA
BANGLADESH BIMAN
CAAC CHINA
CAMEROON AIRLINES
CANADA 3000
CANADIAN AIRLINES
CATHAY PACIFIC
CHINA AIRLINES
CHINA EASTERN
CHINA NORTHERN
CHINA NORTHWEST
CHINA SOUTHERN
CHINA UTD AIRLINE 2
CONGO AIRLINES
CONTINENTAL AIRLINES
CUBANA
DAGESTAN AIRLINES
DELTA AIR LINES
DUBAI AIR WING
EGYPTAIR
ELAL
EMIRATES INTL
ETHIOPIAN AIRLINES
EVA AIR
FEDERAL EXPRESS
GARUDA
GHANA AIRWAYS
GULF AIR
IRANAIR
ISRAIR LTD

JAPAN AIRLINES
KENYA AIRWAYS
KOREAN AIRLINES
KUWAIT AIRWAYS
LAN CHILE
LIBYAN ARAB AIRLINES
LOTUS AIR
MALAYSIAN AIRLINES
MEA AIR LIBAN
NIPPON CARGO
NORTHWEST AIRLINES
NOUVELAIR TUNISIE
NOVA AIRLINES
PAKISTAN INTL AIRL
QANTAS AIRWAYS
QATAR AIRWAYS
ROYAL AIR MAROC
ROYAL BRUNEI
ROYAL NEPAL AIRLINES
SAA
SAUDIA
SHOROUK AIR
SINGAPORE AIRLINES
SRILANKAN AIRLINES
SYRIAN ARAB AIRLINES
TACV CABO VERDE
TAM MERIDIONAIS
THAI INTERNATIONAL
TUNIS AIR
TWA UNITED AIRLINES
UNIVERSAL WEATHER
US AIRWAYS
UZBEKISTAN AIRWAYS
VARIG VASP
VIETNAM AIRLINES
WORLD AIRWAYS
YEMENI

Appendix C

List of Acronyms

AEA Association of European Airlines

ANS Air Navigation Services

ANSP Air Navigation Services Providers

ASM Airspace Management

ATC Air Traffic Control

ATM Air Traffic Management

ATS Air Traffic Services

CASA Computer Assisted Slot Allocation

CRCO Central Route Charges Office

CFMU Central Flow Management Unit

DEA Data Envelopment Analysis

DMU Decision Making Unit

EBAA European Business Aviation Association

ENV CFMU Environment System

ERA European Regions Airline Association

FIR Flight Information Region

GDP Gross Domestic Product

IAOPA International Council of Aircraft Owner and Pilot Association

IATA International Air Transport Association

ICAO International Civil Aviation Organization

IFR Instrumental Flight Rules

OLS Ordinary Least Squares

PBR Performance-Based Regulation

PRC Performance Review Commission

PRU Performance Review Unit

ROR Rate-of-Return

TFP Total Factor Productivity

VFR Visual Flight Rules

Bibliography

[1] Seraj Y. Abed, Abdullah O. Ba-Fail, Sajjad M. Jasimuddin, "An econometric analysis of international air travel demand in Saudi Arabia", *Journal of Air Transport Management*, Vol.7, pp. 143-148, 2001

[2] M. Abrahams, "A service quality model of air travel demand: an empirical study", *Transportation Research*, Part B, Vol.23B, pp. 213-223, 1989

[3] N. Adler, J. Berechman, "Measuring airport quality from the airlines' viewpoint: an application of Data Envelopment Analysis", *Transport Policy*, Vol.8, pp. 171-181, 2001 [4] G. Andreatta, "Preliminary Investigation on market-based demand management strategies for European airports and air routes“, Discussion paper, University of Padova, Italy, November 2001

[5] Association of European Airlines, *Yearbook* 2001 July 2001

[6] J. Asensio, "The success story of suburban railways: determinants of demand and policy implications", *Transport Policy*, Vol.7, pp. 295-302, 2000

[7] N. Barnier, P. Brisset, T. Rivière, "Slot allocation with Constraint Programming: Models and Results“, ENAC-CENA, France, 2001

[8] P. Bogetoft, "Incentives and productivity measurements" *International Journal of Production Economics*, Vol.39, pp. 67-81, 1995

[9] M. Brons, E. Pels, P. Nijkamp, P. Rietveld, "rice Elasticities of Demand for Passenger Air Travel: A Meta-Analysis" Tinbergen Institute Discussion Paper TI 2001-047/3, 2001

[10] G. Burghouwt, J. Hakfoort, "The evolution of the European aviation network, 1990-1998" *Journal of Air Transport Management*, Vol.7, pp. 311- 318, 2001

[11] L. Castelli, R. Pesenti, W. Ukovich, "DEA-like models for efficiency evaluation of specialised and interdependent units", European *Journal of Operational Research*, Vol.132, pp. 274-286, 2001

[12] L. Castelli, R. Pesenti, W. Ukovich, "DEA-like models for the Efficiency Evaluation of Hierarchically Structured Units" *European Journal of Operational Research*, accepted for publication, 2002

[13] A. Charnes, W. Cooper, A. Y. Lewin, L. M. Seiford, *Data Envelopment Analysis: Theory, Methodology and Applications*, Kluwer Academic Publishers, 1994

[14] W. Cooper, L. M. Seiford, K. Tone, *Data Envelopment Analysis*, Kluwer Academic Publishers, 2000

[15] J. Cubbin, G. Tzanidakis, "Regression versus data envelopment analysis for efficiency measurement: an application to the England and Wales regulated water industry", *Utilities Policy*, Vol.7, pp. 75-85, 1998

[16] J. de Leeuw, I. Kreft, "Random coefficient models for multilevel analysis", *Journal of Educational Statistics*, Vol.11, pp. 57-86, 1986

[17] P. L. de Matos, R. Ormerod, "The application of operational research to European air traffic flow management - understanding the context", *European Journal of Operational Research*, Vol.123, pp. 125-144, 2000

[18] EUROCONTROL Central Route Charges Office, *Principles for establishing the cost-base for route facility charges and the calculation of the unit rates*, Doc. 99.60.01/1, in force on 1 August 1999

[19] EUROCONTROL Central Route Charges Office, *Report on the Operation of the Route Charges System in 1997, 1998, 1999, 2000*

[20] EUROCONTROL Central Route Charges Office, *The EUROCONTROL Route Charges System*, October 1998

[21] EUROCONTROL Performance Review Unit, *The PRC's European ATM performance measurement system*, June 1999

[22] EUROCONTROL Performance Review Commission, *Performance Review Report PRR3-Year 1999*, April 2000

[23] EUROCONTROL Performance Review Unit-EUROCONTROL Experimental Centre, *Progress Towards Cost-Benchmarking of the European ATM System*, July 2000

[24] EUROCONTROL Central Office for Delay Analysis, *Delays to Air Transport in Europe-Annual 2000*, January 2001

[25] EUROCONTROL Central Flow Management Unit, *The CFMU Handbook-Edition 7.0*, February 2001

[26] EUROCONTROL Performance Review Commission, *Performance Review Report PRR4-Year 2000*, April 2001

[27] EUROCONTROL Performance Review Unit-EUROCONTROL Experimental Centre, *Update of the Cost-Benchmarking Model for ANSPs/States in 1999*, July 2001

[28] EUROCONTROL Performance Review Unit – KPI Drafting Group, *Cost Effectiveness and Productivity KPIs*, Working Paper, October 2001

[29] EUROCONTROL Central Office for Delay Analysis, *ATFM Delays in Europe-October 2001*, November 2001

[30] P. Forsyth, "Total Factor Productivity in Australian domestic aviation", *Transport Policy*, Vol.8, pp. 201-207, 2001

[31] L. Fridström, H. Thune-Larsen, "An econometric air travel demand model for the entire conventional domestic network: the case of Norway", *Transportation Research*, Part A Vol.17A, pp. 385-393, 1983

[32] A. Ghobrial, A. Kanafani, "Quality-of-Service model of Intercity Air-Travel Demand", *Journal* of *Transportation Engineering* Vol.121, pp. 135-140, 1995

[33] D. Gillen, A. Lall, "Developing measures of airport productivity and performance: an application of Data Envelopment Analysis", *Transportation Research Part E* Vol.33E, pp. 261-273, 1997

[34] C. Guran, "Customers and Actors of ATM: Military Users", *Air & Space Europe*, Vol.2, pp. 53-57, 2000

[35] G. R. Hall, "Electricity pricing and regulatory practice in a competitive environment-Analysis of alternative ratemaking methodologies", Prepared for Asian Development Bank and the Philippines Energy Regulatory Board and Department of Energy, May 2000

[36] P. Hogge, "Airlines: Customers and Actors of ATM", *Air & Space Europe*, Vol.2, pp. 44-49, 2000

[37] P. G. Hooper, D. A. Hensher, "Measuring Total Factor Productivity of airports: an index number approach", *Transportation Research Part E*, Vol.33E, pp. 249-259, 1997

[38] Tae Hoon Oum, W. G. Waters II, Jong-Say Yong, "Concepts of price elasticities of transport demand and recent empirical estimates an interpretative survey", *Journal of Transport Economics and Policy*, Vol.26, pp.139-154 and 164-169, 1992

[39] T. Jamasb, M. Pollitt, "Benchmarking and regulation: international electricity experience", *Utilities Policy*, Vol.9, pp. 107-130, 2001

[40] T. Jamasb, M. Pollitt, "Benchmarking and regulation of electricity transmission and distribution utilities: lesson from international experience", University of Cambridge, December 2000

[41] M. Janic, "Liberalisation of European aviation: analysis and modelling of the airline behaviour", *Journal of Air Transport Management*, Vol.3, pp. 167-180, 1997

[42] J. D. Jorge-Calderón, "A demand model for scheduled airline services on international European routes", *Journal of Air Transport Management*, Vol.3, pp. 23-35, 1997

[43] S. C. Kumbhakar, C. A. Knox Lowell, *Stochastic Frontier Analysis*, Cambridge University Press, 2001

[44] Independent Pricing and Regulatory Tribunal of New South Wales, "Efficiency and Benchmarking of NSW Electricity Distributors", Discussion Paper, February 1999

[45] Independent Pricing and Regulatory Tribunal of New South Wales, "Regulation of electricity network service providers-Price control, issues and options", Discussion Paper, March 1999

[46] IATA, *Annual Report 2001*, May 2001

[47] International Council of Aircraft Owners and Pilot Associations-European Region, *What is General Aviation and What Do They Want?*, 2001

[48] International Council of Aircraft Owners and Pilot Associations-European Region, *What is General Aviation and Aerial Work?*, October 2001

[49] K. J. Mason, "The propensity of business travellers to use low cost airlines", *Journal of Transport Geography*, Vol.8, pp. 107-119, 2000

[50] K. J. Mason, R. Gray, "Short haul business travel in the European Union: a segmentation profile", *Journal of Air Transport Management*, Vol.2, pp. 197-205, 1995

[51] S. Nahmias, Production and Operations Analysis, R. D. Irwin Ed., 1993

[52] A. R. Odoni, "Congestion Pricing for Airports and En Route Airspace", *Proceedings of the Workshop ATM '99*, pp. 100-109, Capri, Italy, September 26-30, 1999

[53] S. Oussedik, D. Delahaye, "Reduction of Air Traffic Congestion by Genetic Algorithms", Centre de Mathématiques Appliquées, Ecole Polytecnique, Palaiseau Cedex, France

[54] E. Pels, P. Nijkamp, P. Rietveld, "Relative efficiency of European airports", *Transport Policy*, Vol.8, pp. 183-192, 2001

[55] J. P. Pfeifenberger, W. B. Tye, "Handle with care-A primer on incentive regulation", *Energy Policy*, Vol.23, pp. 769-779, 1995

56] C. Pusch, “Air Traffic Management”, *Air & Space Europe*, Vol.3, pp. 255- 257, 2001

[57] T. R. Roycroft, “Alternative regulation and the efficiency of local exchange carriers: evidence from the Ameritech states”, *Telecommunications Policy*, Vol.23, pp. 469-480, 1999

[58] J. Sarkis, “An analysis of operational efficiency of major airports in the United States”, *Journal of Operations Management*, Vol.18, pp. 335-351, 2000

[59] J. W. Sawkins, “Yardstick competition in the English and Welsh water industry”, *Utilities Policy*, Vol.5, pp. 27-36, 1995

[60] K. R. Sharma, P. Leung, H. M. Zaleski, “Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches”, *Agricultural Economics*, Vol.20, pp. 23-35, 1999

[61] B. Van Houtte, “Towards a Single European Sky: Initiatives of the European Commission to reform Air Traffic Management”, *Air & Space Europe*, Vol.2, pp. 24-27, 2000

[62] G. Williams, “Will Europe's Charter Airlines be replaced by the New Breed of Low Cost Carriers?”, *Aerogram*, Vol.9, pp. 11-13, 2000

[63] B. Williamson, “Incentives for Service Quality: getting the framework right”, *The Electricity Journal*, pp. 62-70, June 2001

[64] A. Yatchew, “Incentive Regulation of Distributing Utilities using Yardstick Competition”, *The Electricity Journal*, pp. 56-60, January-February 2001

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