New tools for competition measurement in network industries.

The case of air transport *

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Abstract. Any company operating in a network industry may use the structure of its network – the location of the nodes and the links among them – as a means by itself to exercise market power. To provide competition agencies with adequate instruments to evaluate the relevance of this problem, this paper proposes several new tools for concentration measurement based on the use of origin-destination matrices. Air transport sector provides a suitable example to test these tools, not only because of its network structure, but also due to the liberalization process it was involved into from 1987 to 1997. Our empirical results suggests that competition has increased, but a number of market imperfections still persist, possibly preventing an economically optimal resource utilization from a pan-European viewpoint. In fact, the hub and spoke network structure dominates the industry, giving advantages to some carriers and preventing a larger degree of competition. The attempts by low-cost carriers of exploiting the niches left by the larger companies have been fiercely responded by these, so that their future success is uncertain.

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1. Introduction

During the 1990s, an extensive deregulation and privatization process dramatically changed the market structure and the shape and intensity of regulation in many infrastructure industries around the world. Energy, telecommunications, water and several transport sectors all have experienced a wide liberalization process mostly aimed at opening them up to competition. As a consequence of this reform the economic literature has recently witnessed a renewed interest in studying the implications for competition policy of these changes. It appears that one of the most relevant contributions is that the network structure of these industries provides new perspectives to be considered in detail.[1]

Within the transport sector, one of the most suitable examples to study this process is the European air industry, not only because of its natural properties as a network industries – a set of airports and connecting routes – but also because from 1987 to 1997 it was gradually liberalized by means of several deregulation packages enacted by the European Commission. These packages sought to reconcile a more liberal bilateral agreements system that some members (United Kingdom, The Netherlands and Ireland) had pursued a few years before, with the more traditional and protectionist 'flag-carrier' system heavily defended by other countries (Germany, France, Italy and Spain, among others). On April 1st, 1997 the formal deregulation of the airline industry within the European Union (EU) was finally completed. Since then, any technically qualified EU airline can operate scheduled flights in any region of the Union, even in wholly domestic routes, without the restraints on fares or capacity that had prevailed during more than fifty years. Following a US-imported pattern, several carriers decided to reorganize their networks from 'point to point' (or direct flights) into 'hub-and-spoke' systems and a number of low-cost airlines emerged to serve not only the seasonal and mostly southbound tourist segment that had so far been flying charter, but also other high-value clients in search of cheaper seats on selected destinations (Berechman and de Wit, 1996). National governments and officials at the European Commission were optimistic. It was predicted that competition among

[1] References on this issue are growing. Koski and Kretschmer (2004), and many other contributions in the same issue of the *Journal of Industry, Competition and Trade*, provide an interesting survey. Similarly, Economides (2003) contributes to define and classify the more relevant topics of competition policy in network industries.

airlines would soar, and price and services would improve in an unprecedented way (see Button *et al.*, 1998, or Hakfoort, 1999).

According to Fridstrøn *et al.* (2004), these predictions were overoptimistic. Travelers are now skeptically sharing the extended opinion that prices have not decreased too much and, although services have probably increased and new routes have emerged, the real impact of the whole process has been relatively lower than the effect experienced in the US after their air sector liberalization in the 1980s. The overall perception of many analysts is that not much competition has been achieved so far. A few bankrupted companies (*Sabena*, *Swissair*), or in financial distress (*Air France, Olympic Airways, Alitalia*), have confirmed that excess capacity was a distinguishing feature of this market before the reform, but also that many governments are still reluctant to abandon the flag-carrier model.

In the recent years the sector has been more hardly hit by external shocks (the aftermath of September 11th, as well as the global economic downturn and the SARS effect in Asia) than by internal competition forces. As compared to the US, an excessively large number of domestic airlines manage to survive in the unified intra-European market. This is so because in most countries little advantage is conceded to foreign companies that come to operate in national airports, still dominated by local incumbents benefited by 'grandfather rights' in the slot assignment process. Since price competition in the major routes is almost ruled out, many companies have refocused their strategies into two directions: on one hand, the old flag-carriers and trunk-line companies (the 'high-cost' sector) are rearranging their (internal and external) structure in search of consolidating past advantages and of a favorable positioning in case of future mergers and alliances. On the other hand, new and old companies are increasingly exploiting the low-cost traveler segment on a scheduled way, gaining market share to traditional charter flights.

To examine the competition effects of these strategic movements – mostly related to the evolution of the firms' market shares – this paper will analyze the evolution of the air industry market structure in the EU since 1984 using concentration indices, which will be then interpreted as overall proxies for market power. This approach is not new in the transport literature: several papers have addressed the same issue before in Europe, but many of them have so far exploited only the geographic implications or the local impact of the results,[2] and few of these works have specifically connected concentration indices with their effects on competition as it is usually carried out in other industrial organization analysis. As a major drawback of this methodology, it should be acknowledged that leaving aside the study of the effects of competition on the level and number of airfares, or the overall quality provided by the carriers could be a significant omission. However, it could be also argued that these are often short term effects, which translate into long term patterns through changes in market shares.[3]

The major contribution of this paper is to add new evidence to the discussion of how competition has increased (if any) in the air transport sector at the intra-European level by analyzing the changes in concentration and network structure between 1984 and 2001 in the European market of scheduled flights. Our analysis attempts to capture both the potential effects of new entries (or exits) on specific routes and the route reorganization of the main companies in response to these challenges. From a methodological viewpoint, we aim to introduce an explicitly consideration of the network design in the measurement of concentration, by adapting some simple tools of matrix algebra.

After this introduction, the structure of this paper is as follows. In Section 2 we first characterize the air transport sector as a network industry by highlighting its most relevant technical and economic features related to the network. Then, as a theoretical foundation for the competition analysis, Sections 3 and 4 depart from the usual concentration measurement procedures used in industrial organization and discuss how to implement them in the European air industry. We point out that market definition is the key issue in the implementation process and propose two alternatives: the route or the airline. For each of these two approaches a specific methodology is then fully developed

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[2] See for example, O'Kelly (1998), Burghouwt and Hakfoort (2001, 2002) or Burghouwt *et al.* (2003). A recent exception is provided by Lijesen (2004), who applies the Herfindahl index to the aviation markets, although its methodology differs from ours. A recent paper by Carlsson (2004) also studies prices and departures in European domestic aviation markets using the Herfindahl index as a proxy for market power in oligopolistic city-pair routes. Regarding the effects of increased competition on service quality (although in the US market), see Mazzeo (2003).

[3] Examples in this extensive line of research include a long list of papers, such as Marin (1995), De Wit (1996), or even Betancor and Campos (2000).

focusing onto three key variables for competition: number of flights, passengers carried (demand side) and seats supplied (supply side). In Section 5 we briefly describe the data selection process and then use the methods presented in the previous section to empirically analyze the evolution of air transport concentration in Europe from different approaches. Section 6 finally concludes summarizing the results and providing a digression on their policy implications for the near future.

2. Air transport as a network industry

The aviation industry can be described as a network: a system of links (routes) that connect nodes (airports) moving passengers and cargo among them. As a network industry, aviation is characterized by large network externalities in the sense that the costs and revenues involved in carrying passengers on different, interconnected routes are interdependent. Thus, according to Caves *et al.* (1984), there are large economies of scale, scope and density that may origin either at the supply (cost, production) side or at the demand (revenue, consumption) side.

Supply side economies of scale originate from using larger aircraft (assuming a constant load factor), from increasing the load factor, or from longer stage lengths. All of these reduce the cost per passenger-kilometer. However, economies of scale due to firm size are quickly exhausted in the European airline industry, although the smaller size of European carriers – as compared to their American counterparts – could be also considered as a signal of the positive returns to scale that still exhibits the European air sector. On the demand side, indirect economies of scale may appear as a result of increasing returns to scale on the supply side. Such effects are probably of limited importance, although it might be argued, e.g., that the more economical, larger aircraft may also appear more comfortable and secure to the traveler, and hence induce additional air travel demand.

Economies of scope on the supply side occur when the cost of producing two products or services by the same firm is lower than when they are produced by separate firms due to synergies. The most important source of economies of scope in the aviation industry arises from the complementarities of routes within the network. By operating several interconnected routes, an airline is able to utilize aircraft, crew, reservation systems, and other overhead cost items in various city-pair connections, which is particularly important when slot capacity at airports is limited. Airlines operating several flights out of one airport obtain flexibility to adjust their network to changes in the demand pattern. But perhaps even more important economies of scope emerge from the demand side: a carrier offering a larger network of services will be more attractive to the traveler, since she will have more destinations to choose from and a larger probability of finding a suitable connection from her particular origin to any given destination. Economies of scope on the demand side are often intensified by the marketing practices of the airlines, such as the frequent flyer programmes and the corporate discount schemes. These may create artificial economies of scope because customers avoid a certain switching cost if they concentrate their demand to one or a few airlines.

Finally, supply side economies of density exist if an airline's unit cost declines when the airline adds flights or seats on existing routes, all other things held constant. These increasing returns to density are due primarily to improved utilization of aircraft capacity and crew. The demand side economies of density are also important: a higher route frequency will decrease the average time cost experienced by the traveler and hence induce a higher demand for air transport, especially from business travelers. This feedback mechanism implies that the demand for travel in a network is in a sense self-reinforcing, and is referred to as the *Mohring effect*. As the demand for travel increases, a higher frequency of departures can be supported, and a smaller average generalized cost – including the fare and the value of time – is incurred by the individual user. This in turn induces a still higher demand, and so on until equilibrium is reached.

All these technical and economic features of air transport have direct implications for market organization. In opposition to the simpler 'direct flights' network, a particularly extended way of organizing an aviation network since the 1980s is the hub-and-spoke mode of operation. Rather than operating a large number of point-to-point, non-stop routes, the airline company channels all or most passengers through a hub airport, from which all connections extend like the spokes of a wheel. In this way the number of different non-stop routes needed to serve all possible pairs of destinations is drastically reduced, allowing for quite remarkable cost savings. The operation of a hub-and-spoke network often allows an airline to offer air services on routes, which in isolation do not generate sufficient volume of traffic to justify service. On some spoke routes, the load factor will be raised from a level below to a level above the minimum viable scale load factor. Judging by the experience after more than two decades of deregulated aviation markets in the US, the airline industry – when left without regulation – will tend to consolidate into a few, large air carriers with continent-wide hub-and-spoke networks (Gillen *et al.*, 1990).

While economically efficient to the individual carrier firm, the hub-and-spoke system of operation may have strong anti-competitive effects. The economies of scope and density characteristic of these networks are such as to grant the hub airline considerable market power at and around its hub. Since different airlines choose to operate hubs at different airports, the hub-and-spoke system as operated among a set of large individual carriers is liable to practically divide the market between the airlines. Although the networks of different carriers overlap, very few origin-destination pairs, if any, will exhibit more than two carriers operating non-stop flights.

Thus, even though the European airline industry has been liberalized for some time, almost 75% of all non-stop routes within the European Economic Area (EEA) were monopolized in 2000 (see **Table 1**), and 95% were either monopoly or duopoly routes. In terms of seat capacity, the situation is somewhat better, although one notes that no more than 13% of the seats are offered on routes serviced by more than two airlines.

Table 1. Competition on intra-EEA, non-stop routes (July 2000)

Number of carriers on route	Number of routes	Percentage of routes	Number of seats	Percentage of seats
1 (Monopoly)	3445	73,2	3650165	41,7
2 (Duopoly)	1056	22,4	3960942	45,2
3	177	3,8	1001285	11,4
4	20	0,4	113265	1,3
5	8	0,2	31870	0,4
Total	**4706**	**100 %**	**8757527**	**100 %**

Source: European Commission (2001).

The hub-and-spoke mode of operation has a longer history in Europe than in the US. It has grown out of the past regulatory framework and of the prevailing geographic and political conditions, rather than as an autonomous market process. Each nation has had its own flag-carrier, with a privileged position in and around its domestic market and frequently a large government ownership share. These airlines have been benefiting from considerable amounts of subsidies or direct financial support from the state. The flag-carrier typically organizes its network around a hub located near the national capital or main business centre. At this airport, the flag-carrier tends to have considerable direct and indirect influence on slot allocation practices, on ground handling services, and on other essential facilities. Backed by its own government, the carrier usually also tends to obtain privileged positions in whatever bilateral aviation agreements are signed with other countries. Each flag-carrier therefore enjoys considerable market power at and around its domestic hub. Thus, although there are almost as many flag-carriers as there are European nations, the competition between them is severely restricted, as they have been able to divide the market between them to a very considerable extent.

In summary, the hub-and-spoke mode of operation generates abundant network externalities on the cost side as well as on the revenue side. The incremental cost of operating an extra route in a hub-and-spoke network is often smaller than suggested by the average unit cost of the network. Moreover, an extra route may generate feeder traffic – and hence revenue – to the larger network. It will, in other words, be relatively inexpensive for an incumbent hub airline to cross-subsidize a single spoke route or a limited set of such routes. Essentially, this leaves a dominant hub airline with the opportunity to fight a rival new entrant through increased capacity, disproportionately reduced fares, and/or other predatory strategies.

These anti-competitive effects of hub-and-spoke networks are likely to be strongly reinforced by the carriers' frequent flyer programmes (and vice versa), by their dominance of slots, and by the tacit (or explicit) collusion mechanisms in the form of tolerated alliances. The market shares gained in the last few years by low-cost carriers offering point-to-point services seem insufficient to reverse the trend towards a more concentrated – less competitive – sector. Therefore, it is high time to devise the tools and provide an empirical analysis of the evolution of concentration in the European air markets.[4]

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[4] This idea has been supported by several recent papers. For example, Balfour (2004) points out the contradictions of EU competition policy in the air transport sector, whereas Brueckner and Pels (2004) provide a tentative consumer welfare analysis of the increased concentration in European airlines. For an account of the competition between 'high-cost' and 'low-cost' carriers, see Franke (2004).

3. Measurement of concentration in air transport

Measurement of market concentration is always an attempt of answer with a single value the question of to what extent the economic activity within a particular industry is controlled by a handful of firms. This will be always open to subjective interpretations, since any comparison among different individuals often requires the judgment of whether their differences allow or not a valid comparison. The usual approaches range from providing a diversity of inequality measurements (together with standard concentration indices), to create new (or adapt existing) indices to take into account the specificities of the sector under scrutiny.[5] We will follow these two approaches; firstly, in this section, we adapt standard concentration indices to the air transport sector. Then, in the next section, a new set of tools will be proposed to take into account some of the network characteristics of this industry.

3.1. Adapting traditional concentration indices to the air industry

A basic feature associated with the traditional study of market concentration is that it often incorporates two relevant aspects of industry structure, namely, size inequalities and the number of firms. For this reason it is now customary to distinguish between the *relative concentration indices*, that focus on how much is the difference (or inequality) of firm sizes within a given distribution of firms, and the *absolute concentration indices*, that emphasize the relative importance of each firm within its industry (as a proxy for market power).

In markets where firm sizes greatly differ among compared individuals, such as the European aviation market (where currently co-exist 'high-cost' carriers with smaller 'low-cost' airlines), relative versus absolute concentration is often a very relevant discussion. For example, the existence of a large number of small operators that gather an important share of output on a given route yields concentration results totally opposed to the case of the same market share being under the control of one or two large companies. These criticisms suggest the need of redefining standard concentration indices to consider the differences among firms (Geroski, 1983).

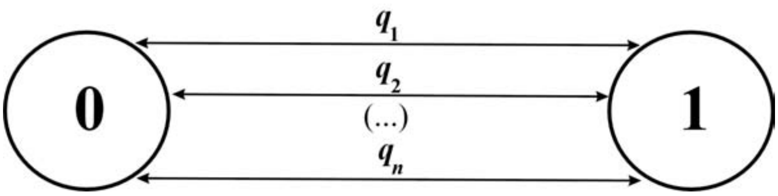
[5] **Appendix A** provides a quick review of the most usual concentration indices used in industrial organization.

In the case of air transport, the network properties that characterize this industry include the number of airports (and, possibly, the distance among them), the flights or seats offered by the companies (even distinguishing among different time intervals along the day or the week), and the actual demand (passengers carried over specific routes). Depending on how these elements are implemented in the empirical work, two major approaches can be followed to measure the level of concentration in the air industry. The first method, more traditional, defines the inter-city route (as a single pair of origin-destination airports) as the basic unit of analysis, applying then (variations of) the standard concentration indices. The second approach (Section 4) uses each airline as the basic unit of analysis and tries to specifically explore the network structure of each airline. Each one of these approaches implicitly conveys a different definition of the market where concentration is measured, as Veldhuis (1997) points out. However, both analyses are relevant to figure out the true level of concentration in the industry.

3.2. The inter-city approach: the use of traditional concentration indices

Consider a (national or international) city-pair route as described in Figure 1, where 0 and 1 (arbitrarily) design the origin and destination airports. This route is served by n different carriers, all of them offering their customers a two-way direct transport service. To avoid further complications we assume no significant differences among the quality of each company (same air and ground services) and fully concentrate on the quantity of services provided, denoted by q_i for firm i (i =1,…,n).

Figure 1. The inter-city (route) approach to concentration measurement



Variable q_i usually refers to the number of flights per company (on a daily, weekly, monthly or annual basis), but it might reflect the number of passenger seats offered (thus capturing differences in each company's types of aircrafts and fleet composition). Furthermore, since demand can be below supply, q_i could be also defined as the actual number of passengers carried by each company. In any case, $Q=q_1+\ldots+q_n$ would represent, the total traffic on any given route, which is implicitly considered as the 'market' where the n firms are competing.[6]

Once each market is defined in this way, the use of the concentration indices in Table 2 is straightforward. Many studies simply calculate the variance and put it together with a couple of absolute concentration measures. In early works it was frequent to rely on the CR4-index, which is defined as the sum of market shares of the four largest suppliers. This index, along with its family of CR8, CR20 and CR50-indices, has been widely used for market power analysis and regulatory policy. The main problem with this indicator is the arbitrary character of its cut-off point. In some markets, for example, the two or the five largest suppliers may be more relevant.

This feature is especially important in measuring changes in the level of competition. Most recent studies on market competition are based on indices derived from economic theory, like the Herfindahl index (H), which is based on oligopolistic competition. The H-index links to industry profits the relative sizes of the firms in a standard Cournot model, and its inverse, $1/H$, may be interpreted as the number of equally sized firms that an equally competitive market would have.[7] As a drawback, it tends to give excessive weight to larger firms; therefore several adjustments have been proposed in the literature. The most successful is the entropy index (E), which improves the influence of smaller firms. Since H and E can be showed to be particular cases of a general class of index (Hannah and Kay, 1977), they both are still routinely reported in most studies on market concentration. By applying these indices to each route, it could be then easily analyzed how concentration evolves along time. Despite being a necessary preliminary work, this approach has at least three major limitations:

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[6] By recalling that these are direct flights (see Figure 1), note that passengers and passengers-kilometers would yield the same result, since the n companies in the route would operate on the same distance. Alternatively, revenue data could be also used in the definition of q_i. However, this raises a number of methodological objections: the effect of changing prices and pricing strategies, the need of adjusting monetary values in cross-country and across time comparisons, more difficult access to comparable data,… For these reasons we will stick to *quantity* data.

[7] The link between this index and the underlying theory was established by Cowling and Waterson (1976). Its solid theoretical foundations favored its adoption in 1984 by the US Department of Justice as a concentration measure for merger reviews. This practice has ever since been followed by several other regulatory bodies.

1. First of all, it is critically dependent on the route sampling process. The choice of unrepresentative city-pairs would invalidate any analysis of, for example, the evolution of concentration in the European air industry. However, since an excessively large number of routes would probably disperse the results, a compromise between these two effects should be achieved. In addition, it is also critical the selection of time intervals for comparison purposes, although the annual nature of the databases used in empirical work often preclude other possibilities than year-by-year comparisons.

2. A second criticism lays in the aggregate nature of the definition of q_i. In air transport networks concentration of traffic may be important in three dimensions: production (how flights and passengers are distributed among different carriers), time (how flights are concentrated on specific time-intervals within the day or week), and quality (how passengers with different preferences choose among different types of services – first class, business, tourist – offered by the carriers within the same flight). Although all these three dimensions are crucial for competition analysis, the approach described so far only allow us to deal with the first of them. Time concentration is a continuous source of controversy in many congested airports, where the most valuable slots are assigned to companies enjoying 'grandfather rights'. Quality concentration is a useful indicator to detect consumers' patterns, providing a unique insight on the prospects of new business segments, such as 'low-cost carriers'. Unfortunately, most air transport databases (see Section 5) do not allow carrying out empirical works with these two levels of aggregation.

3. The final shortcoming of the intercity approach is that it completely misses the network properties of air transport discussed so far. Although it certainly exists, competition among airlines is seldom limited to a single route (especially in many European domestic markets). The intercity approach does not consider the network definition – in terms of number of airports served and the distance among them – of each carrier's output, which should as a key factor and therefore should be completed with a different approach.

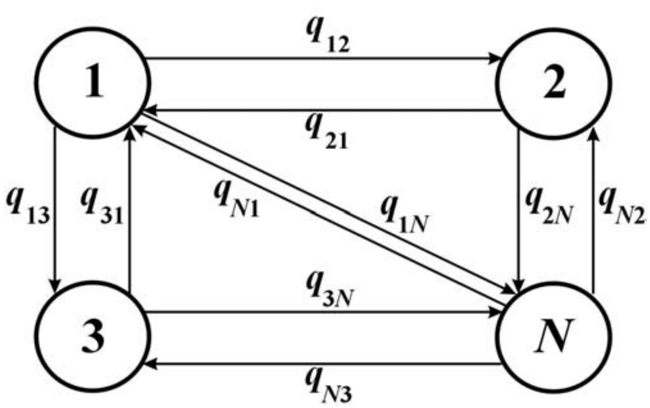
These drawbacks, particularly the last one, do not necessarily discard the use of the inter-city approach to the measurement of competition in the airline sector. In fact, in Lijesen *et al.* (2001) it is explicitly advocated to study the competition in civil aviation in Europe, also recalling that, ultimately, the critical factor carriers compete for is the traveler. If a traveler wants to get from 1 to 2, she is not interested in the domestic market as a whole, nor in either of the individual airports in it, since this traveler can only choose from carriers offering a service between cities 1 and 2. If competition is to benefit the consumer, it is bound to do so at a city pair level.

However, the city-pair may not be the level the regulator is interested in, as he would rather want to know about the region he has regulatory power over, a bundle of routes where a certain carrier is believed to be dominant or the region where a certain event has effects. If for instance two companies are to merge, a regulator would be interested in all the city pair markets that these carriers are active on. In this case, competition indicators measured at the city pair level can be aggregated, for instance by taking the weighted average of the indicators for all routes that the future mergers are active on. In any case, these concentration indicators should be used with caution and great attention should be paid to the definition of the market and the importance of imperfect substitutes. The simultaneous use of several indicators, along with economic intuition and common sense reduces the risks involved in this approach.

4. - Concentration measurement at the airline-level: an OD matrix

As an alternative means to overcome the above described limitations, a completely different approach to market concentration measurement can be suggested by exploiting the characteristics of each carrier's network.

Figure 2. The airline approach to concentration measurement



Consider, as depicted in Figure 2, an airline (say, *i*) serving a network composed of *N* airports, where $q_{hj} \geq 0$ denotes the total volume of air traffic between airports *h* and *j* (with $h, j = 1, \ldots, N$ and $h \neq j$). Note that, since the distance between airports may differ, the definition of *q* should now specifically include either the flights or the seats (both multiplied by the flown distance), or the usual passenger-kilometer data. By collecting all the q_{hj} pair together we can easily construct the origin-destination matrix for airline *i* for any given period of time *t* (namely, OD_i^t), which simultaneously serves to summarize the airline's network structure and the actual distribution of its traffic among airports:

$$OD_i^t = \begin{bmatrix} 0 & q_{12} & q_{13} & \cdots & q_{1N} \\ q_{21} & 0 & q_{23} & \cdots & q_{2N} \\ q_{31} & q_{32} & 0 & \cdots & q_{3N} \\ \cdots & \cdots & \cdots & 0 & \cdots \\ q_{N1} & q_{N2} & q_{N3} & \cdots & 0 \end{bmatrix}, \quad (1)$$

where, by convention, we shall assume that the rows will represent the origins and the columns the destinations.

4.1. Properties of the origin-destination matrix

It is worth noting several interesting properties of the *OD* matrix. First, it is always an $N \times N$ square matrix, although some its elements may be zero (*incomplete* network, with empty routes). Particularly, by construction, all the elements in the main diagonal are zero, that is, $q_{hh} = q_{jj} = 0$. When no other element is zero, the network is said to be *complete*. The *OD* matrix is asymmetric, unless incoming and outgoing traffics coincide, $q_{hj} = q_{jh}$. In such (rare) case the matrix can be simply defined by the elements above (or below) the main diagonal.

A second property is that the economic characteristics of an airline's network are embedded in the internal structure of its *OD* matrix. For example, as mentioned above, it is usual to distinguish between two major types of networks: fully connected ones (FC) and hub-and-spoke (HS) networks, as depicted below.

Figure 3. Fully Connected vs. Hub-and-Spoke networks

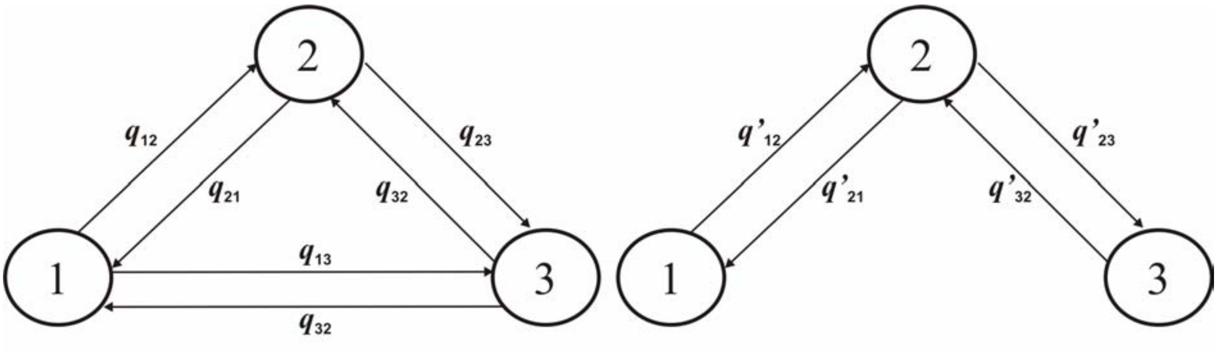


Figure 3 (left) illustrates a FC network where there are N=3 airports denoted 1, 2, and 3, where all passengers fly nonstop from origin to destination through three possible (two-way) routes: route 1-2, route 2-3, route 1-3. Figure 3 (right) illustrates a typical HS network, where route 1-3 does not longer exist. Passengers between 1 and 3 now fly through the hub airport, 2. The OD matrices of these networks clearly differ. Traffic will be assigned to certain rows or columns (relative to the others) thus reflecting the central or peripheral nature of certain airports. In addition, the hub-and-spoke network would be an incomplete one – with zero elements other than the main diagonal – since small airports ('spokes') would mostly have only direct flights with the hub(s). When the network is plenty of direct connections among all its N airports, the OD matrix would be complete.

By adapting expression (1), it is easy to show that the structure of the OD matrices of FC and HS networks would be, respectively:

$$OD_{FC} = \begin{bmatrix} 0 & q_{12} & q_{13} \\ q_{21} & 0 & q_{23} \\ q_{31} & q_{32} & 0 \end{bmatrix} \qquad OD_{HS} = \begin{bmatrix} 0 & q'_{12} & 0 \\ q'_{21} & 0 & q'_{23} \\ 0 & q'_{32} & 0 \end{bmatrix} \tag{2}$$

where q'_{12}, q'_{21}, q'_{23}, q'_{32} should now include the travelers that used to fly on route 1-3 (provided that the change from a FC to a HS network does not alter the total number of travelers). Furthermore, note that different companies, with different network structures should have different OD matrices.

4.2. Comparing networks

How to summarize into a single (and comparable across different matrices) value these characteristics? One obvious answer is to use some kind of matrix operator that captures the information encapsulated in the elements (rows and columns) of a matrix. According to the definitions presented in **Appendix B**, the best candidates are the *permanent* and the *norm*.[8]

The permanent of a matrix, **perm**(*OD*), adds all multiplicative permutations of its elements, thus condensing the information they contain. If the number of zeros is large, it will yield a lower value than in the case of a complete network. Thus, the lower the value of the permanent, the more likely than the structure represents a 'hub-and-spoke' style network. To confirm or discard this result we can also calculate either the **1-norm** or the **∞-norm** (only one of these), which respectively take into account the information by destinations (columns) or origins (rows). When comparing two *OD* matrices, a larger norm means a more concentrated network around a particular airport. The **Frobenius norm** of the *OD* matrix, given by the square root of the sums of the squares of the terms of the matrix, resembles the Herfindahl index defined in **Appendix A**, its advantage lies in considering both rows and columns simultaneously.

Finally, note that since the dimension (N) of any given *OD* matrix may differ among firms or across time (for the same firm) it is useful to denote it also as N_i^t, and any cross-section or temporal comparison using the matrix operators must take into account this feature. An easy adjustment would be simply to redefine each q_{hj} as a relative value $s_{hj} = q_{hj}/Q_i^t$, where Q_i^t represents the overall sum of the total traffic by columns and rows:

$$Q_i^t = \sum_{h=1}^{N_i^t} \sum_{j=1}^{N_i^t} q_{hj} \ . \tag{3}$$

4.3. A numerical example

To illustrate these ideas more clearly let us proceed with a numerical example based on Figure 3. Consider first a fully-connected network represented by matrix OD_1, where route 1-2 is large, route 2-3 is medium size, and route 1-3 is small. All routes are assumed to be symmetric and numeric values are normalized to [0,1] to simplify calculations. Then:

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[8] The *trace* operator is obviously discarded, since the elements of the main diagonal are all zero in our *OD* matrices. The *determinant* operator is less informative than the *permanent*, since it subtracts part of the traffic and could yield (meaningless) negative values.

$$OD_1 = \begin{bmatrix} 0 & 1 & 0.25 \\ 1 & 0 & 0.50 \\ 0.25 & 0.50 & 0 \end{bmatrix} \quad (4).$$

A second possibility is a FC network with three asymmetric routes, represented by matrix OD_2. Note that all one-way flights have been increased by 25% in comparison to OD_1:

$$OD_2 = \begin{bmatrix} 0 & 1.25 & 0.3125 \\ 1 & 0 & 0.6250 \\ 0.25 & 0.50 & 0 \end{bmatrix} \quad (5).$$

Alternatively, consider a HS network where route 1-3 is suppressed. We assume that total number of travelers remains unchanged and former users of route 1-3 are now evenly distributed through the hub airport. Thus, the new OD matrices for the symmetric and asymmetric cases above are respectively given by OD_3 and OD_4:

$$OD_3 = \begin{bmatrix} 0 & 1.125 & 0 \\ 1.125 & 0 & 0.625 \\ 0 & 0.625 & 0 \end{bmatrix} \qquad OD_4 = \begin{bmatrix} 0 & 1.40625 & 0 \\ 1.125 & 0 & 0.78125 \\ 0 & 0.625 & 0 \end{bmatrix} \quad (6).$$

It is now straightforward to compare these networks by using the elements of matrix algebra described above. **Table 2** provides a quick summary of results for this simple example:

Table 2: Comparing networks: a numerical example

	Fully connected network		**Hub and spoke network**	
	Symmetric routes	**Asymmetric routes**	**Symmetric routes**	**Asymmetric routes**
Determinant	0.25	0.35156	0	0
Permanent	0.25	0.35156	0	0
2-Norm	1.2311	1.4232	1.287	1.59
1-Norm	1.5	1.75	1.75	2.0313
∞-Norm	1.5	1.625	1.75	1.9063
Frobenius norm	1.602	1.8339	1.82	2.0837

A quite interesting feature that emerges from these results is that the FC case with symmetric routes can be considered as an ideal benchmark to later compare other network configurations, since it yields the lowest values for the norms. As mentioned above, the determinant and the permanent are not very useful tools in this case, particularly when the matrices have too many zeros, since it does not allows to discriminate between low concentration and a very sparse network.[9] Note also that the values of the norms also increase with asymmetry in routes, thus providing another interesting point of comparison. Since the numerical values of this example are just simulated we will not attempt an economic interpretation of them, and move instead to real example.

4. Competition in European air transport: network analysis

This section is devoted to empirically analyze the methodologies above described. We start by characterizing the properties of the databases used in our investigation, highlighting their main advantages and limitations. We then proceed to describe how the sampling procedure was carried out, and then immediately present a summary of the most relevant results obtained using the concentration measurement procedures discussed above.

4.1. Data characteristics and sample selection

As in many other empirical papers, the objectives of our analysis have been downsized and adjusted to data availability and reliability. In the European air transport sector the main source of information is the official statistics collected by the International Civil Aviation Organization (ICAO), since data directly obtained from the companies is seldom comparable across them (and even along time). The European Union also provides some information on an EU-wide basis through *Eurostat*, whereas the airports sometimes publish some traffic data. In all cases we rely on aggregate route information (it never distinguishes different types of passengers within each route) collected on annual terms (monthly data should be sometimes preferable to evaluate the competitive strategies of the firms and to take into account the seasonality of air travel and the existence of peak-load periods through the year).

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[9] Matrices with a large number of zeros are precisely referred to as sparse matrices. They are dealt with by some special algebra procedures we have preferred not to include in this paper. See Cullen (1990) for details.

For this study, focused on the intra-European air transport market we have selected a representative sample of routes and companies from *Traffic By Flight Stage*, the detailed traffic database elaborated by ICAO, using data directly provided by the airlines. Our sample includes information for most relevant European city-pair routes, disaggregated by company, of volume of scheduled passengers, total capacity and available seats for the period 1985-2000. It also collects the type of plane and the number of flights per plane. We have chosen the 25 busiest European airports (Amsterdam, Athens, Barcelona, Berlin, Berlin, Brussels, Copenhagen, Dublin, Düsseldorf, Frankfurt, Geneva, Lisbon, London, Madrid, Manchester, Milan, Munich, Newcastle, Nice, Paris, Rome, Stuttgart, Venice, Vienna, and Zurich) and the 100 densest routes among them every year. The result has been 16386 observations corresponding to different 95 airlines which, in terms of flights, passengers and seats – our three target variables – represent on average almost 80% of the (international) intra-European air transport market. For the airline-centered approach we just selected 13 companies representing 70% of scheduled flights in the intra-European market between 1985 and 1990. They included the largest (current or former) flag-carriers (Air France, British Airways, Iberia, Lufthansa, SAS, Alitalia, KLM, Finnair, Sabena, and Swissair), two non-flag-carriers (Air Europa, Spanair) and even a low-cost operator (Easy-Jet), whose data were available for at least three consecutive years.

4.2. Results and discussion

In this section we present the results from applying the tools described in Section 3 and 4 to the selected sample. We will follow the same methodological order described above: first, the intercity approach (where the unit of analysis is the city-pair route), and then, the airline approach (where the study is focused around the origin-destination matrix of each airline). Tables are presented at **Appendix C**.

The intercity approach

The intercity approach examines the evolution of concentration on the 100 densest city-pair European routes from 1984 to 2000.[10] For each route and year we have the number of operators, their number of flights, the passengers they transported and the seats offered by each of them. With this information we can carry out a standard concentration measurement analysis for each route and year using the tools described in **Appendix A**.

Our results are summarized in **Table C.1**, where we first report the *average* number of operators (over the 100 densest routes) and then – for the number of flights, carried passengers and seats – the *average* of one absolute concentration measure (standard deviation) and the *averages* of two relative ones (CR-4 and Herfindahl indices).

Starting from 1984, the evolution of the average number of competitors in the densest routes exhibits a progressive increase that is consistent with the progressive introduction of liberalization policies (the so-called 'packages', released by the European Commission in 1987, 1990 and 1992, and the liberal bilateral agreements that several countries had agreed upon before). Note, however, that between 1984 and 1987, the average number of competitors on the 100 densest routes is very low (scarcely above 2,00), thus indicating that many of these routes were only operated by two companies, possibly one flag-carrier from the origin, and another flag-carrier from the destination city. The effect of the 1987 and 1990 packages seem very low: the average number of carriers on route increases at the same pace as before. After 1992, however we observe a slight acceleration culminating around 1997-1998. This is the period with a larger increase in competitors on European routes. Afterwards, it seems that the market becomes more stable – maybe because airports and skies saturation – and the possibility of continued growth is exhausted.

When we look to the columns reporting the standard deviations (in terms of flights, passengers and seats), the picture is less clear. These values reflect that, on average, the dispersion around the mean has increased along time in all cases. This growth was particularly acute until 1997 (especially in

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[10] From year to year, the routes included in the list only change very slightly (± 2). In the 17-year period of our study we used 114 different routes.

flights and passengers), but the final years in our sample show a slower trend. The conclusion could be the same: competition after 1997 seems not to be growing fast, although the imperfect nature of absolute concentration measures as the standard deviation demands further analysis.

The use of concentration indices allows a greater precision, since larger values of these can be directly interpreted as more concentration (a value of 1 is tantamount to monopoly power. Both the CR-4 and Herfindahl indices depart in 1984 from very high values, suggesting that the four largest operators on each route controlled over 99% of traffic. In many routes, as mentioned above, there were just one or two operators, and only minor and marginal companies 'competed' with them. Again, the 1987 and 1990 packages seemed ineffective, although concentration is somehow reduced after 1992. After 1997, particularly in the case of passengers, the level of concentration grows again – perhaps the leading companies introduce larger aircrafts – and this trend continues until the end of our sample.

To confirm our results, we also performed the calculation of the Entropy index and the Relative Entropy (see **Appendix A**), but its interpretation did not qualitatively changed the results from the Herfindahl index. In addition, we compared our results with those from Lijesen *et al*. (2002) and Lijesen (2004), where concentration indices are also used. Despite their sample and methodology differs from ours and our sample period is larger, they also detect a U-shape turn in the evolution of concentration in air transport markets in Europe measured at the city-pair route level. During the 1980s and until 1992, there is a slow decrease in concentration which accelerates after 1992 – although it is difficult to attribute this to the deregulation packages. After 1998, despite the formal culmination of this process after April 1st 1997, competition has not increased on average on the 100 densest European routes in terms of market shares. Just the opposite is true: the figures show a growing trend to concentration since few routes have seen the emergence of a relevant number of new competitors.

The airline approach: matrix analysis

The airline approach shifts the focus of the analysis from the route to the airline, thus allowing to specifically considering the characteristics and structure of each carrier's physical network. As described in Section 4, we firstly elaborated the *OD* matrix for each company and year. We took into account their network size (or total number of airports served, *N*), which changed across companies and along years (but very slightly). Then we filled each origin-destination cell with the number of flights (multiplied by the distance in kilometers between airports) and the passenger-kilometers flown.[11] Using the MATLAB mathematical package we then calculated the permanent and the norm of the resulting 220 matrices, whose values are summarized in Tables C2 and C3. For simplicity, we only report the value for the Frobenius norm (although the 1-norm was also calculated).

Consider first the permanent in **Table C2**, where the values have been normalized between 0 and 1. By recalling that the lower the value of the permanent, the more likely than the network represents a 'hub-and-spoke', our results show – not surprisingly – that most of the flag-carrier companies (particularly Air France, Iberia, KLM and Lufthansa) concentrate most of their passengers carried on a single or a pair of airports.

The values calculated for the number of flights are, on average, larger (see final column). This result indicates that companies fly between several airports, but only a handful of them are relevant from the point of view of passengers carried. A closer look to the type of aircraft used in several routes (for example, for Iberia or Air France, although this is not reflected in the table) confirms that smaller, feeder routes, are served by smaller planes, thus reinforcing the hub-and-spoke model. It is also quite interesting to note that non-flag-carriers companies (Air Europa and Spanair) rely less on this sort of network model and, as can be expected, the low-cost carrier (only Easy-Jet in our sample) has – in general – higher values for its permanent. Finally note also the evolution of permanents along time, mostly decreasing. Our results suggest that most companies readjust their network configuration during the 1980s and 1990s, thus positioning for a more competitive market. In particular, again the flag-carriers seemed to intensify their hub-and-spoke network strategy.

Looking at the results in **Table C3** we can somehow compare *OD* matrices across companies through their Frobenius norms. A larger norm means a more concentrated network around a particular city. In terms of flights, this is the case of British Airways (London), Air France (Paris), Iberia (Madrid) and KLM (Amsterdam). Some of the companies (Iberia, Air France) tend to increase the

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[11] For the airline approach we omitted the use of seats as a target variable, since there is not a straightforward way to translate it into seats-kilometers.

value of their norms along time, whereas others reduce it. Interestingly, note that the non-flag-carriers (Air Europe and Spanair), and the only low cost carrier (Easy-Jet) have smaller values. The remaining companies do not exhibit significant trends. The values in terms of carried passengers provide a similar explanation.

5. Conclusions

Market power measurement has always been a traditional issue in many empirical industrial organization studies. The extensive deregulation and privatization process undergone by many infrastructure industries around the world during the 1990s has brought it back to the forefront of the tasks of many competition agencies. The economic characteristics of these industries demand an explicit treatment of their network properties when dealing with them. This has been the main aim of this paper, which has been particularly focused on the measurement of competition in the European air transport market.

Our work has provided both new theoretical tools and empirical findings about the measurement of competition in a market where its network characteristics often preclude the open confrontation of rivals on an equal basis. Our analysis of the 1984-2000 period suggests that despite the fact that the EU air travel markets have been gradually deregulated and competition has therefore increased, a number of market imperfections still persist, possibly preventing an economically optimal resource utilization from a pan-European viewpoint.

As in many other sectors with former public operators, flag carriers depart from an advantageous situation. Since entry is limited due to a high level of congestion in main airports and a slot-assignment system based on ‘grandfather rights’, not surprisingly high concentration has emerged in many routes even after the liberalization. Furthermore, in reply to the pro-competition measures taken by the Commission, many companies have opted for strategies that favor alliances or mergers (as the recent case by KLM and Air France), in order to exploit returns to scale and gain a better positioning in the global markets.

On a route level analysis, we have showed that the number of carriers in each route is still lower than the maximum allowed by the current regulation; the concentration indices show a decline in the early 1990s, but then an increase afterwards. On an airline level analysis, the hub and spoke network structure dominates the industry, giving advantages to some carriers and preventing a larger degree of competition. The attempts by low-cost carriers of exploiting the niches left by the larger companies have been responded by these by cutting costs (and services) and turning their interest also to the low-cost segment.

In summary, the liberalization packages of the 1990s did not end the story in the transport sector. There are reasons to fear that, without a more vigorous competition policy both at the national and EU levels, the welfare losses stemming from an insufficient competitive pressure on airlines are due to increase rather than diminish over time. We observe signals suggesting that the European aviation industry may be facing a period of major consolidation. The merge of some relevant airlines has been already discounted by many analysts as a matter of time. This may in some circumstances have positive effects on economic efficiency. But in combination with the anti-competitive effects of the hub-and-spoke operations, frequent flyer programmes, and other restrictions on competition, the horizontal and vertical concentration in the aviation industry represents a formidable challenge to competition authorities at the national and European level. A forceful competition policy will be required in order to enhance, or even preserve, the present degree of competition in the air travel markets.

A final particular caveat is worth noting here. Air transport is a fast changing industry, very sensitive to external shocks. The wave of international terror initiated after the September 11th terrorist attack, the subsequent wars and political turmoil everywhere, or simply the hike in the price of petrol, or the global economic downturn, may significantly affect any prediction about the future evolution of this industry. The conclusions of this paper are therefore conditioned to a stable horizon for the European Union.

Appendix A: A quick review of standard concentration indices

Concentration indices are traditionally used to provide a synthetic summary of market structure, as well as to evaluate the existing degree of competition in particular industries. They are simply defined over any output variable (e.g., physical production, sales, employment, assets, etc.), which is then related to the industry as a whole. Thus, if q_i denotes the output of firm i within an industry of n firms, then total industry output is given by:

$$Q = q_1 + \ldots + q_n = \sum_{i=1}^{n} q_i ,$$

where firms are usually ranked by size. Correspondingly, the share of total output of the i^{th} firm is defined by $s_i = q_i/Q$, and the mean output by $\overline{q} = Q/n$.

Table A. Traditional concentration measures in industrial organization

Relative concentration measures			
	Definition	**Complete equality**	**Complete inequality**
Variance	$\sigma^2 = \sum_{i=1}^{n} (q_i - \overline{q})^2 / n$	0	∞
Standard deviation	$\sigma = \sigma^{1/2}$	0	∞
Coefficient of variation	$CV = \sigma / q$	0	$(n-1)^{1/2}$
Gini coefficient	$G = (1/n) \sum_{i=1}^{n} (n - 2i + 1) s_i$	0	$(n-1)/n$
Absolute concentration measures			
	Definition	**Minimum (equal shares)**	**Maximum (one firm)**
Concentration ratio (of *k*-order)	$CR_k = \sum_{i=1}^{k} s_i$	k/n	1
Herfindahl index	$H = \sum_{i=1}^{n} s_i^2$	$1/n$	1
Entropy index	$E = \sum_{i=1}^{n} [s_i \ln(1/s_i)]$	$\ln n$	0
Relative Entropy index	$RE = E / \ln n$	1	0
Hannah-Kay index	$HK(a) = \left[\sum_{i=1}^{n} s_i^{1+a} \right]^{1/a}$	N^{1-a}	1

<u>Source</u>: Adapted from Curry and George (1983).

Appendix B: matrix operators for network comparisons

Let $A=\{a_{ij}\}$ define a square $N\times N$ matrix. The following operators' definitions are standard in matrix algebra (see Cullen, 1990, for instance):

- **Trace.** The trace of an $N\times N$ matrix is the sum of the diagonal elements.
- **Permanent.** The permanent of an $N\times N$ matrix a_{ij} is the sum of certain products of the entries. Specifically,

  $$\text{perm}(a_{ij}) = \sum_{\sigma} a_{1\sigma(1)} a_{2\sigma(2)} \ldots a_{N\sigma(N)} ,$$

  where σ ranges over all the permutations of {1, 2,…,N}.
- **Determinant.** The determinant of an $N\times N$ matrix a_{ij} is the sum and difference of certain products of the entries. Specifically,

  $$|A| = \det(a_{ij}) = \sum_{\sigma} (-1)^{\text{sgn}(\sigma)} a_{1\sigma(1)} a_{2\sigma(2)} \ldots a_{N\sigma(N)} ,$$

  where σ ranges over all the permutations of {1, 2,…,N} and $(-1)^{\text{sign}(\sigma)}=\pm 1$, depending on whether σ is an even or odd permutation.
- **Norm.** For a vector, its **2**-norm, or *Euclidean norm*, is defined by the Euclidean length

  $$\left\| \begin{matrix} a \\ b \end{matrix} \right\| = \sqrt{a^2 + b^2} .$$

  In the case of matrices, the **2-norm**, or *Euclidean norm*, of a matrix A is its largest singular value,[12] defined by the number

  $$\|A\| = \max_{x \neq 0} \frac{\|Ax\|}{\|x\|} .$$

  There are three particular cases of relevance:

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[12] Any $m\times n$ real matrix A can be factored into a product $A=UDV$, with U and V real orthogonal $m\times m$ and $n\times n$ matrices, respectively, and D a diagonal matrix with positive numbers in the first rank-A entries on the main diagonal and zeroes everywhere else. The entries on the main diagonal of D are called the singular values of A. This factorization $A=UDV$ is called a singular value decomposition of A.

- The **1-norm** of a matrix is the maximum among the sums of the absolute values of the terms in a column:

$$\|A\|_1 = \max_{1\le j\le N}\left(\sum_{i=1}^{N}|a_{ij}|\right).$$

For example, for a 2×2 matrix: $\left\|\begin{matrix} a & b \\ c & d \end{matrix}\right\|_1 = \max\left(|a|+|c|,|b|+|d|\right)$.

- The **∞-norm** of a matrix is the maximum among the sums of the absolute values of the terms in a row:

$$\|A\|_\infty = \max_{1\le i\le N}\left(\sum_{j=1}^{N}|a_{ij}|\right).$$

For example, for a 2×2 matrix: $\left\|\begin{matrix} a & b \\ c & d \end{matrix}\right\|_\infty = \max\left(|a|+|b|,|c|+|d|\right)$.

- The **Hilbert-Schmidt norm** (or Frobenius norm)[13] of a matrix A is the square root of the sums of the squares of the terms of the matrix A.

$$\|A\|_F = \left(\sum_{\substack{1\le j\le N\\1\le i\le N}}|a_{ij}|^2\right)^{1/2}.$$

Any of the above defined matrix operators summarizes into a single value (part of) the information embedded in a matrix. For concentration measurement purposes we will use as input the origin-destination matrix for each major European carrier at different time periods (OD_i^t), whose general term is $\{a_{hj}\}$ (where, h arbitrarily represents the origin, and j the destination). Refer to Section 3 for a discussion of the advantages and disadvantages of each operator for the measurement of the internal structure of each company's network.

[13] This is also the norm of a *Frobenius form* (also called a rational canonical form), which is a block diagonal matrix with each block the companion matrix of its own minimum and characteristic polynomials. Each of the minimum polynomials of these blocks is a factor of the characteristic polynomial of the original matrix. The polynomials that determine the blocks of the rational canonical form sequentially divide one another.

Appendix C: Concentration in European air transport: some results

Table C.1: Intercity approach: evolution of concentration by city pair routes (*)

	Number of operators per route	Number of flights			Passengers			Seats		
		Standard deviation	CR-4 index	Herfindahl index	Standard deviation	CR-4 index	Herfindahl index	Standard deviation	CR-4 index	Herfindahl index
2000	4,22	1958	0,9866	0,5419	212378	0,9836	0,5809	287973	0,9802	0,5589
1999	4,24	1975	0,9787	0,5306	214892	0,9881	0,5718	287037	0,9863	0,5451
1998	4,32	1993	0,9720	0,5002	213420	0,9829	0,5262	240895	0,9828	0,5071
1997	4,34	1951	0,9768	0,4890	192880	0,9740	0,5231	216788	0,9815	0,4987
1996	4,48	1528	0,9632	0,4735	172232	0,9687	0,5084	212889	0,9862	0,4948
1995	4,31	1510	0,9570	0,4207	166813	0,9588	0,4518	208266	0,9641	0,4292
1994	4,84	1471	0,9523	0,4308	154557	0,9670	0,4445	205436	0,9797	0,4214
1993	4,81	1495	0,9682	0,5472	148773	0,9716	0,4635	210380	0,9652	0,4318
1992	3,44	1364	0,9787	0,6229	139995	0,9871	0,4731	183071	0,9789	0,4138
1991	3,05	1322	0,9763	0,6211	136749	0,9812	0,4806	162955	0,9708	0,5139
1990	2,99	1283	0,9796	0,7186	125353	0,9842	0,4981	163625	0,9826	0,5947
1989	2,97	1177	0,9716	0,7158	136481	0,9907	0,5281	166376	0,9858	0,5841
1988	2,80	1120	0,9842	0,7339	132426	0,9932	0,5393	156294	0,9800	0,6065
1987	2,35	1006	0,9999	0,7454	110011	0,9979	0,5507	131109	0,9903	0,6148
1986	2,34	919	0,9980	0,4217	104536	0,9781	0,4321	128089	0,9654	0,3925
1985	2,07	930	0,9917	0,4181	104095	0,9680	0,4199	124858	0,9522	0,3826
1984	1,98	906	0,9960	0,4658	99745	0,9758	0,4640	125551	0,9646	0,4207

(*) Analysis was carried out upon the 100 densest city-pair routes each year. Reported values refer to the averages over these routes.

Table C.2: Airline approach: permanent of the OD matrices by company and year

	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	MEAN
FLIGHTS																		
Air Europa	0,32	0,31	0,34	0,28	0,22	0,27	0,18	-	-	-	-	-	-	-	-	-	-	0,27
Air France	0,12	0,11	0,12	0,10	0,11	0,10	0,12	0,13	0,10	0,11	0,09	0,10	0,12	0,18	0,11	0,10	0,12	0,11
Alitalia	0,15	0,14	0,18	0,22	0,16	0,16	0,15	0,17	0,12	0,12	0,18	0,15	0,13	0,14	0,18	0,21	0,22	0,16
British Airways	0,12	0,11	0,12	0,22	0,21	0,20	0,20	0,17	0,22	0,20	0,24	0,24	0,17	0,16	0,24	0,23	0,16	0,19
Easy-Jet	0,64	0,74	0,82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,73
Finnair	0,21	0,20	0,16	0,19	0,22	0,26	0,22	0,21	0,14	0,19	0,15	0,18	0,18	0,16	0,13	0,12	0,12	0,18
Iberia	0,20	0,21	0,22	0,20	0,20	0,23	0,21	0,22	0,21	0,21	0,23	0,21	0,22	0,22	0,22	0,23	0,22	0,22
KLM	0,32	0,30	0,30	0,31	0,31	0,36	0,32	0,32	0,22	0,31	0,33	0,34	0,31	0,31	0,34	0,32	0,33	0,31
Lufthansa	0,22	0,24	0,21	0,20	0,24	0,24	0,23	0,22	0,21	0,22	0,33	0,24	0,22	0,21	0,21	0,24	0,22	0,23
Sabena	-	-	0,13	0,09	0,10	0,12	0,12	0,11	-	-	-	-	-	-	-	-	-	0,11
SAS	0,24	0,23	0,25	0,25	0,24	0,26	0,27	-	-	-	-	-	-	-	-	-	-	0,25
Spanair	0,29	0,32	0,28	0,32	0,34	0,33	0,38	-	-	-	-	-	-	-	-	-	-	0,32
Swissair	0,13	0,18	0,18	0,17	0,18	0,16	0,17	-	-	-	-	-	-	-	-	-	-	0,17
PASSENGERS																		
Air Europa	0,13	0,11	0,12	0,08	0,06	0,05	0,03	-	-	-	-	-	-	-	-	-	-	0,08
Air France	0,01	0,00	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,01	0,01	0,00	0,02	0,00	0,01	0,00	0,02	0,01
Alitalia	0,02	0,04	0,02	0,02	0,06	0,06	0,04	0,07	0,02	0,02	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,03
British Airways	0,01	0,01	0,02	0,02	0,01	0,02	0,02	0,03	0,02	0,03	0,04	0,04	0,05	0,06	0,04	0,03	0,03	0,03
Easy-Jet	0,45	0,34	0,22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,34
Finnair	0,11	0,10	0,12	0,09	0,07	0,06	0,11	0,14	0,17	0,09	0,08	0,08	0,08	0,06	0,03	0,02	0,02	0,08
Iberia	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,01	0,02	0,01
KLM	0,02	0,00	0,00	0,01	0,01	0,00	0,02	0,02	0,02	0,01	0,03	0,02	0,01	0,01	0,02	0,02	0,02	0,01
Lufthansa	0,02	0,00	0,01	0,00	0,00	0,00	0,03	0,02	0,01	0,02	0,03	0,04	0,02	0,01	0,01	0,02	0,02	0,02
Sabena	-	-	0,00	0,00	0,00	0,00	0,02	0,01	-	-	-	-	-	-	-	-	-	0,01
SAS	0,04	0,03	0,04	0,05	0,03	0,06	0,08	-	-	-	-	-	-	-	-	-	-	0,05
Spanair	0,19	0,12	0,08	0,08	0,08	0,16	0,18	-	-	-	-	-	-	-	-	-	-	0,13
Swissair	0,09	0,08	0,08	0,07	0,07	0,06	0,18	-	-	-	-	-	-	-	-	-	-	0,09

Note: Companies are alphabetically ordered. Values have been normalized between 0 and 1 (a lower value reflects a hub-and-spoke network)

Table C.3: Airline approach: Frobenius norm of the OD matrices by company and year (in millions)

	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	MEAN
FLIGHTS																		
Air Europa	57,26	63,93	84,33	23,37	18,86	13,04	11,96	-	-	-	-	-	-	-	-	-	-	38,96
Air France	314,88	282,77	255,28	249,80	259,82	253,73	237,58	231,01	216,59	208,95	195,67	163,76	163,28	130,29	131,33	126,50	125,30	208,62
Alitalia	112,45	114,37	100,60	86,32	85,01	80,07	79,65	79,32	70,45	12,93	57,67	59,93	60,19	47,46	57,45	55,30	50,07	71,13
British Airways	260,96	242,66	185,64	178,28	176,95	182,90	148,79	129,42	137,71	137,43	146,38	139,74	135,36	127,38	122,95	122,23	115,57	158,26
Easy-Jet	77,53	61,63	50,93	39,57	-	-	-	-	-	-	-	-	-	-	-	-	-	57,42
Finnair	146,45	123,89	132,10	123,92	118,49	111,42	96,66	101,21	102,62	83,78	79,26	83,40	52,39	41,64	47,05	53,07	87,19	93,21
Iberia	304,76	286,66	290,74	281,88	286,02	281,40	272,73	285,93	218,73	205,23	232,43	195,12	207,40	156,41	150,92	153,54	148,66	232,86
KLM	235,45	215,35	220,75	140,36	165,86	162,88	142,39	135,21	90,77	101,76	117,47	120,91	136,22	135,02	118,79	105,16	101,21	143,86
Lufthansa	199,01	203,04	146,42	133,87	122,20	142,88	129,52	121,92	116,64	113,52	110,21	97,08	82,36	79,53	72,71	72,06	87,70	119,45
Sabena	-	-	160,37	147,48	147,48	147,84	139,69	147,76	-	-	-	-	-	-	-	-	-	148,44
SAS	102,32	98,99	100,20	114,36	98,32	88,84	90,03	-	-	-	-	-	-	-	-	-	-	99,01
Spanair	28,21	12,27	31,80	32,46	20,48	18,00	21,40	-	-	-	-	-	-	-	-	-	-	23,52
Swissair	160,27	152,77	175,01	123,50	106,66	95,41	101,97	-	-	-	-	-	-	-	-	-	-	130,80
PASSENGERS																		
Air Europa	2413,4	1281,8	509,7	1347,8	1024,7	5108,4	5371,6	-	-	-	-	-	-	-	-	-	-	2436,77
Air France	28658,0	24880,0	21280,0	20904,0	18917,0	17756,0	20697,0	19197,0	19386,0	19576,0	20850,0	21420,0	20312,0	14178,0	17193,0	17570,0	16869,0	19979,0
Alitalia	16398,0	13920,0	13421,0	11030,0	9297,7	9370,8	8855,0	8784,9	8872,2	7251,8	8879,9	8751,3	6428,7	5873,2	5318,5	6002,1	7474,0	9172,3
British Airways	35087,0	32887,0	32816,0	31151,0	30555,0	31292,0	33450,0	32897,0	27105,0	23959,0	26397,0	23182,0	22942,0	19792,0	17544,0	18507,0	17172,0	26866,76
Easy-Jet	9296,1	7240,0	5164,3	916,8	-	-	-	-	-	-	-	-	-	-	-	-	-	5654,3
Finnair	9022,7	8810,0	8517,7	7622,6	7042,0	6733,1	6340,6	5870,0	5351,0	833,5	4703,4	4638,6	4472,3	2472,6	3209,4	4123,6	2871,8	5449,11
Iberia	27195,0	24920,0	19804,0	18269,0	16799,0	17920,0	14536,0	12452,0	12803,0	12248,0	12839,0	11680,0	11111,0	10515,0	9801,2	9522,8	9801,2	14836,25
KLM	2284,4	1937,8	1567,5	1297,5	1507,1	1683,2	1478,0	1207,9	1761,1	1610,1	1656,3	2377,5	1931,4	1912,9	2454,6	3873,7	3881,5	2024,85
Lufthansa	11572,6	11536,8	11347,8	11748,6	762,8	14223,0	13209,0	13175,0	11571,0	10204,0	10669,0	9299,0	8044,6	8038,6	7260,2	7209,6	9125,5	9941,01
Sabena	-	-	16571,0	15928,0	14579,0	13632,0	13396,0	13071,0	-	-	-	-	-	-	-	-	-	14529,5
SAS	3192,8	2234,0	3278,2	3216,7	3458,3	3545,5	2238,2	-	-	-	-	-	-	-	-	-	-	3023,39
Spanair	1009,1	1455,0	1551,2	1748,4	1962,2	2126,6	2156,2	-	-	-	-	-	-	-	-	-	-	1715,53
Swissair	13856,0	13362,0	9346,4	9096,3	9166,1	9868,9	10257,0	-	-	-	-	-	-	-	-	-	-	10707,53

Note: Companies are alphabetically ordered.

References

Balfour, J. (2004): “EC competition law and airline alliances”, *Journal of Air Transport Management*, 10, 81-85.

Berechman, J. and J. de Wit, (1996): “An analysis of the effects of European aviation deregulation on an airline’s network structure and choice of a primary West European hub airport”, *Journal of Transport Economics and Policy*, September, 251-270.

Betancor, O. and J. Campos (2000): “The first decade of European air transport deregulation”, *Public Works Management and Policy*. October, 135-146.

Brueckner, J.K. and E. Pels (2004): “European airline mergers, alliance consolidation, and consumer welfare”, *CESInfo Working Paper No. 1154*

Burghouwt, G. and J.R. Hakfoort (2001): “The European aviation network, 1990-1998”, *Journal of Air Transport Management*, 7(5) 311-318.

Burghouwt, G., and J.R. Hakfoort (2002): “The geography of deregulation in the European aviation market”, TESG, 93 (1) 100-106.

Burghouwt, G., J.R. Hakfoort and J. R. van Eck (2003): “The spatial configuration of airline networks in Europe”, *Journal of Air Transport Management*, 9, 309-323.

Button, K., K. Haynes and R. Stough (1998): *Flying into the future. Air transport policy in the European Union,* Edward Elgar Publishing Limited, Cheltenham.

Carlsson, F. (2004): “Prices and departures in European domestic aviation markets”, *Review of Industrial Organization*, 24, 37–49.

Caves, D.W., L.R. Christensen and M.W. Tretheway (1984): “Economies of density versus economies of scale: why trunk and local airline services differ”. *Rand Journal of Economics*, 15, 471–489.

Cowling, K. and M. Waterson (1976): “Price costs margins and market structure”, *Economica*, 43, 267-274.

Cullen, C. (1990): *Matrices and linear transformations*, 2nd ed., Dover, New York.

Curry, B. and K. George (1983): “Industrial concentration: a survey”, *Journal of Industrial Economics*, 31 (3), March, 203-255.

de Wit, J. (1996): “An analysis of the effects of European aviation deregulation on an airline’s network structure and choice of primary West-European hub airport”, *Journal of Transport Economics and Policy*, 30, 251-274.

Economides, N. (2003): “Competition policy in network industries”. Stern School of Business, NYU. Online available at: http://www.stern.nyu.edu/networks/site.html

European Commission (2001): *Updating and developments of economic and fares data regarding the European air travel industry*. 2000 Annual Report; online accessible at http://www.europa.eu.int/comm/transport/themes/air/english/at_13_en.html.

Franke, M. (2004): “Competition between network carriers and low-cost carriers – retreat battle or breakthrough to a new level of efficiency?”, *Journal of Transport Economics and Policy*, 10, 15-21.

Fridstrøn, L., F. Hjelde, H. Lange, E. Murray, A. Norkela, T.T. Pedersen, N. Rytter, C.S. Talén, M. Skoven and L. Solhaug (2004): “Towards a more vigorous competition policy in relation to the aviation market”, *Journal of Transport Economics and Policy*, 10, 71-79.

Geroski, P. (1983): “Some reflections on the theory and applications of concentration indices”, *International Journal of Industrial Organization*, 1, 79-94.

Gillen, D.W., T.H. Oum and M.W Tretheway (1990): “Airline cost structure and policy implications”. *Journal of Transport Economics and Policy*, 24, 9–34.

Hakfoort, J.R. (1999): “The deregulation of European air transport: a dream come true?”, TESG, 90 (2) 226-233.

Hannah, L. and J.A. Kay (1977): *Concentration in modern industry*. Cambridge University Press. Cambridge.

Koski, H. and T. Kretschmer (2004): “Survey on competing in network industries: firm strategies, market outcomes and policy implications”, *Journal of Industry, Competition and Trade*, Bank Papers, 5-31.

Lijesen, M.G. (2004): “Adjusting the Herfindahl index for close substitutes: an application to pricing in civil aviation”, *Transportation Research (Part E)*, 40, 123-134.

Lijesen, M.G., P. Nijkamp and P. Rietveld (2002): “Measuring competition in civil aviation”, *Journal of Air Transport Management*, 8, 189-197.

Marin, P. (1995): “Competition in European aviation: pricing policy and market structure”. *The Journal of Industrial Economics*, 43, 141-159.

Mazzeo, M.J. (2003): “Competition and service quality in the U.S. airline industry”, *Review of Industrial Organization*, 22, 275-296.

O’Kelly, M.E. (1998): “A geographer’s analysis of hub-and-spoke networks”, *Journal of Transport Geography*, 6 (3) 171-186.

Reynolds-Feighan, A. (1998): “The impact of US airline deregulation on airport traffic patterns”, *Geographical Analysis*, 30 (3) 234-253.

Reynolds-Feighan, A. (2001): “Traffic distribution in low-cost and full-service carrier networks”, *Journal of Air Transport Management*, 7 (5) 265-275.

Veldhuis, J. (1997): “The competitive position of airline networks”, *Journal of Air Transport Management*, 3 (4) 181-188.