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Do European Carriers dominate their Hubs?

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Abstract We analyze the phenomenon of hub dominance by developing a model relating fares to distance, using the main leg of intercontinental flights for scaling purposes. Our results indicate that at least some of the major European carriers place a mark up on flights originating from or going to their hubs.

Key words: Civil aviation, Hub and spoke system, Market power
JEL codes: L110, L930, R41

1. Introduction

One surprising effect of the deregulation of civil aviation in the United States was the rapid development of hub and spoke systems by nearly all U.S. carriers. Giving way to economically healthy airline operations, the use, and especially the domination of hubs, may hinder competition. In his lengthy paper, Levine (1987) introduced deviations from pure competition in airline markets, among which hub domination. Borenstein (1989) was the first to give empirical proof of this phenomenon, renaming it to airport dominance. In the early nineties, several papers and articles have been published on the price effects of hub domination by U.S. carriers.

Marín (1995) on the other hand finds that European firms on liberalized routes exploit their hub related cost advantages to compete in prices. He explains the differences with the U.S. situation by stating '…*during the period studied the CRSs [computer reservation systems] in the US belong to single companies while in Europe they are shared by several firms, frequent flier programmes were almost non-existent in Europe and direct flight networks prevail in Europe in contrast to a hub-and-spoke systems in the US.*'[1] However, much has changed in European aviation since 1989, the year to which Marín's data apply: both hub-and-spoke networks and frequent flier programs have become common features nowadays. The question arises whether

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European carriers, now that these changes have spread over Europe, also started acquiring hub domination rents. In this paper we will address the question whether Europe's main carriers charge higher prices from flights originating from their hubs.

In the two following sections, we discuss the concept and causes of airport dominance and earlier empirical work on the subject. Section 4 describes the framework for further analysis. The data are described in section 5, followed by our results in section 6. In the final section, we formulate some concluding remarks.

2. A carrier dominating its hub

The concept of airport dominance points at a carrier dominating its hub airport. From this point of view, Levine's term 'hub domination', may be slightly more accurate than Borenstein's 'airport dominance'. One could also argue that the carrier dominates the airport region, not the airport itself, although the latter may also be the case to some extent. Berry (1990) expresses a slightly different point of view, by interpreting the dominant position of a carrier on its hub as a form of product differentiation. All views have in common however that the dominant carrier charges a higher price to passengers originating from its hub, without being punished for it by lower demand. The reasons for this kind of market power lie partly in the nature of hub and spoke operations, partly in marketing devices and partly in other factors.[2]

Frequent flyer programs (FFPs) are a well known marketing device in civil aviation worldwide. With these programs, customers can acquire credit points from a specific carrier in relation to distance traveled. These points can then be used for gifts, free travel or for upgrades (i.e. to have an economy class ticket upgraded to a business class ticket). FFPs make clever use of the principal-agent problem. A frequent business traveler does not have to pay his ticket himself, but he will benefit from the FFP. In this way, the relative reward of FFPs is greater than it would have been for a passenger paying for his own ticket.

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[1] Marín (1995), p. 155.

An important reason for the success of FFPs is sometimes their non-linearity: the awards may then grow as points accumulate. This feature causes increasing marginal returns, thus rewarding loyalty, especially so for the home carrier. After all, the home carrier is the carrier that flies most routes from the travelers home town, thereby offering the largest opportunities to both collect and use points.

Travel agent commission overrides (TACOs) are the equivalent of FFPs for travel agents. Like FFPs, TACO's rely on the principal-agent problem, letting passengers pay for the travel agent's reward. By making the travel agent's commission dependent of the revenue he generates for the airline, and by doing this in a nonlinear way, the carrier offers a strong incentive for loyalty to the agent. Like with FFPs, the airline offering the largest number of destinations, is likely to have the most effective override program. Any rational travel agent would therefore stick to the TACO program of the home carrier in his own region. To avoid the abuse of travel agents' commissions as loyalty programs, the European Commission issued guidelines that limit the nonlinear character of the instrument.[3]

As we mentioned before, FFP en TACO programs are most effective for the carrier serving the largest number of destinations, and this is likely to be the home carrier. Apart form serving the largest number of destinations, the home carrier is also likely to serve most destinations from its hub at a higher frequency than its competitors, although this may not be the case if the destination is a competitor's hub. Other things being equal, higher frequency makes an airline more attractive to customers, since it enlarges their chances of departing at their desired time. This may also be a reason why travelers, especially those with high time values, are willing to pay a higher price for a flight with the home carrier.

Another possible source of market power of a carrier on its hub airport is that it may have some bureaucratic control over the airport. Not only is the home carrier the hub's best client, it is often the airport's main source of financing. Especially at

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[2] Apart from the factors mentioned below, Computer Reservation Systems (CRSs) are also seen as a source of market power. The rise of multi-owner and independent CRSs on the internet has diminished its influence however.

congested or near-congested airports, this may give rise to control over airport operations, giving the main carrier an instrument to deter entry or hinder competitors.

The causes for airport dominance mentioned above, have been acknowledged before by other authors, such as Berry (1990) and Borenstein (1989). However, since their studies focus on U.S. situations, they have not mentioned another cause that may also be a source of rents for airlines. When there is a national airline, or flag carrier, travelers are likely to be biased in favor of their own flag carrier. Since almost any European country, as a matter of fact probably almost any country outside the USA, has a flag carrier (or a former flag carrier), national pride is likely to be one more source of dominance of a carrier at its hub. Of course, the presence of domestic competitors may reduce the importance of a flag carrier.

3. Earlier empirical work

The first to tackle the problem of airport dominance empirically, was Severin Borenstein in his 1989 paper. Borenstein relates the fare paid for a trip to cost-inducing and demand related characteristics of the trip. Next he uses relative prices for scaling. The dependent variable is the logarithm of the price of a carrier on a route relative to the price of an other carrier on that same route. By scaling to a competitor on the same route, Borenstein is able to reduce the model to carrier specific differences only.

The variable reflecting hub dominance in Borenstein's paper is the average of a carrier's share of daily passengers originating at the two endpoints of the route, weighted by the proportion of passengers on the route who originate at each endpoint. Borenstein finds the effect of this variable on fare differences to be significantly positive, indicating dominant positions of carriers on their hubs.

In his 1991 paper, Borenstein again uses differences on the same routes as a scaling method. This time however, the share of traffic on a route is the dependent variable. Again, Borenstein finds significant positive results, indicating that carriers exercise

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[3] See OECD (2000), page 217-8 for these guidelines.

some market power over their hubs. Borenstein (1991) also tries to isolate the effect of Computer Reservation Systems. He finds that the effect is small and statistically insignificant.

Berry (1990) estimates a structural model, using airport presence as an explanatory variable in both cost and demand equations. Airport presence is defined as the number of top 50 cities served by an airline out of a given city. Berry finds that airport presence has a positive effect on demand and at the same time lowers costs. Though Berry interprets airport presence as product differentiation and therefore different then Borenstein's market power approach of hub dominance, their results point in the same direction.

Evans and Kessides (1993) use a fixed effects estimation method to test whether airport and route dominance, both measured by respective market shares, have a significant effect on fares. They find that airport dominance confers substantial pricing power upon the carrier, which is consistent with earlier results by Borenstein (1989, 1991) and Berry (1990). However, they also find that the isolated impact of route dominance on fares, is insignificant, contrary to Borenstein's findings. Evans and Kessides explain this difference by stating that, contrary to airports, routes are contestable, since planes can easily be switched between routes, whereas airport facilities and FFPs can not.

Berry, Carnall and Spiller (1996) extend Berry's earlier work on the influence of airport presence on costs and demand. Using an unobserved product characteristic to capture restrictions placed on a ticket, and thus implicitly dividing the market between 'tourists' and 'business' travelers, they find that airport presence has a positive effect on demand and a negative effect on costs. The cost-reducing effect of airport presence can be interpreted as the returns stemming from the economic rationale of the hub and spoke system. The effects are labeled 'hub premium', leaving aside whether it stems from product differentiation, market power or both.

Goetz and Sutton (1997, p. 258) also find some indications of market power on concentrated hub markets. They find that '…passengers flying from small-city airports to major airports paid 34 percent more if the major airport was concentrated and 42 percent more if both the small-city and the major airport were concentrated.'

Marín (1995) has been the first to address the issue in a European context, by estimating both a market share and a price equation, in a regulated and a deregulated segment.[4] Marín finds that the effect of airport presence is not significant in a regulated environment and significantly negative in a deregulated environment. This implies that, contrary to the U.S. situation, European carriers in a deregulated environment tend to exploit the cost reducing effect of airport presence in order to compete in prices. Marín (1995) explains the difference between his European results and earlier U.S. estimates by signaling significant differences in the causes of market power. In Europe at that time, CRSs were owned by multiple European carriers, FFPs hardly existed in Europe and the hub and spoke system had not yet gained as much ground yet as it had in the U.S. aviation industry. Because of these differences, several causes of hub dominance had less impact than in the U.S., which may explain the absence of hub dominance in Marín's results.

4. Analytical Framework

Our analysis rests on the assumption that fares are cost related. Furthermore, we assume that costs are distance related. When we combine these assumptions, we find that there should be a relationship between fares and distance. Earlier empirical work analyzing this relationship includes Hansen (1990) and Windle and Dresner (1999). Hansen (1990) uses a model relating fare to market characteristics. He finds that variables other than distance related variables, like market size and concentration, have no statistically significant effects. Distance indicators were significant, but the R^2 of 0.73 implies that there are also other factors than distance that determine fares.

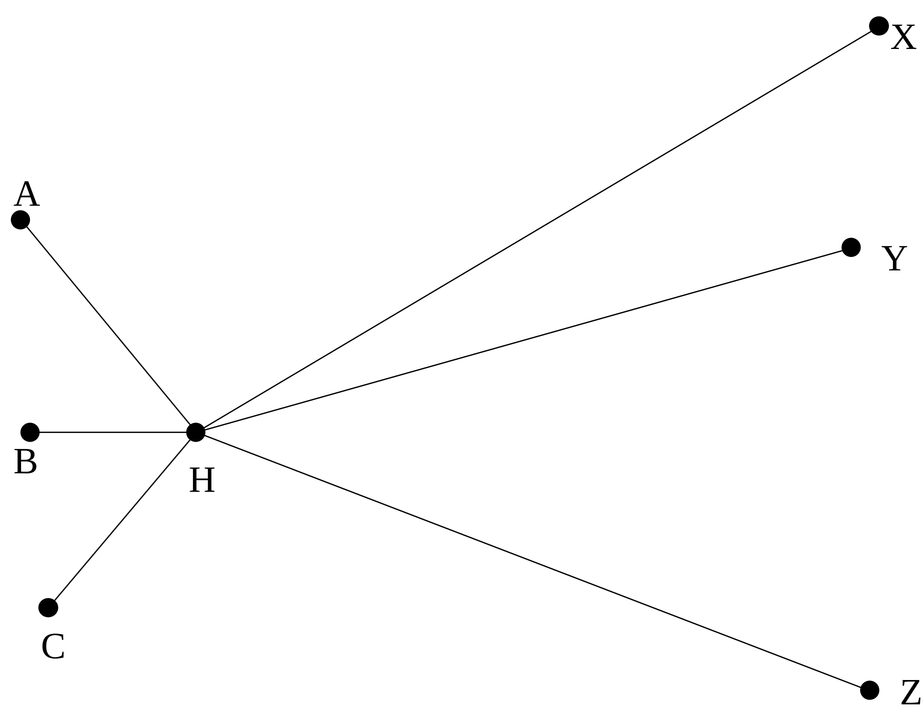
Windle and Dresner (1999) estimate a model explaining fares on five categories of routes from variables such as distance, distance squared and population, using dummies for slot controlled routes, vacation routes and eleven quarter dummies. In

[4] Marín uses a similar interpretation of airport presence as Berry (1990). Also, his definition is much alike, though fit to the European situation.

four out of five route categories, the influence of distance is statistically significant, in three out of five also distance squared was significant. In two categories population (the product of the populations of the origin and destinations cities) had a significant negative influence. The vacation route dummy had a significant negative impact along the line, and the influence of the slot control dummy was significant and positive in two out of four categories.[5]

The message above is clear: there is a statistically significant relationship between fare and distance. The impact of other variables is not always clear however. Now let us turn from the relationship between fare and distance to the analytical framework of this paper.

Figure 1: A simple hub and spoke network



Consider a simple hub and spoke network, as shown in figure 1. In this network, we define H as the hub, A to C as close spokes and X to Z as distant spokes. Assuming distance-related fares, we define the natural logarithm of the fare of a flight from hub H to destination Z as:

[5] This feature is somehow comparable to hub premiums, since it shows that market power, in this case

$$\log fare_{HZ} = \alpha_{HZ} + \beta_{HZ} \log dist_{HZ} + \chi C + hdp \qquad (1)$$

Where $dist_{HZ}$ is the distance from airport H to airport Z, C is a vector of unobservable company specific factors and α_{HZ} β_{HZ} and χ are parameters. The variable hdp represents the hub dominance premium, an *extra* markup that the home carrier is confident enough to place on hub originating fares. We should keep in mind however, that this is a *relative* measure. Consider a situation where we, as we will do later in the paper, analyze fares of five different companies. If we use the maximum number of four company specific hdp's in our specification, the choice of the numeraire would determine the sign of the hdp's. This problem is however easily solved, since there exists no such thing as negative airport dominance. So the company with the lowest hdp should be the numeraire. The numeraire company is then the one with the weakest airport dominance, which doesn't necessarily mean it has no dominance at all. In order to account for airport specific cost factors, we add dummies for the origin and destination:[6]

$$\log fare_{HZ} = \alpha_{HZ} + \beta_{HZ} \log dist_{HZ} + \chi C + \varphi_H H + \varphi_Z Z + hdp \qquad (2)$$

Similar to equation (2), we define the fare of a flight from origin A via hub H to destination Z as:

$$\log fare_{AHZ} = \alpha_{AHZ} + \beta_{AHZ} \log dist_{AHZ} + \chi C + \varphi_A A + 2\varphi_H H + \varphi_Z Z \qquad (3)$$

Note that we entered the dummy for the hub airport twice, since a return flight lands and takes of at the hub twice. Next, we use the distinction between close and distant spokes for scaling purposes, by defining relative fare, *Rfare* as:

$$Rfare = \frac{fare_{AHZ}}{fare_{HZ}} \qquad (4)$$

a barrier to entry through scarce slots, leaves room for higher fares.

[6] An alternative for the airport dummies would be to enter the country's income per capita, to model some form of price discrimination. This did not yield statistically significant results.

When we substitute equations (3) and (2) into equation (4), we get:

$$\log Rfare = a_{AHZ} + b_{AHZ} \log dist_{AHZ} + cC + j_A A + 2j_H H + j_Z Z - a_{HZ} - b_{HZ} \log dist_{HZ} - cC - j_H H - j_Z Z - hdp \qquad (5)$$

Which simplifies to:

$$\log Rfare = a + b_{AHZ} \log dist_{AHZ} + j_A A + j_H H - b_{HZ} \log dist_{HZ} - hdp \qquad (6)$$

where:

$$a = a_{AHZ} - a_{HZ} \qquad (7)$$

Next, we distinguish between two specifications. First, in specification A, we assume that:

$$b = b_{AHZ} = b_{HZ} \qquad (8)$$

so we rewrite:

$$\log Rfare = a + b \log Rdist + j_A A + j_H H - hdp \qquad (A)$$

with:

$$Rdist = \frac{dist_{AHZ}}{dist_{HZ}} \qquad (9)$$

In our second specification (B), we rewrite equation (6) in order to avoid having to make the assumption expressed in equation (8):

$$\log Rfare = a + b_{AHZ} \log Rdist + j_A A + j_H H + (b_{AHZ} - b_{HZ}) \log dist_{HZ} - hdp \qquad (B)$$

Parameter β represents the fare elasticity of a small increase in distance, which should be comparable to the cost elasticity of a small increase in distance. In aviation, costs are positively related to distance, but less than proportionally, so we expect β to be between 0 and 1. If we find that b_{AHZ}-b_{HZ} does not differ significantly from zero, the hypothesis stated in equation (8) can not be rejected, and (B) simplifies to (A). If both parameters differ significantly, we would expect the sign of b_{AHZ}-b_{HZ} to be negative, because of the less than proportional relation of costs to distance mentioned above.

Up to this point, we have assumed that the only deviation from cost related fares comes from airport dominance. Differences in fare may however also come from differences in competition on specific routes. We use the Herfindahl-Hirschman index (HHI) to account for differences in route competition. For consistency in scaling, we would like to use the HHIs of routes A-H-Z and H-Z. Any route A-H-Z is almost certainly a monopoly route however, since shared hubs are non existent in Europe. Therefore, we consider route A-Z as the relevant route, with A-H-Z as a close substitute. For consistency, we will calculate the HHI for route A-Z, $HHI_{A\text{-}Z}$, using all direct and one-stop flights between A and Z. In the same manner, we define $HHI_{H\text{-}Z}$, as the HHI for route H-Z and all its one-stop alternatives. We rewrite:

$$\log Rfare = a + b \log Rdist + j_A A + j_H H - hdp + f_{HZ} HHI_{HZ} + f_{AZ} HHI_{AZ} \qquad \text{(A')}$$

Now the question arises what the effect of route competition on *Rfare* will be. Recall figure 1, where a carrier flies from A to Z via H. Suppose competition increases on the main leg, H-Z. Two effects can be distinguished. The first effect, which we will call the *direct* effect is that the carriers operating route H-Z will lower their prices. Our second effect, the *indirect* effect, comes from competition between close substitutes. The competition increase on H-Z also means an increase in competition for any carrier operating a direct route from A-Z, since the number of close substitutes rises. So the price of a direct route from A to Z will decrease, forcing other carriers to lower their prices for indirect flights from A to Z, such as A-H-Z.

The effect of the HHI of route H-Z on *Rfare* in equation (A’) is therefore ambiguous. If the direct effect is larger than the indirect effect, the sign will be negative and vice versa. The same line of reason holds for the sign of the effect of HHI_{AZ}, be it with opposite outcomes.

Although the HHI is widely used and accepted as an indicator for competition, it does have some limitations. One of those limitations, brought forward by Hannan (1997), is that the HHI implicitly gives equal weight to the roles of market share inequalities and the number of competitors. Hannan solves this problem by decomposing the HHI into the variation of outputs and the inverse of the number of competitors:

$$HHI = \frac{V^2}{N} + \frac{1}{N}$$

One way of testing whether the implicit equal weight assumption is right, is to estimate parameters for both indicators and check whether their signs differ significantly. A slightly different approach is to use the inverse number of competitor as an additional explanatory variable and test whether it differs significantly from zero.[7] So we adjust (B) in the following way:

$$\log Rfare = a + b_{AHZ} \log Rdist + j_A A + j_H H - hdp + (b_{AHZ} - b_{HZ}) \log dist_{HZ} + f_{HZ}(HHI_{HZ} + \frac{l_{HZ}}{N_{HZ}}) + f_{AZ}(HHI_{AZ} + \frac{l_{AZ}}{N_{AZ}}) \quad \text{(C)}$$

5. Description of the data set

We selected ten European origins and five non-European destinations. Eight out of these ten origins are also intercontinental hubs for their flag carrier. In selecting the origins and destinations, we tried to combine geographical spread with low numbers of missing values.[8] The airports used in the analysis are summarized in table 1. Combining the airports, and for obvious reasons omitting routes originating from its own hub (for instance AMS-AMS-JFK), we arrive at 9×8×5=360 observations.

[7] See Hannan (1997) for a further explanation.
[8] The latter is especially important with destinations. If one carrier doesn't serve one destination, nine observations are lost.

Table 1: *Origins, hubs and destinations in the sample*

From (abbreviation)	Via (carrier)	To (abbreviation)
Amsterdam (AMS)	Amsterdam (KLM)	New York JFK (JFK)
Paris Charles de Gaulle (CDG)	Paris Charles de Gaulle (Air France)	Los Angeles (LAX)
London Heathrow (LHR)	London Heathrow (British Airways)	Tokyo (NRT)
Frankfurt (FRA)	Frankfurt (Lufthansa)	Cairo (CAI)
Milan Malpensa (MXP)	Milan Malpensa (Alitalia)	Singapore (SIN)
Brussels (BRU)	Brussels (Sabena)	
Venice (VCE)	-	
Athens (ATH)	Athens (Olympic)	
Zurich (ZRH)	Zurich (Swissair)	
Prague (PRG)	-	

The fare and frequency data are retrieved from the internet page of Travelocity, using a strict set of rules for comparability of fares (see appendix A for more details). Due to missing links in the networks of the carriers, 138 observations were missing from the data. For all BA flights to Tokyo, fare data were unavailable, leaving a dataset of 213 observations. Table 2 summarizes the number of observations by destination and carrier. The information in the table is somewhat biased because there are no fare data available for British Airways' flights to Tokyo. However, we can still recognize some characteristics of the European airline market. First of all, we see the important function of Singapore as a hub to South East Asia and Australia for European carriers. Also the U.S. destinations are served from a large number of origins, except by Alitalia, Sabena and Olympic. The latter are clearly the smaller carriers in the sample.

Table 2: *Number of observations by destination and carrier*

	JFK	LAX	NRT	CAI	SIN	Total
KLM	9	8	6	7	9	39
Air France	9	9	9	3	9	39
British Airways	8	9	-*	2	8	27
Lufthansa	9	8	9	8	9	43
Alitalia	3	5	-	6	8	22
Sabena	5	-	6	-	-	11
Olympus	-	-	-	2	-	2
Swissair	7	6	9	-	8	30
Total	50	45	39	28	51	213

* BA serves Tokyo. However, no fare data were available

We collected fare data for unrestricted economy class, which more or less means that we aim our focus at the lower part of the market for business travelers. There are several good reasons to do so. First of all, some causes for airport dominance, such as FFPs, higher frequencies and direct flights, apply especially to business travelers. So, if airport dominance appears, it is most likely to do so in business markets.[9] The upper segments of the business markets however, are very small, and not available on every route. Especially on very short haul routes, airlines offer commuter flights, with only one class to choose from. An other reason to choose unrestricted fares, is that two restricted fare may not relate to the same product, since restrictions may differ substantially.

Table 3 summarizes fare and distance data. The striking point in this table is that the minimum of *Rfare* is below unity. This means that some carriers actually offer flights from A via H to Z at a fare lower than the fare of the main leg (H-Z) of that flight. As a matter of fact, we found 47 observations with *Rfare* below unity. Although most (33) of them are less then four percent below unity, this is a first indication of the presence of hub domination.

Table 3: *Descriptive statistics*

	Mean	sd	minimum	maximum
Fare (US$)	3094.08	1092.67	1073.60	5367.90
Distance (Miles)	5388.22	1658.92	1609	8242
Rfare	1.141	0.278	0.479	3.023
Rdist	1.106	0.180	1.015	3.153

6. Empirical results

We estimated specification (A), omitting all non-significant variables, finding positive and significant hub dominance premiums for Swissair, Air France and Lufthansa.[10] Table 4 presents the results for the estimation. Note that the sign of ϕ_{HZ} is positive, meaning that the indirect effect, as defined in section 4, is larger than the direct effect of competition.

When checking the outliers of specification (A), we found an intriguing pattern around flights from Brussels to U.S. destinations. A closer look revealed that British Airways, Air France and Swissair charge significantly lower fares for flights from

[9] This is consistent with the findings of Berry, Carnal and Spiller (1996).
[10] As we stated before, the company with the lowest hdp should be the numeraire. In the specification used here, Sabena is the numeraire, with Alitalia, Olympic, KLM and British Airways not differing significantly.

Brussels via their hubs to U.S. destinations. Apparently, these carriers are fighting a price war over Brussels. Although we cannot be exactly certain on the explanation for this price war, Brussels seems to be a logical place for such an event, since it is the only airport in the densely traveled North-West of Europe without a strong international carrier based on it. We model this ‘Battle for Brussels’ by a dummy for the combination of origin (Brussels), carriers (British Airways, Air France and Swissair) and destinations (JFK, LAX) involved.

Both from the t-values of the distinctive parameters as from the log likelihood, it shows that specification (C) with the Battle for Brussels dummy is superior to specifications (A) and (B).[11] The positive and significant value of λ_{HZ} indicates that the HHI is in this case an inadequate indicator of competition, and that the number of competitors matters more then the skewness of their marketshares. Furthermore, we find that the elasticity of fare to distance differs significantly between short and long haul flights and has the expected sign.

Table 4: *Regression results for log Rfare (t-values between brackets)*

		A	A (BRU)	C
Constant	α	0.62	0.58	1.32
		(5.5)	(5.7)	(4.7)
log Rdist	β	0.55	0.52	0.37
		(4.5)	(4.8)	(2.9)
cost difference between legs	β_{AHZ}-β_{HZ}			-0.08
				(-2.7)
hub dominance premium for Air France	hdp_{AF}	0.16	0.15	0.14
		(4.6)	(4.8)	(4.8)
hub dominance premium for Lufthansa	hdp_{LH}	0.15	0.16	0.15
		(4.3)	(5.3)	(5.2)
hub dominance premium for Swissair	hdp_{SR}	0.19	0.16	0.14
		(4.8)	(4.7)	(4.1)
Battle for Brussels dummy			-.052	-.056
			(-7.6)	(-8.3)
log of HHI of main leg	ϕ_{HZ}	0.24	0.21	0.19
		(4.5)	(4.5)	(4.1)
extra weight for number of competitors within HHI	λ_{HZ}			0.51
				(3.2)
Log likelihood		62.3	88.8	96.2
adjusted R^2		0.33	0.48	0.51

Our results can be interpreted, as we mentioned before, in a hub premium. This premium reflects the extra price the carrier is confident enough to ask for a route originating from the dominated hub. For Air France and Swissair, this premium is about 14 percent, for Lufthansa it is slightly higher at 15 percent. These results are comparable to those in Berry, Carnal and Spiller, 1996. They find a hub premium of 19% for type 2 passengers on large hubs, roughly the US equivalent of the fares studied here.

7. Concluding remarks

Our results indicate that hub premiums are not typical for the U.S. aviation sector. We find that Lufthansa, Swissair and Air France charge significant premiums for direct flights from their hubs. Our results for Air France, Swissair and Lufthansa are consistent with those of Borenstein (1989, 1991), Berry (1990), Evans and Kessides (1993) and Berry, Carnal and Spiller (1996), who also find positive hub premiums.

There are however some limitations to our results. First of all, we did not use a quantified measure of hub dominance. Furthermore, our counter-intuitive finding that the indirect competition effect is larger than the direct effect implies that further research on competition in network settings may yield interesting results.

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[11] The latter is not shown in the table.

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Appendix A: Rules for collecting data

The following rules were used when collecting fare data:

- All trips are 1 person, round trip flights on unrestricted economy class seats.
- All departure flights must arrive on the first Thursday morning, from a month after booking the flight.
- All return flights must leave the next Tuesday morning or as soon after that as possible.
- No switching between airlines is allowed. Some exceptions apply, see below.
- No extra stop is allowed.
- All data on flights sharing a hub and a destination, must be collected on the same day.

There are some exceptions to the airline switching rules:

- On ten routes from Prague, one or both feeder flights are operated by Czech Airlines. Czech Airlines has a code sharing agreement with all the carriers in the sample on routes from and to Prague.
- There are three code sharing flights between KLM and Alitalia, who belong to the same alliance.
- KLM once uses its subsidiary KLM UK as a feeder for Heathrow-originating flights.
- Air France uses the TGV as a feeder for Brussels-originating flights in three observations.
- In two cases, KLM uses Air France as a return feeder for Paris-originating flights.

We have tested if these exceptions led to significantly different results by adding dummies for each of the five exceptions mentioned above and found that none of them were significantly different from zero.

Apart from the rules mentioned above, a further restriction is implemented, in order to ensure that no other cost differences blur the image. This restriction states that the second leg of an A-H-Z route must have the same flight number as the H-Z route. For example, if KLM flight from Amsterdam to New York has flight number KL641, then the second legs of all indirect KLM flights to New York must have the same flight number. We relax this restriction a little, by allowing the second leg flight to have another flight number, say, KL643 if the fares for KL641 and KL643 are equal. It goes without saying that the same conditions should hold for the return flight.

Appendix B: deriving the Herfindahl-Hirschman index

The *Herfindahl-Hirschman index (HHI)* is a widely accepted indicator for concentration on a market, and is defined as the summed squares of market shares:

$$H = \sum \left(\frac{x_i}{\sum x_i} \right)^2$$

where x_i is defined as the output sold by company i. In European aviation, output measures are however not available on a route level. Here, we use frequency as an output indicator. In aviation, one could question whether ‘a route’ and ‘a market’ are the same thing. From the passengers’ point of view, the market consists of all flights from his origin to his destination city. Therefore, we would also have to take indirect routes from A to Z into account if we were to examine the concentration level on the A-Z route. For pragmatic reasons (the number of alternatives would get uncontrollable), we limit our analysis to one-stop routes. We feel that this limitation has no severe drawbacks on our results, since travelers in the fare class we study (economy without restrictions, which about resembles the lower class business traveler) are unlikely to take trips with more than one stop into account, given the fact that every city pair in the sample has sufficient frequency on direct and one-stop flights.

Comparing direct and one-stop flights creates the need to correct for the inconvenience of the latter. Here, we do so by dividing the frequency of company i by the extra mileage factor:

$$H = \sum \left(\frac{x / emf}{\sum x / emf} \right)^2$$

with:

$$emf = \frac{dist_{1stop}}{dist_{direct}}$$

Implicitly we assume here that a flight with a five percent longer flight distance implies a five percent lower convenience.