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Economies of Scale and Spatial Scope in the European Airline Industry

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Title: Economies of Scale and Spatial Scope in the European Airline Industry

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1. INTRODUCTION

The main objective of this paper is to determine whether the market strategies followed by European carriers are simply a consequence of marketing policies, or if there are also Economies of Scale in costs associated with the expansion of production.

By modelling cost performance of European airlines with a translog cost function, we are able to determine the existence Economies of Density, Economies of Network Size and Economies of Spatial Scope for each company.

With these different indicators we are able to contribute with information that can help to explain the behavior of firms, and to anticipate the possible evolution of the market after the period considered in the data set. However, we do not believe that this information is the only way to explain the behavior of companies in the market. In addition to cost structure, marketing strategies and demand response are important components of the observed behaviour of firms. For example, by expanding the number of routes served, companies diversify their production vector; this, in turn, has cost implications, but even more important is how demand responds to this diversification. When a carrier adds a new route to its production vector, it is able to capture customers from other routes who can use this new route as a leg in their trip. Users place a high value on the time spent in layovers, and they are willing to pay for a reduction in total travel time.

2. THE EUROPEAN DEREGULATION POLICY

The third package was implemented between January 1993 and April 1997. The market was completely opened to cabotage in April 1997 for European airlines. But this package also gave companies complete freedom to establish fares and opened doors to purchase ownership of other European carriers. Carriers responded to the new market conditions with three main strategies: first, mergers and acquisitions, either in domestic or external markets; second, setting up low cost carriers; and third, airline alliances (for more details see Chang and Williams, 2002).

The main objectives of these three strategies were the consolidation of domestic markets and the expansion of operation in new external market. In this case using infrastructure of existing carriers was a direct way to enter new markets. On the other hand, entering new markets was subject to the availability of a scarce resource slots owned by incumbents.

These strategies allowed companies to expand production. By expanding the set of products in new markets, companies were able to exploit Economies of Scale. Setting up new low cost carriers and acquiring established firms did not always have the expected results; however, airline alliances have been established as a stable strategy for most companies. With this policy companies exploit the advantages of denser networks.

By adding new routes, companies become more attractive to customers. When customers are deciding which carrier to fly, they do not only look at the fare, but also at total travel time, which is an important element in their decisions. Currently, the airline market is structured in a hub-and-spoke design, which for many require that users take more than one flight to arrive at their final destination. By flying with the same company, users can reduce time for connections and avoid missing a connection. Therefore, even if there are Constant Returns to Scale for carriers, the average social cost function declines when output is rising (see Mohring, 1972).

Alliances allow companies to offer consumers denser routes, share cost and slots with other carriers, and avoid antitrust policies. Some of these alliances have

converged in definitive mergers, as in the recent cases of Lufthansa and SwissAir, or Air France and Lufthansa.

Although there are important differences between US and European deregulation processes, it seems that both tend towards the concentration of production in the long run. This agrees with previous results of Scale elasticities obtained in the literature. At the beginning of the US deregulatory process, an intensive entry of new companies was observed in the market. However, after that initial period, equilibrium processes started to work. The result was that some of new entrants companies either began to leave the market, or to merge with bigger carriers. The combination of two issues defined this process: first, the hub and spoke structure, which was strengthened by companies during this period and second, the possession of slots by the major carriers in the main hubs.

After deregulation, US concentration decreased for longer routes and increased for shorter ones (Borenstein, 1992). In 1977 the eight largest companies were responsible for 81% of production; in 1991, over 90%. The hub-and-spoke structure allows companies to serve more airports, with higher loads.

Companies not only compete in price, but also through marketing. Hub and spoke networks provide an advantage for bigger companies by increasing the number of destinations served and reducing connection costs (compared with a situation in which the user has to change carriers). Other marketing factors also appears

relevant, including frequent flyer programs and priority access to reservations, but overall, the main advantage is held by companies that have slots in important hubs.

3. THE MODEL

To answer our question we are estimating a cost function for the European airline industry. In order to avoid the effect of other industries and regulations on our model, we only include European airlines. It has been previously reported that the European airline market is different from the American market in several ways (see for example Ng and Seabright, 2001). The origin of these differences is, in part, due to the different regulatory histories of the two markets, as well as their different carrier sizes.

The solution to the dual problem of minimizing the expenditure function, subject to the transformation function, gives us the conditioned demand function. The conditioned demand function defines the specification of the cost function (see Baumol et al, 1981). Furthermore, because of availability of information we are forced to use aggregate data to model the cost performance of carriers.

We are also assuming that firms minimize a linear expenditure function. Linearity comes under the assumption that operators are input prices takers. The dual relation between the cost and the transformation functions allows us to study production by estimating the cost function (McFadden, 1978).

Measures of Cost Performance

How to measure cost performance in air transport industries have been largely discussed in transport literature. Different indices have been proposed and used for this purpose. The most commonly used have been different measures of Economies of Scale. Nevertheless a number of different points of view and critiques of the more commonly used indices have arisen.

Caves et al (1984) use a translog cost function with measures of the aggregated outputs and the number of points served by airlines as the indicator of Network Size. With this estimation the authors are able to estimate two different measures of cost performance that they call Economies of Density and Economies of Scale. Several others have replicated this methodology in different case studies, while others have criticized the real interpretation of the Economies of Scale indicator because it does not hold the Density of the network constant when it is expanded (see Xu et al 1994, Jara-Díaz and Cortes, 1996, Oum and Zhang 1997).

In a recent innovative work, Basso and Jara-Díaz (2005) propose the use of an indicator that avoids the criticisms to the Economies of Scale measurement of Caves et al. (1984). They calculate a measure of Economies of Spatial Scope. In their paper, these authors propose and use this indicator in a cost function that uses the number of points served as an indicator of Network Size.

By using the number of routes that an airline serves as an estimator of the Network Size, we are able to reinterpret the measure of Economies of Scale proposed by Caves et al. (1984). In our case this indicator shows how cost responds to a

proportional change in the total Tonnes-kilometers served by a firm, as well as the number of routes. We consider our measure an appropriate indicator of the effect of Network Size increase on cost because it expands the network while holding the average tons-kilometers served by each route constant.

In this article we use the methodology proposed by Basso and Jara-Díaz (2005), and apply it to a case in which the number of routes is used as an indicator of the Network Size. In addition, by estimating both total and variable cost functions, we are able to calculate an index of excess firm capacity. This index takes into consideration the level of the fixed inputs used by the firms and compares it with the theoretical optimum level that is obtained by comparing the total and variable cost functions.

The Economies of Scale and Density

Once we have obtained cost elasticities for the vector of production, we are able to obtain the Scale elasticity in order to characterize the technology for the European airline market (Panzar and Willig, 1977). In order to compare our results with those obtained in the literature, we maintain the same definition of Economies of Density (*ED*) as in Caves et al (1984). We use the same definition that these authors used for Economies of Scale, but because we include the number of routes, we call this estimator Economies of Network Size (*ENS*). These indicators are calculated as follows:

$$ED_i = \frac{C(W, Y)}{\sum_i \frac{\partial C(W, Y)}{\partial Y_i} Y_i} = \frac{1}{\sum_i \frac{\partial C(W, Y)}{\partial Y_i} \frac{Y_i}{C(W, Y)}} = \frac{1}{\sum_i \pi_{y_i}} \quad (10)$$

$$ENS_i = \frac{1}{\sum_i \pi_{y_i} + \pi_{N_i}} \quad (11)$$

where π_{y_i} is the cost elasticity given by the regressor of the estimated equation, and π_{N_i} is the regressor for the number of routes served by company i .

ED indicates how production increases when all inputs increase in a fixed proportion. This is under the assumption of a radial analysis, and therefore holds the proportion of production vector constant, ENS indicates how production increases proportionally with respect to inputs when the number of routes served increases proportionally. This indicator maintains the average use of the routes constant, because it holds the total ton-km by route of the different outputs constant. As we are able to estimate the total and variable cost functions, we can also obtain ED_i and ENS_i by using the results of the estimated variable cost function. In order to do so, we need to make the following changes:

$$ED_i^{cv} = \frac{1 - \pi_Z}{\sum_i \pi_{y_i}} \quad (12)$$

$$ENS_i^{cv} = \frac{1 - \pi_Z}{\sum_i \pi_{y_i} + \pi_{N_i}} \quad (13)$$

where π_Z is the cost elasticity of Z , the vector of fixed inputs.

The Economies of Spatial Scope

Basso and Jara-Díaz (2005) proposed a new approximation to measure how the cost of an air carrier changes when it decides to add a new airport to its network. They explain that the vector of production included in the specification of cost functions Y is a vector of aggregate products; it hides the real vector of products y_{ij} , which would be the number of passengers (or in our case the weight) and weight of freight carried on each route (or the combination between the origin i and the destiny j) served by one company.

Therefore, when a company serves N_P points, it is potentially able to serve $N_P \cdot (N_P - 1)$ different combinations between these points. Even though the authors do not discuss the fact that actual use of this network can be different from the potential number of combinations, this fact does not have any effect in their estimation method.

In our case, because we use the real number of routes served by the airlines, which differ in an important way from the potential number of combinations, we need to make use of an assumption about how firms decide to use their potential available networks. We solve this problem by assuming that the number of new routes used when a new airport is added to the network is determined by maintaining the average use of the potential network during the sample period.

For example, consider the case in which a company that serves two airports has the following real vector of production: $Y^A = (y_{12}, y_{21}, 0, 0, 0, 0)$. When adding a new airport,

the vector of potential products would change to $Y^D = (y_{12}, y_{21}, y_{13}, y_{31}, y_{23}, y_{32})$. We consider the question of whether it is less expensive for the company to produce all the routes together, or to create a new company for the new routes with the production vector $Y^B = (0, 0, y_{13}, y_{31}, y_{23}, y_{32})$, comparing the cost of producing separately $C(Y^A) + C(Y^B)$ with the cost of producing jointly $C(Y^D)$.

The authors apply the concept of Economies of scope to this difference and call it Economies of Spatial Scope. Since the vectors A and B are orthogonal, we can answer this question by considering whether the company has Economies of scope for that partition of the production (Panzar and Willig, 1981).

In that case, there would Economies of scope if the cost of producing jointly is lower than the cost of producing separately in two firms. The indicator for this is as follows:

$$ESS_i = \frac{1}{C(Y_i^D)} [C(Y_i^A) + C(Y_i^B) - C(Y_i^D)] \quad (14)$$

In our case if, $ESS_i > 0$, then there are Economies of Spatial Scope in the firm i with respect to partition Y_A, Y_B of the total production vector Y_D .

However, the information needed to calculate ESS is incomplete. We know the aggregate vector of production for the scenario A , but not for scenarios B or D . In order to estimate the cost corresponding to these new points, we need to have an estimate of the number of routes and the total production for points B and D . One alternative proposed by Basso and Jara (2005) is to calculate the new aggregate level of production Y_D required to hold the Density (σ) of the actual routes served

constant. The Density can be calculated by dividing the total number of passengers carried on each route by the number of routes served (N_R).

$$d = \frac{\sum_i \sum_j y_{ij}}{N_R} \quad (15)$$

Basso and Jara-Díaz (2005) also obtain the average length of haul (A/h) in order to express the Density as a function of the aggregate product, which is the dependent variable in the estimated cost function.

$$Alh = \frac{Y}{\sum_i \sum_j y_{ij}} \quad (16)$$

Substituting, we get

$$d = \frac{Y}{Alh \cdot N_R} \quad (17)$$

Basso and Jara-Díaz (2005) propose two alternatives: simply hold A/h constant, or estimate Alh as a function of the number of points served. They did not find large differences in the results when comparing the two cases. In our case we assume that A/h is held constant. By doing so, we are able to calculate the aggregate level of production for B and D , holding the Density of the network constant, as follows:

$$d = \frac{Y^A}{Alh \cdot N_R^A} = \frac{Y^D}{Alh \cdot N_R^D} \quad (18)$$

which implies,

$$Y^D = \frac{N_R^D}{N_R^A} Y^A \quad (19)$$

Once we have calculated Y^D , we can calculate Y^B as the difference between Y^D and Y^A .

Basso and Jara-Diaz (2005) develop this expression as a function of the number of points served instead of the number of routes, as we do.

$$Y^D = \frac{(N_p^A + 1)}{(N_p^A - 1)} Y^A \quad (20)$$

4. RESULTS REPORTED IN PREVIOUS LITERATURE

The translog cost function is the most popular specification used to estimate cost performance of the airline industry. Caves et al (1984), using panel data from 1970 to 1984, found substantial Economies of Density, and constant returns to Scale. They reported that both local and trunk carriers show Economies of Density, even if trunk carriers have an advantage in average cost¹. Although the number of points served is similar, trunk airlines have higher load factors and higher average stage lengths. Caves et al 1984, agree with other studies that also have found Economies of Scale for US trunk carriers (Keeler 1978 and White 1979).

Gillen et al (1990) estimate the elasticity of Economies of Scale and Economies of Density with a sample of data from US and Canadian airlines. Data were available for the period from 1964 to 1980. They wanted to test if the Economies of Scale reported

¹ In 1978 cost per passenger-mile per trunk airlines was 7,7 cents, for local carrier was 11,2 cents.

for US carriers were also present for Canadian carriers, which are generally smaller than US carriers. With five input prices and five products indexed in a hedonic production function, they find a Density elasticity of 1.24. Scale elasticity, including the number cost elasticity for the number of points served, was 1.07. Oum and Zhang (1991)², Windle (1991)³, Kumbhakar (1992)⁴, Keeler and Formby (1994)⁵ and Baltagi Griffin and Rich (1995)⁶ have also reported the existence of Economies of Density.

Using multivariate regression and efficiency frontier techniques, Liu and Lynk (1999) questioned whether the results of the studies carried out for US market would be present, after the deregulation process. With a small database of US carriers, but over a period that permits them to model performance of carriers several years after US deregulation, they find an average elasticity of Scale of 1.16. They obtained a negative, but not significant, parameter estimate for the number of points served.

More recently Hansen et al (2001) compared different specifications for US carriers and obtained a consistently elasticity of Scale of 1.2. They use data from eleven quarters between 1995 and 1997 for ten domestic US carriers. Using multivariate regression and efficiency frontier analysis, Ng and Seabright (2001) use a very complete data base from 1982-1995 to estimate long run and short cost functions as Gillen et al (1990) did. They include observations of twelve European and seven US

² Panel 64-81, Canadian Market. Translog.

³ Panel 70-83. International. Translog.

⁴ Panel 70-84, US market. Mcfadden model.

⁵ Panel 88-90, US market. Translog.

⁶ Panel 71-86, US market. Translog.

carriers. They obtained an average Density elasticity of 1.19 and an average elasticity of Scale of 1.09.

Table 4 shows calculated elasticities of Economies of Density and Network Size for the industry evaluated with respect to the mean of the sample, and as defined in section three. We also provide estimates of these indicators for each firm, using the observations from the last year of available data. We provide the probability of this value being less than one, using one of the methods proposed by Papke and Wooldridge (2005). The result of Economies of Density and Economies of Network Size reported for the European airline industry is comparable to results from previous studies. The results show, on average, considerable Economies of Density in the industry. By expanding all inputs in the same proportion, production will increase more than proportionally, so companies are able to reduce total unit costs of production. By expanding production and number of routes proportionally, companies' total unit costs will be only slightly reduced, and using the total cost function, we cannot reject the null that Economies of Network Size exist, on average.

The translog cost function also allows us to evaluate the elasticity of Density and Scale for each company. This gives us the opportunity to explore more accurate information regarding the production process of each company. We have done so for the last observation available for each company. The results are reported in the second half of Table 4. Almost all companies show increasing returns to Density. The only company for which elasticity is not significant greater than one is Virgin.

Excluding this case, the biggest company, British Airways, shows the smallest elasticity. Therefore it is the company that has most extensively made use of its returns to Scale in the last year of the sample.

Table 4 also shows that several companies have increasing returns to Network Size. This implies that they can reduce their costs by expanding the Network Size, and provides statistical evidence that these firms' cost characteristics are consistent with the expansion, merger and alliance strategies widely used by airlines to expand their production.

Table 4: Economies of Scale and Network Size

	<i>ED</i>	<i>p-value</i> (<i>ED</i> <1)	<i>ENS</i>	<i>p-value</i> (<i>ENS</i> <1)
<i>Industry using TC Function</i>	1.25	0.0000	1.07	0.0035
<i>Industry using VC Function</i>	1.27	0.0006	1.04	0.1269
By Firm ⁽¹⁾				
<i>Air France</i>	1.28	0.0002	1.26	0.0005
<i>Alitalia</i>	1.31	0.0000	1.23	0.0000
<i>Austrian</i>	1.49	0.0000	1.02	0.3799
<i>British Airways</i>	1.10	0.0455	1.18	0.0185
<i>British Midland</i>	1.15	0.0326	1.65	0.0141
<i>Finnair</i>	1.17	0.0009	1.21	0.0046
<i>Iberia</i>	1.50	0.0000	1.28	0.0000
<i>Klm</i>	1.17	0.0014	1.04	0.1134
<i>Lufthansa</i>	1.19	0.0024	1.19	0.0060
<i>Olympic</i>	1.35	0.0000	1.46	0.0012
<i>Sas</i>	1.17	0.0018	1.32	0.0000
<i>Swissair</i>	1.20	0.0000	1.01	0.4095
<i>Tap</i>	1.41	0.0000	1.08	0.1456
<i>Virgin</i>	1.05	0.2294	0.84	0.9954

(1) Using Total Cost Function

Table 5 shows the results of the spatial Economies of scope as proposed by Basso and Jara-Diaz (2005). Our results show that some of the companies have Economies of Spatial Scope. We can check if our results depend on the assumption that the proportion of potential routes effectively used when a new airport is add to

the network, by simulating changes in the R parameter. We find that the interpretation of the results does not change.

Table 5: Economies of Spatial Scope

	<i>ESS</i>
<i>Air France</i>	-0.0030
<i>Alitalia</i>	0.0000
<i>Austrian</i>	-0.0138
<i>British Airways</i>	-0.0029
<i>British Midland</i>	0.1496
<i>Finnair</i>	-0.0020
<i>Iberia</i>	0.0091
<i>Klm</i>	-0.0038
<i>Lufthansa</i>	-0.0027
<i>Olympic</i>	0.0157
<i>Sas</i>	0.0056
<i>Swissair</i>	-0.0094
<i>Tap</i>	-0.0087
<i>Virgin</i>	-0.0500

In bold Economies of Spatial Scope.

The results in Table 5 show that not all companies would have Economies of scope with the new vector of production as a result of adding a new airport to their network. The results are related to the actual number of routes, as Basso and Jara-Diaz (2005) reported in their paper.

Even when the interpretation of these results seems to contradict the interpretation of Economies of Network Size previously discussed, we think that we should consider the interpretation of Economies of Scope with some caveats. First, we do not find any statistical properties of this indicator that allow us to infer whether this value is statistically different from zero⁷. Additionally, calculating this indicator requires

⁷ Basso and Jara-Diaz (2005) do not discuss this issue. Nevertheless, we are currently developing a way to calculate standard errors for this indicator.

prediction of the cost of an extremely small firm (the firm that represents production at point B). This involves making predictions about a total cost that is outside the range of values in the sample, where the predictive power of any econometrically estimated function is clearly reduced.

5.CONCLUSIONS

Deregulation implemented by the European Commission in the 1980's and 1990's radically changed conditions under which European airlines compete in the market. Since deregulation, the market has been fully open to cabotage, companies are free to establish fares, and most have changed from public to private property. Some companies have responded to this new situation by merging with other companies (as in the case of Air France and KLM, or Lufthansa and Swiss Air). However, airline alliances have been the dominant strategy.

With a database of European airlines, we have modelled cost performance of companies in order to determine if cost structure has contributed to these strategies. With this objective we have modelled two translog cost functions, total and variable cost. By introducing into the specification of our models the number of routes served by each company, we are able to generate a more accurate measure of the Network Size, and a reinterpretation of the indicator of Economies of Network Size. This estimation also gives us the opportunity to study the existence of Economies of Scope more precisely.

For most air carriers we have found evidence that Economies of Density and Economies of Network Size exist in the European airline industry. Our results also show the existence of Economies of Spatial Scope for some companies in the sample.

These results allows us to answer affirmatively the question that guides this research, and to provide evidence that expansion strategies of firms are related not only to marketing and demand behavior, but also to firms' cost structures.

Regulatory agencies can expect firms to continue developing strategies that help them to take advantage of the available Economies of Scale, which will likely continue increasing the concentration in the airline industry.