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Economies of Density, Network Size and Spatial Scope in the European Airline Industry

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Abstract

In this article we use four different indices to measure cost performance of the European Airline Industry. By using the number of routes as an indicator of Network Size, we are able to estimate indicators of Economies of Density, Network Size and Spatial Scope. By estimating total and variable cost functions we are also able to calculate an index of the excess capacity of the firms. For this purpose, we use data from the years 1984 to 1998, a period during which several deregulation measures were imposed on the European airline industry. Some of the implications of this deregulation process for the cost performance of the industry are presented and discussed. Our results suggest that in the year 1998, almost all the firms had Economics of Density in their existing networks, while several of the firms also had Economies of Network Size and Economies of Spatial Scope. All of the firms had excess capacity of fixed inputs. These results support our hypothesis that fusion, alliance, and merger strategies followed by the principal European airlines after 1998 are not just explained by marketing strategies, but also by the cost structure of the industry.

Keywords: *Economies of Scale, Spatial Scope, Airlines Cost Functions, Transport Economics.*

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1. Introduction

The liberalisation process implemented by the European Commission changed conditions in which European airlines operated in the market. Deregulation opened domestic markets in all European countries to any European company. Over a period of ten years, legal monopolies and government aid for airlines disappeared. In order to accomplish this reduction in aid, handicaps were covered by public funds. Most companies have now been privatised.

The open sky policy has led companies to an important restructuring of their productive processes, as we show in this paper. Companies have focused on improving their efficiency in order to compete with each other. However, the airline market is still concentrated; the three biggest companies carry more than forty percent of the total passenger-kilometres. On the other hand, the European market is also characterised by the smaller size of its carriers, compared with the American carriers. The production of the two biggest European companies is between sixty and seventy percent of the biggest American companies. Although the recent merger between Air France and KLM means that they are jointly responsible for the third-highest number of passengers-kilometres flown, they still continue operating as two independent companies.

The European airline industry’s main strategy has been to raise production. This has been accomplished by mergers and acquisitions in both domestic and external markets, setting up new companies focused on the low-cost market, and participating in alliances with other carriers in order to share costs and obtain benefits derived from the expansion of routes served.

European Commission is studying the consequences of this process for passengers and airlines in order to define policies focused on the protection of consumer rights and to guarantee competitive conditions in the market. In this paper we model the cost performance of companies in order to determine the possible existence of Economies of Scale for European companies. These results have been extensively reported for the American and international markets. However, this paper is the first one which models cost performance with a sample of only European companies, in order to avoid the effect of other industries and regulations on our model.

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. By estimating total and variable cost functions, we are able to estimate the level of overinvestment in the European airline industry.

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.

In the second section of this paper we briefly describe the relevant consequences of the deregulation process carried out by the European Commission. In the third section we describe the econometric model used to estimate both the long and short run cost functions, as well as the methodology used to estimate the different indices for measuring cost performance in the industry. In the fourth section we describe and present the main characteristics of the data used in the econometric analysis. In the fifth section we present and analyze the results of the estimated cost functions and indices mentioned above. Finally, we discuss our conclusion and further research in the last section.

2. The European Deregulation Policy

The evolution of cost performance of European companies during the period studied in this paper has been affected by the circumstances in which deregulation was carried out in Europe. Knowing some details of the deregulation process we are able to have a better understanding of the results of this work.

Not many years ago, flag carriers, supported by legal monopolies, dominated the domestic markets in most European countries. Airlines shared intra-European routes through bilateral agreements. Companies were owned mainly by governments, and losses were supported by public funds. Today many conditions have changed. Most of the former flag carriers have been privatized, government aid has largely disappeared, and legal monopolies no longer exist. The market is theoretically open to new entrants. The liberalization process implemented by the European Commission has radically changed market conditions.

European airlines now have complete freedom to enter and exit any domestic or intra-European market. Following the philosophy of the Treaty of Rome, the European Commission is now studying the consequences of deregulation on companies and consumers. The objective is to analyze the results in order to define what policies are needed to ensure competition and protect consumer rights.

The deregulation process was implemented by the European Commission in three stages, between December 1987 and April 1998. The first liberalisation package started by relaxing some rules regarding bilateral market share agreements, and limiting the ability for governments to respond to the establishment of new fares by companies. Until then, airlines had operated intrastate routes sharing market capacity at 50%.

The second package, implemented in June 1990, gave companies more flexibility to share the intrastate route market and to set fares. The main objective of the European Commission was to introduce competitiveness, eliminate barriers that could limit entry, and limit government aid to carriers.

However, the crisis in the early 1990's was particularly acute in the European airline industry. Most companies were owned by governments and subject to public policies. Therefore, they were not able to compete in an open market. The handicaps of flag carriers were covered by public funds during this period. Government aid was subject to certain conditions; for example, aid might be provided as part of a restructuring program to restore the long-term viability of a company, and aid could not be used to increase capacity. It might be self contained, so aid might be granted once. Companies such as Iberia, Sabena, Air Lingus, Tap, Air France, Olympic and Alitalia received subsidies from their governments.

The third package was implemented between January 1993 and April 1997. The market was completed 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. Therefore, many trips 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).

We model a translog cost function, which is a second order Taylor's series expansion of an unknown function (in our case a cost function). Second derivatives of these functions are not restricted, which allow us to obtain interesting conclusions about the cost performance for companies modelled[3].

The existence of Economies of Scale is defined by the technology. It is a long run problem; therefore, it assumes that all companies are minimizing their expenditure functions. However, in the short run, the firm will move away from its optimal input point as demand fluctuates. One way to solve this problem is to estimate the short run cost function and use it to derive the long run function. Another method is to try to change the temporal reference of data to one in which all inputs can be changed.

The temporal reference of a database defines which inputs can be considered fixed. A sample with monthly data is not appropriate for estimating a long run cost function, because there are most likely inputs that the company cannot change within that time frame. For an airline this could be the number of planes or even the number of employees. However, it is necessary to take into account that there are a certain set of inputs, known as quasi-fixed inputs that become variable for different temporal references. When considering a temporal reference of one year, these inputs could again include planes or employees. In that case, those types of inputs could be considered as variable as well (Oum and Zhang, 1991).

The Specification

We model both total cost (*TC*) and variable cost (*VC*) functions[4]. For both cost functions, we use a vector of two products (*Y*), passenger-kilometers and freight-kilometers flown, measured Tonnes both. For the total cost function we use prices for four inputs (*W*): energy, labour, materials and capital. In the variable cost function, we substituted the price of capital by the number of planes (*Z*) as a proxy of the size of the company.

As the vector of production is an aggregate measure of the real vector, we have added a set of variables (*Q*) to qualify the production in order to introduce more information about the production characteristics of the different carriers (Spady and Friedlander, 1978). These variables are: the average stage length[5], which is a measure of the average length of trips (*A*), the load factor (*L*) and the number of routes served (*N*).

In general, we expect that firms with the same vectors of production and inputs prices, and longer average stage length, have lower average cost per unit of production. This is because firms reduce costs with longer trips, since the highest costs are associated with take-off and landing operations. The load factor measures how full each carrier's planes are, on average. Once again, we can expect a negative sign on the derivative of the average cost with respect to the load factor.

Finally as an indicator of Network Size we use the number of routes served by each company. Using this variable has two main advantages. First, it generates a more accurate measure of the Network Size than number of points served, used before in the literature. Suppose we have two air carriers with the same vector of production, input prices, and

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[3] Characteristics of translog cost functions are detailed in *Panzar, and Willig (1977).*
[4] This also will allow us to estimate the level of excess of capacity for European airlines.
[5] Measured as number of kilometres divided by number of departures.

number of points served, but with different numbers of routes served. Even when both have the same number of airports, they do not have the same network. By modelling the cost function using the number of routes served by each company instead of the number of points served, we reduce the information captured by the disturbances and thus improve the econometric results. Therefore, while maintaining the same number of degrees of freedom, we are able to capture more information. On the other hand, by using this variable we can reinterpret the indicator of Economies of Scale used previously in the literature as an indicator of Economies of Network Size, as will be explained later in more detail. Finally we add a time trend variable in order to capture how costs have changed over time.

$$TC = f(Y, W, Q, T)$$

$$VC = f(Y, Wv, Q, Z, T)$$

We use the common procedure of deviating observations with respect to the mean. This method has two advantages. First, it reduces the potential problem of multicollinearity because of the large number of parameters used in the translog cost function. Secondly, for each product the first order parameter allows us to directly capture the cost elasticity estimated evaluated in the mean of the sample. The total and variable cost function specifications are as follows:

$$\ln TC(Y,W,Q) = \alpha_o + \sum_{i=1}^{n} \beta_i \ln(y_i/\overline{y}) + \sum_{i=1}^{m} \lambda_i \ln(w_i/\overline{w}) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln(y_i/\overline{y})\ln(y_j/\overline{y}) +$$

$$+\frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \lambda_{ij} \ln(w_i/\overline{w})\ln(w_j/\overline{w}) + \sum_{i=1}^{m}\sum_{j=1}^{n} \psi_{ij} \ln(w_i/\overline{w})\ln(y_j/\overline{y}) +$$

$$\sum_{i=1}^{r}\delta_i \ln(q_i/\overline{q}) + \frac{1}{2}\sum_{i=1}^{r}\sum_{j=1}^{r} \partial_{ij} \ln(q_i/\overline{q})\ln(q_j/\overline{q}) + \sum_{i=1}^{r}\sum_{j=1}^{n} \mu_{ij} \ln(q_i/\overline{q})\ln(y_j/\overline{y}) + \sum_{i=1}^{r}\sum_{j=1}^{m} \rho_{ij} \ln(q_i/\overline{q})\ln(w_j/\overline{w}) +$$

$$\gamma \ln(T/\overline{T}) + \kappa \ln(T/\overline{T})(T/\overline{T})$$

$$
\begin{aligned}
&\ln VC(Y,W_v,Q,Z) = \alpha_o + \sum_{i=1}^{n}\beta_i \ln(y_i/\overline{y}) + \sum_{i=1}^{m}\lambda_i \ln(w_i/\overline{w}) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln(y_i/\overline{y})\ln(y_j/\overline{y}) + \\
&\frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m}\lambda_{ij}\ln(w_i/\overline{w})\ln(w_j/\overline{w}) + \sum_{i=1}^{m}\sum_{j=1}^{n}\psi_{ij}\ln(w_i/\overline{w})\ln(y_j/\overline{y}) + \\
&\theta\ln(Z/\overline{Z}) + \frac{1}{2}\theta\ln(Z/\overline{Z})^2 + \sum_{i=1}^{n}\nu_i\ln(Z/\overline{Z})\ln(y_i/\overline{y})) + \sum_{i=1}^{m}\varphi_i\ln(Z/\overline{Z})\ln(w_i/\overline{w}) \\
&\sum_{i=1}^{r}\delta_i\ln(q_i/\overline{q}) + \frac{1}{2}\sum_{i=1}^{r}\sum_{j=1}^{r}\partial_{ij}\ln(q_i/\overline{q})\ln(q_j/\overline{q}) + \\
&\sum_{i=1}^{r}\sum_{j=1}^{n}\mu_{ij}\ln(q_i/\overline{q})\ln(y_j/\overline{y}) + \sum_{i=1}^{r}\sum_{j=1}^{m}\rho_{ij}\ln(q_i/\overline{q})\ln(w_j/\overline{w}) + \sum_{i=1}^{r}\eta_i\ln(q_i/\overline{q})\ln(Z/\overline{Z}) + \\
&\gamma\ln(T/\overline{T}) + \kappa\ln(T/\overline{T})(T/\overline{T})
\end{aligned}
$$

On the other hand, in order to ensure that the estimated functions have certain desirable homogeneity properties, we impose the following set of restrictions on the parameters related to input prices.

$$
\sum_{i=1}^{m}\lambda_i = 1 \qquad \sum_{i=1}^{m}\lambda_{ij} = 0 \qquad \sum_{i=1}^{n}\psi_{ij} = 0 \qquad \sum_{i=1}^{n}\rho_{ij} = 0
$$

For the variable cost function we also add the following restriction:

$$
\sum_{i=1}^{m}\partial_{ij} = 0
$$

We also impose the restriction of symmetric cross effects, which allows us to reduce the number of parameters as follows:

$$
\beta_{ij} = \beta_{ji} \qquad \lambda_{ij} = \lambda_{ji} \qquad \partial_{ij} = \partial_{ji} \qquad \mu_{ij} = \mu_{ji} \qquad \rho_{ij} = \rho_{ji} \qquad \eta_{ij} = \eta_{ji}
$$

Using Shephard's Lemma (Shephard, 1953), taking the derivative of cost function we are able to obtain the share cost equation for each input. For the total cost function, we obtain four share cost equations as follows:

$$
S_i^{TC} = \frac{\partial \ln TC(Y,W,Q)}{\partial \ln w_i} = \lambda_i + \sum_{i=1}^{m}\lambda_{ij}\ln(w_i/\overline{w}) + \sum_{j=1}^{n}\psi_{ij}\ln(y_j/\overline{y}) + \sum_{i=1}^{r}\rho_{ij}\ln(q_i/\overline{q}) \qquad \forall_i = 1,..,4
$$

For the variable cost system we have one equation less. In this case, the share equations have the following structure:

$$S_i^{VC} = \frac{\partial \ln VC(Y,W,Q,Z)}{\partial \ln w_i} = \lambda_i + \sum_{i=1}^{m} \lambda_{ij} \ln(w_i / \overline{w}) + \sum_{j=1}^{n} \psi_{ij} \ln(y_j / \overline{y}) + \sum_{i=1}^{r} \rho_{ij} \ln(q_i / \overline{q}) + \varphi_i \ln(Z / \overline{Z}) \qquad \forall_i = 1,..,4$$

Finally we estimate the model using Zellner's SUR method (Zellner, 1962), running a system of equations composed of the main cost equation, either the total or variable cost function, and the share cost equations.

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-Diaz 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 measure 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 Density and Network Size

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:

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

$$ENS_i = \frac{1}{\sum_i \pi_{y_i} + \pi_{N_i}}$$

where π_{yi} is the cost elasticity given by the regressor of the estimated equation, and π_{Ni} 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:

$$ED_i^{CV} = \frac{1-\pi_Z}{\sum_i \pi_{y_i}}$$

$$ENS_i^{CV} = \frac{1-\pi_Z}{\sum_i \pi_{y_i} + \pi_{N_i}}$$

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 produc,ts 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:

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

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 (*d*) 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).

$$d = \frac{\sum_i \sum_j y_{ij}}{N_R}$$

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

$$Alh = \frac{Y}{\sum_i \sum_j y_{ij}}$$

Substituing, we get

$$d = \frac{Y}{Alh \cdot N_R}$$

Basso and Jara-Díaz (2005) propose two alternatives: simply hold *Alh* 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 *Alh* 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:

$$d = \frac{Y^A}{Alh \cdot N_R^A} = \frac{Y^D}{Alh \cdot N_R^D}$$

which implies,

$$Y^D = \frac{N_R^D}{N_R^A} Y^A$$

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.

$$Y^D = \frac{(N_P^A + 1)}{(N_P^A - 1)} Y^A$$

Basso and Jara-Diaz (2005) follow that method because they used data from Gillen et al (1990) to obtain the new aggregate level of production; these data did not include the number of routes served, but only the number of points served. The difference is that they calculate the Economies of scope for a larger number of routes served - the total number of possible combinations - which is in general a bigger number than the real number of routes served.

Since we are using the real number of routes served as an estimation of Network Size, we hold the proportion between the real and the potential number of routes served constant for each company. Hence, the number of new routes added to the network when a new airport is included is estimated by:

$$N_R = R \cdot N \cdot (N-1)$$

where *N(N-1)* is the number of potential combinations when N airports are in the network and *R* is the proportion of real use of routes. In our case we estimate *R* by calculating the average use of the potential number of routes, given the number of airports that each firm serves during each year of the sample.

We now use the estimated Y^B, Y^D, N^B and N^D, deviated from the sample mean, to calculate the predicted cost to obtain *ES*.

Overinvestment in Capacity

By minimizing the total cost function, we obtain conditioned input demand for each input, even capital. This provides the optimal level of input for each level of production.

$$TC = VC(Y, W, Z) + rZ$$

where *r* represents the price for capital input, and Z is the real level of capital input.

Gillen et al (1990) obtain the optimal elasticity of variable cost with respect to capital stock, π_k^*, which is defined as the share of capital cost with respect to variable cost.

$$\pi_k^* = \frac{-rk}{VC}$$

After that, they test the optimality condition by testing the difference between the actual and optimal capital elasticities.

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 cost[6].Although the number of points served is similar, trunk airlines have higher load

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

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 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)[7], Windle (1991)[8], Kumbhakar (1992)[9], Keeler and Formby (1994)[10] and Baltagi Griffin and Rich (1995)[11] 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 carriers. They obtained an average Density elasticity of 1.19 and an average elasticity of Scale of 1.09.

5. The Data.

The sample is a data panel for fifteen airlines and covers the whole period of the deregulation process in Europe. The production of these fifteen airlines is around 73% of the total European industry production for 1998 (see Table 1). We have data available from 1984 to 1998. Data have been collected from official publications of the *International Civil Aviation Organization (ICAO)*. There are 173 observations, and all data have been adjusted to (real) 1998 values.

The sample includes the three largest European companies: British Airways, Lufthansa and Air France. These companies together carry around 43% of the total production for the European market. In general European airlines are smaller than their American counterparts,

[7] Panel 64-81, Canadian Market. Translog.
[8] Panel 70-83. International. Translog.
[9] Panel 70-84, US market. Mcfadden model.
[10] Panel 88-90, US market. Translog.
[11] Panel 71-86, US market. Translog.

British Airways' production, for example, is around 60%-70% of the biggest US carriers' production (Chang and Williams, 2002). Although Air France recently merged with KLM, and together they represent the third-largest airline company in the world in terms of production and the first-largest in terms of revenues, in the sample they are treated as different companies. Even today, they do not operate as a single carrier.

In order to gain a better understanding on the cost performance of carriers we can focus on some figures and on the data presented in Table 1. British Airways is the carrier with the highest number of employees, followed by Air France and Lufthansa. Austrian, Virgin, and British Midland have smaller staffs, with around five thousand employees each, ten times less than the two biggest carriers. Also, by number of kilometres flown, the three largest carriers maintain the same ranking. However, Virgin, a company focused mainly in international flights, climbs in the rankings, and is located very close to Finnair, but behind Swiss Air or Iberia.

Looking at the number of departures, Lufthansa, which also has the largest number of routes, is in first place, followed by Air France. British Airways is located close to the top, but behind SAS. Virgin is in last place. This allows us to reach some conclusions about the types of destinations served by each airline.

Looking at some productivity figures, we gain a better understanding of the production process of companies included in our sample. Virgin has the highest productivity by employee, measured as number of tons-kms by employee, followed by Lufthansa and KLM. British Airways is behind Alitalia and Swissair. Finally, looking at the number of hours flown by plane, Swiss Air and Virgin are the two companies that ask their planes for the highest effort, followed by Airfrance and KLM.

During the period considered in this study all carriers in the data sample have increased production considerably. The growth was especially important in the 1990's. Companies with the highest growth have been Virgin, KLM, British Midland, and Austrian. Air France, Alitalia, British Airways, Finnair, and Lufthansa have nearly tripled their production.

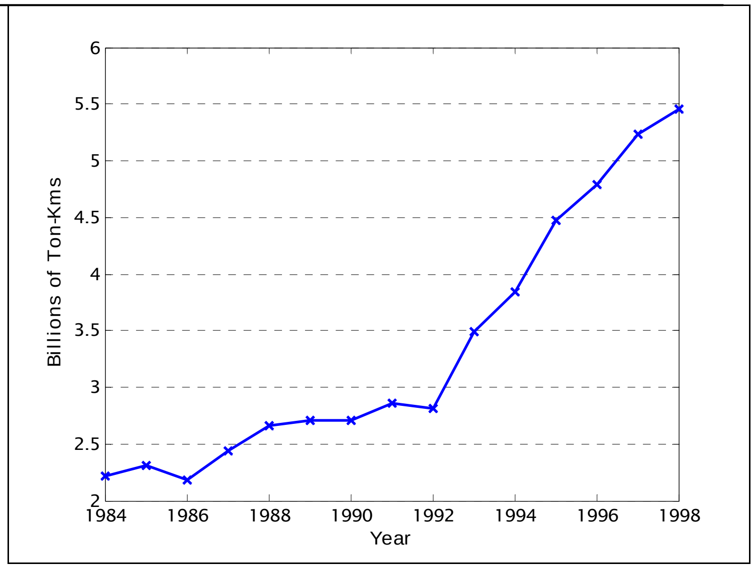

Figure 1. Average production for the sample 1984-98 (Ton-kms flown)

The new market conditions imposed by the European Commission led companies to improve their efficiency in order to compete in an open market. One input on which carriers have focused is labour. Companies such as Olympic, Alitalia, and Tap have reduced the number of employees during this period. Companies such as Iberia and Lufthansa have achieved their rise in production while maintaining the same number of employees. Figure 1 shows that companies have increased average employee productivity during the sample period.

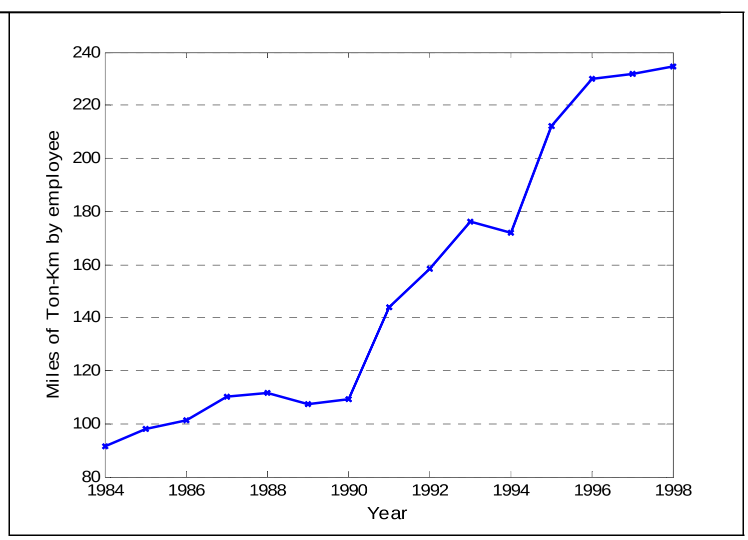

Figure 2. Average productivity per employee (Ton-km flown/number employees)

With respect to productivity of capital, European airlines increased the number of hours and kilometers flown per plane. Figure 3 shows the evolution of the number of tons-kms flown by plane on average during the period studied.

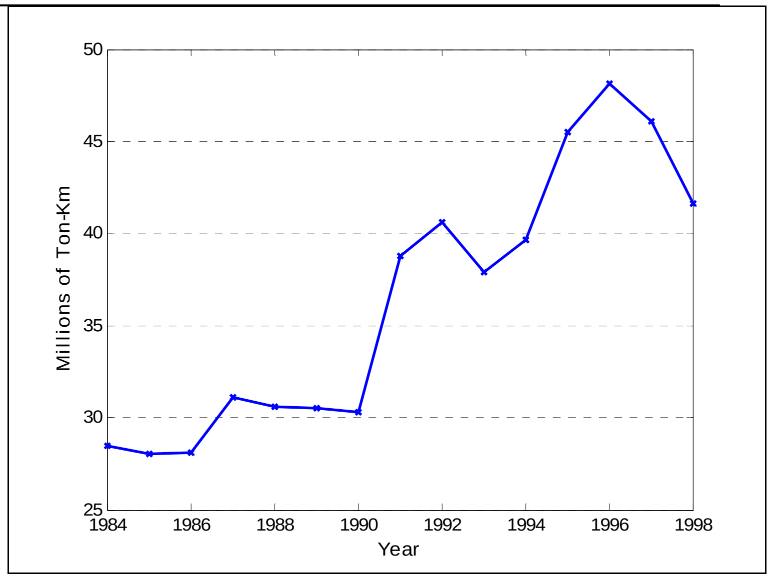

Figure 3. Average productivity per plane (Ton-km flown/number planes)

Table 1: Description of the Industry (data 1998)

Carrier	***Ton-kms flown (000) (1)***	***Number of employees (2)***	***Number of planes***	***Kilometres flown***	***Number of routes***	***Number of Departures***	***Productivity by employee (1)/(2)***	***Hours flown per plane***
Air France	12.239.557	49.092	203	557.483.000	769	402.966	249.319	4.102
Alitalia	(*) 5.064.512	15.501	147	299.985.000	569	278.703	326.722	3.689
Austrian	811.045	4.561	35	64.397.000	194	42.969	177.822	3.115
British Airways	15.481.175	55.751	280	595.864.000	572	326.893	277.684	3.318
British Midland	300.734	5.548	48	47.763.000	59	95.955	54.206	2.583
Finnair	1.441.919	9.003	57	107.394.000	189	121.532	160.160	3.323
Iberia	3.688.248	23.966	112	244.695.000	463	144.235	153.895	3.656
Klm	9.714.433	27.303	113	299.546.000	582	156.714	355.801	3.948
Lufthansa	13.935.046	34.246	295	586.942.000	1.053	502.569	406.910	3.410
Olympic	940.239	7.356	56	70.053.000	184	95.415	127.819	2.473
Sas	2.646.866	20.713	179	255.713.000	356	336.729	127.788	2.719
Swissair	4.927.396	17.111	68	219.951.000	402	165.135	287.967	4.986
Tap	1.103.253	8.500	34	78.590.000	210	53.730	129.794	3.568
Virgin	2.873.822	5.032	24	81.475.000	56	11.986	571.109	4.305

(*) = production of year 1997.

6. Results

Table 2 shows the main results for the estimated total and variable cost models. The total set of parameters estimated is shown in the appendix. As equations are deviated with respect to the mean, first order parameters report the cost elasticity evaluated with respect to the mean of the observations.

For both aggregate products the sign is positive, as expected. Transportation of passengers has a strong influence on both the total and variable cost. In the first case, a increase in production of passenger by one percent increases total cost by 0,72% and variable cost by 0,44%. These are similar to values obtained in the previous literature, before taking into account that they are evaluated with respect to the mean of our observations.

Elasticities for inputs prices also have the expected sign. In all cases an increase in the price of inputs raises the cost of production. The parameter for cross-product elasticity between the two components of the production vector reports the cost complementarity. In our case, we can reject the existence of cost complementarity between the products. The reason can be that although both products can coincide in the same plane production process is independent.

By introducing a time trend in the model (*T*) we are able to capture how cost changes across time by effects that are not included in the other explanatory variables. We can interpret the negative sign that we found on the square of T, to mean that there is a first period in which costs increased and a second period in which costs decreased. Using the results, we found that the inflection point of the function with respect to this variable occurs around 1992[12]. We also detect this point as a point of change in our descriptive analysis, since that by this year companies started a process in which productivity of their inputs also increases. As we mentioned while describing European Commission policy during this period, many flag carriers received public financing to cover handicaps. This result has encouraged us to explore in a more detailed way the changes in productivity and other variables due to the deregulation process; however, those results are outside the scope of this work.

[12] We can show that the variable capturing the time trend of the total cost function has a maximum around 1992. Note that without considering the intercept, which implies just a parallel shift in the cost function, the part of this function that depends on time is $-0.0726T-0.03652T^2$. Taking derivatives of this expression and setting it equal to zero, we find T'=-0.0726/(2*0.03552)=-0.994. Recall that this variable is in log and is deviated from the mean, which has a value of 8.1. Hence, the year of maximum cost, controlling for the other explanatory variables, is Tmax=1984+(exp(-0.994)+8.01)=1992.

Table 2: Estimated Total and Variable Cost Functions

	Coefficient	***Std. Error***	***t-Statistic***	***Prob.***
Total Cost Function				
Passengers	0.7247	0.0312	23.2241	0.0000
Freight	0.0784	0.0272	2.8803	0.0041
Energy	0.1129	0.0021	54.0665	0.0000
Personal	0.2971	0.0044	67.5276	0.0000
Other Materials	0.5329	0.0034	157.8914	0.0000
Capital	0.0572	-	-	-
*Passenger*Freight*	0.0751	0.0180	4.1730	0.0000
Average Stage Length	-0.9530	0.0333	-28.5862	0.0000
Load Factor	-0.6317	0.1407	-4.4898	0.0000
Number Of Routes	0.1272	0.0398	3.1915	0.0015
Time	-0.0726	0.0189	-3.8454	0.0001
*Time*Time*	-0.0365	0.0116	-3.1389	0.0018
Variable Cost Function				
Passengers	0.4415	0.0494	8.9415	0.0000
Freight	0.0892	0.0272	3.2775	0.0011
Energy	0.1246	0.0023	53.0421	0.0000
Personal	0.3152	0.0052	60.8879	0.0000
Other Materials	0.5602	-	-	-
*Passenger*Freight*	0.2387	0.0689	3.4614	0.0006
Average Stage Length	-0.5788	0.0502	-11.5280	0.0000
Load Factor	-0.3536	0.1373	-2.5758	0.0102
Number Of Routes	0.1185	0.0398	2.9780	0.0030
Capital	0.3269	0.0431	7.5847	0.0000
Time	-0.1006	0.0520	-1.9338	0.0536
*Time*Time*	0.3332	0.1833	1.8174	0.0696

Table 3: R^2 Estimated Total Cost Functions

	Total Cost R^2	**Variable Cost R^2**
Cost Function	0.99	0.99
Energy Cost Share	0.88	0.66
Personal Cost Share	0.69	0.77
Materials Cost Share	0.86	0.83

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

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

	ESS
Air France	-0.0030
Alitalia	0.0000
Austrian	-0.0138
British Airways	-0.0029
British Midland	**0.1496**
Finnair	-0.0020
Iberia	**0.0091**
Klm	-0.0038
Lufthansa	-0.0027
Olympic	**0.0157**
Sas	**0.0056**
Swissair	-0.0094
Tap	-0.0087
Virgin	-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 zero[13]. Additionally, calculating this indicator requires 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.

By optimizing the total cost function, we are able to obtain the optimal elasticity for capital, as discussed in section 3. Comparing this with the real elasticity of capital, we are able to deduce that whether companies are over-investing in capacity, as Gillen et al (1990) did. The first column in Table 6 shows the difference between the real and

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

the optimal capital elasticities. In all cases this measure is positive and significantly different than zero, which indicates that all companies are over investing in capacity.

Table 6: Index of Excess Capacity by Firm

	Exc.Cap	***p-value (EC<0)***
Air France	0.3644	0.0000
Alitalia	0.3855	0.0000
Austrian	0.5282	0.0000
British Airways	0.6313	0.0000
British Midland	0.8943	0.0000
Finnair	0.5469	0.0000
Iberia	0.4884	0.0000
Klm	0.3693	0.0000
Lufthansa	0.3981	0.0000
Olympic	0.5057	0.0000
Sas	0.4387	0.0000
Swissair	0.3106	0.0000
Tap	0.4772	0.0000
Virgin	0.4957	0.0000

7. 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 contributes 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. Finally, we also find over-investment in capacity by all firms.

The exploration of the data and the inclusion of a time trend in our econometric model show an important break in the tendency of productivity and cost in the year 1992, probably as a result of the deregulation measures implemented to cover handicaps of companies. This process allows companies to adapt their respective productive processes to the new, competitive conditions in the market.

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.

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Appendix: Completes Result of Estimations

1. Total Cost Function Pasimonoius Model

System: TLSINEMPPARS					
Estimation Method: Seemingly Unrelated Regression					
Date: 04/22/05 Time: 10:56					
Sample: 1 173					
Included observations: 173					
Total system (balanced) observations 692					
Convergence achieved after: 1 weight matrix, 4 total coef iterations					
		Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1	22.08196	0.017518	1260.544	0.0000
C(2)	2	0.724715	0.031205	23.22405	0.0000
C(3)	3	0.078396	0.027218	2.880275	0.0041
C(4)	4	0.112863	0.002087	54.06652	0.0000
C(5)	5	0.297089	0.0044	67.52757	0.0000
C(6)	6	0.532869	0.003375	157.8914	0.0000
C(9)	7	0.102384	0.003217	31.82952	0.0000
C(10)	8	0.153367	0.008805	17.41731	0.0000
C(11)	9	0.185706	0.005917	31.38502	0.0000
C(22)	10	-0.02712	0.00373	-7.26999	0.0000
C(23)	11	-0.06544	0.002701	-24.2233	0.0000
C(25)	12	-0.08361	0.006455	-12.9525	0.0000
C(13)	13	0.075066	0.017988	4.173041	0.0000
C(15)	14	-0.05692	0.009789	-5.81535	0.0000
C(16)	15	0.052147	0.007473	6.97777	0.0000
C(18)	16	0.008149	0.002197	3.708808	0.0002
C(19)	17	0.034484	0.007678	4.491354	0.0000
C(20)	18	-0.03664	0.005773	-6.34635	0.0000
C(28)	19	-0.63173	0.140704	-4.48976	0.0000
C(29)	20	-0.95299	0.033337	-28.5862	0.0000
C(30)	21	0.127172	0.039847	3.191504	0.0015
C(31)	22	-10.5434	1.730348	-6.09325	0.0000
C(32)	23	0.43868	0.126471	3.46863	0.0006
C(35)	24	-0.23193	0.052077	-4.45358	0.0000
C(36)	25	0.304402	0.093665	3.249905	0.0012
C(37)	26	-0.24795	0.052683	-4.70647	0.0000
C(40)	27	0.063173	0.012383	5.101618	0.0000
C(41)	28	0.021625	0.009334	2.316848	0.0208
C(43)	29	0.059724	0.005374	11.11294	0.0000
C(44)	30	-0.01178	0.004473	-2.63335	0.0087
C(46)	31	-0.14218	0.009839	-14.4508	0.0000
C(47)	32	-0.01724	0.007135	-2.41611	0.0160
C(50)	33	0.077008	0.021551	3.573354	0.0004
C(49)	34	0.18851	0.035836	5.260373	0.0000
C(53)	35	0.335707	0.073512	4.566718	0.0000
C(56)	36	0.106325	0.031122	3.416337	0.0007
C(57)	37	-0.0726	0.018881	-3.84538	0.0001
C(58)	38	-0.03652	0.011633	-3.13889	0.0018
Determinant residual covariance			1.90E-13		

Equation: CT=C(1)+C(2)*YP+C(3)*YM+C(4)*PE+C(5)*PP+C(6)*PO+(1			
-C(4)-C(5)-C(6))*PC+C(9)*0.5*PE*PE+C(10)*0.5*PP*PP+C(11)			
*0.5*PO*PO+(C(9)+C(22)+C(23)+C(23)+C(10)+C(25)-(C(23)+C(25)			
+C(11)))*0.5*PC*PC+C(13)*YP*YM+C(15)*YP*PP+C(16)*YP*PO			
-(C(15)+C(16))*YP*PC+C(18)*YM*PE+C(19)*YM*PP+C(20)*YM			
*PO-(C(20)+C(19)+C(18))*YM*PC+C(22)*PE*PP+C(23)*PE*PO+(			
-C(9)-C(22)-C(23))*PE*PC+C(25)*PP*PO-(C(23)+C(10)+C(25))*PP			
*PC-(C(23)+C(25)+C(11))*PO*PC+C(28)*L+C(29)*A+C(30)*N+0.5			
*C(31)*L*L+0.5*C(32)*A*A+C(35)*YP*N+C(36)*YM*L+C(37)*YM*A			
-(C(40)+C(41))*PP*L+C(40)*PP*A+C(41)*PP*N-(C(43)+C(44))*PE			
*L+C(43)*PE*A+C(44)*PE*N-(C(46)+C(47))*PO*L+C(46)*PO*A			
+C(47)*PO*N-(C(50)+C(49))*PC*L+C(49)*PC*A+C(50)*PC*N			
+C(53)*A*N+C(56)*N*N+C(57)*T+C(58)*T*T			
Observations: 173			
R-squared	0.993235	Mean dependent var	21.54659
Adjusted R-squared	0.991381	S.D. dependent var	1.013756
S.E. of regression	0.094113	Sum squared resid	1.195731
Equation: SE=C(4)+C(9)*PE+C(18)*YM+C(22)*PP+C(23)*PO+(-C(9)			
-C(22)-C(23))*PC-(C(43)+C(44))*L+C(43)*A+C(44)*N			
Observations: 173			
R-squared	0.879129	Mean dependent var	0.113303
Adjusted R-squared	0.87476	S.D. dependent var	0.042545
S.E. of regression	0.015056	Sum squared resid	0.037631
Equation: SP=C(5)+C(10)*PP+C(15)*YP+C(19)*YM+C(22)*PE+C(25)			
*PO-(C(23)+C(10)+C(25))*PC-(C(40)+C(41))*L+C(40)*A+C(41)*N			
Observations: 173			
R-squared	0.693413	Mean dependent var	0.295128
Adjusted R-squared	0.678458	S.D. dependent var	0.096354
S.E. of regression	0.054637	Sum squared resid	0.489575
Equation: SO=C(6)+C(11)*PO+C(16)*YP+C(20)*YM+C(23)*PE+C(25)			
*PP-(C(23)+C(25)+C(11))*PC-(C(46)+C(47)) *L+C(46)*A+C(47)*N			
Observations: 173			
R-squared	0.855219	Mean dependent var	0.528199
Adjusted R-squared	0.849077	S.D. dependent var	0.107116
S.E. of regression	0.041613	Sum squared resid	0.285723

2. Variable Cost Function Pasimonious Model

System: TRANSLOGCV2PARS				
Estimation Method: Seemingly Unrelated Regression				
Date: 04/22/05 Time: 14:40				
Sample: 1 173				
Included observations: 173				
Total system (balanced) observations 692				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	22.06951	0.01733	1273.449	0
C(2)	0.441474	0.049374	8.941495	0
C(3)	0.089167	0.027206	3.277455	0.0011
C(4)	0.124578	0.002349	53.0421	0
C(5)	0.315182	0.005176	60.88785	0
C(7)	-0.37302	0.193989	-1.92289	0.0549
C(20)	-0.07915	0.003868	-20.4616	0
C(19)	-0.02116	0.00338	-6.25966	0
C(21)	-0.09817	0.005464	-17.9658	0
C(12)	0.238655	0.068948	3.461404	0.0006
C(15)	0.002484	0.006596	0.376548	0.7066
C(17)	0.045165	0.005696	7.928642	0
C(18)	-0.03801	0.005543	-6.85693	0
C(22)	-0.57884	0.050212	-11.528	0
C(23)	-0.35356	0.137261	-2.5758	0.0102
C(24)	0.118516	0.039797	2.978013	0.003
C(25)	-0.05807	0.110182	-0.52701	0.5984
C(26)	-0.15073	0.072558	-2.07736	0.0382
C(29)	-0.08776	0.008955	-9.80036	0
C(33)	-0.20785	0.05404	-3.84611	0.0001
C(34)	0.135976	0.046089	2.950282	0.0033
C(35)	-0.32676	0.052397	-6.23621	0
C(36)	0.044036	0.043436	1.013826	0.311
C(38)	0.029769	0.009624	3.093099	0.0021
C(39)	-0.02853	0.008246	-3.46001	0.0006
C(41)	0.255459	0.25847	0.988351	0.3233
C(42)	0.342602	0.068748	4.983474	0
C(43)	-8.64011	1.68383	-5.13122	0
C(45)	0.2524	0.077224	3.268394	0.0011
C(46)	-0.05671	0.015656	-3.62232	0.0003
C(47)	-0.01534	0.009026	-1.69958	0.0897
C(48)	0.326919	0.043102	7.584737	0
C(50)	0.255188	0.107999	2.362877	0.0184
C(51)	-0.21891	0.065621	-3.33602	0.0009
C(53)	-0.08409	0.00811	-10.3676	0
C(54)	0.075422	0.00938	8.040473	0
C(55)	-0.10057	0.052005	-1.93377	0.0536
C(56)	0.333172	0.183326	1.817377	0.0696
Determinant residual covariance		3.05E-12		

Equation: CV=C(1)+C(2)*YP+C(3)*YM+C(4)*PE+C(5)*PP+(1-C(4)-C(5))			
*PO+C(7)*0.5*YP*YP+(C(20)+C(19))*0.5*PE*PE-(C(19)+C(21))			
*0.5*PP*PP-(C(20)+C(21))*0.5*PO*PO+C(12)*YP*YM-(C(15))*YP			
*PE+C(15)*YP*PO-(C(17)+C(18))*YM*PE+C(17)*YM*PP+C(18)			
*YM*PO+C(19)*PE*PP+C(20)*PE*PO+C(21)*PP*PO+C(22)*A			
+C(23)*L+C(24)*N+C(25)*YP*A+C(26)*A*YM-(C(29))*A*PE+C(29)			
*A*P-(C(33)+C(34))*L*PE+C(33)*L*PP+C(34)*L*PO+C(35)*N*YP			
+C(36)*N*YM-(C(38)+C(39))*N*PE+C(38)*N*PP+C(39)*N*PO			
+C(41)*A*L+C(42)*A*N+C(43)*0.5*L*L+C(45)*0.5*N*N+C(46)*T			
+C(47)*T*T+C(48)*Z+C(50)*Z*YP+C(51)*Z*YM-(C(53)+C(54))*Z			
*PE+C(53)*Z*PP+C(54)*Z*PO+C(55)*Z*A+C(56)*Z*L			
Observations: 173			
R-squared	0.994773	Mean dependent var	21.48068
Adjusted R-squared	0.99334	S.D. dependent var	1.010711
S.E. of regression	0.082481	Sum squared resid	0.918422
Equation: SE=C(4)-(C(19)+C(20))*PE-(C(15))*YP-(C(17)+C(18))*YM			
+C(19)*PP+C(20)*PO-(C(33)+C(34))*L-(C(29))*A-(C(38)+C(39))*N			
-(C(53)+C(54))*Z			
Observations: 173			
R-squared	0.662936	Mean dependent var	0.113303
Adjusted R-squared	0.637656	S.D. dependent var	0.042545
S.E. of regression	0.02561	Sum squared resid	0.104938
Equation: SP=C(5)-(C(19)+C(21))*PP+C(17)*YM+C(19)*PE+C(21)*PO			
+C(38)*N+C(33)*L+C(53)*Z			
Observations: 173			
R-squared	0.67322	Mean dependent var	0.295128
Adjusted R-squared	0.661409	S.D. dependent var	0.096354
S.E. of regression	0.056067	Sum squared resid	0.52182
Equation: SO=(1-C(4)-C(5))-(C(20)+C(21))*PO+C(15)*YP+C(18)*YM			
+C(20)*PE+C(21)*PP+C(29)*A+C(39)*N+C(34)*L+C(54)*Z			
Observations: 173			
R-squared	0.832678	Mean dependent var	0.528199
Adjusted R-squared	0.823439	S.D. dependent var	0.107116
S.E. of regression	0.045009	Sum squared resid	0.330207