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Liberalisation and efficiency in international air transport

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Abstract

This paper sets out to compare the economic and technical efficiency of international air transport companies, within the new liberalisation framework that characterises the period of 1996–2000. For this purpose, two stochastic frontiers are estimated, one for cost function, the other for production function. From these estimations we obtain indexes for, respectively, economic and technical efficiency. Our evidence suggests that the benefits of increasing competition in terms of efficiency, is being large for the Asian companies.

Keywords: Efficiency; Deregulation; Air transport; Stochastic frontier

1. Introduction

International air transport has gone through profound changes since the end of the 1970s. Air transport in the United States became totally liberalised in 1978, while Europe embarked on the same road 10 years later, the full process being completed in 1997.[1] Where the Asian countries are

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[1] A detailed review of the liberalisation process in Europe is to be found in Rey (2000).

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concerned, today's domestic markets continue to be very fragmented, these countries still being bound by very restrictive bilateral agreements (Oum and Lee, 2002). However, the threat posed by the creation of international alliances between American and European companies is pushing these countries towards air transport liberalisation. In Chin (1997), we observe that one of the first measures was the entry onto the market of "second-level" companies,[2] thereby increasing competition within the domestic markets, to the detriment of the traditional national companies, which had been operating as large monopolies.

As for company ownership, the 1980s and 1990s witnessed the privatisation of numerous international companies, among which we find British Airways, Singapore Airlines, Japan Airlines (JAL) and Iberia.

These changes were introduced in order to stimulate competitiveness in domestic and international markets and improve the results of air companies, many of which have been fundamentally restructured in a deep way so as to survive in more competitive contexts. The international alliances and code-share agreements[3] that have been arrived at constitute good examples of this.

Such a transformation of the industry calls for an analysis of the consequences on air transport companies efficiency, and this is what our article sets out to do. Previous studies of the subject, such as Forsyth et al. (1986), Encaoua (1991), Oum and Yu (1995) and Inglada et al. (1999), compared periods of regulation and liberalisation, reaching the conclusion that liberalisation led to gains in efficiency for air companies.

This article is structured into three sections: firstly there is an exposition of the methodology used, secondly, there is a description of data and variables and, lastly, we present the results of the estimation with our conclusions.

2. Methodology

The most common way of estimating both economic and technical efficiency is by using efficiency frontier methodology. This approach basically consists in adjusting data to a particular technological frontier and estimating the efficiency measures, comparing the values observed with the optimums defined by the frontier. In this kind of estimation one needs to assume a special frontier type and choose a procedure for the estimation.

As Bauer (1990) points out the are two competing paradigms on how to construct frontiers. One uses mathematical programming techniques, the other employs econometric techniques. The chief advantage of the mathematical programming or Data Envelopment Analysis (DEA) approach is that no explicit functional form need be imposed on the data. However, the calculated frontier may be warped if the data are contaminated by statistical noise (such as luck and weather). Frontier estimation employing DEA methodology has often been applied in the transport field, see for instance Alam et al. (1998), Gillen and Lall (1997) or Adler and Golany (2001) for air transport.

[2] To name some of them: Silk Air, Eva Airways, Japan Asia Airways, All Nippon Airways, Asiana, Saempati and Dragon Air.

[3] There are many examples, but one of the most recent is the code-share agreement between the air companies of Vietnam and American Airlines in July 2001.

On the other hand, the econometric approach (with stochastic frontier analysis) can handle statistical noise, but it imposes an explicit, and possibly overly restrictive, functional form for technology (flexible functional forms allow for a more sophisticated technology).[4] This technique was originally developed within a cross-sectional context, in which the objective is to compare the efficiencies of producers. More recently alternative techniques have been extended for use in a panel data context (see Schmidt and Sickles, 1984 in a stochastic frontier context or Charnes et al., 1985 for DEA). Unless panel data are available, an explicit distribution for the inefficiency term must be imposed as well. If panel data is disposable the researcher can relax many of the more restrictive assumption about the inefficiency disturbances. In particular with panel data, researchers no longer have to assume that the level of inefficiency is independent of the regressors and no longer have to impose a particular distribution for the inefficiency terms, making these restrictions testable propositions. We have used these advantages in this paper where we present an empirical exercise with panel data.

2.1. Economic efficiency

The frontier cost function represents the minimum cost of producing a particular output level, given the technology and the prices of the production inputs used.

Our study involves the estimation of a stochastic parametric cost function using the corresponding econometric model. These types of cost functions have been widely employed in the transport field, with appropriate modifications, by Nash and Preston (1996) for rail transport, and by Oum and Zhang (1991) for air transport.

To calculate economic efficiency, a cost function is estimated via the application of the methodology developed by Schmidt and Sickles (1984) using a panel data. With panel data techniques, each producer is observed over a certain time period. The cost function can be defined as:

$$c_{at} = \alpha + c(w_{at}, y_{at}; \beta) + v_{at} + u_a \quad (1)$$

where c is the observed cost; α is the constant; w is the input price vector; y is the output; β is a technological parameter vector, $a = 1, \ldots, A$ are indices of the different producers and $t = 1, \ldots, T$ are years.

The residue v_{at} is a random disturbance with the usual properties: independently and identically distributed (iid) with zero mean and constant variance, and registers the effects of statistical noise. On the other hand, u_a records the degree of economic efficiency of the ath company. Thus, $u_a \geqslant 0$ for all a, and it is distributed identically with mean μ and variance σ_u^2, and independent of v_{at}, that is to say, $u_a \approx D(\mu, \sigma_u^2)$. The fact that the inefficiency term has no time specification signifies that economic efficiency only varies between companies and not over time.

Given that $E(u_a) = \mu$ we can define:

$$u_a^* = u_a - \mu \quad \alpha^* = \alpha + \mu;$$

[4] In the specific case under study, the functional form selected was flexible functional form: the translogarithmic. This is a quadratic function corresponding to a second order Taylor-series progression.

so that the u_a^* is iid with mean 0. Then in Eq. (2)

$$c_{at} = \alpha^* + c(w_{at}; y_{at}; \beta) + v_{at} + u_a^* \tag{2}$$

the error terms v_{at} and u_a^* have zero mean, and most of the results of the panel data literature can be apply directly. Thus, we can apply the fixed effects model or the random effects model depending on whether or not one is willing to assume that technical inefficiency is uncorrelated with the regressors (output and input prices vector, in this case). If we can assume that there is not this correlation we can estimate consistently the random effects model using generalised least squares (GLS). However, it may be incorrect to assume that inefficiency is independent of the regressors. In this case, we can estimate by means the so-called *within* estimator which treats the u_a term as fixed, that is to say, it estimates a separate intercept for every firm.[5] Then, the model (2) becomes

$$c_{at} = \alpha_a + c(w_{at}; y_{at}; \beta) + v_{at} \tag{3}$$

where $\alpha_a = \alpha + \mu_a = \alpha^* + \mu_a^*$.

This can be done by suppressing the constant term and adding a dummy variable for each of the N firms or, equivalently, by keeping the constant term and adding $(N - 1)$ dummies.[6]

The chief advantage of the within estimator is that its consistency does not hinge on uncorrelatedness of the regressors and the individual effects. Is also does not depend on the distribution of the effects, since in treating them as fixed it simply proceeds conditionally from whatever their realisations may be.

Once the individual intercepts have been estimated we simply define

$$\widehat{\alpha} = \min(\widehat{\alpha}_a) \quad \text{and} \quad \widehat{u}_a = \widehat{\alpha}_a - \widehat{\alpha}$$

Finally, once u_a has been estimated, and if we assume a model with the cost in logarithmic terms we have that:

$$\text{Ln}\,\text{EE}_a = C_{at}^* - C_{at} = -\widehat{u}_a \Rightarrow \text{EE}_a = \exp(-\widehat{u}_a) \tag{4}$$

where EE is the economic efficiency index; C is the observed cost (in logarithm) and C^* is the cost function (in logarithm) which represents the minimum cost given the actual output and the input prices vector.

2.2. Technical efficiency

Koopmans (1951) provided a formal definition of technical efficiency: a producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus, a technically inefficient producer could produce the

[5] To contrast the null hypothesis that effects and regressors are uncorrelated it is possible to apply the Hausman specification test which is based on the differences between the various estimators.

[6] Another equivalent procedure is to apply OLS after expressing all data in terms of deviations from the firm means. In the latter case, the N intercepts are recovered as the means of the residuals by firm. Moreover, it is possible to have a consistency problem with the estimated intercepts (α_a) because the theory requires that $T \to \infty$.

same outputs with less of at least one input, or could use the same inputs to produce more of at least one output.

In this sense, there are two approaches for analysing technical efficiency. The first, known as input-orientated technical efficiency, analyses the ability of a firm to use the minimum quantity of inputs to produce a given set of outputs.

The second approach, output-orientated technical efficiency, centres on the possibility of increasing the output without changing the number of inputs. In this study, to estimate the degree of technical inefficiency of air companies, a parametric production function was used, making it possible to obtain indicators of technical efficiency for different companies. To do this, we use the panel data methodology originally proposed by Schmidt and Sickles (1984).

The model runs as follows: with a panel of T periods of observations of A companies, technology can be represented by the following production function

$$y_{at} = b + f(x_{iat};\beta) + \varepsilon_{at} - \partial_a \tag{5}$$

where y is the output; x is the input vector ($i = 1,\ldots,n$); b is the constant; β is a technological parameter vector; $a = 1,\ldots,A$ are indices of the different producers and $t = 1,\ldots,T$ are years.

The ε_{at} error term represents statistical noise and is assumed to be iid with zero mean and constant variance. The ∂_a term represents technical inefficiency and, correspondingly $\partial_a \geqslant 0$ for all a. We assume the ∂_a to be iid with mean d and variance σ^2_∂ and independent of the ε_{at}. That is to say, $\partial_a \approx D(d, \sigma^2_\partial)$.

We can rewrite the model as follow. First, given that $E(\partial_a) = d$ we can define:

$$\partial^*_a = \partial_a - d \quad b^* = b - d$$

so that the ∂^*_a is iid with mean 0. Then in Eq. (6)

$$y_{at} = b^* + f(x_{iat};\beta) + \varepsilon_{at} - \partial^*_a \tag{6}$$

the error terms ε_{at} and ∂^*_a have zero mean and we can estimate as we have explained in the previous section. Then, applying the fixed effects model, we have:

$$y_{at} = b_a + f(x_{iat};\beta) + \varepsilon_{at} \tag{7}$$

where $b_a = b - \partial_a; = \ b^* - \partial_a{}^*$.

To obtain technical efficiency indexes we define

$$\widehat{b}_a = \max(\widehat{b}_a) \quad \text{and} \quad \widehat{\partial}_a = \widehat{b} - \widehat{b}_a$$

and finally, if the output is in logarithm terms we have that:

$$\mathrm{Ln}\,\mathrm{TE}_a = Y_{at} - Y^*_{at} = -\widehat{\partial}_a \Rightarrow \mathrm{TE}_a = \exp(-\widehat{\partial}_a) \tag{8}$$

where TE is the output oriented technical efficiency index; Y_{at} is the observed output (in logarithm) and Y^*_{at} is the maximum output (in logarithm) given the actual inputs.

2.3. Empirical specification

In order to determine the economic and technical efficiency of various air companies, it is necessary to estimate a cost and a production frontier function.

Following Eq. (3) the translog total cost function used would adopt the following expression:

$$C_{at} = \alpha_a + \alpha_y \ln y_{at} + \alpha_{yy}\frac{1}{2}\ln y_{at}^2 + \sum_{i=1}^{n}\beta_i \ln w_{iat} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln w_{iat}\ln w_{jat} + \sum_{i=1}^{n}\rho_{yi}\ln y_{at}\ln x_{iat} + \sum_{t=1}^{T}\alpha_T T + v_{at} \quad (9)$$

Similarly, following Eq. (7) the production function would take on this form:

$$y_{at} = b_a + \sum_{i=1}^{n}\beta_1 \ln x_{iat} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln x_{iat}\ln x_{jat} + \sum_{t=1}^{T}\alpha_T T + \varepsilon_{at} \quad (10)$$

where $i,j = 1,\ldots,n$ is the number of inputs; $a = 1,\ldots,A$ is the number of air companies; $t = 1,\ldots,T$ are years; α_a and b_a are the individual effects; α_T are the coefficient of the variable time dummy T; and v_{at} and ε_{at} are the error terms with the characteristics explained above.

3. The data

A panel of 20 international air companies over the period 1996–2000 was selected, seven of which are European (Lufthansa, KLM, SAS, Finnair, Spannair, Iberia, British Airways), six North American (American Airlines, United, Delta, Northwest, USAir, Continental), one Canadian (Canadian), two Mexican (Aeroméxico and Mexicana), and four from Asia, Japan Airlines (JAL), Korean Air, Cathay Pacific (Hong Kong) and Singapur Airlines (SIA). They are all large-scale companies carrying out international flights. There are annual observations for them all. ICAO statistics form the basic reference (Digest of Statistics from the International Civil Aviation Organisation). These are completed with the data published by the IATA (International Air Transport Association),[7] World Air Transport Statistics. Using both sources of information we constructed our own data base, with the purpose of estimating a production function and a cost function for the air transport industry, in line with the methodology described in the previous section. The production function would run like this:

$$Y = F(L,K,E) \quad (11)$$

where Y, is production, arrived at using the number of km-tons available (as a joint indicator comprising km-passengers and km-tons available), L, represents the total number of workers in the air industry, K, represents the capital, arrived at using the capacity of the planes available (expressed as tons available per plane) and E is a proxy for the energy used, calculated using the number of kilometres covered.

The cost function would run like this:

$$C = f(Y, W_{\mathrm{L}}, W_{\mathrm{K}}, W_{\mathrm{E}}, W_{\mathrm{S}}) \quad (12)$$

[7] Published financial data supplied by countries in their national currencies is transformed into US dollars by the ICAO. To cut out the effects of inflation, all the statistics are deflated using the GNP deflator measured in constant 1991 currency.

where each of the variables represents the following: C is the operating costs or operational total; Y is the output, being available ton-km, which includes both passengers and cargo; W_L is the labour factor price, obtained as the cost of cabin staff divided by the number of cabin workers; W_E is the energy price, obtained by the energycost divided by the number of kilometres flown; W_K is the capital price, arrived at by the capital cost divided by available capacity (capital costs include insurance, hiring of equipment, maintenance, depreciation and amortisation); W_S is the price of materials and other services, arrived at as the cost of all the other components not previously included, divided by the number of departures executed by the aircraft.

In addition, we tested the inclusion of other variables to record additional output characteristics, such as load factor and average distance covered in a flight stage (total kilometres flown/number of departures). Nevertheless, none of these variables proved to be significant.

4. Results of the estimation

The results of the estimations are shown in Tables 1–4.[8] With regard to the cost function (Table 1), both the total cost and the regressors are in logarithms and have been normalised (divided by the geometric mean). In this way, the first order coefficients can be interpreted as cost elasticity. The heteroscedasticity was corrected using White's method (1980). All the coefficients display the expected signs, and are significant.

This function was estimated with the fixed effects panel data model. The Hausman test (1978) was performed to verify if it was possible to maintain the null hypothesis of an absence of correlation between individual effects and explanatory variables. From the result obtained (see Table 1), it was confirmed that it is not possible to sustain that hypothesis and, consequently, the appropriate course of action is to use the fixed effects model.

So 20 dummy variables (α_a) were used, one per company, with the purpose of capturing specific individual effects for each of them. As we have explained in Section 2.1, in efficiency studies these effects are interpreted as economic efficiency indices for each company (EE).

The economic efficiency index, constructed from Eq. (4), ranges from 0 to 1. The results are shown in Table 2, and reveal that the Asian companies are economically the most efficient, with Cathay Pacific and SIA out in the lead, followed by Korean Air and JAL. The American companies exhibit indices for economic efficiency that are very low by comparison. The same situation is to be observed in the European companies, while the German Company LUFHTANSA and SAS from Scandinavia display the lowest index values.

In Table 3, meanwhile, we show the estimation of the stochastic production function. The estimated first order coefficients (which have been also normalised) are also significant and have the expected sign. Using this estimated frontier, it is possible to obtain the indices for technical efficiency (TE), calculated in accordance with Eq. (8). The values obtained from the TE (see Table 4)

[8] The estimation was carried out with the statistical program TSP43.

Table 1
Estimation of the cost function

Variable	Coefficients	t-Statistic
$L(Y)$	0.6789	6.5151**
$L(W_L)$	0.1057	2.1112**
$L(W_E)$	0.2312	3.8480**
$L(W_K)$	0.2905	5.4448**
$L(W_S)$	0.3725	5.7286**
$L(Y)L(Y)$	−0.1850	−2.9415**
$L(W_L)L(W_L)$	−0.0506	−0.8998
$L(W_L)L(W_K)$	0.1501	2.0327**
$L(W_L)L(W_E)$	0.0067	0.1184
$L(W_L)L(W_S)$	−0.1061	−1.4642
$L(W_E)L(W_E)$	0.0906	0.6215
$L(W_E)L(W_K)$	−0.1028	−1.9301*
$L(W_E)L(W_S)$	0.0054	0.0469
$L(W_K)L(W_K)$	0.1078	−1.0039
$L(W_K)L(W_S)$	0.0605	0.8773
$L(W_S)L(W_S)$	0.0402	0.3426
$L(Y)L(W_L)$	0.0814	2.6877**
$L(Y)L(W_E)$	−0.0231	−0.6551
$L(Y)L(W_K)$	−0.0793	−3.0743**
$L(Y)L(W_S)$	0.0209	0.4846
D_{T97}	0.0177	1.3333
D_{T98}	0.0339	1.5569
D_{T99}	0.0368	1.6106
D_{T00}	0.0012	0.0467
R-squared	DW	SE regression
0.99	1.71	0.05

Hausman test, Chi squared (20) = 56.77.
* Significant at 10%.
** Significant at 5%.

generally prove to be higher than the EE indexes but also situate the Asian companies in first place.

Our evidence suggest that the benefits of increasing competition in terms of efficiency is large for Asian airline industry. From the end of the 1980s, the national company monopoly was broken and entry was granted to "second-level" companies, whose interests left a powerful mark on air transport policy in Asia. Hooper (1996) describes how various competing companies sprang up in a number of Asian countries and the effect this had on international traffic in Korea, the Philippines, China, India and Japan.

As a consequence, the Asian air market is powerful and growing very rapidly. But, apart from the introduction of competition, some Asian companies possess characteristics that make them more efficient when compared to their American and European counterparts. To take the examples of SIA and Cathay Pacific, both companies have a prestigious reputation, for their passenger customer service, efficient collection and delivery of baggage, the cleanliness of their aircraft, and so on.

Table 2
Indixes of economic efficiency

Company	Indixes of economic efficiency (EE)
Lufthansa (Germany)	0.2801
KLM (Holland)	0.5392
SAS (Scandinavia)	0.2142
Finnair (Finland)	0.3690
Spannair (Spain)	0.4172
Iberia (Spain)	0.3487
British airways (UK)	0.4250
American (USA)	0.2333
United (USA)	0.2345
Delta (USA)	0.2205
Northwest (USA)	0.2871
USAir (USA)	0.2040
Continental (USA)	0.2913
JAL (Japan)	0.6143
Canadian (Canada)	0.5696
Aeromexico (Mexico)	0.3502
Mexicana (Mexico)	0.3367
Korean AIR (Korean Republic)	0.7334
Cathay Pacific (China)	1
SIA (Singapore)	0.9763

Table 3
Production function estimators

Variable	Coefficients	*t*-Statistic
$L(L)$	0.1417	1.9677**
$L(K)$	0.4690	7.6228**
$L(E)$	0.4180	4.3762**
$L(L)L(L)$	1.3253	3.1259**
$L(K)L(K)$	0.2263	2.0861**
$L(E)L(E)$	0.2734	1.1041
$L(L)L(K)$	−0.6449	−4.2967**
$L(L)L(E)$	−0.6524	−2.0121**
$L(K)L(E)$	0.3632	3.4078**
D_{T97}	0.0077	0.7565
D_{T98}	0.0221	1.5089
D_{T99}	0.0247	1.5755
D_{T00}	0.0187	0.8442
Average	0.432	
R-square	DW	SE regression
0.99	1.43	0.03

Hausman test, Chi squared (9) = 17.09.
** Significant at 5%.

Table 4
Indixes of technical efficiency

Companies	Indixes of technical efficiency (TE)
Lufthansa (Germany)	0.5407
KLM (Holland)	0.7359
SAS (Scandinavia)	0.3476
Finnair (Finland)	0.4689
Spannair (Spain)	0.5403
Iberia (Spain)	0.4186
British Airways (UK)	0.6571
American (USA)	0.5419
United (USA)	0.5922
Delta (USA)	0.5431
Northwest (USA)	0.5531
USAir (USA)	0.3827
Continental (USA)	0.4656
JAL (Japan)	0.8344
Canadian (Canada)	0.6194
Aeromexico (Mexico)	0.5073
Mexicana (Mexico)	0.4880
Korean Air (Korean Republic)	0.8906
Cathay Pacific (China)	1
SIA (Singapore)	0.9286

With respects to inputs, labour market is much more flexible than European and American and their aircraft incorporate planes of the latest generation.

Lastly, but of strategic importance, we must mention their "Computer Reservation System" (CRS). In Asia, Abacus is a system that was established by the six regional airlines, including Cathay Pacific and SIA. It is in operation in Singapore and Hong Kong. Likewise, Abacus has reached an agreement with the Japanese company All Nippon, which will allow it to control the Asian market.

The European CRS, Amadeus, by comparison, despite having come into operation before the Asian system, shows many deficiencies in performance. The Asian companies, in consequence, are right up front, exploiting the evident advantages that allow them to control the market.

5. Conclusions

In this article, we have compared the technical and economic efficiency of 20 international air companies for 1996–2000. The companies are based in countries whose exposure to the liberalisation process varies. In the USA, for instance, the market has been completely liberalised since 1978, while the European market reached completion in 1997, yet the most recent experience of opening up to competition is that of the Asian countries, whose clearest liberalisation agreements were struck at the end of the 1990s.

Four air companies from these countries, Cathay Pacific (Hong Kong), SIA (Singapore), Korean Air (Korean Republic) and JAL (Japan), actually obtain the highest values for economic and technical efficiency, leaving the American and European countries far behind.

Therefore there are benefits of increasing competition for Asian airline industry. Additionally, we can point the well established reputation for quality enjoyed by some of their companies, their flexible labour market and the Abacus Computer Reservation System's far greater efficiency when compared to the European equivalent, Amadeus.

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