Technical Efficiency and Productivity Growth in an Era of Deregulation: the Case of Airlines

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1. INTRODUCTION

The evolution of commercial air transport activity was subject in the eighties to major institutional changes designed to liberalize a sector that until then was heavily protected by national and international regulations. The Airline Deregulation Act (ADA) of 1978, which removes rate and route regulations in the U.S. domestic market, may be considered as the starting point of this process that was followed by the liberalization of the international North Atlantic and Pacific markets and, more recently, by the EEC directives on the same subject. These deregulations differ in many aspects. They share, however, a common objective: fostering airline competition and performance.

From this point of view, the liberalization process in air-transport markets constitutes an excellent field of analysis for economic research. Among the different aspects under study, performance measurement is, without any doubt, an unavoidable step in the evaluation of the consequences of deregulation[1]. It is certainly the aspect that most retained the attention of economists and the present study comes within the same framework. Our purpose is to measure airlines' technical efficiency and productivity growth over the period 1977 to 1988.

To this end, we build a set of panel data composed of thirty-three airlines, generally operating in scheduled international markets, using data collected by the International Civil Aviation Organization (ICAO, 1977-91). On the basis of these data we construct several *production frontiers* of airline activities, one for each three-year period, using a non-parametric approach: *Data Envelopment Analysis* (DEA).

The main characteristic of this exercise is that besides physical indicators of outputs and inputs, we incorporate two variables representative of output and input attributes, a measure of market performance, the *average weight load factor* and a measure of route network density, the *average number of aircraft departures per 100.000 km.* From our

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Financial support from the Belgian Science Foundation (FRFC n°2.4534.90) and the SPPS (PAC-90/94:141) are acknowledged. We wish to thank PHILIPPE BARLA, HENRY-JEAN GATHON, CLAUDE JEANRENAUD, PIERRE PESTIEAU, PONTUS ROOS, the participants of the Seminar on Local Government Finance (Neuchâtel, June 25-28, 1993) and of the Third European Workshop on Efficiency and Productivity Measurement (Louvain-la-Neuve, October 21-23, 1993) for helpful suggestions.

1. In an instructive paper, PESTIEAU and TULKENS (1993) demonstrate the necessity of performance measurement as an essential tool for public policy orientation and for efficiency improvement.

point of view, the evolution of airline route network density is the best indicator of changes introduced by airlines in response to deregulation, and the evolution of load factor performances is the best indicator of the success of these changes. Consequently, the information contained in these variables cannot be neglected in measuring airlines' performances.

Based on DEA frontier estimations, we will be able to compare the level of technical efficiency reached by each airline in the sample. Furthermore, following the approach proposed by FARE, GROSSKOPF and ROOS (1993), we will be able to estimate a Malmquist index of productivity and to identify the changes in productivity due either to *technological progress* or *efficiency change*, or to the influence of output and input attribute variables.

The results obtained vary a lot from one airline to another and from period to period. They show, however, that a general improvement in technical efficiency was achieved in the eighties by the majority of the airlines included in the sample. These results seem to confirm that a more competitive environment leads to efficiency improvement, as seems to be the case of Asian airlines involved in a technological *catching up* process. However, technological progress, indicated by the positive shifts of production frontiers, appear as an advantage confined to airlines operating worldwide. Furthermore, only a few airlines obtain productivity gains due to route network density and load factor changes. Summing up, productivity growth is the privilege of airlines that succeed in these different sources of growth.

The paper is organized as follows. In Section 2, recent trends in airline activities are analyzed in the light of the information provided by a sample composed of thirty-three airlines. In Section 3 we present the methodology applied to measure technical efficiency and productivity growth. Section 4 is devoted to the presentation of the main results.

2. A PANEL OF AIRLINES

One of the best documented facts in international comparisons of airlines is the substantial differences existing between European and North American domestic fares. As shown in AEA (1984), the average fare per mile on European routes was, in 1983, 50% higher than those practised on U.S. domestic routes. Does that mean European airlines are as inefficient allocatively and technically as we are induced to believe from these figures? This is one of the questions that we try to answer in this paper by the estimation of airlines' production frontiers.

The starting point of our study was to set up a panel of airline carriers that includes North American, European and Far East Pacific airlines. Our objective was to gather together a set of airlines operating simultaneously in domestic and international markets and subject to different regulatory conditions. The names of these airlines as well as their country of origin are given in Table 1.

The performances of fifteen European airlines and nine originating from East Asia and Oceania will be compared with North American airlines, represented by six U.S. trunks and three Canadian carriers. The main characteristic of this panel is that it does not include new entrants or airlines operating exclusively in non-scheduled markets. Moreover, all the airlines selected were operational in 1977 and in 1988 with the only exception of Pacific Western, purchased by CP Air in 1986.

The institutional environment in which these airlines operate is determined by national and international regulations. As indicated before, the North American carriers, the U.S. in particular, took advantage of a more open institutional environment during the eighties. Moreover, under the pressure of the U.S. authorities and operators, a far-reached liberalization of the international North Atlantic and Pacific aviation markets was obtained. Incidentally, European and Asian airlines were also subject to open competition in those regions of the world. Otherwise, the deregulation of the European domestic market is taking place in two different ways. On the one hand, through new bilateral agreements between national authorities and, on the other hand, through multilateral agreements taking the form of EEC directives, like those adopted in 1987[2].

Another fact to be mentioned: all the U.S. airlines are private firms whereas most of the other airlines are state-owned companies, as is the case of most of the European airlines. This fact explains why European countries have had difficulties in accepting the principle of total deregulation, which threatens aviation markets that were considered until now as a total or partial monopoly of their national airlines[3].

In order to estimate production frontiers, we define first a production technology in which only two inputs (labor and aircraft) are combined to produce transportation capacities, *available tons-kilometer*, in freight and passenger services. As in BARLA and PERELMAN (1989) we adopt here a narrow definition of the airlines' activity limited to the operation of aircraft. Capital is represented by total available aircraft capacity, defined as the sum of all aircraft's transport capacity[4] weighted by the number of days they have been able to operate in the year. Labor is restricted to flying personnel (pilots and co-pilots, other cockpit personnel and cabin attendants). We preferred this measure of labor to the total number of workers, in order to avoid measurement bias due to subcontracting policies applied by several airlines in ground operations.

In Table 1 we present the evolution of these variables obtained from ICAO (1978-1988) files on an annual basis. These statistics illustrate the steep growth path that most airlines followed over the observed period. This is, for instance, the case of some Asian airlines that tripled their production (Cathay, Thai and Singapore Airlines). Most European carriers also developed their activities quickly over the period, but to a lesser

2. For a discussion of the deregulation process see: BAILEY, GRAHAM and KAPLAN (1985) for the U.S.; GUILLEN, OUM and THRETHEWAY (1985) for Canada; and BARRETT (1987), MC GOWAN and SEABRIGHT (1989) and ENCAOUA (1991) for Europe.
3. See MC GOWAN and SEABRIGHT (1989), ENCAOUA (1991) and OECD (1988).
4. Average maximum take-off weight (in tons).

degree. In the case of North American airlines the variations are large too but in several cases result from mergers and takeovers.

As indicated before, the main objective of this research is to measure technical efficiency, but it appears that this type of study will be misleading if we do not take into account some specific route network and output characteristics.

On the one hand, as was shown by BAILEY, GRAHAM and KAPLAN (1985), and more recently, by MC GOWAN and SEABRIGHT (1989) and BORENSTEIN (1991), one of the main consequences of deregulation in the U.S. was the reorganization of airline route networks and in particular the emergence of *hubs,* dominated generally by only one or two carriers.

Moreover, a similar process was anticipated in the European market and a series of recent mergers seems to confirm these predictions[5]. Airline companies operating in the European domestic market were highly protected against competition from new entrants until the middle of the 80's. Flights, fares and revenues were generally regulated by bilateral agreements among national carriers. With the relaxation of these regulations[6] each carrier will try to adapt its supply in order to maintain its market position.

In order to take into account the impact of these changes, we introduce two characteristics of the airlines' activity into our performance study. On the input side, a variable representative of the network density: the average number of aircraft departures per 100.000 km (it is the reciprocal of the *average stage length*); and on the output side, a variable representative of market performance: the weight load factor, calculated as the ratio of *ton-km performed over* available ton-km. In Table 2, we present, for each company and period, the average values taken by these variables.

Concerning the network indicator, a wide range of values is observed. Some airlines, like the Malaysian and Indian Airlines, operate high density networks, while others, like Qantas, operate low density networks with aircraft stage lengths of more than three thousand kilometers on average. In most cases airline carriers are evolving in the direction of low density networks favored by the introduction of wide-bodied aircrafts. Some airlines, however, seem to follow a different policy. This is clearly the case of Alitalia and SAS among the European companies, as well as that of Pakistan Airlines in Asia, and those of American, Pan Am, and Continental Airlines in the U.S. Note, however, that in the last three cases this evolution towards lower density networks is partially the result of mergers and takeovers[7].

5. MC GOWAN and SEABRIGHT (1989) anticipate this evolution in the absence of market power regulations.
6. For instance, the deregulation of the air links between the United Kingdom and The Netherlands in the early eighties went in this direction.
7. After its bankruptcy, Continental Airlines merged with Texas Air, People Express, Eastern, New York Air and Frontier; TWA absorbed Ozark in 1986 and Pan American sold its Pacific Division to United Airlines in 1985.

When we look at weight load factors, also presented in Table 2, it appears that North American airlines are less efficient in terms of aircraft loading and that no noticeable variation was observed during the period covered by the data.

In the next sections we compare the levels of technical efficiency and the gains in productivity achieved by each company, taking into account the output and input characteristics mentioned above.

3. MEASURING TECHNICAL EFFICIENCY AND PRODUCTIVITY GROWTH

In order to estimate airlines' technical efficiency we adopt the Data Envelopment Analysis (DEA) approach devised by CHARNES, COOPER and RHODES (1978). It consists of the estimation of a convex multi-output/multi-input production frontier based on observable data and on a linear programming optimization technique[8].

Let us give some explanations about the method. In fact, the production function is interpreted as the frontier of a set (called the production set) and not only as a relationship between input and output quantities. In figure 1, we consider only one output and one input; Y is the production set, i.e. it includes all the feasible combinations of input-output. The boundary of this set $y = f(x)$ corresponds to the maximum achievable quantities of output, for any given level of input, or also the minimum required quantity of input for any given level of output.

Every productive activity belonging to the frontier is defined as efficient while those lying in the production set are inefficient. But how will we measure the extent to which a firm is inefficient? We use a *distance* concept: an inefficient activity is at some positive distance from the frontier. For example, the input measure of efficiency, taken along the input axis, measures the fraction of input actually used which would be optimal (i.e. minimal so that the firm is efficient) given the output level. For example, $0j/0i > 1$ in figure 2, means that A is inefficient in input terms.

8. For a survey on alternative parametric and non-parametric frontiers, see the book edited by FRIED, LOVELL and SCHMIDT (1993) and, for DEA methods, the chapter by ALI and SEIFORD.

Figure 1

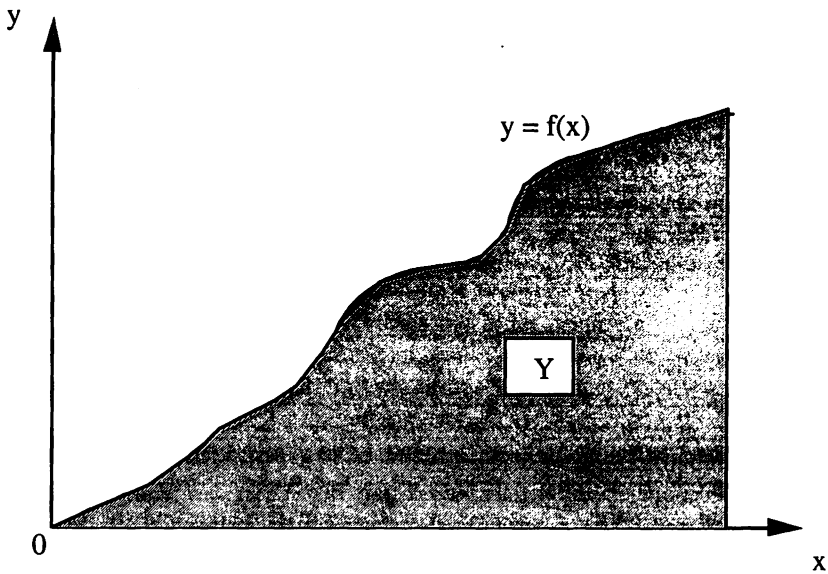
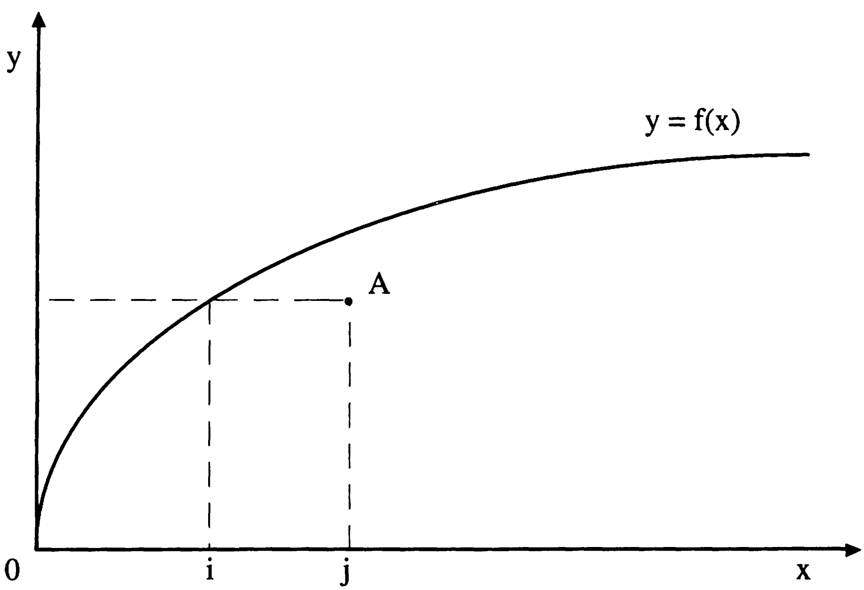


Figure 2



In the case of airlines we construct a DEA frontier *for each three-year period*[9]: 1977-79, 1980-82, 1983-85 and 1986-88. Following FARE, GROSSKOPF and ROOS (1993), we incorporate two attribute variables in the construction of these frontiers[10]. For each observation (firm) r^* in period t we solve a linear programming problem of the form:

$$D_r^t\,(y^{r^*,t}, a^{r^*,t}, x^{r^*,t}, b^{r^*,t})^{-1} = \min_{\lambda,\, z^r} \lambda\ ; \tag{1}$$

subject to:

$$\sum_{r=1}^{R} z^{r,t}\, x_m^{r,t} \le \lambda\, x_m^{r^*,t},\ \forall\ m = 1, \ldots, M\ ;$$
$$\sum_{r=1}^{R} z^{r,t} b^{r,t} \le \lambda\, b^{r^*,t}\ ;$$
$$\sum_{r=1}^{R} z^{r,t} y_n^{r,t} \ge y_n^{r^*,t},\ \forall\ n = 1, \ldots, N\ ;$$
$$\sum_{r=1}^{R} z^{r,t}\, a^{r,t} \ge a^{r^*,t}\ ;$$
$$z^{r,t} \ge 0\ , r = 1, \ldots, R\ .$$

D_r^t is a distance function indicating the maximum proportional reduction (λ) of inputs x_m^t and attribute b^t that firm r^* can realize with the given technology in period t in order to produce the same quantities of outputs y_n^t and attribute a^t. D_r^t is then an indicator of input efficiency.

Note that the $z^{r,t}$ (r = 1, ..., R), which are parameters to be estimated, indicate the weights given to each observation in the construction of the frontier. In the case of the linear program (1) constant returns to scale are assumed.

Another measure of input efficiency, free of input and output attribute influences, can be obtained in a similar way. It will be a pure technical efficiency distance function, that we indicate as follows:

$$D_r^t\,(y^{r^*,t}, x^{r^*,t}) \tag{2}$$

9. Due to missing data and in order to keep a maximum of airlines for the estimation of each production frontier, we adopt the three-year periods as the (time) framework of analysis.
10. Note that in their application, FARE, GROSSKOPF and ROOS (1993) include attribute variables that are at the same time qualitative output characteristics.

One of the most interesting extensions of frontier analysis is its application to productivity measurement[11]. The key idea is that when panel data on production activities are available, sequential estimation of production frontiers and technical efficiency allows the estimation of productivity growth.

In the framework of the non-parametric DEA approach, FARE, GROSSKOPF and ROOS (1992) proposed the construction of a Malmquist index of productivity whose estimation uses distance functions for consecutive periods. Taking into account input and output attributes, this index of productivity ($M_r^{t,t-1}$) is obtained as the product of two factors, efficiency change ($E_r^{t,t-1}$) and technological progress ($T_r^{t,t-1}$), which are calculated in the following way:

$$M_r^{t,t-1} = E_r^{t,t-1} \,.\, T_r^{t,t-1} \tag{3}$$

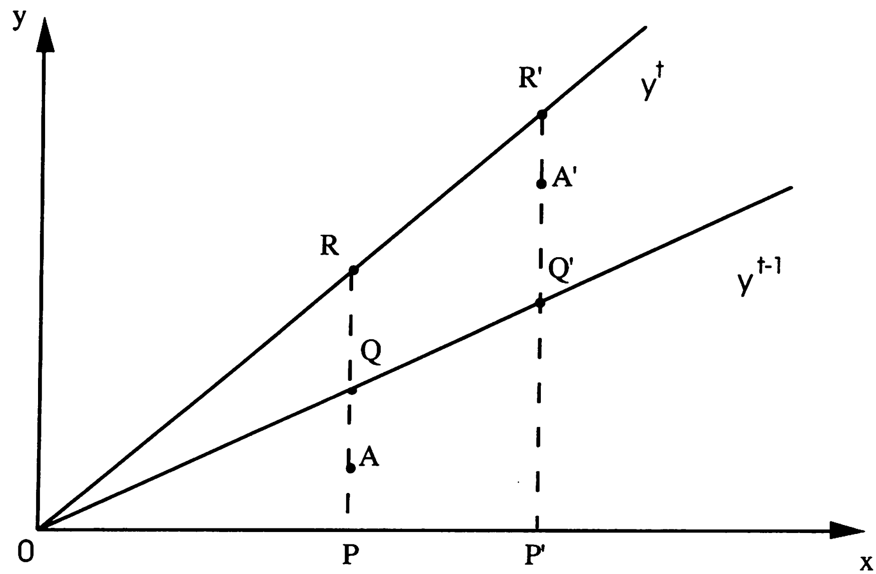
$$= \frac{D_r^t\,(y^t, a^t, x^t, b^t)}{D_r^{t-1}\,(y^{t-1}, a^{t-1}, x^{t-1}, b^{t-1})} \cdot \left[\frac{D_r^{t-1}\,(y^t, a^t, x^t, b^t)}{D_r^t\,(y^t, a^t, x^t, b^t)} \, \frac{D_r^{t-1}\,(y^{t-1}, a^{t-1}, x^{t-1}, b^{t-1})}{D_r^t\,(y^{t-1}, a^{t-1}, x^{t-1}, b^{t-1})}\right]^{1/2}$$

The first factor, also known as a catching up effect, is obtained as the ratio between efficiency scores achieved in periods t and t-1. Technological progress is obtained as the geometrical mean of changes observed at the frontier level in both periods. Note that in order to estimate technological progress, we estimate distance functions for observations in period t with respect to the frontier evaluated in period t-1, and vice-versa.

Graphically (figure 3), technical efficiency in output terms is calculated as the distance between the observed output and the frontier. For instance, a firm located in A in period t-1 and in A' in period t improves its productivity. This results from efficiency change since PA/PQ < P'A'/P'R' and from technological progress represented by the shift of the frontier function from y^{t-1} to y^t.

11. NISHIMIZU and PAGE (1981) proposed a similar approach based on parametric frontier estimations and TULKENS and VANDEN EECKAUT (1993) on non-parametric Free Disposable Hull (FDH) estimations. For a survey of the alternative approaches, see GROSSKOPF (1993).

Figure 3



The Malmquist index is obtained as the product of efficiency change and technical progress, as in equation (3):

$$M_r^{t,t-1} = \left[\frac{PQ}{PA} \cdot \frac{P'A'}{P'R'}\right] \cdot \left[\frac{PR}{PQ} \cdot \frac{P'R'}{P'Q'}\right]^{\frac{1}{2}} . \tag{4}$$

Furthermore, an alternative estimation and decomposition of the Malmquist index was proposed in FARE, GROSSKOPF and ROOS (1992). It is obtained as the product of two terms: one of them indicates the change in productivity due to input and/or output attributes ($A_r^{t,t-1}$) and the other the change due exclusively to physical variables ($P_r^{t,t-1}$):

$$M_r^{t,t-1} = A_r^{t,t-1} \cdot P_r^{t,t-1} , \tag{5}$$

where

$$A_r^{t,t-1} = \left[\frac{D_r^{t-1}(y^{t-1}, a^t, x^{t-1}, b^t)}{D_r^{t-1}(y^{t-1}, a^{t-1}, x^{t-1}, b^{t-1})} \frac{D_r^t(y^t, a^t, x^t, b^t)}{D_r^t(y^t, a^{t-1}, x^t, b^{t-1})}\right]^{\frac{1}{2}} ,$$

and

$$P_r^{t,t-1} = \left[\frac{D_r^{t-1}(y^t, a^t, x^t, b^t)}{D_r^{t-1}(y^{t-1}, a^t, x^{t-1}, b^t)} \frac{D_r^t(y^t, a^{t-1}, x^t, b^{t-1})}{D_r^t(y^{t-1}, a^{t-1}, x^{t-1}, b^{t-1})}\right]^{\frac{1}{2}}$$

Note that in both terms the attributes and physical variables are alternatively kept constant in both periods[12]. As in FARE, GROSSKOPF and ROOS (1992) we assume that the technology allows strong availability of inputs, outputs and attributes, an assumption that seems to be reasonable in the context of the airline activities described here.

In Section 4, we present the results obtained by the estimation of DEA frontiers for our panel of airlines. Two remarks must be made. One is that the efficiency measures obtained,which are input-oriented, are represented by their reciprocal and in average percentages for each three-year period. The other is that all the productivity growth indices as well as their components are presented in average rates of growth by year with positive and negative values corresponding, respectively, to positive and negative changes in productivity. As a result of these transformations, the decomposition of productivity indices must be considered as a close approximation of the exact values.

4. AIRLINES' PERFORMANCE ESTIMATIONS

Numerous studies have been dedicated to the measurement of airlines' performance. These studies have gone beyond simple partial productivity measurement only from the eighties. CAVES, CHRISTENSEN and THRETHEWAY (1984) and SICKLES (1985) estimate airlines' total factor productivity on the basis of an econometric study of airlines' cost functions. More recently, SICKLES, GOOD and JOHNSON (1986), BAUER (1988), KUMBHAKAR (1990) and GOOD, NADIRI and SICKLES (1991), combined the estimation of airlines' cost and factor demand functions with frontier analysis and proceeded to technical and allocative efficiency comparisons. SCHMIDT and SICKLES (1984), BARLA and PERELMAN (1989), MANZINI (1990) and GOOD et al. (1993) estimated parametric production frontiers and technical efficiency using stochastic parametric techniques and panel data. In fact, the estimations of BARLA and PERELMAN (1989) show that regulated airlines are, on average, as efficient as deregulated ones. Besides, the airlines operating in deregulated markets do not perform as well as regulated airlines during the crisis periods but they become more efficient under favorable economic conditions. Moreover, MANZINI (1990) finds that the structure of ownership (public/private) has no clear influence on the technical efficiency of the airlines. However, the joint effect of the structure of ownership and the regulations significantly affects efficiency.

In Tables 3 to 6 we report the main results obtained by the application of the methodology presented in Section 3. First of all, in Table 3, we present the levels of technical efficiency corresponding to two alternative DEA frontier estimations. On the one hand, the results obtained when the attribute variables are taken into account and, on the other hand, those obtained without these attributes. Remember that these variables

12. This decomposition is obtained on the hypothesis of non-separability between physical variables and attributes. FARE, GROSSKOPF and ROOS (1993) indicate the way to obtain alternative estimations assuming separability.

are the weight load factor on the output side and the number of aircraft departures per 100,000 km, on the input side.

These results allow us to say that, regardless of the approach used, the average levels of technical efficiency reached in the eighties are higher than those obtained in the late seventies[13]. It is, however, among the Far East/Pacific airlines that the convergence towards efficiency is the most significant. This phenomenon,which must be interpreted as a catching-up effect, was also observed in other industrial activities as reported in FECHER and PERELMAN (1992) and in FARE et al. (1994).

Concerning the European carriers, the results presented here show that, on average, they are technically less efficient that the other carriers. Given the slow evolution of European markets towards deregulation, we are tempted to believe that more liberalization of the aviation markets will be the remedy for technical inefficiencies. The answer is however not so clear-cut. When we go into details we notice that, on the one hand, some major carriers, like Lufthansa, KLM and Air France, reach high levels of efficiency while, on the other hand, British Airways, Alitalia and Swissair, do not exceed at any time the efficiency threshold of 80%. The case of British Airways is puzzling. Aiming at efficiency, this company was privatized and subjected to substantial deregulation on different markets at the begining of the eighties[14]. It continues to appear as rather inefficient when compared, above all, with its fellow British Caledonian.

As can be observed in Table 3, the scores obtained when taking into account the network characteristics are in all cases higher than those obtained with a purely technical frontier. This is an expected result under DEA, when more dimensions are taken into account in linear programming problems. Moreover, there are some airlines that take relatively greater advantage of this modification: on the one hand, some small carriers like Pacific Western, Aer Lingus or Finnair and, on the other hand, most companies included in the "Asia and Oceania" group that operate in low density networks for geographical reasons.

These results are confirmed in Table 4, where Malmquist indices of productivity are reported. The Far East/Pacific companies realize the best scores with annual rates superior to 2% for the three periods analyzed. North American and European carriers obtain also positive, but low scores during the period 1980-82, probably as a consequence of the second oil crisis.

Here again it is crucial to go into the details of individual results. The situation is in fact rather heterogeneous within each group of carriers. So, it appears that the airlines that obtained the best results over all the periods are Japan Airlines and Singapore Airlines in the "Asia and Oceania" group, American and TWA among the North American carriers and Lufthansa, Finnair and Air France in Europe.

Following this set of leading companies we find another set composed of airlines that also obtained positive but less significant results in all periods. In this group we include

13. Note that the second oil crisis occurred in 1979 but affected airlines' activities in 1980 and 1981 too.
14. On British Airways privatization, see ASHWORTH and FORSYTH (1984).

Qantas, British Caledonian, KLM and Delta Airlines. For the other carriers the results vary over time like, for instance, Continental and Pan Am, two carriers that finally went bankrupt.

On the right side of Table 4 we report the results corresponding to productivity changes due to the inclusion of the two attribute variables. Here again, the best results were obtained by the Asian airlines, but these performances were mainly achieved by two carriers: Qantas and Singapore Airlines. Among the European carriers only UTA, a company that operated essentially on long-haul routes, obtained substantial positive results in the three periods. Two bad performances must be underlined: British Caledonian for two consecutive periods and Sabena in the 1986-88 years. Finally, among the North American carriers no clear-cut results appear except for the high positive scores attained by Continental, Pan Am and TWA in the 1983-85 period, most probably, as a result of mergers.

Summing up, except for a few airlines, these results show a great variability. This is probably the consequence of changing market conditions taken into account here by the weight load factor variable. Nevertheless, we do not find any direct evidence of the influence of structural changes in route networks, like those made by U.S. carriers after the ADA application, that had a significant influence on productivity.

In order to have a clearer view of all the estimations, we report in Table 5 the average annual rates of growth for the entire period. In this table the Malmquist indices of productivity ($M_r^{t,t-1}$) are decomposed in two alternative ways: on the one hand, as the results of technological progress ($T_r^{t,t-1}$) and efficiency changes ($E_r^{t,t-1}$) or, on the other hand, as the result of attribute changes ($A_r^{t,t-1}$) and physical changes in outputs and inputs ($P_r^{t,t-1}$).

Our first remark is that among the set of carriers that reached high productivity rates we find five of the largest airlines in the sample, that means carriers operating worldwide. Note that, on the one hand, they shared the highest rates of technological progress (from 1.6% to 1.9% per year from 1977 to 1988) and, on the other hand, they were able to remove technical inefficiencies. These airlines are: Japan Airlines, Air France, Lufthansa, American and TWA and, to a lesser extent, Delta, Qantas and Singapore Airlines, which are reaching the leading group.

Another noticeable set is composed of carriers like Indian Airlines, British Caledonian and Finnair which, even if they operated on a lower scale and could not share the technological progress realized by the leading carriers, were able to improve technical efficiency and to obtain satisfactory results. The last group is composed of the carriers that experienced very low or negative growth rates within the period. These firms appear to be condemned to merge or to be purchased by larger airlines. This is exactly the scenario that prevailed in the U.S. sky after more than ten years of deregulation and is the same as that going on in the European markets today.

5. CONCLUSIONS

The study presented here brings to light the reasons that pushed several airlines to merge when markets were deregulated. With minor exceptions, only the airlines operating on a worldwide scale have been able to take maximum advantage of technological progress. Asian airlines obtained the best results in terms of efficiency gains as the result of a technological catching up process. Unexpectedly, for U.S. carriers we have not found any clear evidence of productivity gains coming from structural changes in their route network organization.

These results are not definitive. We will be able to have a more definitive appraisal of the consequences of the deregulation shocks in aviation markets only in some years, when the situation of airlines will have been consolidated. They illustrate, however, the main orientations taken by the sector in response to these changes and they should be useful for designing the new regulatory and institutional environments.

Last but not least, note that the results presented here concern essentially airlines' productive efficiency, which is not necessarily correlated with allocative efficiency. An example of this is the case of Air France. In our study, this firm appeared as one of the best in terms of technical efficiency and growth. It today faces serious financial problems that probably endanger its future development.

Table 1

Airline Characteristics (1977-1988)[1]

Airlines	*Available ton-km*[2]				*Production factors*[3]			
	Passenger		*Freight*		*Staff*		*Aircraft*	
	1977-79	1986-88	1977-79	1986-88	1977-79	1986-88	1977-79	1986-88
Cathay (Hong Kong)	6715	20947	3325	16691	1215	3168	9807	25094
Indian Airlines	4748	9847	525	1345	988	1402	7385	11329
Japan Airlines	35786	56842	23509	51043	6408	7909	61251	89839
Korean Airlines	10281	18166	11252	23314	1262	2398	17764	37801
Malaysian Airlines	3399	9480	1272	4396	869	1576	5591	12784
Pakistan Airlines	6879	10893	5274	7895	1401	1721	13042	18499
Qantas (Australia)	19063	29865	7408	13692	2525	3962	21373	33858
Singapore Airlines	12228	30704	7372	20117	2237	3577	17873	33372
Thai (Thailand)	5430	17277	2341	8736	654	1905	6756	20991
Asia and Oceania	19914	32545	12597	26114	3366	4401	31803	47184
Aer Lingus (Ireland)	3241	3723	1603	1454	931	714	5063	6369
Air France	32631	41133	24445	46792	5700	6947	49990	68184
Air Inter (France)	4114	9097	350	819	1218	2076	7811	13676
Alitalia	17703	21529	8404	13710	3456	4165	26513	29523
AUA (Austria)	1809	2801	496	878	400	663	2298	4089
British Airways	50237	58123	20536	32793	9620	9921	73042	86971
British Caledonian	5472	11326	4179	8439	1377	1727	9362	14029
Finnair (Finland)	4662	8111	1394	2808	963	1268	8476	9435
Iberia (Spain)	19918	25345	9119	10636	3384	3965	27068	36132
KLM (Netherlands)	19924	28540	15207	25787	2609	3747	28356	39847
Lufthansa (Germany)	26744	43126	22911	52430	5353	8605	41048	69594
Sabena (Belgium)	7116	8130	6745	8070	1392	1565	11551	15897
SAS (Scandinavian)	16178	17752	8607	7697	3238	3769	24783	30019
Swissair	14419	19542	8198	14049	2516	3339	19534	27751
UTA (France)	5962	7409	9565	9512	1003	1193	11675	12851
Europe	25609	33312	15340	28710	4717	5828	38019	51319
Air Canada	29349	30582	19272	23777	4327	4631	42779	44387
American (US)	67313	127563	33061	43233	9822	16490	97973	136892
Continental (US)	20848	79282	11516	30781	3556	9458	22932	85701
CP Air (Canada)	11256	19724	4631	11160	1470	2854	13364	22199
Delta (US)	55090	106818	18786	33656	8395	13889	65995	109759
Eastern (US)	57412	77730	12706	20700	9053	11205	69155	93944
Pacific Western (Canada)	2497	3678[4]	1844	1130[4]	650	668[4]	4482	4929[4]
Pan Am (US)	52301	63021	36627	22355	6172	6927	68206	74784
TWA (US)	65758	74998	30080	26624	9254	8270	99048	86472
North America	52977	86417	24755	30036	7596	10963	71972	95642
All	38298	58116	19582	28792	5934	7945	53893	71293

1 Mean values weighted by available ton-km.
2 In 100,000 of ton-km.
3 The staff corresponds to the total number of flying personel. The aircraft are represented by the weighted sum (in 1,000 tons) of average maximum take-off weights multiplied by the days available in the year.
4 1983-85.

Table 2

Weight load factors and route network densities[1]

Airlines	*Weight load factor* 1977-79	1980-82	1983-85	1986-88	*Aircraft departures per 100,000 km* 1977-79	1980-82	1983-85	1986-88
Cathay (Hong Kong)	65.6	67.4	70.0	71.2	54	51	44	41
Indian Airlines	68.6	63.8	66.1	72.4	194	184	181	173
Japan Airlines	61.8	61.9	64.8	67.4	47	43	42	40
Korean Airlines	58.2	70.1	.	72.6	66	53	.	68
Malaysian Airlines	65.5	65.9	68.4	74.6	226	210	212	191
Pakistan Airlines	50.4	53.6	57.3	56.8	96	90	96	102
Qantas (Australia)	60.8	61.7	63.3	69.3	28	27	25	25
Singapore Airlines	69.5	69.7	71.0	73.2	53	45	42	35
Thai (Thailand)	63.1	63.4	65.1	66.7	50	44	40	45
Asia and Oceania	61.9	64.1	65.9	69.3	61	57	56	55
Aer Lingus (Ireland)	64.8	65.6	66.3	67.8	115	116	129	143
Air France	61.0	62.0	66.6	66.3	83	73	73	74
Air Inter (France)	58.5	58.3	57.2	60.3	207	202	198	197
Alitalia	60.5	59.8	63.5	68.6	92	91	88	95
AUA (Austria)	46.3	43.1	45.2	45.9	130	120	118	118
British Airways	61.3	62.4	64.8	62.9	81	78	78	73
British Caledonian	58.6	58.7	61.3	57.9	87	83	77	60
Finnair (Finland)	55.5	56.3	59.1	64.3	154	154	146	126
Iberia (Spain)	55.9	58.0	63.8	65.9	130	115	107	104
KLM (Netherlands)	59.7	61.8	67.6	69.6	67	64	59	57
Lufthansa (Germany)	62.1	60.6	63.7	66.0	99	95	94	91
Sabena (Belgium)	61.8	65.2	71.7	71.3	85	83	81	83
SAS (Scandinavian)	56.2	58.4	63.2	64.1	129	136	142	142
Swissair	57.6	58.4	64.0	63.2	101	98	90	88
UTA (France)	58.5	58.3	60.4	58.5	38	36	33	28
Europe	59.8	60.6	64.5	65.2	93	89	88	85
Air Canada	49.7	51.0	52.7	54.3	94	84	81	78
American (U.S.)	54.3	53.1	53.7	53.1	75	68	73	79
Continental (U.S.)	51.4	49.9	60.2	52.0	101	86	75	79
CP Air (Canada)	60.6	60.6	58.2	56.2	64	66	63	73
Delta (U.S.)	51.8	47.2	47.7	49.5	134	117	110	100
Eastern (U.S.)	58.1	54.2	55.3	55.2	120	108	107	99
Pacific Western (Canada)	47.8	51.1	50.5	.	228	210	195	.
Pan American (U.S.)	57.3	54.0	57.2	57.7	40	44	52	61
TWA (U.S.)	51.9	53.2	55.5	54.5	67	67	64	74
North America	54.1	52.4	54.3	53.4	86	80	81	82
All	57.3	57.5	60.0	60.5	85	79	78	77

1 Mean values weighted by avaiable ton-km.
Source: ICAO (1977-1991).

Table 3

Technical efficiency of airlines[1]

Airlines	*Technical efficiency with attributes* 1977-79	1980-82	1983-85	1986-88	*Technical efficiency without attributes* 1977-79	1980-82	1983-85	1986-88
Cathay (Hong Kong)	0.872	0.983	0.995	0.968	0.699	0.853	0.975	0.936
Indian Airlines	0.700	0.924	0.906	0.976	0.664	0.865	0.793	0.867
Japan Airlines	0.713	0.986	0.953	0.963	0.668	0.834	0.839	0.868
Korean Airlines	0.959	0.985	.	0.978	0.943	0.973	.	0.968
Malaysian Airlines	0.695	0.948	0.877	0.876	0.619	0.896	0.791	0.747
Pakistan Airlines	0.651	0.721	0.702	0.773	0.651	0.698	0.651	0.719
Qantas (Australia)	0.980	0.999	1.000	1.000	0.910	0.891	0.846	0.897
Singapore Airlines	0.817	0.966	0.958	0.994	0.748	0.921	0.955	0.979
Thai (Thailand)	0.970	1.000	1.000	0.991	0.847	0.916	0.958	0.921
Asia and Oceania	0.815	0.965	0.947	0.963	0.759	0.872	0.867	0.898
Aer Lingus (Ireland)	0.935	0.971	1.000	1.000	0.657	0.668	0.655	0.588
Air France	0.797	0.898	0.902	0.946	0.792	0.877	0.828	0.902
Air Inter (France)	0.564	0.742	0.797	0.729	0.539	0.725	0.729	0.663
Alitalia	0.702	0.728	0.778	0.772	0.682	0.722	0.775	0.750
AUA (Austria)	0.956	0.966	0.985	0.994	0.804	0.783	0.760	0.684
British Airways	0.748	0.794	0.767	0.742	0.701	0.792	0.765	0.707
British Caledonian	0.729	0.932	0.951	0.968	0.714	0.864	0.875	0.871
Finnair (Finland)	0.574	0.772	0.864	0.976	0.562	0.661	0.734	0.857
Iberia (Spain)	0.767	0.816	0.787	0.735	0.755	0.816	0.770	0.712
KLM (Netherlands)	0.891	0.954	0.986	0.955	0.874	0.954	0.961	0.952
Lufthansa (Germany)	0.848	1.000	0.966	0.982	0.843	0.993	0.965	0.948
Sabena (Belgium)	0.848	0.985	1.000	0.859	0.846	0.969	0.937	0.739
SAS (Scandinavian)	0.684	0.706	0.697	0.631	0.682	0.697	0.680	0.601
Swissair	0.792	0.895	0.797	0.769	0.792	0.886	0.797	0.745
UTA (France)	0.992	1.000	1.000	1.000	0.965	1.000	0.998	0.991
Europe	0.791	0.876	0.872	0.865	0.770	0.859	0.841	0.823
Air Canada	0.802	0.829	0.793	0.795	0.789	0.828	0.792	0.795
American (U.S.)	0.821	0.866	0.951	0.977	0.713	0.861	0.943	0.930
Continental (U.S.)	0.959	0.944	1.000	0.973	0.959	0.942	1.000	0.973
CP Air (Canada)	0.899	0.987	0.993	0.931	0.867	0.961	0.981	0.904
Delta (U.S.)	0.879	0.971	0.949	0.968	0.851	0.969	0.948	0.965
Eastern (U.S.)	0.876	0.927	0.873	0.835	0.847	0.925	0.872	0.825
Pacific Western (Canada)	0.796	0.867	0.950	.	0.669	0.772	0.801	.
Pan American (U.S.)	0.996	0.993	0.972	0.942	0.931	0.937	0.948	0.934
TWA (U.S.)	0.840	0.801	0.920	0.929	0.733	0.793	0.911	0.923
North America	0.878	0.910	0.930	0.933	0.816	0.895	0.921	0.918
All	0.838	0.909	0.913	0.917	0.791	0.878	0.884	0.883

1 Means values weighted by available ton-km.

Table 4

Malmquist index of productivity
Average growth rates per year[1]

Airlines	*Malmquist with attributes*			*Productivity change due to attributes*		
	1980-82 1977-79	*1983-85* 1980-82	*1986-88* 1983-85	*1980-82* 1977-79	*1983-85* 1980-82	*1986-88* 1983-85
Cathay (Hong Kong)	- 1.26	2.34	0.53	2.03	0.86	0.93
Indian Airlines	3.79	- 1.03	2.76	1.05	- 2.48	- 1.08
Japan Airlines	5.89	3.93	4.31	2.03	- 5.13	1.58
Korean Airlines	- 0.92	.	.	2.15	.	.
Malaysian Airlines	4.94	- 3.65	0.33	0.22	- 1.13	- 2.27
Pakistan Airlines	- 0.79	0.88	2.98	1.04	- 0.74	- 1.85
Qantas (Australia)	0.15	1.75	2.56	2.64	7.01	1.38
Singapore Airlines	2.86	1.95	3.56	0.67	5.65	7.71
Thai (Thailand)	- 5.00	0.42	- 1.79	1.99	- 2.07	5.02
Asia and Oceania	2.18	2.15	2.65	1.77	- 0.24	2.29
Aer Lingus (Ireland)	- 4.48	1.32	- 1.39	- 0.64	0.29	1.26
Air France	0.64	3.69	5.35	0.29	- 1.51	- 1.07
Air Inter (France)	4.75	0.15	- 1.18	- 0.02	1.93	1.09
Alitalia	- 1.20	3.50	1.78	0.01	0.93	2.72
AUA (Austria)	- 7.12	- 1.91	- 2.13	- 1.26	0.43	1.35
British Airways	2.25	- 0.38	1.48	0.05	2.74	- 0.63
British Caledonian	1.73	2.06	0.66	0.00	- 2.57	- 2.77
Finnair (Finland)	1.73	3.26	4.85	- 0.40	2.98	2.31
Iberia (Spain)	0.00	- 0.91	- 0.43	- 1.61	3.13	- 3.03
KLM (Netherlands)	0.45	1.23	1.62	0.03	- 1.34	1.84
Lufthansa (Germany)	2.68	3.42	2.93	0.02	0.83	4.78
Sabena (Belgium)	1.35	3.35	- 6.92	1.74	2.48	- 6.45
SAS (Scandinavian)	- 2.32	0.54	- 1.47	0.06	1.29	0.03
Swissair	0.77	- 0.99	0.85	- 0.69	- 1.07	2.95
UTA (France)	- 1.54	1.02	- 1.20	2.37	1.90	2.09
Europe	0.80	1.63	1.70	0.03	0.64	0.77
Air Canada	- 1.20	0.76	2.66	0.21	0.64	- 0.44
American (U.S.)	3.00	3.44	4.24	0.07	- 3.88	- 0.10
Continental (U.S.)	- 3.47	3.36	0.96	0.33	8.05	0.07
CP Air (Canada)	- 0.24	1.51	- 1.17	- 0.08	0.04	- 2.33
Delta (U.S.)	1.97	0.20	2.81	0.01	0.92	- 0.47
Eastern (U.S.)	0.65	- 1.03	0.53	- 1.82	0.51	- 2.04
Pacific Western (Canada)	- 2.57	2.45	.	- 0.93	- 0.33	.
Pan Am (U.S.)	- 1.89	- 2.69	0.67	- 1.07	2.47	- 0.71
TWA (U.S.)	0.52	5.03	2.59	- 1.65	2.91	- 0.60
North America	0.31	1.27	2.15	- 0.67	0.93	- 0.62
All	0.84	1.56	2.10	0.04	0.62	0.38

1 Mean values weighted by available ton-km.

Table 5

Malmquist decomposition (1977-1988)[1]
Average annual rates of growth

Airlines	Malmquist index	*First decomposition* Technological progress	Efficiency change	*Second decomposition* Due to attributes	Due to inputs and outputs
Cathay (Hong Kong)	0.74	0.20	0.49	1.13	- 0.41
Indian Airlines	1.82	- 1.47	3.16	- 0.96	2.76
Japan Airlines	4.64	1.74	2.75	- 0.45	4.99
Korean Airlines	- 0.92	- 1.81	0.87	2.15	- 3.14
Malaysian Airlines	0.34	- 1.64	1.84	- 1.23	1.56
Pakistan Airlines	1.17	- 0.79	1.92	- 0.63	1.76
Qantas (Australia)	1.62	1.43	0.20	3.49	- 2.00
Singapore Airlines	2.85	1.00	1.82	5.20	- 2.56
Thai (Thailand)	- 1.87	- 2.00	0.12	2.02	- 4.10
Asia and Oceania	2.36	0.60	1.68	1.36	0.89
Aer Lingus (Ireland)	- 1.51	- 2.29	0.75	0.29	- 1.81
Air France	3.44	1.63	1.80	- 0.81	4.21
Air Inter (France)	0.85	- 1.23	1.93	1.08	- 0.25
Alitalia	1.45	0.48	0.97	1.33	0.12
AUA (Austria)	- 3.55	- 4.00	0.43	0.26	- 3.81
British Airways	1.15	1.31	- 0.18	0.62	0.50
British Caledonian	1.40	- 1.36	2.62	- 1.94	3.27
Finnair (Finland)	3.52	- 2.02	5.33	1.80	1.74
Iberia (Spain)	- 0.44	0.09	- 0.57	- 0.59	0.07
KLM (Netherlands)	1.16	0.55	0.59	0.30	0.85
Lufthansa (Germany)	3.02	1.70	1.27	2.28	0.71
Sabena (Belgium)	- 0.97	- 0.86	- 0.14	- 0.96	0.00
SAS (Scandinavian)	- 1.11	- 0.19	- 0.96	0.44	- 1.56
Swissair	0.23	0.73	- 0.58	0.57	- 0.37
UTA (France)	- 0.59	- 0.67	0.09	2.12	- 2.77
Europe	1.41	0.68	0.70	0.51	0.87
Air Canada	0.76	0.82	- 0.08	0.13	0.63
American (U.S.)	3.68	1.92	1.78	- 1.22	4.81
Continental (U.S.)	0.83	0.97	- 0.15	2.09	- 1.37
CP Air (Canada)	- 0.10	- 0.13	- 0.01	- 0.99	0.88
Delta (U.S.)	1.81	0.87	0.92	0.08	1.72
Eastern (U.S.)	0.04	0.68	- 0.67	- 1.12	1.12
Pacific Western (Canada)	- 0.14	- 3.12	2.90	- 0.63	0.50
Pan American (U.S.)	- 1.39	- 0.80	- 0.59	0.20	- 1.64
TWA (U.S.)	2.76	1.64	1.13	0.23	2.53
North America	1.35	0.87	0.48	- 0.15	1.46
All	1.56	0.75	0.78	0.36	1.15

1 Mean values over the whole period, weighted by available ton-km. The Malmquist indices are approximately close to the sum of the components. The differences are due to the transformations effectued to obtain a decomposition in terms of average growth rates per year.

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SUMMARY

In this paper we measure technical efficiency and productivity gains in airline activities. Non-parametric frontiers and Malmquist indices of productivity are estimated for thirty-three airlines observed over the period 1977-1988. We identify three sources of growth: technological progress, efficiency change and route network characteristics. The results bring to light the reasons that pushed several airlines to merge when markets were deregulated.

RESUME

Ce papier propose des mesures d'efficacité technique et de gains de productivité pour un secteur particulier: le transport aérien. Des frontières non paramétriques et des indices de productivité de Malmquist sont dérivés sur la base de trente-trois compagnies aériennes observées entre 1977 et 1988. Nous identifions trois facteurs de croissance de productivité: le progrès technique, le changement d'efficacité et les caractéristiques du réseau aérien. Les résultats de cet article aident à comprendre les différentes raisons qui ont poussé plusieurs compagnies à fusionner lorsque le marché était en pleine déréglementation.

ZUSAMMENFASSUNG

In diesem Artikel schlagen wir Messungsmethoden für technische Effizienz und Produktivitätsgewinne im Lufttransportsektor vor. Nicht-parametrische Grenzen und Produktivitätsindizes von Malmquist werden auf der Basis von 33 Fluggesellschaften, die zwischen 1977 und 1988 untersucht wurden, abgeleitet. Wir stellen dabei drei Faktoren für das Produktivitätswachstum fest: den technischen Fortschritt, die Effizienzänderung und die Eigenschaften des Flugnetzes. Anhand der Ergebnisse dieses Artikels kann erklärt werden, weshalb mehrere Gesellschaften während der Entreglementierung des Marktes fusionert haben.