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# Productivity? of US Airlines After Deregulation

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**Abstract**

We analyse a sample of airline firms most recently examined by Alam and Sickles (2000) and extended by Good, Sickles and Weiher (2005) to include an index of circuity as one of our measures of service quality of airline travel. An additional measure of quality of airline travel is timeliness and is measured by FAA data on the percentage of flights that arrived on time. The two traditional outputs are scheduled and non-scheduled revenue passenger miles. We find that accounting for characteristics such as circuity and percentage of flights arriving on time does affect productivity. Our findings confirm anecdotal accounts of a decline in airline service quality since deregulation, yielding in general lower rates of productivity growth in our sample when quality variables such as indirect routeing and delays are explicitly introduced into the technology. Our findings also point out the power of index number techniques to account for service quality changes and could serve a similar function in analysing post-deregulatory dynamics in other industries such as telecommunications, electric power, distribution and financial services.

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# 1.0 Introduction

The purpose of this paper is to provide estimates of total factor productivity (TFP) growth for US airlines, while taking account of some of the service quality effects on consumers of the increased inconvenience ('circuity') that arises out of increasing reliance on the hub and spoke system. The measure of total factor productivity we use allows us to include directly our measure of this aspect of service quality. In addition, the productivity measure we use does not require data on prices, which is particularly useful in our application since we do not have prices for these service qualities.

Traditional growth accounting and index number approaches face the problem that prices of service quality typically do not exist since such outputs are generally not marketed. An alternative that does not require price information is the Malmquist productivity index, which is based on ratios of Shephard (1953, 1970) distance functions. These do not require information on prices, which suggests that they would be an appropriate methodological tool.

We analyse a sample of airline firms most recently examined by Alam and Sickles (2000) and extended by Good, Sickles, and Weiher (2005) to include, among other variables, an index of circuity as a measure of service quality of airline travel. The data set covers 13 carriers during the period from 1979I to 1994IV quarterly. An additional measure of service quality of airline travel is timeliness and is measured by FAA data on the percentage of flights that arrived on time. It is available from 1987I to 1994IV for a subset of ten of the carriers in the original sample. The specification of inputs and characteristics is the same in both cases; inputs: labour, energy, materials, long and short haul flying capital; characteristics of capital equipment such as the average size of the planes in the fleet, average age of the fleet, and a fuel efficiency index; characteristics of the system network as measured by average stage length of the carrier's flights and system load factor. The two traditional outputs are scheduled and non-scheduled revenue passenger miles.

As part of our exercise we compare productivity with and without our measures of inconvenience. Any loss in productivity is an indirect measure of the cost of reducing circuity in the system. It also provides an estimate of the potential upward bias of ignoring the impact of circuity on consumers. Our productivity measure is estimated using frontier techniques and it may be decomposed into efficiency change and technical change. Thus we may also see whether accounting for circuity results in reduced efficiency, or a shift in the frontier of technology. To anticipate our major results, we find that accounting for characteristics such as circuity and percentage of flights arriving on time does affect productivity. Our results confirm anecdotal accounts of a decline in service quality since deregulation, yielding in general lower rates of productivity growth in our sample when service variables such as indirect routeing are explicitly introduced into the technology.

The paper begins with a discussion of how we model the joint production of traditional outputs and service quality both conceptually and empirically. Next we turn to a discussion of the Malmquist Productivity Index in Section 3. Section 4 discusses the data used in our empirical illustration. Results are provided in Section 5 and Section 6 concludes.

## 2.0 Modelling Technologies with Service Quality

The production of traditional outputs is often accompanied by the simultaneous or joint production of service quality. In our case the desirable outputs are passenger and freight miles, and the quality of service is captured by 'circuity', which is a measure of the inconvenience to customers caused by flying with the hub and spoke system.

If we wish to measure productivity and account for both quantity and quality of service, we should obviously explicitly account for their joint production. If we denote traditional outputs by $y \in \Re^M_+$, service quality outputs by $q \in \Re^I_+$, and inputs by $x \in \Re^N_+$, then the technology may be written as

$$T = \{(x, y, q) : x \text{ can produce } (y, q)\}. \tag{1}$$

The technology consists of all feasible input and output quantities and qualities.

To model the joint production of the quantity and quality of service, it is convenient to model the technology in terms of the output sets, that is

$$P(x) = \{(y, q) : (x, y, q) \in T\}. \tag{2}$$

Clearly $T$ can be recovered from $P(x)$ as

$$T = \{(x, y, q) : (y, q) \in P(x), x \in \Re^N_+\}. \tag{3}$$

Thus the technology is equivalently represented by either its output sets $P(x)$, $x \in \Re^N_+$ or its technology set $T$.

In order to develop a framework for the empirical measurement of productivity with service quality we need to formulate an explicit reference technology. Here we assume that at each time period $t = 1, \ldots, \bar{t}$ there are $k = 1, \ldots, K$ observations of inputs, outputs, and service quality

$$(x^{t,k}, y^{t,k}, q^{t,k}), k = 1, \ldots, K, t = 1, \ldots, \bar{t}. \tag{4}$$

Following Färe, Grosskopf, and Lovell (1994) we define the output sets from the data as an activity analysis or data envelopment analysis (DEA) model, namely

$$P^t(x^t) = \left\{ \begin{array}{rl} (y^t, q^t): \quad \sum_{k=1}^{K} z_k^t y_{km}^t \geqslant y_m^t, & m = 1, \ldots, M, \\ \sum_{k=1}^{K} z_k^t q_{ki}^t \geqslant q_i^t, & i = 1, \ldots, I, \\ \sum_{k=1}^{K} z_k^t x_{kn}^t \leqslant x_n^t, & n = 1, \ldots, N, \\ z_k^t \geqslant 0, & k = 1, \ldots, K \end{array} \right\}, \tag{5}$$

where $z_k^t$ are the intensity variables, which serve to form the technology from convex combinations of the data.

## 3.0 The Malmquist Productivity Index

To introduce the Malmquist (output-based) productivity index,[1] we first define the Shephard output distance function as

$$\vec{D}_o(x, y, q) = \inf\{\theta : (y/\theta, q/\theta) \in P(x)\}. \tag{6}$$

Following Färe *et al.* (1989) we define the Malmquist Productivity Index between period $t$ and $t+1$ as

$$\text{Malm} = \left( \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \right)^{1/2}, \tag{7}$$

where the superscript on the distance function refers to the period of the reference technology and the superscript on the $(x, y, q)$ represents the period of the data under evaluation relative to the reference technology. In the empirical study below we measure outputs and inputs in terms of both quantitative as well as qualitative measures.

To show how these distance functions may be calculated using activity analysis (or DEA techniques) let us consider $D_o^t(x^{t+1}, y^{t+1})$. This mixed

[1] This index was introduced by Caves, Christensen, and Diewert (1982). It was given empirical content based on DEA techniques by Färe *et al.* (1989). For a survey, see Färe, Grosskopf, and Roos (1998).

period distance function is the solution to the following linear programming problem

$$\begin{aligned}
\vec{D}_o^t(x^{t+1,k'}, y^{t+1,k'}, q^{t+1,k'}) &= \max \beta \\
\text{subject to } \sum_{k=1}^{K} z_k^t y_{km}^t &\geqslant \beta y_{k'm}^{t+1}, m = 1, \ldots, M, \\
\sum_{k=1}^{K} z_k^t q_{ki}^t &\geqslant \beta q_{k'i}^{t+1}, i = 1, \ldots, I, \\
\sum_{k=1}^{K} z_k^t x_{kn}^t &\leqslant x_{k'n}^{t+1}, n = 1, \ldots, N, \\
z_k^t &\geqslant 0, k = 1, \ldots, K.
\end{aligned} \tag{8}$$

Note that on the left-hand side the data are from period $t$; this means that the reference technology is constructed from period $t$ data. We are evaluating the data on the right-hand side, which is from the next period, $t+1$. The other distance functions are similarly defined.

The Malmquist index may be decomposed into two components, namely

$$\text{Efficiency Change (Effch)} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1}}{D_o^t(x^t, y^t)},$$

$$\text{Technology Change (Tch)} = \left[\frac{D_o^t(x^{t+1}, y^{t+1}}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right]^{1/2},$$

The product of these two components equals the productivity index,

$$\text{Malm} = \text{Effch} \cdot \text{Tch}. \tag{9}$$

Next we turn our attention to our empirical illustration and then to our estimation results.

## 4.0 Application to the US Airline Industry

In this section we provide a discussion of the variables used in our measurement of productivity in the presence of service quality.

### 4.1 Input and output data

The labour input was composed of 93 separate labour accounts aggregated into five major employment classes (flight deck crews, flight attendants, mechanics, passenger/cargo/aircraft handlers, and other personnel). Using the expense and head count information from above, the expense per person quarter and the number of person quarters were calculated. The multilateral Törnqvist–Theil price and quantity indices for the labour input were then derived.

The objective of the energy input category is to capture aircraft fuel only. Fuel that is used for ground operations and electricity are both captured in the materials index. The energy input was developed by combining information on aircraft fuel gallons used with fuel expense data per period. This input has undergone virtually no change because these accounts remained substantially unchanged over the 23-year span of our data set. The multilateral Törnqvist–Theil index number procedure is used to provide normalisation of the data.

The materials input comprises 69 separate expenditure accounts aggregated into twelve broad classes of materials or other inputs that did not fit into the labour, energy, or flight capital categories. Carrier-specific price or quantity deflators for these expenditure groups were unavailable. Instead, industry-wide price deflators were obtained from a variety of sources. These price deflators were normalised to 1. 0 in the third quarter of 1972.

The number of aircraft that a carrier operated from each different model of aircraft in the airline's fleet is available from DOT Form 41, Schedule T2. Data on the technological characteristics for the approximately 60 types of aircraft in significant use over the period 1970 to 1992 were collected from *Jane's All the World's Aircraft* (1945 to 1982 editions). The average number of aircraft in service was constructed by dividing the total number of aircraft days for all aircraft types by the number of days in the quarter. This provides a gross measure of the size of the fleet (number of aircraft).

In order to adjust this measure of flight capital, we also construct the average equipment size. This was measured with the highest density single-class seating configuration listed in *Jane's* for each aircraft type. The fleet wide average was weighted by the number of aircraft of each type assigned into service. In some cases, particularly with wide-bodied jets, the actual number of seats was substantially less than described by this configuration because of the use of first-class and business-class seating. Our purpose was to describe the physical size of the aircraft rather than how carriers chose to use or configure them.

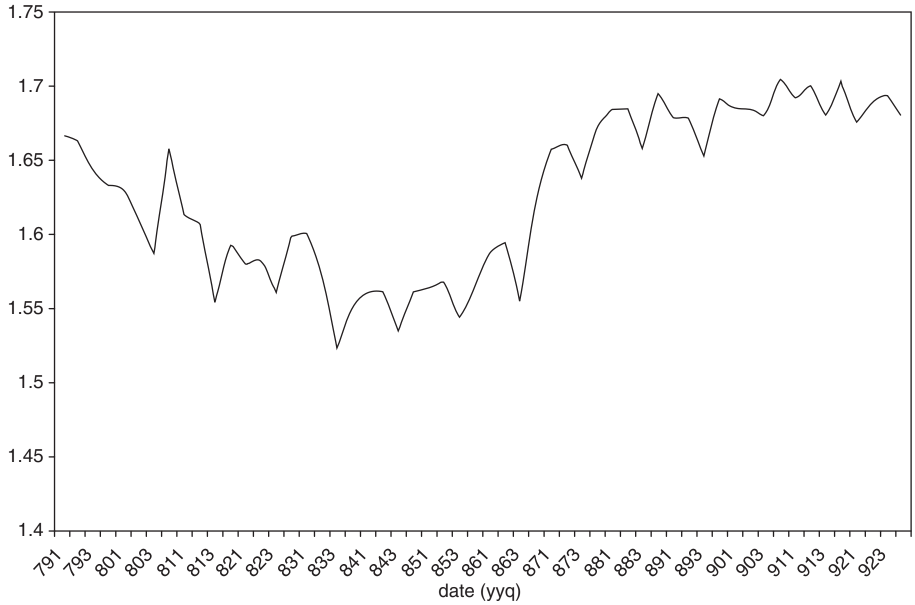
We used the average number of months since the FAA's type-certification of aircraft designs as our measure of fleet vintage. Our assumption is that the technological innovation in an aircraft does not change after the design is type-certified. Consequently, our measure of technological age does not fully capture the deterioration in capital and increased maintenance costs caused by use. Our measure does capture retrofitting older designs with major innovations, if these innovations were significant enough to require recertification of the type. Finally, it is clear that the major innovation that took place during the 1960s and 1970s was the conversion to jet aircraft. While many carriers had largely adopted this innovation prior to the study period, it was by no means universal. Many of the local service airlines used turboprop aircraft as a significant portion of their fleets. We implemented this aspect by measuring the proportion of aircraft in the fleet that are jet powered. The proportion of wide-bodied aircraft was also calculated.

Revenue output is disaggregated into scheduled and non-scheduled output. Nonscheduled output includes cargo and charter operations. The price per unit (passenger-mile or ton-mile) of the relevant service was constructed by dividing the revenue generated in the category by the physical amount of output in that category. These prices were normalised to 1.0 in the baseline period. In cases where a carrier offered only one type of service (the convention was to call this 'first class'), the service was redefined to be coach class. The Törnqvist–Theil index number procedure was used in constructing the two categories of service.

### 4.2 Network configuration and circuitous routeing

Much has been made out of changes in airline networks by increased use of hub-and-spoke type networks. Airlines find these network configurations useful because they allow for higher passenger densities on individual routes. However, indirect routeing of passengers is usually something that passengers would like to avoid. Their time is valuable. Indirectly routeing a passenger, especially when it involves changes of planes is definitely less desirable than a direct flight. There are some exceptions to this. Indirectly routed passengers will often accrue more frequent-flyer miles than directly routed passengers. Another benefit of connecting flights is that it affords the passenger with increased frequency of service. Other characteristics involving network configuration for passengers include origin–destination combinations for which no airline offers service. These situations require that a passenger take part of their trip on one airline and the remainder on at least one other airline. This interlining is generally considered a lower quality of service for the passenger than if their entire trip was on a single airline. Changing airlines is perceived to increase the likelihood that baggage will be mishandled or misdirected; it also typically increases the distance between gates at the connecting airport. The passenger also perceives reduced coordination between the carrier on the first segment and the second. The Department of Transportation's Origin/Destination database DB1A provides a 10 per cent sample of all

**Figure 1**
*Average Number of Ways (round trip = 2, one way = 1)*

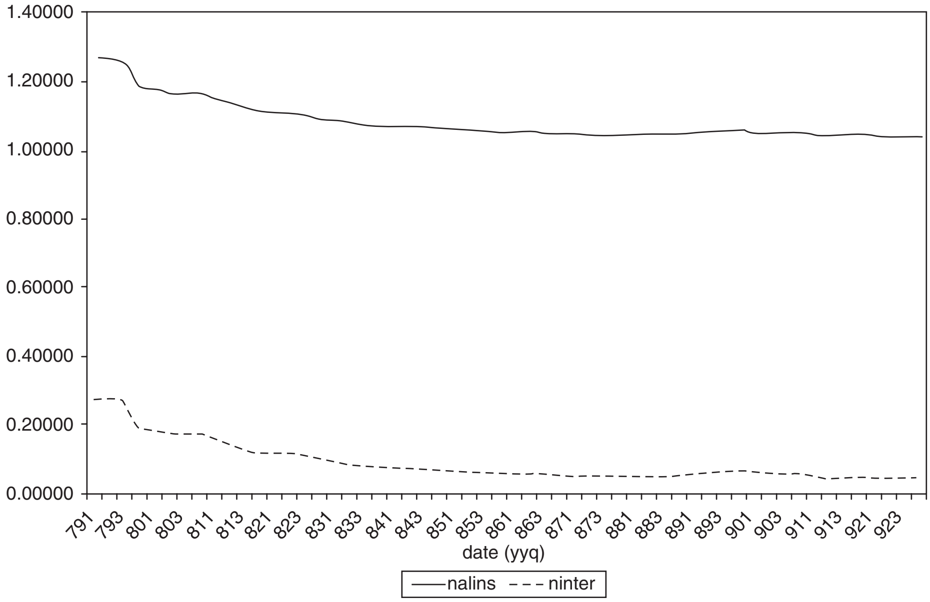



domestic tickets and allows us to identify many of the characteristics of the trip. Most fundamentally, we can identify the origin of a trip, and the ultimate destination as indicated by a trip break. Approximately 95 per cent of trips are either one way or round trip (depending on the year) with a small number of multibreak tickets involving as many as 23 different flights. More complex routeings tend to be slightly more prevalent in later years than in earlier ones.

The ticket itinerary allows us to measure the number of airlines taking part in the trip as well as a count of the number of times the airline changes (interlines). The changing patterns over our study period for these characteristics for one way and round trip tickets are summarised in Figures 1 and 2. For one way tickets, the number of airlines (NALINS) and the number of interlines (INTER) are very nearly the same. Twenty-eight per cent of the tickets had more than one airline and the average number of interlines was 28 per cent in 1979-1. By 1992-4 only 4 per cent had passengers interlined. The pattern for round trip tickets is quite similar. In 1979-1 nearly half of the round trip itineraries involved more than one airline. Some of these involved more than one interline as an itinerary started with one carrier, switched to a second, then went back to the first carrier on the return. The information from the Origin and Destination data also allows us to measure the number of segments in a ticket. While

**Figure 2**

*Average Over One-Way Trips: Number of Airlines vs. Number of Interline Segments*

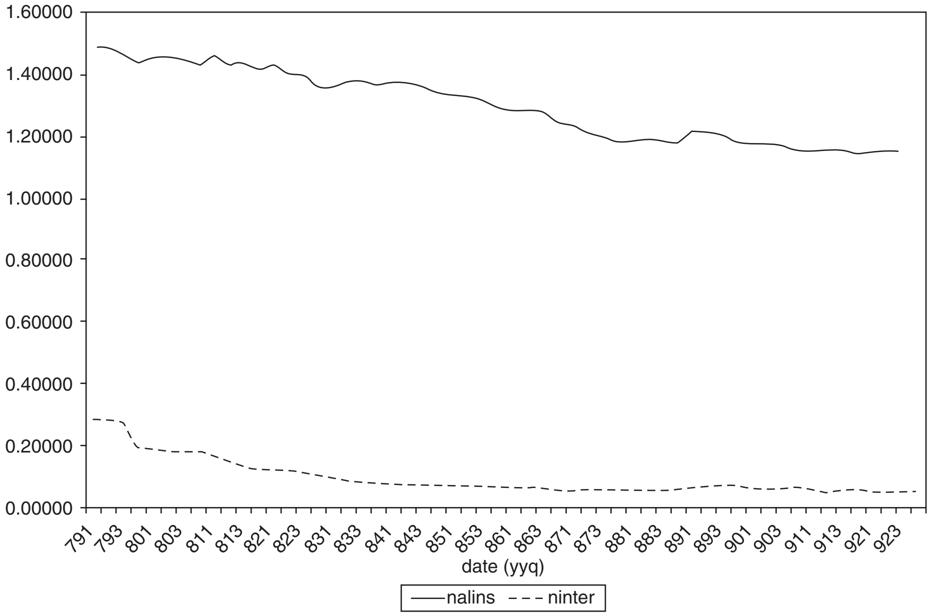



these are not considered as a bad, from the passengers perspective, as an interline, a new segment does require that a change of plane occur. These are summarised for one way and round trip tickets in Figure 3.

The minimum number of segments for a one way ticket is one. Approximately half of the one way itineraries involved an additional segment in 1979-1. But this number fell by 1984 to about 25 per cent, suggesting an improvement in the quality of airline service as fewer changes of plane appear to be required. A very different pattern emerges for round trip tickets that have a minimum of two segments. In 1979-1 the average number of segments was 2.8, which increased to 3.05 by 1992-4, indicating a reduction in the quality of service. At 3.0 it suggests that approximately half of the itineraries involved a change of planes on the outbound and inbound portions of the trip. The rationale behind the difference in the one way and round trip ticket patterns is not clear. It may suggest a correlation between one way and full fare tickets, which have a higher quality of demanded service for the large premium in price. On the other hand, while the presumption behind round trip tickets is that they describe the full trip, we know that not to be the case for one way tickets since the passenger will require, at the minimum, an additional ticket for the return flight. Consequently the presumption that a full fare ticket involves the ultimate destination seems less well founded.

**Figure 3**

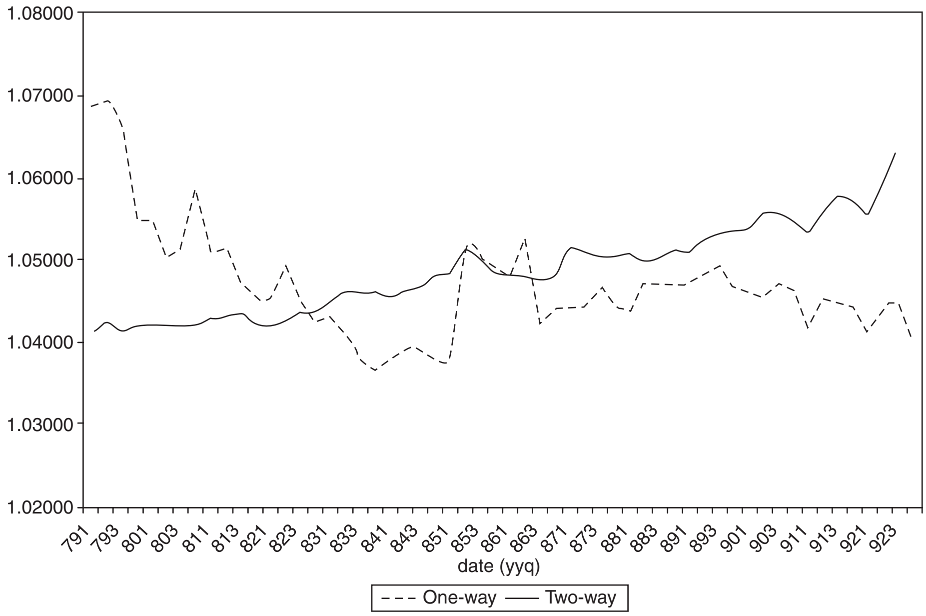
*Average Over Round Trips: Number of Airlines vs. Number of Interline Segments*




An additional way to characterise the network quality associated with a particular ticket is to examine its circuity (Figure 4). An indirect routeing forces the passenger to travel more miles than they would prefer. We measure the circuity of an itinerary by taking the number of miles of a direct routeing of the passenger (measured with great circle distances) as the denominator and the sum of the number of miles associated with each actual ticket segment (measured by the great circle distances that correct for the curvature of the earth) as the numerator, that is, values greater than one indicate that the routeing is not direct. A small amount of circuity is associated with trips averaging about 5 per cent for both one way and round trip tickets. This is generally declining for one way tickets and increasing for round trip tickets and suggests that while changes of planes may be necessary, they occur at an airport that is in the same direction as a direct routeing would take the traveller.[2] For our empirical work we create a single index of circuity (rather than separate one way and round trip measures) and define our index such that larger numbers reflect more direct routeing.

[2]Circuity does not allow us to capture indirect routeing that does not involve a change of planes since we do not have any information on the routeing of flights or flight numbers in the Origin and Destination (DB1A) data.

**Figure 4**
*Circuity for One-Way and Round Trip Tickets*




## 4.3 Flight convenience and availability

Passengers typically have clear preferences regarding the time of travel. This may involve a clear preference as to the time of departure or the time of arrival at the destination. The willingness to accept other flight times varies a great deal with trip purpose. Two measures of service quality that deal with the availability of a seat at the time desired are flight frequency and load factor. Flight frequency at the airport level is the number of scheduled departures over the quarter and is based on the Department of Transportation's Airport Activity Statistics. As more and more departures are offered at an airport, the average amount of schedule delay (the delay that occurs between the desired time and actual time) decreases. The patterns for different airport categories, the average daily departures for large airports ranked in the top 20 airports, medium sized airports ranked from 100–120, small airports ranked from 300–320 and very small airports ranked 400–420 in terms of their total enplanements between 1979 and 1992, indicate that there has been an increase of approximately 34 per cent in the daily departures for the large airports, a 20 per cent increase in the daily departures for medium sized and small airports, and an 80 per cent reduction in the number of daily departures for very small airports.

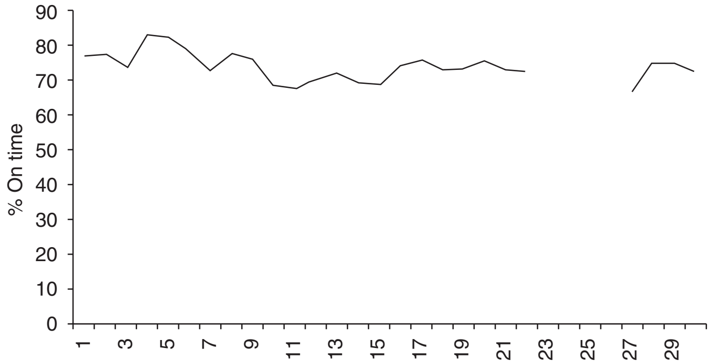
Simply because there is a departure is no guarantee that a seat will be available. Airlines with a high load factor will have a propensity to fill a larger fraction of their flights. High load factors may be a good thing from the perspective of the airlines (filling otherwise empty seats has a very low cost associated with it) but not from the perspective of the passenger. Unfortunately, we do not have load factor at any level of detail other than the carrier level during the quarter. This is generally related to flight frequency with a lower number indicating more frequent flights and consequently a higher level of service. Other definitions of load factor are possible, such as dividing the total passenger revenue collected by the total that would be collected were the planes flown full (derived from the passenger capacity output times passenger capacity price). The data suggest that there has been a slight decline in the availability of flights over the study period. There are other potential measurement approaches for assessing changes in this aspect of service at more detailed levels. Finding out that a flight is not available can occur at the time reservations are made or during boarding. DOT maintains data on the number of passengers denied boarding either voluntarily or involuntarily. Involuntary denials are very rare since carriers offer passengers fairly good inducements to delay their travel plans (typically free tickets along with first class upgrades and hotel accommodations if necessary for accepting the next flight out).

Another proxy used to measure the quality of service is the average stage length. Generally, the shorter the flight, the higher the proportion of ground services required per passenger-mile and the more circuitous the flight (a higher proportion of aircraft miles flown is needed to accommodate the needs of air traffic control). This generally results in a higher cost per mile for short flights than for longer flights. Average stage length is found by dividing total revenue aircraft miles flown by total revenue aircraft departures.

### 4.4 Airport congestion and flight delay

Flight delays are an important aspect of service quality. Passengers have a great deal of anxiety over missed connections and delayed or cancelled flights. The Department of Transportation currently maintains detailed flight delay information on an individual flight basis. However, as with any measure for service quality these delay data are not perfect measures for our purposes. First, they are available only starting in September of 1987, more than half way through our study period. Second, they are prohibitively expensive for this research project. Third, the delay data have essentially changed their meaning over time. Airlines have recognised that passengers use delay information in the selection of flights. They have

**Figure 5**
*On Time Performance (1987III–1994IV)*




countered this by increasing the scheduled duration of the flight to increase on-time performance. Fourth, a paramount objective in the nation's air traffic system is safety. Flight delays are not included in the aggregate delay statistics for weather or equipment safety reasons to eliminate any incentive to improve apparent service quality at the expense of safety. Reservations systems have countered this by incorporating both the scheduled duration of the flight and delay information into their prioritisation of flights for display. The good features of this data are that it provides very detailed information on actual flight operations. It provides information on taxi time both on takeoff and departure, and time in flight along with scheduled departure and arrival times. This allows us to identify airport congestion as well as flight specific delay information. On the other hand, while not impossible, connecting this information to the origin and destination ticket information is far from a trivial exercise. It would require obtaining an airline specific aggregation of flight segments over the quarter of all those flights that provided direct or multi-stop service on a particular coupon segment. In order to measure airport congestion and flight frequency we utilise FAA data on flight delays during a quarter for a carrier. These are displayed in Figure 5 and show a somewhat variable pattern in the percentage of flights that arrived on time for the airlines in our sample.

## 5.0 Estimation Results

The original data, which includes the index of circuity (one of our measures of service quality of airline travel), covers the period from 1979 to 1994, includes 13 carriers, and is quarterly. An alternative measure of the effect

**Table 1**
*Descriptive Statistics: Model Variables (N = 670)*

| *Measure* | *Mean* | *St. Dev.* | *Min* | *Max* |
|---|---|---|---|---|
| Labour | 93695379.70 | 68740119.68 | 1114600.00 | 289780000 |
| Energy | 27086136.87 | 20109437.64 | 1804700.00 | 94679000.00 |
| Materials | 85083888.21 | 71986598.27 | 5617000.00 | 293930000 |
| Short haul | 169.45 | 104.10 | 28.33 | 457.30 |
| Long haul | 53.23 | 57.83 | 0 | 243.68 |
| Pass. rev. miles | 495440704 | 421930553 | 20661000.00 | 2006800000 |
| Non-rev miles | 57112070.39 | 59930926.44 | 547330.00 | 243870000 |
| Circ | 0.702 | 0.231 | 0.180 | 1.574 |
| On time | 79.73 | 5.55 | 66.10 | 94.60 |
| Stage length | 616.97 | 222.38 | 203.89 | 1626.40 |
| Load factor | 0.60 | 0.06 | 0.44 | 0.77 |
| Ave. size | 179.31 | 46.27 | 8.05 | 262.88 |
| Ave. age | 188.79 | 25.50 | 128.88 | 863.45 |
| Fuel index | 0.31 | 0.07 | 0.19 | 1.06 |

of timeliness is FAA data on the percentage of flights that arrived on time. This was first available in 1987, and is available for only ten of the carriers in the original sample.

The specification of inputs and characteristics is the same in both cases — inputs: labour, energy, materials, long and short haul measures of capacity; characteristics: stage length, load factor, average aircraft size, average age of the fleet, and average fuel efficiency of the fleet. Outputs include passenger revenue miles and non revenue miles. The circuity index is our first explicit measure of service quality of the carrier on average. The percentage of flights that arrived on time is our second explicit measure of service quality of the carrier on average. Descriptive statistics are included in Table 1.

Using the index number procedures outlined above we next estimate productivity growth with and without the circuity index for each of the carriers in our sample as well as with the FAA percentage on time variable as an alternative to our circuity measure. Sample means are summarised in Table 2 for the overall index (Malm) as well as the efficiency and technical change components.

Results in Table 2 suggest that when we include circuity as a measure of service quality there has been a small decline in productivity growth for our sample over this time period. The model using the on time variable as well as the model with no service quality characteristics exhibits a slight increase in productivity growth on average. The on time model has a slightly higher average productivity growth than the model that does not account for quality characteristics; thus our two versions of service quality

**Table 2**
*Descriptive Statistics: Productivity Change*

| *Measure* | *Mean* | *St. Dev.* | *N* |
|---|---|---|---|
| Malm (no quality) | 1.0003 | 0.0278 | 146 |
| E. ch(no quality) | 1.0000 | 0.0202 | 146 |
| Tch (no quality) | 1.0028 | 0.0319 | 146 |
| Malm (circularity) | 0.9976 | 0.0218 | 358 |
| E. ch (circularity) | 1.0000 | 0.0103 | 358 |
| Tch (circularity) | 0.9976 | 0.0215 | 358 |
| Malm (on time) | 1.0013 | 0.0278 | 358 |
| E. ch (on time) | 0.9989 | 0.0202 | 358 |
| Tch (on time) | 1.0028 | 0.0319 | 358 |

give different overall results. The circuity model shows the deterioration we would expect relative to the model without service quality. The on time version shows better performance than the model with no quality characteristics. This is perhaps consistent with the general impression passengers have that airlines now estimate longer flight times to improve their on time performance. Thus our preferred model of service quality is the circuity model.

Figures 6, 7, and 8 provide summary information in the form of box-plots for the temporal pattern of estimated productivity indices. Figure 6 is the

**Figure 6**
*Malmquist No Service Quality*

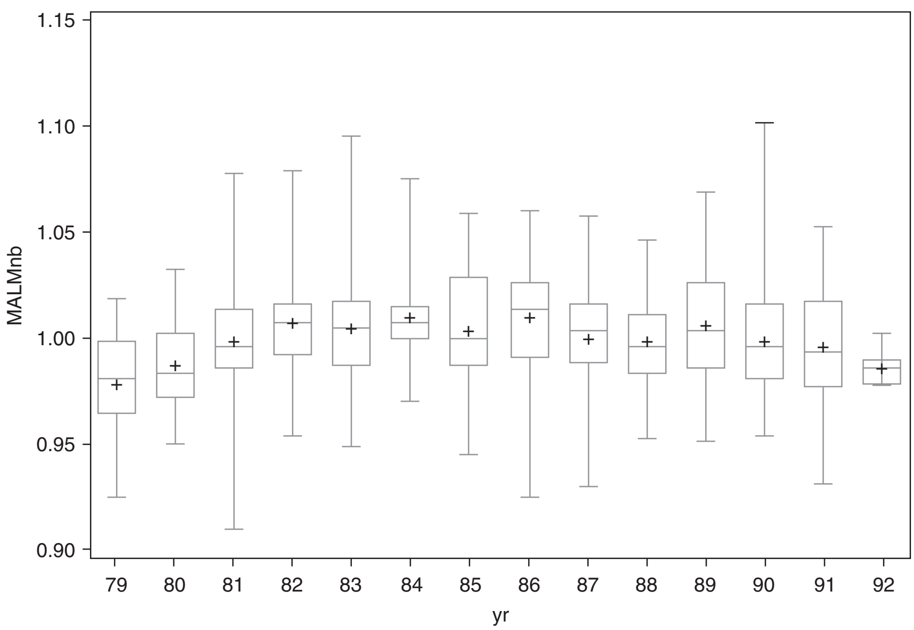


**Figure 7**
*Malmquist with Circuity*

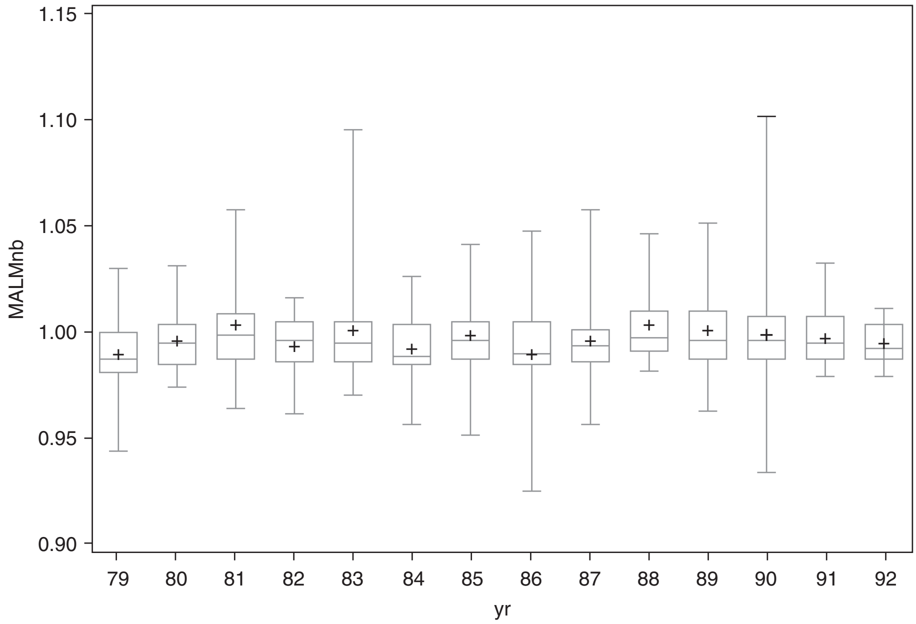



**Figure 8**
*Malmquist with On Time*

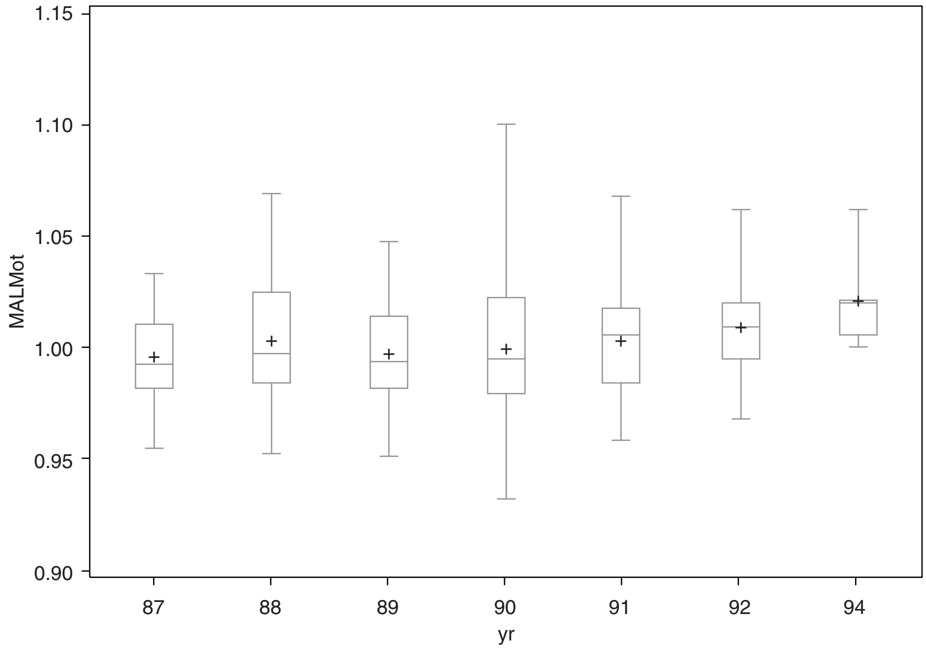
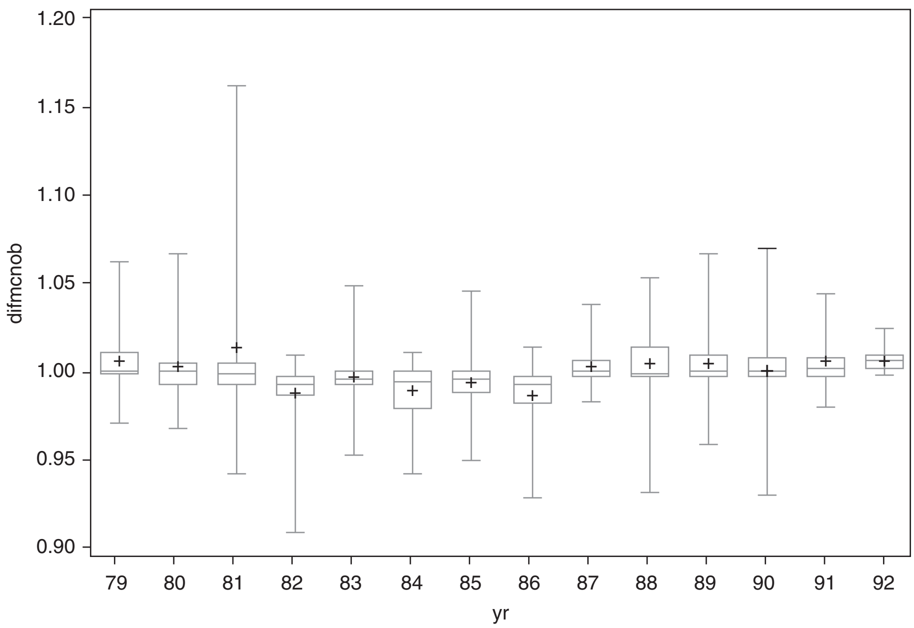


**Figure 9**
*Ratio of Malmquist With and Without Circuity*

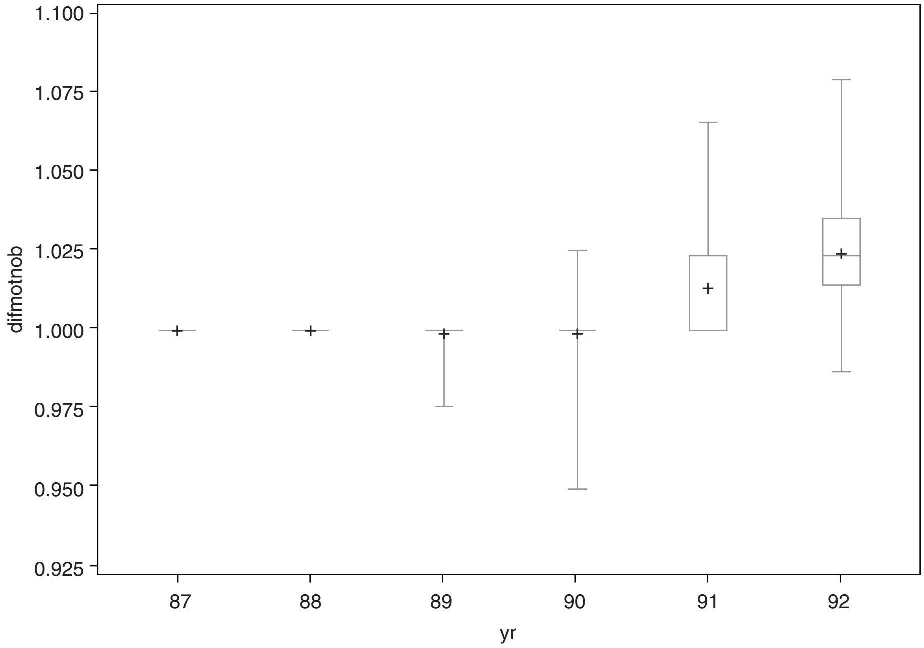



basic model with no service quality characteristics, Figure 7 displays the model with the circuity variable. Figure 8 displays results augmenting the model with the on time measure of service quality. We also include summary information (box-plots) for the ratio of the productivity index with circuity to the index with no service quality (Figure 9) and a similar ratio for the on time service quality measure (Figure 10). Here values greater than one indicate that performance with the indicated quality variable exceeds that of the model with no service quality. Again, the on time versus no quality results suggest higher productivity growth when we include on time performance; the circuity versus no quality suggests the opposite.

To test whether the visual evidence was significant we ran a battery of nonparametric tests (using the SAS NPar1way procedure), which test the null of equality of various location parameters. The probabilities are included in Tables 3 and 4 for the various tests. These suggest that the null is rejected for virtually all the tests for both productivity growth with and without circuity (Table 3) and with and without the on time variable (Table 4).

Our findings of productivity growth decline when proper accounting is made for the characteristics that are identified as declines in service quality during the post-deregulation epoch, consistent with anecdotal experience and the call for a return to regulation by a number of consumer travel

**Figure 10**
*Ratio of Malmquist With and Without On Time*




groups. Although we do not advocate the reregulation of the industry, to ameliorate the deterioration of service quality as measured by our service quality variables — the competitive market appears to be addressing this issue — we do note that such quality changes are often overlooked when analysing the successes of deregulatory initiatives in the US and elsewhere. We do advocate the use of methods such as those presented herein in order to quantify properly the impacts that deregulation has on consumers as well

**Table 3**
*Nonparametric Location Tests: With and Without Circularity*

| | *(Probability > test statistic)* | | |
|---|---|---|---|
| *Test* | *Malmquist* | *Efficiency change* | *Technical change* |
| ANOVA | 0.6001 | 0.0018 | 0.0025 |
| Wilcoxon | 0.0001 | 0.1007 | 0.0029 |
| Kruskal–Wallis | 0.0001 | 0.1003 | 0.0029 |
| Median | 0.0001 | 0.0229 | 0.0001 |
| van der Waerden | 0.0001 | 0.2055 | 0.0223 |
| Savage | 0.9976 | 0.0001 | 0.0001 |
| Kolmogorov–Smirnov | 0.0001 | 0.0001 | 0.0001 |
| Kuiper | 0.0001 | 0.0001 | 0.0001 |

**Table 4**
*Nonparametric Location Tests: With and Without On Time*

| *(Probability > test statistic)* | | | |
|---|---|---|---|
| *Test* | *Malmquist* | *Efficiency change* | *Technical change* |
| ANOVA | 0.0008 | 0.0052 | 0.0001 |
| Wilcoxon | 0.2009 | 0.0037 | 0.0001 |
| Kruskal–Wallis | 0.0009 | 0.0034 | 0.0001 |
| Median | 0.0006 | 0.0023 | 0.0001 |
| van der Waerden | 0.0035 | 0.0108 | 0.0001 |
| Savage | 0.0001 | 0.6592 | 0.0001 |
| Kolmogorov–Smirnov | 0.0457 | 0.0630 | 0.0160 |
| Kuiper | 0.0542 | 0.0542 | 0.0542 |

as producers. Recall that our results suggest that productivity growth declines when we include circuity as a measure of service quality. Productivity growth using on time as the service quality measure and/or ignoring quality altogether, as would be done in a traditional productivity study, suggests that there has been a slight increase in productivity growth on average. This is not surprising given the way in which carriers have gamed the term on time by simply increasing posted flight times. Were analysts, both those within the industry and those in the business of financing the large losses at most legacy airline companies, to recognise such productivity growth regress it would seem that business decisions may be impacted in a substantive way. Moreover, before and soon after deregulation, there was a significant growth in the use of widebodied aircraft flying nonstop in dense markets. However, the hub and spoke systems put in place by most legacy airline would imply the use of relatively smaller aircraft. Circuitous routeing via hub airports consumes fuel and time. However, it may also provide benefits to travellers due to increased flight frequency and benefits to the airline because of higher load factors. Our findings also point out the power of the index number techniques to account for service quality changes and could serve a similar function in analysing post-deregulatory dynamics in other industries that have recently been going through the throes of deregulation, such as telecommunications, electric power, distribution, and financial services.

## 6.0 Summary

In this paper we provide an overview of some approaches to modelling and measuring productivity growth to account for service quality. These have in common an axiomatic production theoretic framework, in which joint production is explicitly modelled. In measuring productivity growth in the presence of quality characteristics, traditional growth accounting and index number approaches face the problem that prices typically do not exist since such outputs are generally not marketed. The alternative we use — the Malmquist productivity index — does not require price information and is based on ratios of Shephard distance functions. These do not require information on prices, which suggests that they would be an appropriate methodological tool. These distance functions are easily computable using linear programming techniques very similar to traditional data envelopment analysis.

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