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Hubbing and Airline Costs

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I. Introduction

The impacts of airline deregulation have been the subject of considerable research. The work generally falls into two categories. The first analyzes the impacts of deregulation on industry structure and conduct. Route structures, marketing strategies, and patterns of market entry, exit, and concentration are among the topics considered in these studies. Despite this breadth of subject matter, investigations in this category are similar in their focus on "value-neutral" impacts and avoidance of normative issues.

The second strand of airline deregulation research focuses on the performance of the industry since deregulation. Efficiency, service quality and convenience, and equity are among the major criteria employed to evaluate that performance. Although much of the work in this category is circumspect in its use of normative terminology, it has clear normative implications. Whereas investigations in the first set look at what the industry is doing differently, these consider whether it is doing "better" or "worse."

Both types of studies have produced valuable results, but they also raise further questions. One largely unexplored area concerns the relationship between structure and conduct on the one hand and performance on the other. The existing literature, in focusing rather exclusively on one or the other of these sets of variables, has avoided the task of establishing links between them. For example, while post-deregulation productivity growth and route structure changes has received considerable attention, the connection between these trends has yet to be investigated.

That connection is the subject of this paper Specifically, we consider the effect of air network hubbing on airline productivity Has increased hubbing contributed to increased productivity? Or are these trends unrelated, or even opposed, to one another? To investigate this issue, we include measures of hubbing in the specification of airline cost functions, and calibrate them using pooled cross-sectional data spanning the 1976-84 time period. We find no direct connection between the degree of hubbing and and airline cost levels over these years We argue that the significance of this finding depends upon the nature of the process underlying the trend toward increased hubbing, a process not yet thoroughly understood.

The balance of this paper includes four sections In Section 2, we review trends in airline productivity and hubbing, and discuss theoretical bases for relating these trends. Our methodology is described in Section 3 , and our results are presented in Section 4 Section 5 assesses the implication of our findings for the productivity-hubbing relationship.

2. Productivity and Hubbing - A Review of the Evidence

There is substantial evidence that airline productivity growth has accelerated since deregulation. Increased hubbing of air carrier route networks has also been observed. Finally, there is a theoretical basis for associating increased hubbing with gains in productivity. Here, we review evidence of hubbing and productivity trends and discuss possible connections between them.

Trends in Productivity

Caves, Christianson, and Trethaway[1] have carried out the most thorough research to date on productivity trends in the airline industry. They employ superlative index numbers as measures of input and output in order to measure total factor productivity (TFP). Some five categories of output (first class, coach, and charter passenger miles, freight, and mail ton-miles) and five categories of input (labor, aircraft, ground property and equipment, fuel, and materials) are considered in their analysis. These categories are aggregated together on the basis of revenue and cost shares, respectively, according to formulas developed by Caves, Chistianson, and Diewart.[2]

Their results suggest that TFP of both the trunks and the local carriers increased thoughout the 1970s, but that gains accelerated during the latter part of the decade as regulation was relaxed. For trunks, the average annual TFP increase from 1970-75 was 2.6 per cent, jumping to 4.9 percent in the 1975-80[3] period For locals, the comparable figures were 4.0 percent and 6.3 per cent, while for the industry as a whole they were 2.8 percent and 5.1 percent.

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[1] Douglas Caves, Laurits Christensen, and Michael Tretheway, "Productivity Performance of U.S. Trunk and Local Service Airlines in the Era of Deregulation," *Economic Inquiry*, XXI (July 1983), pp. 312-324.

[2] Douglas Caves, Laurits Christenson, and W. Erwin Diewart, "Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers," *Economic Journal*, 92 (March 1982), pp. 73-86.

[3] Although legislation deregulating the airlines was not passed until 1978, the CAB began to liberalize its policies concerning route awards and fare levels in 1975 The authors therefore compare the 1970-75 and 1975-80 periods in their assessment.

The authors attempt to assess sources of airline productivity gain by performing analysis of covariance regressions of TFP growth using airline operating characteristics--output level, load factor, stage length, and available capacity--as independent variables. Changes in these characteristics--particularly increased output--are found to account for most of the acceleration in TFP growth during the late 1970s Insofar as these sources of accelerated growth themselves stem from deregulation, one can conclude that the latter has improved airline efficiency. The authors, attributing increased output to fare reductions induced by deregulation, credit it for roughly half of the increase in TFP growth during the 1975-80 period

Bailey, Graham, and Kaplan[4] measure productivity growth by comparing changes in airline industry aggregate costs per revenue ton-mile with changes in input factor prices. Like Caves et al., they find accelerating productivity growth for the local airlines from 1975-81, but, in contrast to the former, they find no such pattern for the trunks. This difference is attributed to the inclusion in the time series of 1981, a year when performance was adversely affected by economic recession and the aircraft controllers strike. Indeed, Bailey et al. find that the 1975-78 period witnessed an annual trunk productivity increase of 8.1 percent, followed by an annual rate of 0.5 percent between 1978-81. Any deregulation-induced productivity gains during the latter period were thus apparently dominated by other factors.

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[4] Elizabeth Bailey, David R. Graham, and Daniel P. Kaplan, *Deregulating the Airlines* (Cambridge MA. MIT Press, 1985), Chapter 8

Bailey et al also consider evidence of changes in specific operational characteristics that have a direct bearing on overall efficiency. For example, the authors find that trunk load factors increased fairly steadily between 1974 and 1979, but fell sharply from 1979-81. Nonetheless, during the latter period, load factors were substantially higher than during the two previous recessions (1974-75 and 1969-70) Moreover, when market average load factors are regressed on market characteristics, the sign of the coefficient on the distance variable is found to change from negative in 1969 to positive in 1976 and 1981. This suggests that, whereas airlines were induced to offer excessive number of flights on long-haul routes under CAB-imposed fare structures, deregulation led to a more economically efficient distribution of service levels[5] The authors also find evidence of post-deregulation productivity improvement in higher aircraft utilization rates and seating densities, as well as increased stage lengths, since 1975.

To summarize, there are strong indications that airline productivity has increased as a result of deregulation. The directly observable improvement is most pronounced over the late 1970s, before a weakened economy and the controllers' strike took their toll. Complimenting the direct evidence are trends in load factors and other variables that also suggest a more efficient industry.

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[5] The time savings resulting from increased frequency are independent of route length, while the cost of an additional flight is higher for longer routes. Thus optimal frequencies should decrease with stage length, *ceterus parabus*. Under regulation, however, fares were set so that long-haul routes were potentially the most profitable. This caused carriers to vie for long-haul traffic by offering service frequencies in excess of optimal levels. See G.W Douglas and J.C. Miller, *Economic Regulation of Domestic Air Transport: Theory and Policy* (Washington DC: The Brookings Institute. 1974).

Trends in Hubbing

Comparison of route maps of today with those of the mid-1970s amply demonstrates that airline network hubbing has increased. The now familiar pattern of multiple links emanating from a handful of hub airports has replaced the seeming hodge-podge that characterized many route systems under regulation. In addition to being visually apparent, the increase in hubbing is manifested quantitatively in airline operating statistics.

One indication of a hubbed network is the concentration of operations at a handful of airports which serve as transfer points for connecting traffic. Measures of concentration of an airline's operations can therefore serve as measures of the degree of hubbing of that airline's route network. Methods for measuring concentration have been developed for a variety of social science applications, such as assessing industrial concentration and analyzing income distribution Table 1 shows the results when three such measures are applied to individual airlines' distributions of scheduled departures for the years 1976, 1980, and 1984. The upward trend in these measures is quite apparent. The few instances of downward movement also involve large scale network expansions, which naturally tend to reduce concentration Indeed, it is notable that some airlines (American and United, for example), have increased concentrations of departures despite substantial increases in the number of points served.

Table 1 - Concentration of Departures Among Airports for Selected Airlines, 1976-84

Airline	Herfindahl Index[1]			1-Airport Concentration[2]			4-Airport Concentration[3]			Points Served		
	76	80	84	76	80	84	76	80	84	76	80	84
American	.055	.065	.100	.142	.164	.190	.337	.403	.440	52	58	103
Brannif	.109	.122	n.a	.290	.321	n.a.	.481	.482	n.a.	39	58	n.a.
Delta	.047	.066	.073	.171	.224	.232	.303	.354	.401	74	76	87
Eastern	.052	.062	.065	.172	.207	.219	.336	.360	.363	75	80	89
Frontier	.036	.058	.110	.153	.218	.319	.256	.281	.366	93	96	81
Northwest	.063	.061	.078	.151	156	.234	419	.403	.424	48	48	56
Ozark	.051	.068	.161	.144	.205	.389	.350	.403	.483	48	51	51
Pan Am	.184	.071	.100	.279	.141	.204	.764	424	.549	10	29	40
Piedmont	.034	.040	.060	.080	.080	.189	.253	.280	.365	50	49	64
Republic	n.a	.026	.033	n.a.	.066	.095	n.a.	.244	.296	n.a.	129	117
TWA	.058	.056	.111	.135	.143	.307	.373	.375	.468	38	57	63
United	.044	.055	.064	.142	.164	.190	.337	403	.440	95	95	132
US Air	.047	.060	.078	.144	.189	.243	.321	.368	.401	55	57	69
Western	.069	.080	.083	.162	.170	.208	.430	.471	.468	41	43	64

Notes

[1] Computed by summing the squares of airport shares the airline's total scheduled departures

[2] The share of the airline's total departures from the airport where the airline had the most departures

[3] The combined shares of the airline's total departures from the four airports where the airline had the most departures.

Source CAB Form 41 data as stored on I.P. Sharp data base.

Other indications of increased hubbing include growth in the number of flights connecting smaller airports with larger ones, and increases in the share of trips made on a single airline. Large airports tend to have larger local markets, making them the most desirable sites for hubs. Thus, as more traffic is funneled through hubs, direct flights between smaller airports and larger ones should increase relative to direct connections between the former. Table 2 reveals that this has happened. Likewise, hubbing enables a single airline to serve both trunk and feeder routes, and should therefore increase the share of trips made online Consistent with this expectation, the online share of total trips went from 89.1 percent in 1978 to 96.7 percent in 1983.[6]

Table 2 - Growth in Non-Stop Connections Involving Small and Non-Hubs

	Percent Increase in Non-Stop Flights, 1978 to 1981			
	To Large Hubs	To Medium Hubs	To Small Hubs	To Non-Hubs
From Small Hubs	18.3	-7.1	-23.2	-21.1
From Non-Hubs	12.3	10.5	-21.1	-12.6

Source. Bailey et al. (1985), p. 84.

Thus, increased hubbing of airline networks is evident in a number statistical trends. Increased concentration of operations, more direct flights between small and large airports, and the greater proportion of passengers receiving on-line service all tend to confirm the impression airline route maps graphically convey.

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[6] U.S Civil Aeronautics Board, *Report to Congress on Implementation of the Provisions of the Airline Deregulation Act of 1978*, (Washington DC Civil Aeronautics Board, 1984)

Hubbing and Productivity

The preceding sections have presented evidence of increased productivity and hubbing since deregulation We now consider possible connections between these trends.

The productivity enhancing impacts of airline hubbing are well understood. Airline routes exhibit strong economies of traffic density. These may take several different forms. First, there are economies of aircraft size. As the amount of traffic on a link increases, it becomes possible to use serve the link with larger, more economical, planes. Second, there are economies of schedule frequency. Higher link flows mean that more departures can be scheduled, allowing travelers a greater selection of travel times. Third, while the stochastic nature of travel demand causes temporal variation in traffic, increased traffic density reduces the relative magnitude of this variation. This allows airlines to operate on a regular schedule, with reasonably high load factors, while at the same time offering sufficient capacity to serve most travelers desiring a particular flight.

By consolidating traffic between a large number of origin-destination pairs on a relatively small number of links, hubbing allows increased realization of economies of traffic density. Suppose a given airline serves a total of n communities In order to provide direct service between each city-pair, it would need n^2-n links. But instead, the airline could establish a hub at one of the n airports, and thereby offer one-stop service between each city-pair with only n-1 links For a given level of traffic, this implies a n-fold increase in traffic density on each link.

Hubbing is not the only means of increasing the level of traffic on individual links. Indeed, a much more common strategy in most public transportation systems is to establish linear route structures with relatively closely spaced stops This strategy has also been used in air transportation, where it is called "hedgehopping". However, the costs and passenger inconvenience entailed in making a stop is much greater in air transportation than it is in other modes As a result, post-deregulation route rationalization has involved a move away from hedgehopping and toward hubbing.

These considerations suggest that hubbing could increase productivity in a variety of ways First, airlines that hub could employ larger, more economical, aircraft while maintaining an acceptable level of service frequency. Second, such airlines could maintain higher load factors and still be able to offer most passengers a seat on their preferred flight. Third, the airline could choose to improve service rather than reduce cost[7] For example, instead of increasing the size of aircraft for a given service frequency, the frequency could be increased for a given size of aircraft. Finally, hubbing could allow airlines to avoid the frequent, costly, stops necessitated by hedgehopping.

Yet, there are are also ways in which hubbing can detract from productivity. First, although increased service frequency may result, so also does increased circuity and the inconvenience of transferring flights. On balance, therefore, there is no guarantee that hubbing improves the quality of service

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[7] Increased convenience can be viewed as a form of cost reduction in which the savings take the form of reduced expenditure of passengers' time and effort

experienced by passengers. Increased circuity also means that airlines must supply more passenger miles for a given origin-destination movement

The need to bank flights at the hub can also inhibit efficiency. If connections are to be convenient, arrivals and departures at the hub must be scheduled within a fairly short time period, during which terminal facilities are likely to become congested. The exchange of passengers and baggage between many different aircraft at the hub is complex and time-consuming, and departure of outgoing flights must await the completion of this process. These constraints can result in unavoidable delays as well as slack periods when resources are underutilized. While the concentration of operations at a single airport entailed by hubbing may increase productivity, the temporal concentration can have the opposite effect.

In summary, while there is a basis for associating increased productivity with increased hubbing, it is far from certain that airlines whose networks are more hubbed will actually be more efficient. The link between post-deregulatory trends in hubbing and airline productivity awaits empirical confirmation

3. Methodology

As the previous discussion shows, the productivity improvements deriving from hubbing can be realized in a variety of ways. On the one hand, costs can be decreased, while on the other service can be improved. Moreover, because these benefits arise as a result of increased traffic density, they must be assessed relative to the level of traffic in the markets being served. A complete analysis of the productivity effects of hubbing should therefore take into account the interrelated variables of cost, convenience, and size of market

The analysis presented here falls considerably short of this ideal. The question we attempt to answer is "do airlines that hub more incur lower costs?" Although less fundamental than the relation between hubbing and productivity, the relation between hubbing and costs is nonetheless important. In the first place, the former is a key component of the latter. Secondly, the studies of airline productivity trends cited earlier also isolate on airline costs. The analysis we undertake is therefore consistent with the research objective of relating changes in network structure and airline performance found in these studies.

To explore the relationship between productivity and costs, we analysed data for 13 airlines over the period from 1976 to 1984.[8] We used this data to develop economic cost functions relating output to factor prices and other variables, including the degree of hubbing.[9]

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[8] We considered those airlines used in Table 1, with the exception of Pan Am. To reduce data aquisition costs, we used annual data for even numbered years only. Special circumstances caused us use to eliminate seven observations, including Republic, 1976 and 1978 (airline formed in 1980); Northwest, 1978, Eastern and Ozark, 1980 (airlines were on strike for much of the year); and Brannif, 1982 and 1984 (airline ceased operations due to bankruptcy in 1982, and did not furnish Form 41 data for 1984) This left a total of 58 usable observations.

[9] The I.P Sharp Form 41 data base was the source of all our data When considering airlines with both domestic and international operations, we used data for domestic operations only

A fully specified cost function includes prices of all factors used in production. This presented a problem, because prices of many airline inputs are difficult to determine. We therefore assumed that, with the exception of labor, input prices faced by airlines in any given year were roughly the same This enabled us to substitute dummy variables corresponding to different years for non-labor factor prices. The dummy variables may also represent other cost-influencing factors that may change from year to year but are not explicitly included in the cost function specification.

Because of the great disparity in labor costs faced by different airlines, this variable was incorporated explicitly into our cost models. To assess labor costs, we employed a superindex number technique developed by Caves et al The procedure used the number of employees and associated labor costs in each of twelve personnel categories to compute a superlative index number measuring total labor input.[10] Total labor costs, including payroll and payroll taxes, fringe benefits, and other personnel expenses, was then divided by the index of input to obtain a measure of unit labor cost.

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[10] The index number is computed according to the formula:

$$\ln(L_k) = \sum_{\text{All } i} (W_{ik}+W_{i})(\ln(L_{ik}/L_{i}))/2,$$

where L_k is the index of labor input for observation k, W_{ik} is the share of total payroll going to employees in category i for observation k, $W_{i.}$ is the mean share (over all observations) of payroll for employees in category i, L_{ik} is the number of employees in category i for observation k, and $L_{i.}$ is the geometric mean (over all observations) of the number of employees in category i.

Superlative index numbers were also used to measure airline output. Two categories of output, revenue passenger miles and non-passenger revenue ton-miles, were considered These quantities, combined with the revenue generated by passenger and non-passenger traffic, were used to compute the output index.[11] It should be noted that this output measure does not reflect differences in circuity in the routings offered by different airlines. To the extent that hubbing increases circuity, this omission would tend to bias results in favor of this strategy On the other hand, a substantial effort would have been required to replace route miles with origin-destination miles Moreover, the studies of productivity cited previously also neglect circuity.

Total cost was computed as the sum of operating expenses and the opportunity cost of working capital. The latter was estimated as 15% of the stated total value of operating property and equipment, plus current assets, minus current liabilities

A Cobb-Douglas form, modified to allow for the use of dummy variables, was used to specify the cost function. This specification is consistent with a Cobb-Douglas production function Specifically, if the production function is assumed to take the form:

$$Y = F(OC)L^{a}X^{b},$$

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[11] The formula used was the same as that for labor input, except that two output categories replaced the twelve personnel categories, and revenue shares replaced payroll shares. The revenue shares were computed using data for scheduled services only, while the passenger- and ton-mileage data also included a small amount of non-scheduled service

where Y is output, F(OC) is a function of airline operating characteristics (including hubbing), L is the quantity of labor, and X is the quantity of other inputs, then there is an associated cost function,

$$C = (1/F(OC))Y^d W_L{}^e W_X{}^f,$$

where C is total cost, W_L is the unit cost of labor, and W_X is the unit cost of other inputs. If W_X is a function of time only, this equation can be modified to become:

$$C = (1/F(OC))Y^d W_L{}^e P(t).$$

When, as in our case, t takes only a few different values, $\{t_1,\ldots,t_n\}$, P(t) can be represented as:

$$P(t) = \mathrm{EXP}(\Sigma\, \beta_i D_i),$$

where D_i takes the value one when $t=t_i$ and the value zero otherwise. The exponential form is desirable because it can be linearized with a logarithmic transformation.

Airline costs are known to depend on several other variables in addition to output and factor prices. The most important of these are stage length, load factor, and size of aircraft operated. To control for these effects, we employed measures of average stage length (passenger-miles divided by number of passengers), load factor (passenger-miles divided by available seat-miles), and average aircraft capacity (available ton-miles divided by revenue plane-miles).[12] Because these variables may also mediate hubbing effects, we also tried some specifications without them.

An airline's costs may also be effected by the airports it serves. Large, congested airports result in greater delays, tighter scheduling constraints,

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[12] These variables were introduced in power form to maintain log-linearity.

and more circuitous flight paths In an effort to control for this effect, we included in our models the proportion of departures from three of the most congested airports O'Hare, Laguardia, and JFK Average delays at these airports were among the five highest in the U.S. thoughout the period under study [13]

To incorporate hubbing into our models, we chose to alternatively try each of the concentration measures used in Table 1. These measures, while highly correlated with one another, are sufficiently different to warrant seperate consideration of their influence on airline costs. The 1-airport concentration, for example, is not well-suited for systems with multiple hubs. The 4-airport concentration, while in some respects better suited to multiple-hub systems, fails to detect changes in the concentration of departures among the top four airports. Finally, the Herfindahl index avoids the above defects, but is also subject to influences unrelated to the phenomenon of hubbing.[14] It seemed preferable to try each of these measures rather than choose between their various shortcomings

In addition to the concentration measure, we also included the number of domestic points served by the airline. All other things being equal, the concentration of departures would be expected to decrease as the number of points being served increased. Thus, if route systems A and B are equally

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[13] The variable was introduced in exponential (rather than power) form because it took the value zero in several observations. It should be noted that several other airports are also recognized to be extremely congested, but had greater year-to-year fluctuations in their average delay levels than the three mentioned

[14] Specifically, the index is sensitive to changes in the distribution of departures among airports that are clearly not system hubs.

concentrated in terms of the measures we have defined, but A includes twice as many points, it seems reasonable to conclude that A is "more hubbed." This intuition implies that our analysis should control for the number of points We refer to the concentration measure and the number of points served collectively as the "network variables".[15]

Results

Tables 3, 4, and 5 present estimated coefficients along with their standard errors for the airline cost function under a total of twelve different specifications. The specifications differ with respect to which of the variables stage length, load factor, and capacity, as well which of the network variables, they include. Set I, the results for which appear in Table 3, controls for all three of the former variables. Specifications I-A contains no network variables. Specifications I-B, I-C, and I-D respectively include the 1-airport concentration, 4-airport concentration, and Herfindahl index, plus the number of points served. In the second set of specifications (Table 4), stage length, load factor, and capacity are excluded, while Set III (Table 5) includes stage length but not load factor or capacity. The network variables in Sets II and III correspond to those in Set I. Included with each specification is the coefficient of determination (R-square). Each specification involving network variables also includes the results of an F-test on the hypothesis that these variables do not effect costs (i.e., that their coefficients are zero) An F-statistic of roughly 3.2 or more is necessary to reject this hypothesis with a 95 percent degree of confidence.

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[15] The network variables were included in power form

Table 3 - Regression Results: Full Specification

SPECIFICATION	I-A	I-B	I-C	I-D
Output	0.99	1.00	1.00	1.01
	(.01)	(.01)	(.01)	(.02)
Labor Cost	0.18	0.19	0.23	0.20
	(.08)	(.08)	(.08)	(.08)
1976 Dummy	-0.40	-0.40	-0.39	-0.40
	(.04)	(.04)	(.04)	(.04)
1978 Dummy	-0.31	-0.32	-0.31	-0.31
	(.03)	(.03)	(.03)	(.03)
1982 Dummy	0.09	0.09	0.09	0.09
	(.02)	(.02)	(.02)	(.02)
1984 Dummy	0.03	0.02	0.02	0.02
	(.04)	(.03)	(.04)	(.04)
High Cost Airports	0.69	0.69	0.65	0.67
	(.11)	(.11)	(.11)	(.11)
Stage Length	-0.26	-0.27	-0.26	-0.28
	(.04)	(.04)	(.04)	(.04)
Load Factor	-0.68	-0.74	-0.72	-0.72
	(.14)	(.14)	(.14)	(.14)
Capacity	-0.28	-0.32	-0.31	-0.32
	(.05)	(.06)	(.06)	(.06)
Points Served	--	-0.05	-0.06	-0.04
	--	(.03)	(.03)	(.03)
1-Airport Concentration	--	0.02	--	--
	--	(.02)	--	--
4-Airport Concentration	--	--	-0.04	--
	--	--	(.05)	--
Herfindahl Index	--	--	--	0.02
	--	--	--	(.02)
R-Square	0.998	0.998	0.998	0.998
F-Statistic for H0: Network Variables=0	--	2.56	2.28	2.28

Standard errors in parantheses.

Table 4 - Regression Results: Stage Length, Capacity, and Load Factor Excluded

SPECIFICATION	II-A	II-B	II-C	II-D
Output	0.82	0.81	0.84	0.82
	(.03)	(.02)	(.02)	(.02)
Labor Cost	0.26	0.18	0.25	0.21
	(.19)	(.19)	(.17)	(.18)
1976 Dummy	-0.35	-0.36	-0.37	-0.37
	(.10)	(.09)	(.08)	(.09)
1978 Dummy	-0.31	-0.32	-0.34	-0.33
	(.06)	(.06)	(.05)	(.06)
1982 Dummy	0.04	0.05	0.05	0.05
	(.07)	(.06)	(.05)	(.05)
1984 Dummy	-0.01	0.03	0.04	0.04
	(.09)	(.08)	(.07)	(.08)
High Cost Airports	0.51	0.64	0.60	0.51
	(.29)	(.26)	(.27)	(.29)
Stage Length	--	--	--	--
	--	--	--	--
Load Factor	--	--	--	--
	--	--	--	--
Capacity	--	--	--	--
	--	--	--	--
Points Served	--	0.18	0.02	0.10
	--	(.06)	(.08)	(.07)
1-Airport Concentration	--	-0.06	--	--
	--	(.05)	--	--
4-Airport Concentration	--	--	-0.40	--
	--	--	(.12)	--
Herfindahl Index	--	--	--	-0.13
	--	--	--	(.06)
R-Square	0.983	0.988	0.989	0.987
F-Statistic for H0: Network Variables=0	--	6.97	12.53	8.86

Standard Errors in Parantheses

Table 5 - Regression Results: Capacity and Load Factor Excluded

SPECIFICATION	III-A	III-B	III-C	III-D
Output	0.97	0.97	0.97	0.97
	(.01)	(.02)	(.02)	(.02)
Labor Cost	0.07	0.07	0.09	0.06
	(.08)	(.09)	(.09)	(.09)
1976 Dummy	-0.42	-0.42	-0.42	-0.42
	(.04)	(.05)	(.04)	(.05)
1978 Dummy	-0.36	-0.36	-0.36	-0.36
	(.03)	(.03)	(.03)	(.03)
1982 Dummy	0.10	0.10	0.10	0.11
	(.03)	(.03)	(.03)	(.03)
1984 Dummy	0.08	0.08	0.08	0.08
	(.04)	(.04)	(.04)	(.04)
High Cost Airports	0.77	0.77	0.76	0.78
	(.14)	(.15)	(.15)	(.15)
Stage Length	-0.46	-0.47	-0.46	-0.47
	(.03)	(.04)	(.04)	(.04)
Load Factor	--	--	--	--
	--	--	--	--
Capacity	--	--	--	--
	--	--	--	--
Points Served	--	-0.01	-0.03	-0.002
	--	(.03)	(.04)	(.04)
1-Airport Concentration	--	0.004	--	--
	--	(.03)	--	--
4-Airport Concentration	--	--	-0.05	--
	--	--	(.07)	--
Herfindahl Index	--	--	--	0.01
	--	--	--	(.03)
R-Square	0.997	0.997	0.997	0.997
F-Statistic for H0: Network Variables=0	--	0.06	0.32	0.11

Standard errors in parantheses.

In general, the estimates presented have predicted signs and reasonable magnitudes The output coefficient is very close to unity when stage length is controlled for, suggesting an absence of firm-level scale economies.[16] The labor cost coefficient, while consistently positive, is somewhat lower than expected -- labor costs account for roughly 35 percent of total airline operating expenses -- and is significant at the .05 probability level only when stage length, capacity, and load factor are included in the model. Colinearity of labor cost with these other variables, with the yearly dummy variables, or deficiencies in the cost index employed,[17] could account for these results The yearly dummy variables suggest steadily rising costs between 1976 and 1982, with 1984 cost levels returning to the approximate level of 1980 (the "control" year in our model), a pattern which accords with fuel price trends although it may be influenced by other factors as well. Use of high cost airports appears to substantially increase total costs an airline with one fourth of its departures originating from the three airports so identified would incur costs 20 percent greater than an indentical airline

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[16] When stage length is not controlled for, the coefficient is significantly less than unity. This reflects continued dominance of long-haul markets on the part of large carriers

[17] Specifically, the index was based on numbers of employees rather than the amount of time worked.

with no such departures[18] Finally, the estimated stage length, load factor, and capacity limits all fall within reasonable bounds.[19]

The coefficients on the network variables in specifications I-B, C, and D are quite low. With one exception (the number of points served in I-C), none of the coefficients are significant at the .05 level. Nor, on the basis of the F-statistics, can the hypotheses that the network variables have no effect be rejected. Thus, it appears that when stage length, capacity, and load factor are controlled for, the degree of hubbing does not affect airline costs. The apparent lack of cost saving when these variables are controlled for is not too surprising in light of the discussion of the last section, where it was argued that the productivity enhancement occurs as a result of the higher load factors and/or larger aircraft. On the other hand, it is notable that more strongly hubbed airlines do not experience higher costs, controlling for aircraft size and load factor. If, as speculated above, the temporal concentration of operations at hub airports causes inefficient resource utilization, higher costs would be expected to result. Our results give no indication of this effect.

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[18] Assuming a coefficient of 0.7: exp(0.7/4)=1.19. The one-fourth figure represents the largest proportion of departures from these airports found in our data. This is a surprisingly strong effect, which almost certainly includes more than the direct costs of delay, but what other factors are involved is not immediately apparent.

[19] The load factor estimate of -0.75, for example, is consistent with the proportion of total costs that are "traffic specific", such as expenditures for food, service, and reservations and sales (Bailey et al., 1985, p. 49). In 1981, such costs amounted to 22% of the total incurred by the trunk airlines. This would imply a load factor cost elasticity of -(1.00-0.22) or -0.78, quite close to our figure.

A much different picture of the importance of hubbing emerges when the second set of specifications are considered. When neither stage length, capacity, or load factor are controlled for, estimated coefficients on network variables increase markedly in magnitude. In specification II-B, the number of points on the network appears to significantly increase costs, while in II-C and II-D increased concentration appears to have a substantial cost-reducing effect. (A strong negative correlation between the number of points and the 4-airport concentration and Herfindahl index may account for the results in II-B.) In all three cases, F-tests justify rejection of the hypothesis that the network variables do not affect costs. Rather, airlines with more concentrated operations and/or serving fewer points seem to be significantly more economical.

The increased importance of the network variables in specification II reflects the correlation between them and stage length, capacity, and load factor, as shown in Table 6. To justify excluding these latter variables, one would have to assume that this correlation reflects causality: that longer stage lengths, larger aircraft, and higher load factors result from increased hubbing. We have already argued that such causal relationships may exist between hubbing and aircraft size and hubbing and load factor. It remains to be considered whether a similar causal relationship could underly the correlation between hubbing and stage length. In fact, there is no apparent basis for such a relationship. On the contrary, one would expect that replacing direct, point-to-point service with hubbed service would decrease stage-lengths.[20] The positive correlation between stage length and hubbing suggested by our data is most likely the result, not of a causal relationship, but rather of simultaneous changes in the degree of hubbing and the type of routes served

Table 6 - Correlations between Network Variables and other Operating Characteristics

Network Variable	Stage Length	Load Factor	Capacity
Points Served	-0.042	0.113	-0.068
1-Airport Concentration	0.310	0.272	0.261
4-Airport Concentration	0.638	0.228	0.605
Herfindahl Index	0.414	0.202	0.357

Note: Correlations based on log-transformed variables.

This pattern is most pronounced in the experience of the local service carriers. With deregulation, carriers like Frontier, Ozark, Piedmont, and USAir, were able to offer service on long-haul routes for which they had previously provided feeder service. In exploiting this opportunity, they employed a strategy of establishing service on routes between a single airport in their traditional service area and distant points. USAir, for example, began to offer service between Pittsburgh and several cities in

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[20] Increased hubbing could result in longer average lengths between stops if it led to a reduction in hedgehopping. This would not effect our stage length variable, however, because it is based on enplanements A passenger is considered to be enplaned on a flight only once, regardless of the number of stops it makes

West and South. Likewise, Frontier, Ozark, and Piedmont established long haul service out of Denver, St. Louis, and Charlotte, respectively. As a result, local service passenger-miles on routes over 500 miles more than doubled between 1978 and 1981.[21] Table 1 documents the vast increase in the concentration of departures among these carriers. The Herfindahl indexes for Ozark and Frontier, for example, more than tripled between 1976 and 1984, while those for Piedmont and USAir nearly doubled.

Trunk carrier stage lengths, while not increasing as dramatically as those of the locals, have also edged upward since deregulation In this case, stage length growth has been the result of exit from short-haul markets rather than entry into long-haul ones. Eased restrictions on exit, joint-fare requirements that tended to make short-haul routes less profitable, and aircraft fleets better suited to long-haul service were the primary reasons for this shift. Thus, the trunks' route adjustments, like the locals', involved simultaneous changes in route mix and route structure, creating the spurious positive correlation between hubbing and stage length observed in our data.

As a consequence, stage length must be controlled for if the effects of hubbing on airline costs are to be accurately assessed. The second set of cost function specifications, by excluding a stage length variable, attribute to network variables effects that are largely the result of changes in service offerings. This motivates the third set of cost function specifications, in which stage length is controlled for, but load factor and capacity are not.

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[21] Bailey, Graham, and Kaplan, p.75.

In this set, as in the first, the estimated coefficients on the network variables are very low The magnitude of each of these coefficients is exceeded by its standard error, and F-statistics are extremely low. It therefore appears that the entire effect attributed to network variables in the second set of specifications is actually the result of service changes which occurred simultaneously with, but independently of, increased hubbing.[22] Just as hubbing doesn't increase costs, controlling for load factor and capacity, so also does it fail to decrease costs when these potentially mediating variables are not controlled for.

Conclusions

Our results suggest that the productivity effects of hubbing are not directly manifested in airline cost levels. When other relevant veriables are controlled for, airlines with strongly hubbed route systems incur roughly the same cost to provide a given amount of transportation as those with less hubbed systems. This finding, although succinctly stated, has ambiguous implications for the actual relationship between productivity and hubbing. The interpretation depends in large part on the nature of the process underlying the trend toward increased hubbing.

That trend can be understood in two distinct ways. In the first, a hubbed network is opposed to a linear one. Thus, increased hubbing implies the substitution of two-flight service, with a change at a hub airport, for one-flight (although perhaps multiple-stop), direct, service. This in turn implies

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[22] Similarly, the correlations between hubbing and load factor and between hubbing and capacity shown in Table 6 apparently result from each of these variables being correlated with stage length.

an increase in circuity and decrease in stage lengths, as well as possible increases in service frequency, aircraft size, and load factor. Our study looked for, and failed to find, cost saving effects deriving from increases in the latter two of these variables.

In the second interpretation, hubbing is seen as a consequence of increased vertical integration of trunk and feeder services by individual airlines. For local carriers, this means an expansion into long haul markets to which they had previously provided feed, while for trunks it implies increased self-feeding. These changes effect the route structures and operations of individual airlines, and lead to increased availability of single-line service. They do not, however, imply change of the overall route structure.

These differing conceptions of the hubbing process suggest different interpretations of our results. If increased hubbing is viewed in terms of a shift from linear networks, our results would imply that that hubbing entails higher costs as a result of increased circuity and shorter stage lengths. These effects are not seen directly because our cost functions control for stage length and don't take circuity into account. But insofar as our results give no indication of cost savings, they strongly suggest that hubbing would have a net cost-increasing effect if its circuity and stage-length implications were considered.

This would not necessarily mean that hubbing reduces productivity, for we have also failed to control for variations in service frequency and market density in our analysis. It is therefore possible that the airlines with strongly hubbed networks also serve thinner markets, provide more convenient service, or both.[23]

If hubbing is seen as a process of vertical integration of trunk and feeder services, our results take a different significance. In this case, they simply imply that vertical integration has not significantly effected the cost efficiency of the airline industry. Insofar as such integration improves service by facilitating connections, and without entailing additional costs, it would appear to be a desirable strategy. Of particular note in this regard is our finding that hubbing does not significantly increase costs when stage length, capacity, and load factor are controlled for. This suggests that the efficiency losses stemming from banked schedules are either not very great, or are not internalized by airlines with strongly hubbed networks.

Our investigation does not, therefore, yield definitive conclusions, but it does clarify some important issues. The most important concerns the nature of the hubbing process. Does it imply a fundamental change in the structure of airline networks, or is it merely the result of increased integration of trunk and feeder, or (more likely) does it involve both of these? A related issue pertains to the appropriate level at which to study the effects of hubbing. Is it valid to use the individual airline as the unit of analysis in such an inquiry, or must one consider the industry as a whole? Finally, the ambiguity of our results demonstrates a critical need to refine our concept of airline "output." The significance of a mile of air travel depends upon circuity of route, convenience of schedule and connections, and density of market. These factors must be accounted for before airline productivity, or any connections between this and other variables, can be adequately assessed

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