COST ECONOMIES AND CONSOLIDATION IN THE U.S. AIRLINE INDUSTRY

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June, 1990

Working Paper No. 185

Working Paper Series
Department of Economics, Finance
and Legal Studies
College of Commerce and Business
Administration
University of Alabama

Preliminary - Not for quotation or citation. Comments appreciated.

The authors thank Paul Thistle and Harold Elder for helpful discussion. The usual caveats apply.

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Abstract

Cost economies provide a rationale for recent consolidation in the U.S. passenger airline industry. This paper presents estimates of cost economies for three periods-- immediately before deregulation, immediately following deregulation and a later period that precedes the substantial change in market structure associated with the consolidation movement in the late 1980's. Estimates of costs across time reveal economies of scope and traffic density but not economies of scale, and the extent of the economies have changed during the deregulation process. There is some justification for mergers on the basis of achieving economies of scope and density.

I. Introduction

Deregulation of U.S. airlines represented a radical change in public policy that was based on both long standing economic theory of competition as well as new developments in the contestability of markets. Theory, old and new, considered whether the industry would work effectively in an unregulated environment. The conclusions of the theories differ on the role of economies of scale. In the traditional analysis of cost structure the existence of significant scale economies would necessitate an oligopoly or monopoly market with accompanying inherent inefficiencies, but contestability theory suggests that scale economies need not be a barrier to entry and that concentrated markets may be efficient. In the process of deregulation airlines may have been able to internalize cost economies that were not foreseen under regulation. The new freedom to adopt efficient route structures may have created cost based incentives that led to increased consolidation in the industry structure. This paper investigates this issue by reevaluating the presence of cost economies.

The question of cost economies has become more complex with the addition of the concepts of economies of density and scope. Early studies of the cost structure of airlines, reviewed by Lawrence J. White (1979), considered only economies of scale at the firm level. Results were consistent and emphatic that major airlines had already reached the size at which they captured all available economies and the industry was not a natural monopoly.

White's conclusion was equally definitive concerning the effects of cost structure on consolidation; the nature of airline costs would assure that deregulation would not lead to efficiency seeking increases in market concentration. Recent research has explored airlines as multiproduct firms and distinguished between economies of scale and those of density and scope. The findings of significant economies of density (Caves, Christensen and Tretheway, 1984) and that airline markets are failing tests of contestability (Graham, Kaplan and Sibley, 1983; Morrison and Winston, 1986; Sinha, 1986) compel reconsideration of the effects of cost structure on airline consolidation.

As well known, the industry initially attracted scores of new entrants following deregulation and market concentration diminished (Adrangi, Gritta and Chow, 1986). But, firms engaged in price discrimination schemes on a scale not imagined during regulation (Borenstein and Stein, 1989) and merger waves in 1986 and 1989 left significantly fewer firms. The phenomenon of the hub and spoke route system, which greatly expanded following deregulation, has increased the concentration in city pair markets and at particular airports. The pre deregulation evidence of airlines' cost structure would lead one to expect an industry which would support more small firms, rather than the extensive consolidation that has occurred.

Empirical questions remain about both the behavior of firms and rising concentration and the role of the cost structure in explaining them. Regulation may have prevented the measurement and consideration of the complexities of the airline cost structure and the evidence from previous empirical studies may be misleading. To investigate this issue the magnitude of economies of scale, scope and density need to be measured in a consistent fashion under regulation and deregulation with particular attention focused on the stability of the economies across regimes and over time. This approach permits us to examine whether the cost structure provides a compelling explanation of recent mergers and consolidation in the airline industry. To carry out our study we use a unique data set constructed by Formby, Keeler and Thistle (1990) and the translog cost function to estimate economies of scale, scope and density for three distinct time periods.[1]

The remainder of the paper is organized as follows. Section II briefly discusses the concepts of economies scale, scope and density with reference to the airline industry. Section III

1. We use firm specific quarterly data. Some of the data were published by the CAB, but much of it was collected from the Form 41s for each airline, which is the original reporting document. These data, while unpublished, are publicly available and permit meaningful economic measures of factor use and costs. The data also allow estimation of the translog cost function's many parameters within a narrow time period through pooling firm-level data over time. Other estimates of airline cost functions [e.g. Caves, Christensen and Tretheway 1983, 1984 and Graham, Kaplan and Sibley (1983)] have relied on either cross-sections with relatively few observations or industry-level annual data for relatively long time periods. The details of the data set are provided in Formby, Keeler and Thistle (1990). It is worth noting that Formby, Keeler and Thistle (1990) investigate whether the reductions in costs that were widely anticipated in the deregulation debates actually materialized. Accordingly, they consider shifts in the cost function across time, but do not analyze the structure of costs or investigate economies of scale, scope or density nor do they consider the issue of consolidation in the industry.

presents the results and discusses their implications. The final section provides brief concluding remarks.

II. The Concepts of Economies of Scale, Scope and Density

The notion that a larger firm may be more efficient in the production of its output has evolved with the recognition of the related concepts of economies of scope and density as distinct from scale. This distinction recognizes that firms can become "larger" in a variety of ways with different implications for the nature of competition in an industry.

It has been suggested that airlines experience indivisibilities in their ground operations such as ticket counters, gates, maintenance, inventory of aircraft parts and computer reservations systems and in aircraft equipment (Labich, 1986) or in the costs of providing information about routes and fares (Levine, 1987). Larger firms can specialize to a greater degree in aircraft types, better utilize the technology embodied in large aircraft types and cover both more routes and a larger geographic area. Such indivisibilities suggest that airlines may not be just "marginal costs with wings", and may have possibilities for economies of scale, especially under deregulation with no restrictions on routes or equipment.

The general and preferable definition of scale economies is, allowing all inputs to be adjusted optimally and allowing choice among existing technologies, long run average cost decreases with the scale of output (Panzar and Willig, 1977, 486). A measure of economies of scale for a single output firm was provided by Christensen and Greene (1976, 661) as unity minus the cost elasticity of output. An alternative and more widely used expression is the inverse of the cost elasticity of output, with economies of scale indicated by a value greater than unity, constant returns to scale by unity and diseconomies of scale by a value less than unity. For a multiproduct cost function, the extension of the measure is the inverse of the sum of cost elasticities of all outputs (Brown, Caves and Christensen, 1979, 266; Panzar and Willig, 1977, 488):

$$\text{Returns To Scale} = \left[\sum_{i=1}^{n} E(C, Q_i)\right]^{-1} \qquad (1)$$

This measure has been employed in most recent empirical work for airlines (Caves, Christensen and Tretheway, 1984; Caves and Christensen, 1988) and for other modes of transportation (Caves, Christensen and Swanson, 1981; Harmatuck, 1981; Kim, 1987). Like the work surveyed by White, the more recent research has found no evidence of economies of scale for airlines, even for smaller U.S. national and regional airlines.

For a multiproduct firm, economies of scope imply it is "less costly to produce two or more product lines in one firm than to produce them separately" (Panzar and Willig, 1981, 268). The sources of scope economies are joint and common costs; costs that are shared by production processes so that the use of a resource by one process leaves capacity for use by another process. Joint production allows some of the "sharable input" to be conserved without increasing use of other inputs (Panzar and Willig, 1981, 269).

Airlines have the opportunity for economies of scope between passenger and freight traffic. The design of the aircraft makes the space available in varying proportions, so that costs of operating the aircraft will be common to the two outputs. Computer reservations systems and the hub and spoke route system appear to allow economies of scope in the provision of information about airlines' schedules (Levine). Joy (1986, 249), however, has noted that the airlines' actions imply the existence of diseconomies of scope with regard to certain outputs. As in the U.S., the major Australian airlines tend not to operate routes which would require use of much smaller aircraft. Separately owned or operated commuter airlines flourish in those markets. U.S. airlines combine freight and passenger service, but have generally eliminated their all-freight flights and the air freight market is dominated by all-freight carriers. The major airlines engage in a small amount of charter service but, again, the charter market is dominated by all-charter airlines. Thus, major passenger carriers produce other outputs to the extent that joint or common resources provide capacity at low opportunity cost, but they do not in general produce these outputs with processes that are separate from passenger service.

A more formal measure of economies of scope is whether the marginal cost of one output, within a multiproduct firm is affected by the level of the firm's other products. If there are economies of scope, the partial derivative of the marginal cost expression for one output with respect to another output would be negative:

$$\frac{\partial MC_i}{\partial Y_j} < 0, \qquad (2)$$

where MC_i is the marginal cost for output Y_i and Y_j is another output (Kim, 1987, 736; Harmatuck, 1981, 147).

Economies of density refer to cost reductions as the same volume of passengers is carried in geographically more concentrated patterns (Bailey and Baumol, 1984). A firm realizing economies of density more intensively utilizes ground and terminal facilities. Vehicle size may increase, and it has been most commonly found that capacity increases proportionately more than the costs of constructing or powering larger vehicles. In earlier research Meyer, Peck, Stenason and Zwick (1959, 136) claimed that increases in the size of aircraft do not increase fuel or operating labor costs as much, and were therefore a source of economies of scale. Similarly, economies of density were sometimes referred to as economies of scale at the city pair or route level, or as economies of aircraft size (Bailey and Panzar, 1981, 126-127). Other writers (Harris, 1977; White, 1979; Caves, Christensen and Tretheway, 1984; Kirby, 1986) have distinguished economies of density from those of scale because traffic density and scale of output can be changed independently.

Since deregulation, firms have been able to alter their route network in ways that were not possible under regulation. Light density routes have been abandoned and firms have changed from linear route systems to hub and spoke systems. The use of hubs concentrates traffic at a regional airport, increases the number of passengers flying to another hub and allows the airline to retain more of its passengers rather than interchange with other airlines (Ellison, 1982; Phillips, 1985). As a measure of economies of density, Caves, Christensen and Tretheway (1984, 474) consider the effect on cost as output increases while the number of airports served is held constant, and a more general measure is the cost elasticity with respect to density.

The scale of operation, the scope across various outputs and the density of traffic can all have important and independent effects on cost and distinct firm behaviors would be necessary to capture each of these economies. Whether the different economies exist for airlines and the magnitudes of their potential benefit are empirical questions. If the economies are large or have increased during deregulation, they could provide a justification for recent consolidations in the airline industry

III. Estimates of Economies of Scale, Scope and Density

The change from regulation to deregulation provided U.S. air carriers with substantial latitude for changing routes, modifying operations and consolidating markets. Figure 1 shows the mergers among the major firms and displays how extensive the effects of the unexpected concentration have been. Numerous mergers since 1986 have significantly reduced the number of firms in the industry and few new entrants survive as independent operators. Concentration has increased both on a national level and when individual city pair markets are considered. The major firms now account for about ninety percent of passenger miles, up from eighty percent in 1980 (Graham, Kaplan and Sibley, 1983, 120), and on a local scale a number of major airport hubs are now dominated by individual carriers.

To describe and measure the behavior of costs during the process of these important changes, data were obtained for U.S. airlines for three sample periods, at the end of regulation (1976:1 - 1977:4), immediately following deregulation (1979:3 - 1981:2) and after a period of adjustment to the deregulation environment (1984:1 - 1985:4).[2] Table 1 presents summary information describing the types and magnitudes of cost changes that have occurred for the major airlines for each of these periods. All costs are in real terms. Airlines greatly increased scale, especially passenger service and have moderately increased freight service with the consequent decrease in the freight share of output. Traffic Density, defined as the ratio of passengers in thousands to number of points served, showed a decrease from the first to the second sample but has increased significantly since then. Aircraft Utilization, revenue hours per aircraft operated per day, increased and then decreased, though increasing use of the hub and spoke system should have produced an increase in utilization. Flight Stage Length increased as major airlines exited from the short distance routes

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2. The selection of sample periods avoids recessions, which have a severe distorting effect on airlines. In particular, the second sample period ends before the severe recession that began in 1981:3. The third sample period was chosen to avoid the wave of mergers that began in 1986.

and intermediate stops required by regulation and extended from regional to national markets. The Load Factor increased due to exits from light density markets. One possibility raised by these changes is that the existence, sources and extent of the economies may have changed over these three time periods.

Measures of cost economies and an analysis of the stability of the economies across regimes and over time requires an estimate of the cost function and relevant cost elasticities. The cost function is specified as:

$$C = f(Y_i,\ P_i,\ Z_i), \tag{3}$$

where total cost, C, is a function of a vector of outputs, Y_i (passengers and freight), a vector of input prices, P_i (labor, capital, fuel and all other inputs) and a vector of operating characteristics, Z_i (traffic density, aircraft utilization, flight stage length and load factor). A full description of the estimate is available in Formby, Keeler and Thistle (1990). The firms included in each estimate are those listed in Table 1.[3] Total cost is measured as the total operating expense including depreciation, plus the opportunity cost for the flight equipment operated by the firm. All monetary measures are converted into real terms by dividing by the GNP price deflator. All variables

3. Unlike other studies of airline costs we exclude the smaller national carriers from our sample. There are two reasons for restricting the sample to major airlines. First, the aircraft fleets of the majors and the nationals are noncomparable. Second, the operating characteristics of the majors and the nationals are sufficiently different that it does not appear reasonable to expect a single cost function to adequately characterize both types of carriers.

are normalized as the ratio to the average for the full sample and are in natural logarithms. Available passenger seat-miles and Available ton-miles of freight are the two major outputs representing over ninety percent of revenue. Prices of four inputs are measured for each firm; labor expense including salary, fringe benefits and payroll taxes divided by the number of employees, fuel expense divided by the number of gallons used, the rental price of capital is constructed according to a method due to Jorgenson (1963) and the expense for all other inputs is divided by available ton-miles.

The translog functional form of the cost function is:

$$
\begin{aligned}
\ln C = {} & A_0 + \sum_{i=1}^{n} A_i \ln Y_i + \sum_{i=1}^{m} B_i \ln P_i + (1/2) \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} \ln Y_i \ln Y_j \\
& + (1/2) \sum_{i=1}^{m} \sum_{j=1}^{m} D_{ij} \ln P_i \ln P_j + \sum_{i=1}^{n} \sum_{j=1}^{m} E_{ij} \ln Y_i \ln P_j \\
& + \sum_{i=1}^{m} \sum_{j=1}^{r} F_{ij} \ln P_i \ln Z_i \\
& + \sum_{i=1}^{n} \sum_{i=1}^{r} G_{ij} \ln Y_i \ln Z_i + \sum_{i=1}^{r} H_i \ln Z_i \qquad (4)
\end{aligned}
$$

The factor cost share equations using Shephard's lemma are:

$$
S_i = B_i + \sum_{j=1}^{m} D_{ij} \ln P_j + \sum_{j=1}^{n} E_{ij} \ln Y_j + \sum_{j=1}^{r} F_{ij} \ln Z_j \qquad (5)
$$

Symmetry and linear homogeneity in factor prices imply the following restrictions:

$$D_{ij} = D_{ji}, \sum_{i=1}^{m} B_i = 1, \sum_{j=1}^{m} D_{ij} = 0, \text{ and } \sum_{j=1}^{m} E_{ij} = 0 \qquad (6)$$

The cost function (4) and the cost share equations (5) were estimated jointly by iterative seemingly unrelated regression with the restrictions (6) imposed at each iteration.

Abbreviated results are presented in Table 2. Only the coefficients that are relevant to calculation of the measures of cost elasticities are reported. Most of the coefficient estimates are significantly different from zero and have the expected sign. The estimates did not always meet the second order conditions in terms of the signs of the Hessians. The estimated factor shares and output elasticities were calculated to explore the problem and it lies only in negative cost elasticities for freight for some observations. That may be expected given the jointness of production of the two outputs. For most of the coefficients, there is remarkable consistency in the signs and magnitudes across the estimates for the three sample periods. The translog function provides a good estimate from which the measure of economies will be obtained.

Results are presented in Table 3. The measure of economies of scale is given by equation (1). Economies of scope are evaluated by checking the sign of the derivative in equation (2). Economies of density are measured by calculating the elasticity of total cost with respect to the traffic density variable, Z1, a procedure comparable to the method of Caves, Christensen and Tretheway (1984). The translog function is most appropriate because it imposes no restrictions on these elasticities and the measures may vary with changes in any of the independent variables, in particular the scale of output. It is assumed that input prices and operating characteristics other than traffic density are at the point of approximation which eliminates them from the calculation. Outputs are evaluated at their means (the point of approximation) and at the 25th and 75th percentiles, which are denoted minimum and maximum points.

The measure of returns to scale predominantly shows slight diseconomies of scale which vary with the scale of output. The small standard errors of the coefficient estimates in Table 2 mean that the sums of the cost elasticities of the outputs are not equal to unity. Thus, in general, the behavior of cost with respect to output is reversed from what would be expected if economies of scale existed. The diseconomies of scale are most pronounced for the period just before deregulation. The exception to the finding of slight diseconomies of scale is for the mean and larger scales in the 1979 - 1981 sample, which are characterized by slight economies of scale. More detailed calculations that are not shown in the Table indicate that returns to scale also vary with the combination of passenger and freight, with higher costs occurring more as proportions are more uneven. For the most recent sample period, the degree of diseconomies of scale is quite small indicating essentially constant returns to scale.

The signs of the partial derivative of the marginal cost of either output with respect to the other are consistently negative, implying economies of scope. The degree of economies is much less for the effect of more freight on the marginal cost of passenger service than for the converse. The jointness of freight and passenger service make this result expected. The degree of economies of scope has increased markedly over the three sample periods.

The cost elasticities of density are negative (for all but the mean and larger scales for the 1979 - 1981 period) implying economies of density. As expected, the results indicate that the potential for economies of density was much greater during the period of regulation than for the 1984 - 1985 period. Interestingly, the evidence indicates that an additional small potential remains. These results are consistent with the other studies that have found economies of aircraft size or density of traffic.[4]

We now focus on the implications of the findings for recent consolidations in the airline industry. First, given the pre-deregulation understanding of cost structure the recent merger wave appears anomalous and somewhat alarming in light of the many consistent studies that airlines did not have scale economies. This confirms that both before and after deregulation cost functions closely approximated constant returns to scale. Consequently, economies of scale in the airline industry do not create entry barriers nor do they provide a rationale for consolidation. There must be other explanations for the mergers.

4. Caves, Christensen and Tretheway (1984) also found constant returns to scale and significant economies of density, using a quite different dataset, but a similar time period. They estimate a cost elasticity of density at 0.13, suggesting that additional points can be added to the route structure with little effect on total cost.[

The results in Table 3 clearly indicate airlines had untapped potential for economies of scope and density at the time of deregulation, and mergers would be an important method of achieving them.

Most of the mergers that occurred in the 1980's were of two related types. Many of the mergers had an important "vertical" component in the sense that they combined small regional carriers with larger national airlines into which their traffic fed. Most of the other mergers had similar effects in that they combined airlines operating in different geographic regions. Examples of consolidations of this type include the mergers of Delta/Western and Trans World/Ozark. With the exception of Northwest/Republic, there have been no mergers between major carriers that were direct horizontal competitors. Thus, for the most part, recent mergers have created more extensive geographic route networks rather than directly reducing horizontal competition.

The dominant effect of the mergers in the latter half of the 1980's was to create route systems that are more effective in generating, consolidating and retaining passenger traffic on a single carrier's network. Such mergers are consistent with incentives to access economies of density made possible by consolidating traffic flows between hubs. They are also consistent with efforts to internalize economies of scope across services from spoke to hub and between hubs. The estimates in Table 2 and 3 indicate that economies of scope and density existed prior to deregulation and in the periods following. However, due to regulatory constraints these economies could only be accessed after airlines were given the freedom to adopt cost efficient route structures. Thus, rationalization of the route structure to obtain economies of scope and density offers an explanation of many of the vertical and geographical extension mergers that have occurred.

It should be noted, however, that it is evident from the composition of airlines' fleets that some of the economies of density are realized on the route level at relatively low overall firm scales. Smaller airlines such as Continental and Northwest were early adopters of large capacity aircraft and converted a large proportion of their fleet to these aircraft which capture economies of density. Our evidence indicates that the consolidations which have already occurred achieved a large part of the available economies of density. This suggest that the economies of density rationale for consolidation has basically run its course. However, the evidence suggests that there remains potential for internalizing additional economies of scope and this could possibly lead to additional consolidation of route structures.

While significant, the economies of scope and density demonstrated in this paper are not the only explanation for rising market concentration. Carlton, Landes and Posner (1980) identified strong attractions of a single carrier service that would create demand side benefits for merger. Gillen, Oum and Tretheway (1988) suggest that the product differentiation could be a barrier to entry. Levine (1987) concludes that cost economies are relatively unimportant compared with the contribution of various methods of price discrimination to revenue. Borenstein and Rose (1989) document the pervasiveness of price discrimination under deregulation and find a systematic relation of price dispersion to market structure. Thus, in addition to cost economies, firms have used price discrimination and quality of service to gain advantages over rivals. But this paper shows conclusively that significant economies of scope and density may also have playrd an important role promoting increased consolidation in the industry.

IV. Conclusions

Economies of scale, scope and traffic density derive from distinct causes and have different implications for firm behavior. These three concepts have application to the airline industry and the changes that have occurred since the period of regulation raise questions about the roles of these cost economies in the consolidation of the industry. Whether the cost structure of the industry is conducive to workable competition or contestability depends on the existence and importance of these economies.

Measures for each of the economies are defined and made operational through a translog cost function estimate. Separate estimates are made for three sample periods, before, immediately following and a period considerably after deregulation. Results indicate constant returns to scale or slight diseconomies but not economies of scale. Airlines have achieved much of the economies of traffic density with hub and spoke routes, but some potential remains. Economies of scope exist between passenger and freight services and between hubs and spokes and the potential has increased since deregulation.

Concerns about the consolidation of the airline industry are legitimate as recent tests of contestability have shown. However, estimates of the cost structure indicate that to some extent, consolidation has achieved cost economies and that some potential remains. Mergers are desirable if they achieve the remaining economies of density or scope, but the lack of economies of scale does not support further concentration among major airlines that are direct competitors. On the demand side, consolidation creates qualities of service unavailable in smaller airlines and creates potential for price discrimination, and the advantages may exceed those of cost economies. Further explanation of consolidation in the airline industry should explore demand as well as the cost structure.

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TABLE 1 - AVERAGE VALUES FOR VARIABLES
(per quarter)

Variable Name	1976-77	1979-81	1984-85	All
Total Cost ($000)	531 740	760 410	840 260	703 190
Available Seat Miles (000)	6 537 700	8 214 900	10 380 000	8 259 800
Available Ton-Miles of Freight (000)	307 000	321 600	366 050	329 520
Traffic Density	48.89	37.02	61.09	48.29
Aircraft Utilization	707.94	733.52	691.55	711.94
Flight Stage Length (miles)	654.32	695.41	724.76	689.54
Load Factor (%)	47.68	50.65	52.91	50.27
Freight Share of Output(%)	30.26	27.01	24.97	27.56
Firms Included:	American	American	American	
	Braniff	Braniff		
	Continental	Continental		
	Delta	Delta	Delta	
	Eastern	Eastern	Eastern	
	National			
	Northwest	Northwest	Northwest	
	Pan Am	Pan Am	Pan Am	
		Republic	Republic	
	Trans World	Trans World	Trans World	
	United	United	United	
	Allegheny	USAir	USAir	
	Western	Western	Western	

TABLE 2 - ESTIMATES OF THE TRANSLOG MULTIPLE OUTPUT COST FUNCTION FOR MAJOR U.S. PASSENGER AIRLINES

Independent Variable	Estimated Coefficient		
	1976-77	1979-81	1984-85
Intercept	.0855 (13.26)	.0263 (3.71)	-.0508 (-11.54)
Y_1-Available Passenger miles	.9750 (47.17)	.8833 (48.40)	.9216 (62.16)
Y_2-Available ton-miles of freight	.1220 (7.79)	.1069 (8.24)	.0921 (8.07)
Y_1*Y_1	.2575 (14.98)	.1580 (7.43)	.3342 (10.78)
Y_1*Y_2	-.1966 (-16.05)	-.1954 (-22.54)	-.2989 (-18.70)
Y_2*Y_2	.1486 (10.81)	.1863 (20.68)	.2519 (18.27)
Z_1-Traffic Density	-.0772 (-6.32)	.0121 (0.88)	-.0275 (-1.51)
Z_2-Aircraft Utilization	-.0435 (-2.07)	.0581 (1.94)	-.0596 (-1.69)
Z_3-Flight Stage Length	-.1773 (-9.69)	-.0533 (-2.30)	-.0626 (-2.44)
Z_4-Load Factor	.1213 (3.08)	-.0951 (-1.68)	-.0231 (-0.46)
Y_1*Z_1	-.0404 (-3.37)	.0200 (1.85)	-.0716 (-3.58)
Y_2*Z_1	.0402 (3.79)	.0058 (0.81)	.0691 (4.30)
n	96	96	80
$\bar{R}^2$	.99	.99	.99

The dependent variable is Total Cost. t-values are in parentheses.

TABLE 3 - ESTIMATES OF RETURNS TO SCALE, DENSITY AND SCOPE

I. Returns to Scale = $[\Sigma\ E(C,Yi)]^{-1}$

Outputs	1976-1977	1979-1981	1984-1985
Minimum	0.9168	0.9728	0.9703
Mean	0.9116	1.0099	0.9881
Maximum	0.9238	1.0274	0.9951

II. Returns to Scope = $\partial \ln MC_1/ \partial \ln Y_2$ and $\partial \ln MC_2/ \partial \ln Y_1$

Outputs		1976-1977	1979-1981	1984-1985
Minimum	Y_1	-0.0603	-0.1133	-0.2301
	Y_2	-0.3832	-1.0954	-2.5106
Mean	Y_1	-0.0796	-0.1143	-0.2323
	Y_2	-0.6365	-0.9446	-2.3254
Maximum	Y_1	-0.0486	-0.1110	-0.2305
	Y_2	-0.2685	-0.8098	-2.0941

III. Returns to Density = $E(C, Z_1)$

Outputs	1976-1977	1979-1981	1984-1985
Minimum	-0.0780	-0.0090	-0.0371
Mean	-0.0772	0.0121	-0.0275
Maximum	-0.0656	0.0215	-0.0217

TABLE 1 - AVERAGE VALUES FOR VARIABLES
(per quarter)

Variable Name	1976-77	1979-81	1984-85	All
Total Cost ($000)	531 740	760 410	840 260	703 190
Available Seat Miles (000)	6 537 700	8 214 900	10 380 000	8 259 800
Available Ton-Miles of Freight (000)	307 000	321 600	366 050	329 520
Traffic Density	48.89	37.02	61.09	48.29
Aircraft Utilization	707.94	733.52	691.55	711.94
Flight Stage Length (miles)	654.32	695.41	724.76	689.54
Load Factor (%)	47.68	50.65	52.91	50.27
Freight Share of Output(%)	30.26	27.01	24.97	27.56
Firms Included:	American Braniff Continental Delta Eastern National Northwest Pan Am Trans World United Allegheny Western	American Braniff Continental Delta Eastern Northwest Pan Am Republic Trans World United USAir Western	American Delta Eastern Northwest Pan Am Republic Trans World United USAir Western	

TABLE 2 - ESTIMATES OF THE
TRANSLOG MULTIPLE OUTPUT COST FUNCTION
FOR MAJOR U.S. PASSENGER AIRLINES

Independent Variable	Estimated Coefficient		
	1976-77	1979-81	1984-85
Intercept	.0855 (13.26)	.0263 (3.71)	-.0508 (-11.54)
Y_1-Available Passenger miles	.9750 (47.17)	.8833 (48.40)	.9216 (62.16)
Y_2-Available ton-miles of freight	.1220 (7.79)	.1069 (8.24)	.0921 (8.07)
Y_1*Y_1	.2575 (14.98)	.1580 (7.43)	.3342 (10.78)
Y_1*Y_2	-.1966 (-16.05)	-.1954 (-22.54)	-.2989 (-18.70)
Y_2*Y_2	.1486 (10.81)	.1863 (20.68)	.2519 (18.27)
Z_1-Traffic Density	-.0772 (-6.32)	.0121 (0.88)	-.0275 (-1.51)
Z_2-Aircraft Utilization	-.0435 (-2.07)	.0581 (1.94)	-.0596 (-1.69)
Z_3-Flight Stage Length	-.1773 (-9.69)	-.0533 (-2.30)	-.0626 (-2.44)
Z_4-Load Factor	.1213 (3.08)	-.0951 (-1.68)	-.0231 (-0.46)
Y_1*Z_1	-.0404 (-3.37)	.0200 (1.85)	-.0716 (-3.58)
Y_2*Z_1	.0402 (3.79)	.0058 (0.81)	.0691 (4.30)
n	96	96	80
$\bar{R}^2$	.99	.99	.99

The dependent variable is Total Cost. t-values are in parentheses.

TABLE 3 - ESTIMATES OF RETURNS TO SCALE, DENSITY AND SCOPE

I. Returns to Scale = $[\Sigma\ E(C,Yi)]^{-1}$

Outputs	1976-1977	1979-1981	1984-1985
Minimum	0.9168	0.9728	0.9703
Mean	0.9116	1.0099	0.9881
Maximum	0.9238	1.0274	0.9951

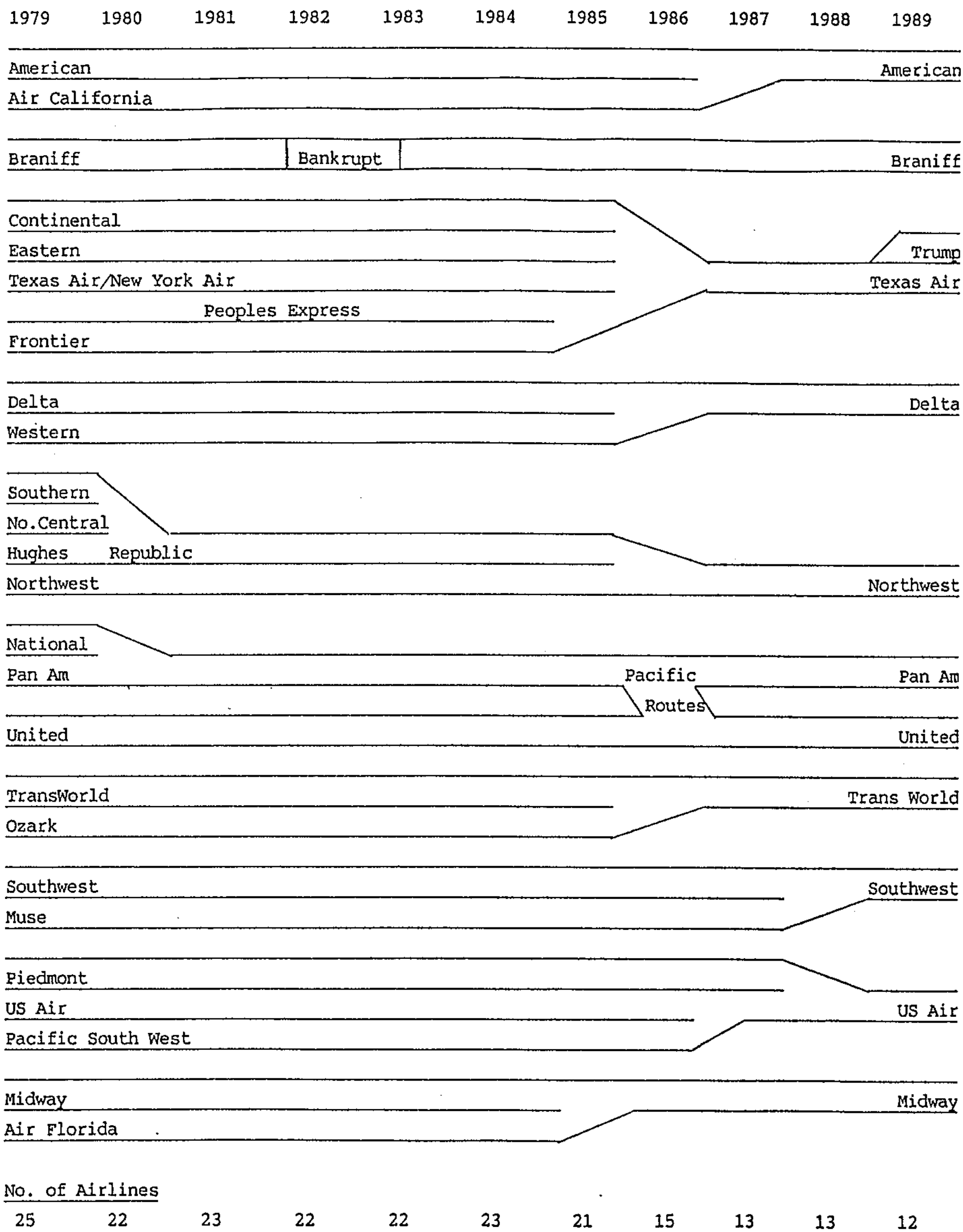
II. Returns to Scope = $\partial \ln MC_1 / \partial \ln Y_2$ and $\partial \ln MC_2 / \partial \ln Y_1$

Outputs		1976-1977	1979-1981	1984-1985
Minimum	Y_1	-0.0603	-0.1133	-0.2301
	Y_2	-0.3832	-1.0954	-2.5106
Mean	Y_1	-0.0796	-0.1143	-0.2323
	Y_2	-0.6365	-0.9446	-2.3254
Maximum	Y_1	-0.0486	-0.1110	-0.2305
	Y_2	-0.2685	-0.8098	-2.0941

III. Returns to Density = $E(C,\ Z_1)$

Outputs	1976-1977	1979-1981	1984-1985
Minimum	-0.0780	-0.0090	-0.0371
Mean	-0.0772	0.0121	-0.0275
Maximum	-0.0656	0.0215	-0.0217

Figure 1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American
Braniff
Bankrupt
Braniff
Continental
Eastern
Texas Air/New York Air
Peoples Express
Frontier
Trump
Texas Air
Delta
Western
Delta
Southern
No.Central
Hughes
Republic
Northwest
Northwest
National
Pan Am
Pacific
Routes
Pan Am
United
United
TransWorld
Ozark
Trans World
Southwest
Muse
Southwest
Piedmont
US Air
Pacific South West
US Air
Midway
Air Florida
Midway
No. of Airlines
25 22 23 22 22 23 21 15 13 13 12