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An Empirical Study of Cost Drivers in the U.S. Airline Industry

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SYNOPSIS AND INTRODUCTION: Recent research on cost driver analysis by Miller and Vollman (1985) and Cooper and Kaplan (1987) suggests that transactions deriving from the diversity of a firm's product line and the complexity of its production process, in addition to output volume, drive overhead costs. As a consequence, it is argued, conventional cost accounting systems based only on volume-related measures, such as units of output, direct labor hours, or machine hours, produce biased and materially misleading cost estimates for managerial decisions on price and product line (whether to continue or discontinue products, or to offer additional products). Systematic biases in cost estimates may also lead to distortions in flexible budgeting systems, variance analyses, and responsibility-accounting systems. Perhaps more important in the long run, omission of operations-based cost drivers may distort the investigation of the likely effects on costs of changes in operating strategies.

Many firms have moved ahead on the basis of this perceived need for more accurate cost estimates and have designed and implemented activity-based costing systems (Schiff 1991). From an academic perspective, however, there is a need for further formal empirical research in this field. Cooper and Kaplan's (1987) evidence is based on field-study discussions with managers in a variety of manufacturing settings and experimentation with cost allocation and product-costing systems based on transactions.

Foster and Gupta (1990) provide some of the first empirical evidence on the correlation of manufacturing overhead with output volume and operations-based measures that reflect characteristics of the manufacturing process. Using data obtained from 37 plants of a single manufacturing firm, Foster and Gupta found that most of the volume-related measures of output

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were highly correlated with manufacturing overhead (MOH), but because only a few measures of manufacturing complexity and efficiency were highly correlated with MOH, their findings leave the impression that systems based on just volume may not significantly distort information generated for managerial decision making.[1] In contrast, we find empirical evidence in favor of incorporating operations-based cost drivers along with measures of volume in cost driver models.

We draw upon previous work in cost accounting and economics to develop analogs in the airline industry for product diversity, production run volumes, and process complexity, and propose a framework for cost driver analysis in the U.S. airline industry. Using a panel of quarterly data for 1981-1985 compiled primarily from traffic and financial statistics submitted by carriers to the Civil Aeronautics Board (CAB) and Department of Transportation (DOT), we specify and estimate a multivariate system of cost functions with multiple cost drivers for the industry during the transition following deregulation. We find both volume- and operations-based cost drivers to be statistically significant. We also demonstrate the potential managerial importance of the operations-based drivers by explaining variations in marginal costs across airlines in terms of operating strategies reflected in the cost driver values.

Empirical cost driver analysis is managerially significant for the industry and period that we examine. The proportion of indirect costs is large, and identification of input consumption for specific services is difficult. During the transition following deregulation, carriers adopted a rich variety of strategies to improve productivity, reduce costs, and increase market share. These strategies directly involved both volume- and operations-based cost drivers. The analytical framework and model that we have developed on the basis of prior literature concerned with the airline industry enable us to examine the differential cost effects of some of the most important strategies adopted.

Key Words: *Cost drivers, Volume-based drivers, Capacity, Operations-based drivers, Cost estimation, Airline industry, Hub-and-spoke strategy, Benchmarking, Variance analysis.*

Data Availability: *Airline cost and production data can be purchased from the Department of Transportation. Data used for this study are available from the authors to researchers willing to share the cost of acquisition.*

THE article is organized as follows. The cost driver model is developed in section I, and the data and estimation procedure are described in section II. In section III, we discuss the empirical findings, focusing on the statistical significance of the operations-based cost drivers that represent strategic choice variables. Section IV

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[1] Foster and Gupta (1990, 310) state that "there is not a strong association between complexity or efficiency variables and MOH levels across the 37 facilities." Banker et al. (1992), however, show that Foster and Gupta's partial correlation approach will tend to bias the test statistic downward, which makes the rejection of the null hypothesis of no association less likely than indicated by the apparent significance level.

contains a discussion of the cost implications of operating choices and an explanation of the variations in the airlines' marginal costs in terms of the cost drivers. Concluding remarks are offered in section V.

I. Cost Driver Model

We model the airline industry cost function as a linear multivariate system of equations to test the importance of volume- and operations-based cost drivers. The model has ten equations, one for each of ten distinct input cost categories. The dependent variables are physical units of inputs, such as labor hours and gallons of fuel, or input costs deflated by appropriate indices. Each equation has its own set of volume- and operations-based drivers as independent variables, depending on theoretical considerations appropriate to the corresponding input. Cost estimates are obtained by multiplying the physical quantities by appropriate prices.

The system of equations is additive and separable with respect to inputs, as in a Leontief-type production process, to reflect the limited possibilities for substitution between inputs that exist in the production of air transportation services once management chooses production arrangements and technology. Managerial choices include those pertaining to aircraft, network configuration, hub concentration, and flight frequency. Direct substitution between inputs, such as pilot labor and ground equipment, or flight attendant labor and fuel, cannot occur once these choices have been made. Indirect substitution between inputs is possible, however, as managers can effectively vary the input proportions by suitably varying their choices of aircraft and production arrangements.

Cost Categories

The input cost categories listed below are subsets of traditional broad economic categories and are based on the operating expense categories of the Uniform System of Accounts used by carriers to file financial data with the CAB and DOT. The dependent variables are physical measures of the inputs when these are available, and deflated cost measures otherwise.

1. Fuel, gallons of jet fuels and oils.
2. Flying operations labor, hours of labor of flight crews, including pilots, copilots, navigators, and flight engineers.
3. Passenger service labor, hours of labor of flight attendants.
4. Aircraft traffic and servicing labor, hours of labor of ground personnel servicing aircraft and handling passengers at gates, baggage, and cargo.
5. Promotions and sales labor, hours of labor of reservations and sales agents primarily, but also of personnel involved in advertising and publicity.
6. Maintenance labor, hours of labor involved in maintenance of flight equipment and ground property and equipment.
7. Maintenance materials and overhead, total cost of maintenance of property and equipment, deflated by the Producer Price Index for fabricated metals.
8. General overhead, total expenses corresponding to supplies, general and administrative personnel, utilities, insurance, communications, and the like, deflated by the GNP Implicit Price Deflator.
9. Ground property and equipment, flows of service from ground property and equipment, calculated with the method developed by Christensen and Jorgen-

son (1969)[2] and including landing fees deflated by the Air Transport Association cost index for landing fees and rental expenses for ground property and equipment deflated by the Producer Price Index for fixed nonresidential structures.

10. Flight equipment, flows of service from flight equipment (airframes, aircraft engines, avionics, etc.), calculated by imputing fair market rental values deflated by the Producer Price Index for fixed-wing aircraft to owned and leased aircraft by aircraft categories.

Industry means of operating costs by category and descriptive statistics for physical measures of inputs and volume- and operations-based drivers are presented in the appendix.

Volume-Based Cost Drivers

The volume- and operations-based drivers for each input category are listed in table 1. In cost accounting, measures of actual outputs are typically used as cost drivers. The economics literature on airline production has followed this practice by using total revenue passenger and ton miles[3] as the volume-based determinant of total costs (Caves et al. 1984; Kirby 1986; Sickles 1985; Sickles and Good 1986). However, it appears that only the costs for personnel who handle passengers and cargo and for those who handle reservations and sales vary in direct proportion to *actual outputs*, that is, to the number of passengers and tons of cargo actually handled. Instead, most costs appear to vary in proportion to *output capacity*, the amount of seating and cargo capacity available. (Carriers offer seating and cargo capacity, on particular flights and aircraft, for sale in the marketplace, but the actual quantities exchanged are determined by the interaction of the supply of capacity and demand.) Fuel consumption and labor hours for scheduled flight crews and attendants vary more with aircraft size, seating capacity, distance, and other characteristics of flights (and aircraft) than with the actual number of passengers and tons of cargo carried. Expenditures on ground property and equipment, general overhead, and maintenance overhead are associated more with the airline's overall productive capacity than with revenue outputs. Also, the cost of aircraft maintenance varies more with the number of flights, hours flown, and characteristics such as the number of engines than with revenue outputs.

In the airline industry, output capacity is typically measured in terms of available seat miles (ASM) and available ton miles (ATM), and actual outputs are measured in terms of revenue passenger and ton miles, or the number of passengers and tons of cargo. Since the major airlines are primarily passenger carriers, for convenience and ease of interpretation, we convert the available cargo capacity to available seating capacity and combine the two in terms of *capacity seat miles* (CSM) as a measure of output capacity.[4]

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[2] The "perpetual inventory" method was developed by Christensen and Jorgenson (1969) to measure the service flow of property assets, and was applied to the airline industry by Caves et al. (1984), Sickles (1985), and Sickles and Good (1986).

[3] A revenue passenger (ton) mile is defined as air transportation service for one passenger and his or her baggage (one ton of cargo) for a distance of one mile.

[4] We use the standard industry conversion factor (one ton of cargo carried one mile is equated with ten passengers and their baggage, at approximately 200 pounds each, carried one mile) to convert available ton miles for cargo to available seat miles and sum to get CSM. Cargo generates a small proportion (5.1 percent on average) of the total revenues for the large air carriers, but tends to be highly correlated with passenger miles (correlation coefficient=0.86). Therefore, we aggregate the two to avoid collinearity problems in estimating our model.

Table 1
Cost Drivers by Input Category

Input Category and Measurement Units	*Cost Drivers (and Hypothesized Signs)*			
	Volume-Based Drivers		*Operations-Based Drivers*	
Fuel in gallons	CSM by aircraft type	(+)	Average stage length	(−)
Flying operations, labor hours	CSM by aircraft type	(+)	Density	(−)
			Hub concentration	(−)
			Hub domination	(−)
Passenger service, labor hours	CSM by aircraft type	(+)	Density	(−)
			Hub concentration	(−)
			Hub domination	(−)
Maintenance, labor hours	CSM by aircraft type	(+)	Density	(−)
			Hub concentration	(−)
			Hub domination	(−)
			Scale	(+)
Maintenance materials and overhead, deflated costs	CSM by aircraft type	(+)	Density	(+)
			Hub concentration	(−)
			Hub domination	(−)
Aircraft and traffic servicing, labor hours	Passengers	(+)	Density	(+)
			Hub concentration	(−)
			Hub domination	(−)
Promotions and sales, labor hours	Passengers	(+)	Density	(+)
			Hub concentration	(−)
			Hub domination	(−)
General overhead, deflated costs	Total CSM	(+)	Density	(+)
			Hub concentration	(−)
			Hub domination	(−)
			Scale	(+)
Group property and equipment, deflated costs	Total CSM	(+)	Density	(−)
			Hub concentration	(+)
			Hub domination	(+)
			Scale	(+)

Note: CSM, capacity seat mile, is defined as the space to carry one passenger and his or her baggage (or one-tenth of one ton of cargo) one mile.

Since differences in aircraft models are hypothesized to be important in determining input requirements for labor for flying operations, passenger service, and maintenance as well as for fuel and maintenance materials and overhead, we have placed various aircraft models into one of eight categories according to fuel consumption and size of flight crew, as shown in table 2.[5] We then compute CSM on the basis of these categories. The relative magnitudes of the coefficient estimates of output capacities by these categories should be consistent with known differences in capacities, fuel efficiency, and labor requirements for flying operations. In contrast, for ground

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[5] These categories were developed on the basis of technical descriptions of various aircraft models in the industry publication *Jane's All the World's Aircraft*. They account for: (1) differences in size and capacity, determined by the number of engines, aircraft body width, and seating density; (2) fuel efficiency; and (3) changes in the percentages of the industry fleet over time, especially as these reflect the phasing out of older, less fuel-efficient models and phasing in of newer, more fuel-efficient models.

Table 2
Aircraft Categories and Characteristics

Aircraft Models	*Characteristics*	*Mean ASM Per Gallon*	*Flight Crew*
Older Aircraft, Regular-Bodied			
McDonnell Douglas DC-9-10/15	2-engine turbofan, 1st generation	35.9	2
British Aircraft BAC-111	2-engine turbofan		
McDonnell Douglas CD-9-30/40/50	2-engine turbofan, 2nd generation		
Fokker 28	2-engine turbofan		
Dassault Falcon-20	2-engine turbofan		
Boeing-727-100	3-engine turbofan, 1st generation	33.8	3
Boeing-727-200	3-engine turbofan, 2nd generation	42.2	3
Older Large Aircraft			
McDonnell Douglas DC-10-10/30/40	3-engine turbofan, regular body	51.2	3–4
Lockheed L-1011			
Boeing-707		46.1	3–4
Boeing-720	4-engine turbofan, regular body		
McDonnell Douglas DC-8	4-engine turbofan, regular body		
McDonnell Douglas DC-8-71	4-engine turbofan, wide body		
Boeing-747	4-engine turbofan, regular body		
	4-engine turbofan, wide body		
Newer, Fuel-Efficient Aircraft			
Boeing-737-200/300	2-engine turbofan, regular body	43.0	2
McDonnell Douglas Super-80	2-engine turbofan, regular body	54.6	2–3
Boeing-757	2-engine turbofan, wide body		
Boeing-767	2-engine turbofan, wide body	57.8	2–3
Airbus Industrie A300B2/B4			

Note: ASM is available seat miles.

property and equipment and general overhead, input requirements depend very little on differences in the aircraft operated. Therefore, a general measure of overall size, total CSM, is used as the volume-based driver for these inputs. For the labor of ground personnel who service aircraft, handle passengers at ticket counters and gates, and handle baggage and cargo, the number of passengers is employed as the volume-based driver.[6] Flight equipment inputs are determined (as an identity) by the models and numbers of aircraft operated and the corresponding real rental values.

Operations-Based Cost Drivers

We draw on the airline industry literature to develop operations-based cost drivers for the production of air transportation services. The drivers represent choices of alter-

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[6] The number of passengers is highly correlated ($r=0.95$) with the number of flights or aircraft handled.

native technologies, as embodied in choices of aircraft models, route structures, flight frequency or density, and traffic flow control. These are analogous to drivers such as production run volume, product line diversity, configuration of the manufacturing process, and control of the flow of production, which have been suggested as potential cost drivers in manufacturing contexts (Hayes and Clark 1985; Miller and Vollman 1985).

Aircraft Type. A manufacturer may have more than one production site, assembly line, or available production technology, each with a unique set of characteristics that make it more or less appropriate for production under any given set of circumstances. For example, one assembly line may be labor-intensive and another capital-intensive. If the price of labor were to increase, the manufacturer would substitute capital for labor by producing a larger percentage of its output on the capital-intensive line. Another example relates to machine setup costs. One machine may be relatively flexible and inexpensive to set up between production runs, and another more time-consuming and costly. The machine with lower setup costs would be used primarily for low volume production runs, and the machine with higher setup costs for high volume runs.

Analogously, carriers choose among different types of aircraft to provide service on any given set of routes. The choice essentially involves different production technologies with differing input intensities and relative efficiencies. For example, wide-bodied aircraft such as Boeing 747s can serve densely trafficked long-haul routes efficiently, while smaller aircraft such as Boeing 737s can serve less densely trafficked short-haul routes relatively efficiently. Aircraft choices depend on network characteristics, particularly route length and traffic density, and the availability of particular models of aircraft.[7] The output capacity on each type of aircraft, in turn, determines the required hours of pilot, copilot, flight engineer, navigator, and flight attendant labor, required levels of maintenance, and required quantities of fuel per CSM.

Aircraft Size and Average Stage Length. In a manufacturing environment, economies are associated with large production runs as setup costs are relatively invariant with respect to batch sizes. In air transportation services, output capacity increases with both the number of seats made available and the distance traveled. Thus, there are two concepts analogous to batch size: aircraft size and stage length. If the volume of traffic is heavy enough for a carrier to use larger aircraft on a given flight and route, more CSM can be delivered for a given level of flight crew labor and fuel costs. Both Bailey et al. (1985) and Kirby (1986) have documented decreases in total costs with increases in average aircraft size, all else held constant. Average stage length (ASL) is the average length of a carrier's flights in miles. It has consistently been cited as a potential source of economies. As ASL increases, economies are achieved because fuel consumption is considerably greater during take-off and landing than at cruising altitude and speed (Kirby 1986; Strazheim 1969). Caves et al. (1984) and Kirby (1986) have both found decreases in total costs with increases in ASL.

Density. By increasing the number of flights over its network, that is, the density with which the carrier services its network, a carrier can offer a more diversified set of

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[7] During the transition following deregulation, in response to increasing competition, changing route structures, and the availability of several newly introduced models of more fuel-efficient aircraft, there was a considerable amount of substitution between aircraft. The percentage of ASM on wide-bodied aircraft declined from 35 percent to 25 percent . The percentage provided with new models increased from approximately 8 percent to 27 percent. However, the adjustment was hampered by long lags between orders and deliveries of new aircraft.

services. The proliferation of flights may come about for two reasons: (1) efforts to provide a more attractive schedule of flights (i.e., a full range of products so customers do not go to other suppliers) and (2) efforts to utilize productive capacity more fully. In the economics literature, the conventional wisdom is that a carrier can utilize inputs more efficiently by operating more flights or carrying more traffic over a given network. There is some empirical evidence, based on a model with a single measure of revenue outputs and highly aggregated categories of inputs, that economies of density obtain (Caves et al. 1984). However, the underlying dynamics in terms of increased production complexity are not addressed.

In contrast, Cooper and Kaplan (1987) recognize that, in efforts to utilize productive capacity more fully and provide a fuller range of products to meet customer needs, manufacturers incur additional overhead. By scheduling more flights over a given network segment, a carrier incurs additional setup costs for each additional flight, in terms of handling aircraft on the ground and enplaning and deplaning passengers and cargo. At the same time, it may be able to better utilize its fixed ground property and equipment and general overhead inputs. For overall economies to obtain, the gains from utilizing ground capacity more fully must outweigh the costs of additional support activities.

Hub Concentration. Reconfiguring production systems can also generate important cost savings. By concentrating production at sites geared toward high volume or throughput, a manufacturer may add to general overhead costs (in terms of increased need for support department inputs, additional supervisory personnel, etc.) but achieve net cost savings because of more efficient use of other inputs.

Organizing networks as hub-and-spoke systems was one of the most important strategies adopted by the airlines during the transition following deregulation (Bailey et al. 1985; Borenstein 1992; DOT 1990; GAO 1985, 1990; Graham and Kaplan 1982). Most carriers developed hub airports and structured their route systems for the arrival and departure of many flights within a few hours of each other, with passengers and cargo exchanging planes in between. Carriers can thus achieve substantial economies, for example, in maintaining and repairing their fleets, in using ground property, equipment, and labor, and by filling larger aircraft on hub-to-hub routes. However, to achieve these economies, it is likely that carriers also must use more administrative and supervisory labor for communications and other support services.

If a manufacturer cannot effectively control the arrival of raw materials and orders for finished goods, there will be periods of congestion and slack in production. This is particularly true when shared facilities must be used to produce several different products or services, with each primarily under the control of a different department or supervisor. Analogous effects are likely to occur in the airline industry, particularly at major hubs where there is intense competition for the use of air traffic control and shared ground facilities, which often results in overscheduling, congestion, and delays.

The magnitudes of the economies a carrier can obtain by concentrating flights through hubs are likely to depend on whether the carrier has some monopoly power, as reflected in dominant market shares, at its hub airports (DOT 1990; GAO 1985, 1990). During 1981–1985, USAir and Piedmont carried 60 to 80 and 60 to 67 percent, respectively, of industry traffic through their hubs. In contrast, United, American, Delta, and Eastern faced stiff competition, often with each other, at their hub airports. For example, at Dallas-Fort Worth, American and Delta competed with Braniff and other carriers for 29 to 52 and 16 to 29 percent shares of traffic, respectively. USAir and Piedmont were thus in a position to schedule their flights relatively more efficiently than United, American, Delta, and Eastern.

Scale. The scale of production is often suggested as a potential source of economies and, as such, may also be thought of as a potentially important operations-based cost driver. Research reported to date, though, suggests that economies of scale are either very small or do not obtain for the airlines. White (1979), Caves et al. (1984), and Sickles (1985) have found nearly constant returns to scale. In a cost accounting framework of constant marginal costs, increasing returns to scale are indicated when fixed costs are present because average costs decrease with increasing levels of outputs. Therefore, ground property and equipment, general overhead, maintenance labor, and maintenance materials and overhead inputs, which have fixed cost components, are likely to have increasing returns to scale associated with them, but constant returns to scale are likely to obtain for other cost categories.

Summary

Operations-based cost drivers are introduced into the equations after multiplying them by total CSM or the number of passengers to estimate their effects on input consumption per unit CSM or passenger. The hypothesized relations between the operations-based drivers and different input requirements are summarized below.

1. For aircraft type and size, the relative magnitudes of the coefficient estimates for CSM by aircraft category are examined to test hypotheses concerning returns to aircraft size. The wide-bodied and newer, efficient aircraft categories are hypothesized to have lower coefficients.
2. Average stage length is measured as the ratio of airborne miles flown to the number of flights. Included in the equation for fuel costs, it is hypothesized to have a negative coefficient.
3. Density is measured as the number of flights provided relative to the number of airports served. The coefficient of this ratio is hypothesized to be positive (decreasing returns) for aircraft and traffic servicing labor and for promotions and sales labor. For ground property and equipment and general overhead, the coefficient is hypothesized to be negative (increasing returns).
4. To capture returns from concentrating flights through hubs, we introduce the following variables into the equations for aircraft and traffic servicing, promotions and sales, flying operations, passenger service, and maintenance labor, maintenance materials and overhead, ground property and equipment, and general overhead. First, we consider the percentage of the carrier's own flights that are routed through its own hub airports where the carrier has considerable market share, 60 or more percent of the total number of flights by all carriers through the airport during a quarter. This cutoff provided a stable classification of hubs over time and is consistent with characterizations in the airlines literature (Bailey et al. 1985; GAO 1990). Second, we consider the percentage of the carrier's own flights routed through its hub airports where the carrier faces substantial competition (the carrier has less than 60 percent of the flights through the airport). The coefficients are hypothesized to be positive for general overhead and negative for the remaining inputs. The coefficients for the percentages of flights through dominated hubs are hypothesized to be greater in absolute magnitude than those for competitive hubs.

5. To capture scale, intercept terms are explicitly included in the equations for ground property and equipment, general overhead, maintenance labor, and maintenance materials and overhead. Positive intercepts are hypothesized to reflect increasing returns to scale.[8]

System of Equations

The empirical model is described by the following system of equations:

Fuel: $y_{m1t}=(\Sigma_{j=1}^{8}\beta_{1j}r_{mjt}+\gamma_{1,4}z_{m4t})x_{mt}+\epsilon_{m1t},$

Flying Operations Labor: $y_{m2t}=(\Sigma_{j=1}^{8}\beta_{2j}r_{mjt}+\Sigma_{k=1}^{3}\gamma_{2k}z_{mkt})x_{mt}+\epsilon_{m2t},$

Passenger Service Labor: $y_{m3t}=(\Sigma_{j=1}^{8}\beta_{3j}r_{mjt}+\Sigma_{k=1}^{3}\gamma_{3k}z_{mkt})x_{mt}+\epsilon_{m3t},$

Maintenace Labor: $y_{m4t}=\beta_{40}+(\Sigma_{j=1}^{8}\beta_{4j}r_{mjt}+\Sigma_{k=1}^{3}\gamma_{4k}z_{mkt})x_{mt}+\epsilon_{m4t},$

Maintenance Materials and Overhead: $y_{m5t}=\beta_{50}+(\Sigma_{j=1}^{8}\beta_{5j}r_{mjt}+\Sigma_{k=1}^{3}\gamma_{5k}z_{mkt})x_{mt}+\epsilon_{m5t},$

Aircraft and Traffic Servicing Labor: $y_{m6t}=(\beta_{61}+\Sigma_{k=1}^{3}\gamma_{6k}z_{mkt})s_{mt}+\epsilon_{m6t},$

Promotions and Sales Labor: $y_{m7t}=(\beta_{71}+\Sigma_{k=1}^{3}\gamma_{7k}z_{mkt})s_{mt}+\epsilon_{m7t},$

General Overhead: $y_{m8t}=\beta_{80}+(\beta_{81}+\Sigma_{k=1}^{3}\gamma_{8k}z_{mkt})x_{mt}+\epsilon_{m8t},$

Ground Property and Equipment: $y_{m9t}=\beta_{90}+(\beta_{91}+\Sigma_{k=1}^{3}\gamma_{9k}z_{mkt})x_{mt}+\epsilon_{m9t},$

Flight Equipment: $y_{m0t}=\Sigma_{j=1}^{8}v_{mjt}n_{mjt},$

where,

y_{mit} = units of input i used by carrier m during quarter t, $i=1,2,\ldots,10$,
x_{mjt} = capacity seat miles provided on aircraft type j, $j=1,2,\ldots,8$,
$r_{mjt}=x_{mjt}/x_{mt}$ = proportion of total output capacity provided by aircraft type j, where $x_{mt}=\Sigma_{j=1}^{8}x_{mjt}$,
s_{mt} = revenue passengers enplaned during quarter t,
z_{m1t} = measure of concentration of flights through competitive hubs,
z_{m2t} = measure of concentration of flights through dominated hubs,
z_{m3t} = measure of density of traffic over a network,
z_{m4t} = average stage length,
v_{mjt} = rental value of aircraft type j,
n_{mjt} = number of aircraft type j in carrier m's fleet, and
ϵ_{mit} = random error term for equation i and quarter t, $i=1,2,\ldots,9$.

The coefficients are estimated for the industry as a whole rather than by firm since the time series for each carrier is relatively short. To investigate whether the parameters differ between carriers, we also estimated the system of equations separately for small and large firms by splitting the sample equally and by separating out the four largest carriers. Estimation results for the four subsamples are similar to those reported for the entire sample and provide the same insights about the importance and relative

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[8] When we included intercept terms in the equations for the other inputs to test hypotheses that constant returns to scale obtain for these inputs, we found none of the intercepts to be significantly different from zero.

magnitudes of the operations-based drivers. In practice, a firm can collect more detailed and frequent data to estimate its own standard input requirements.

II. Data and Estimation

The model is estimated by using a panel of quarterly data from the first quarter of 1981 through the fourth quarter of 1985 for 28 major, national, and large regional carriers (see table 6 for a list). There are observations for all 20 quarters for 24 of the carriers and fewer for the remaining four. The unit of analysis is the domestic operating system of each carrier.[9]

The data are derived primarily from traffic and financial statistics from Form 41 reports submitted by certificated carriers to the CAB and the DOT. They include annual labor inputs by categories of operating functions and inventories of carriers' aircraft fleets, supplemented by semiannual and quarterly update information from Form 41 reports, fleet data published in *Air Transport World*, and information gathered from carriers' annual reports. The measures of hub concentration, market share, and monopoly power are developed from the Form 41 schedules. The data were cleaned by extensively cross-checking calculations, identifying outliers in trended data for each firm, and correcting errors by checking original hard copies of data obtained from the DOT.

As we carried out the estimation, we examined the data for collinearity and the residuals for evidence of violations of the ordinary least squares (OLS) assumptions that can result in inefficient estimates of the regression coefficients or biased and inconsistent estimates of their variances, including serial and contemporaneous correlation and heteroscedasticity.

Serial correlation is to be expected since the observations are quarterly and the effects of random shocks could be expected to last longer than one quarter. Also, technical inefficiency, to the extent that it obtains, is reflected in the error term and can be expected to persist across quarters. There was strong evidence of serial correlation among the residuals for each airline, with estimates of autocorrelation coefficients ranging from an average of 0.58 for maintenance materials and overhead to 0.89 for fuel. To correct for its effects, first-order autocorrelation coefficients for each carrier were estimated by a variant of the Prais-Winsten estimator proposed by Park and Mitchell (1980). The data were transformed, including the first observations for each time series, in the usual manner, and a second set of regressions was run with the transformed data.[10] The Park-Mitchell estimator is consistent and has been found to perform well for short time series and trended data.[11]

Contemporaneous correlation between the residuals by carrier may be expected because of interrelationships between the operating functions and commonalities

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[9] Only the carriers' domestic operating systems were deregulated by the Airline Deregulation Act. International operations were regulated separately, with route and fare agreements negotiated by treaty.

[10] Park and Mitchell (1980) and Doran and Griffiths (1983) found that estimators using all observations provided substantially more efficient estimates of the autocorrelation coefficients than estimators that do not transform the first observation. They found that estimators omitting the first observations with trended data exhibited very low efficiency, often lower than OLS.

[11] It reduces the extent to which the autocorrelation coefficient tends to be underestimated (see Kmenta and Gilbert 1970). All of the estimators tested resulted in underestimated standard errors, which leaves a substantial probability of making a Type I error, although their variants of the Prais-Winsten estimator performed better in this regard than most other estimators. Therefore, we use stringent levels of probability for testing hypotheses and drawing inferences.

within firms. Random shocks affecting one function could have similar or related effects on other functions. There could be similar reactions across functions to events, internal or external to the organization, that have not been modeled (e.g., major changes in management, bitter labor negotiations or strikes, mergers and acquisitions, or bankruptcy proceedings). In a similar vein, there may be some correlation between residuals across carriers.

If either of these forms of contemporaneous correlation are present, the coefficient estimates of *separate* regressions are unbiased and consistent but inefficient, and the estimates of their variances could be biased (Parks 1967). However, we found that the correlations between residuals were small, and therefore gains in efficiency from estimating the equations as a set of seemingly unrelated regressions (SUR) (Zellner 1962) were small.[12] Estimating the model as SUR resulted in only minor changes in the coefficients and decreases in some of the estimates of the standard errors. The system weighted R^2 was 95.6 percent. Most coefficient estimates were within one standard error of those from the separate regressions, and test results were all very similar to those reported here.

Heteroscedasticity could be expected, as the observations for carriers operating at larger scales could have larger variances. Breusch-Pagan (1979) and Goldfeld-Quandt (1972) tests provided somewhat conflicting evidence regarding the presence of heteroscedasticity, and the precise form of the process generating the disturbances was not clear. Therefore, we used White's (1980) procedure to correct for heteroscedasticity and obtain consistent estimators of the variance-covariance matrices. Analyses of the residuals following each stage of estimation did not reveal any evidence of remaining serial correlation, heteroscedasticity, or nonlinearity.

Finally, collinearity did not appear to be a serious problem after transforming the data for serial correlation. Collinearity will make tests of significance of operations-based drivers conservative and estimates of coefficients unstable. The coefficient estimates and corresponding variances were stable with respect to small perturbations in the data. Belsley et al. (1980) condition indices were less than 30 for all equations except passenger service labor, maintenance labor, and maintenance materials and overhead. For these three equations, the proportions of the coefficient variances associated with the characteristic roots were all less than 0.5 except for CSM on Boeing 727-200s and the percentage of flights through competitive hubs.

III. Empirical Results and Discussion

Summaries of the results of the regressions on the transformed data are presented in table 3. The model containing both volume- and operations-based drivers appears to fit very well and provides a good representation of the industry production correspondence. With the exception of ground property and equipment, the percentages of varia-

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[12] There are no efficiency gains from estimating SUR for equations in which all of the independent variables are the same, and the efficienty gains from estimating SUR increase as contemporaneous correlation increases (see Judge et al. 1985; Kmenta 1971). Doran and Griffiths (1983) find lower gains in efficiency when data are trended and there is greater correlation among the explanatory variables across equations. We have several sets of equations with similar sets of explanatory variables. Pearson correlation coefficients among the explanatory variables, by quarter, often are greater than 0.50, and many range from 0.80 to 0.97. The correlations among the residuals across equations, however, tend to be much smaller, with only five of 36 being greater than 0.45. Potential gains in efficiency are also diminished by the small number of quarters for which we have data and the fact that many of our explanatory variables have trended data.

Table 3
Regression Results
(Coefficient Estimates and *t*-Statistics)

Panel A. Equations Containing CSM by Aircraft Category:

		Labor			
	Fuel	*Flying Operations*	*Passenger Service*	*Maintenance*	*Maintenance Materials and Overhead*
Intercept (β_{i0})	—	—		2407	2.30×10^{6}
	—	—		(0.06)	(10.95)***
C9 (β_{i1})	22.21	0.2299	0.2642	0.3783	2.4396
	(21.06)***	(16.05)***	(14.36)***	(4.73)***	(6.93)***
B727-100 (β_{i2})	28.82	0.2511	0.2619	0.4637	3.1131
	(13.06)***	(5.80)***	(4.05)***	(2.84)**	(2.84)**
B727-200 (β_{i3})	21.18	0.2382	0.3244	0.3291	1.5895
	(33.68)***	(9.12)***	(6.54)***	(3.87)***	(2.49)*
DC-10, L1011 (β_{i4})	17.46	0.1425	0.2243	0.2136	1.8999
	(13.12)***	(5.95)***	(5.84)***	(3.86)***	(3.69)**
B747 (β_{i5})	16.73	0.1056	0.1736	0.2572	1.3866
	(14.92)***	(4.53)***	(5.11)***	(5.26)***	(3.00)**
B737 (β_{i6})	19.30	0.1324	0.2719	0.1929	0.2856
	(48.21)***	(4.10)***	(10.20)***	(1.91)	(0.58)
B757, MD-80 (β_{i7})	16.06	0.0958	0.1321	0.2318	3.9511
	(19.58)***	(2.38)*	(2.08)*	(1.80)	(3.04)**
B767, A300 (β_{i8})	16.55	0.1696	0.3404	0.2507	0.9026
	(14.47)***	(5.24)***	(5.55)***	(2.24)*	(0.38)
Competitive Hub by KCSM (γ_{i1})	—	−0.00108	−0.00077	−0.00162	−0.00977
	—	(−3.42)**	(−1.44)	(−1.92)	(−1.13)
Dominant Hub by KCSM (γ_{i2})	—	−0.00123	−0.00119	−0.00355	0.00297
	—	(−3.49)**	(−2.81)**	(−3.71)**	(0.30)
Density by KCSM (γ_{i3})	—	−0.00001	−0.00002	−0.00003	0.00005
	—	(−1.73)	(−2.01)*	(−0.94)	(0.27)
ASL by KCSM (γ_{i4})	−0.0042	—	—	—	—
	(−5.02)***	—	—	—	—
R^2 (Full Model)	99.1%	96.7%	96.9%	93.2%	94.8%
Pr > F (Full Model)	0.0000	0.0000	0.0000	0.0000	0.0000
R^2 (Volume-Based Drivers Only)	98.9%	92.7%	96.3%	88.0%	94.5%
Pr > F (Operations-Based Drivers)	0.0000	0.0000	0.0133	0.0014	0.1172

Note: Traffic by aircraft type measured in KCSM.

KCSM: Thousand capacity seat miles.
ASL: Average stage length

* Significant at 5 percent level
** Significant at 1 percent level
*** Significant at 0.01 percent level

Pr > F (Full Model): Pr > F ($\beta_{ij}=0$, *for* $j=1,\ldots 8$, $\gamma_{ik}=0$ *for* $k=1,\ldots 4$)
Pr > F (Operations-Based Drivers): Pr > F ($\gamma_{i1}=\gamma_{i2}=\gamma_{i3}=\gamma_{i4}=0$)

Table 3—*Continued*

Panel B. Equations Containing Total CSM and Passengers:

	Labor			
	Aircraft and Traffic Service	*Promotions and Sales*	*General Overhead*	*Ground Property and Equipment*
Intercept (β_{i0})	—	—	20×10^6	76×10^6
	—	—	(17.28)***	(15.53)***
Total KCSM (β_{i1})	—	—	4.583	15.269
	—	—	(6.06)***	(2.04)*
Total KP (β_{i1})	905.521	402.973	—	—
	(7.89)***	(7.71)**	—	—
Competitive Hub by KCSM (γ_{i1})	—	—	−0.049	−0.226
	—	—	(−2.67)*	(−2.43)*
Competitive Hub by KP (γ_{i1})	−9.013	−3.686	—	—
	(−3.51)**	(−2.86)**	—	—
Dominant Hub by KCSM (γ_{i2})	—	—	−0.058	−0.260
	—	—	(−2.92)**	(−2.13)*
Dominant Hub by KP (γ_{i2})	−14.795	−8.335	—	—
	(−5.29)***	(−6.23)***	—	—
Density by KCSM (γ_{i3})	—	—	−0.0001	−0.0008
	—	—	(−0.20)	(−0.32)
Density by KP (γ_{i3})	0.066	0.050	—	—
	(1.87)	(2.60**)	—	—
R^2 (Full Model)	87.3%	88.8%	96.9%	24.0%
Pr > F (Full Model)	0.0000	0.0000	0.0000	0.0000
R^2 (Volume-Based Drivers Only)	85.0%	86.6%	96.8%	21.0%
Pr > F (Operations-Based Drivers)	0.0000	0.0000	0.0008	0.0003

Note: KCSM: Thousand capacity seat miles.
KP: Thousand passengers.

* Significant at the 5 percent level.
** Significant at the 1 percent level.
***Significant at the 0.01 percent level.

Pr > F (Full Model): Pr > F ($\beta_{i1}=\gamma_{i1}=\gamma_{i2}=\gamma_{i3}=0$).
Pr > F (Operations-Based Drivers): Pr > F ($\gamma_{i1}=\gamma_{i2}=\gamma_{i3}=0$).

tion in inputs explained by the volume- and operations-based cost drivers range from 88 percent for aircraft and traffic servicing labor to 98 percent for fuel.[13]

The measures representing output volumes are consistently found to be important cost drivers. For all cost categories, the estimates of the coefficients of the volume-based drivers are positive and generally have *t*-statistics that are highly significant. Also, the relative magnitudes of the coefficient estimates for CSM by aircraft categories

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[13] We believe the low explanatory power for ground property and equipment is attributable to inaccuracies associated with calculating a large component of the measure of the dependent variable with the perpetual inventory method, rather than to omitted variables or measurement errors in the explanatory variables.

are generally consistent with the relative capacities and other characteristics of the aircraft.

The estimated coefficients of the operations-based drivers are generally in the expected directions and have *t*-statistics that are significant at fairly high levels. *F*-statistics comparing the error sums of squares restricting and not restricting the coefficients of all four of the operations-based drivers to zero are significant at levels ranging from 0.0000 to 0.0133 for all but one input category. Therefore, a model based only on volume-based drivers is misspecified and likely to have omitted-variable bias. If the omitted variables are correlated with the included variables, variation in input requirements that should be attributed to the excluded operations-based drivers will be attributed to the included volume-based variables and the estimated coefficients for volume will be statistically biased and inconsistent. Even if the omitted and included variables are not correlated, both the estimates of intercept terms and estimates of the variances of all of the coefficient estimates will be statistically biased and inconsistent (Kmenta 1971; Theil 1957).

As may be seen in table 3, panel A, the coefficient estimate for ASL is significantly negative for the fuel cost category. This lends support to the hypothesis that the marginal requirements for fuel inputs diminish as ASL increases.

For promotions and sales labor, the coefficient for density is significantly positive, which indicates that adding flights on a given network requires additional support labor. The coefficient for passenger service labor is significantly negative. Both results are consistent with the findings of Cooper and Kaplan (1987) about product diversity and illustrate the countervailing forces at work with diversification. The coefficients for flying operations labor, maintenance labor, and maintenance materials and overhead are insignificant. We surmise this is related to standardization due to Federal Aviation Administration (FAA) regulations. The coefficients for ground property and equipment and general overhead are also insignificant and may reflect the inherent difficulties in measuring capital inputs.

The results for competitive and dominated hubs follow similar patterns with large, significantly negative coefficients for labor handling passengers, cargo, and aircraft on the ground. The coefficients for ground property and equipment and for flying operations labor are also significantly negative, and those for general overhead are significantly positive.[14] Thus, by adopting a hub-and-spoke strategy, a carrier can achieve fairly substantial economies in the use of most inputs, but reconfiguring production to a more centralized operation requires increases in general overhead inputs.

The results lend support to the hypothesis that carriers that dominate their hubs, and therefore may have some monopoly power, can achieve relatively greater economies from hub concentration than carriers with competitive hubs. The results of asymptotic χ^2-tests indicate that the coefficients for aircraft and traffic servicing, promotions and sales, and maintenance labor are significantly more negative for dominated than for competitive hubs ($pr > \chi^2 = 0.0378$, 0.0005, and 0.0444, respectively). This suggests that carriers that can dominate hubs may be able to schedule, market, and operate flights in a manner that enables them to control the flow of traffic and thereby use their resources more efficiently.

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[14] This provides some of the first detailed empirical evidence for the industry as a whole concerning the magnitude of economies from the adoption of hub-and-spoke systems.

Table 4
Differences in Input Requirements Between Aircraft Types
(Asymptotic χ^2-statistics)

Older Wide-Bodied Models	*Older Regular-Bodied Models*			*Newer Fuel-Efficient Models*		
	DC-9 BAC-111	*B727–100*	*B727–200*	*B737*	*B757 MD-80*	*B767 A300*
Fuel						
DC-10, L-1011	4.7451	11 3508	3.7189	1.8310	−1.4058	−0.9181
χ^2	20.407	89 868	16.966	2.268	1.380	0 129
$\Pr>\chi^2$	0.0000	0.0000	0.0000	0.1321	0.2401	0 7197
DC-8, B707, B747	5.4805	12.0862	4.4543	2.5664	−0.6704	−0.1827
χ^2	44.598	368 669	5.914	5.914	0.344	0.007
$\Pr>\chi^2$	0.0000	0.0000	0.0150	0.0150	0.5577	0.9340
Flying Operations Labor						
DC-10, L1011	0.087386	0.108611	0.095651	−0.010143	−0.046664	0.027088
χ^2	6.444	12.119	16.188	0.239	3 138	0.267
$\Pr>\chi^2$	0.0111	0.0005	0.0001	0.6249	0.0765	0.6056
DC-8, B707, B747	0.124297	0.145522	0.132562	0.026768	−0.009753	0.063999
χ^2	9.437	30.602	30.262	3.409	0.090	2.167
$\Pr>\chi^2$	0.0021	0.0000	0.0000	0 0648	0.7641	0.1410

Note: The first entry in each cell is the difference between coefficients (column less row category).

The estimates for the intercepts in the equations for ground property and equipment, general overhead, and maintenance materials and overhead are positive and significant, and therefore lend support to hypotheses that increasing returns to scale obtain for these inputs. The intercept for maintenance labor is not significant. We surmise that, with FAA maintenance requirements, maintenance labor hours become nearly proportionate to output capacity.

The results of asymptotic χ^2-tests for differences in input requirements for fuel and flight crew labor between older large aircraft, older small aircraft, and newer fuel-efficient aircraft are presented in table 4. Comparisons between older large and small aircraft indicate highly significant differences in coefficients and are consistent with the hypothesis and industry evidence that wide-bodied aircraft require less fuel and flying operations labor inputs than older regular-bodied aircraft. However, sharp differences between older large aircraft and newer models are not indicated. This suggests that the improvements in fuel efficiency and reductions in required crew size for the newer models have made up for the size-based advantages larger aircraft had in the past.

IV. Cost Effects of Managerial Strategies

The empirical results in the preceding section demonstrate that the effects of operations-based cost drivers are statistically significant. We next examine the magnitude of these effects from a managerial perspective. Our model is explicitly constructed so that we can estimate the differential effects of changes in the operations-based drivers on marginal costs by cost category. We also show how operations-based drivers can be incorporated into variance analysis relative to industry benchmarks and used for performance evaluation.

Effects on Marginal Costs

The estimated marginal costs (costs per additional 1,000 CSM) for each aircraft category are presented in table 5. The marginal cost for each input *i* is obtained by multiplying the right-hand side of equation *i* by the price of input *i* and taking the first derivative with respect to CSM. For this illustration, we use the sample averages for the input prices, p_i. When different measures of volume are used as primary cost drivers (numbers of passengers as opposed to CSM), conversion factors are used to obtain the required common denominator. Therefore, for aircraft and traffic servicing labor and promotions and sales labor, we multiply the number of passengers by the CSM per passenger ratio to obtain CSM. For flight equipment, the number of aircraft is multiplied by the CSM per aircraft ratio. The columns and subtotals in panel A contain estimates of the components of marginal costs associated with changes in volume for each aircraft type. Except for flight equipment, these estimates do not differ across carriers. Panel B contains estimates of the components of marginal costs that reflect adjustments, for the operations-based drivers for a representative firm, with operations-based drivers taking on the sample means. The estimates do not differ across aircraft categories. The marginal cost totals combine the incremental costs associated with both direct volume-based drivers and corresponding adjustments associated with managerial decisions to alter the operations-based drivers. With the exception of density, the estimated marginal savings (aggregated across inputs) associated with operations-based drivers are significantly greater than zero.[15]

The estimates presented in table 5 highlight the relative magnitudes of the various components of marginal costs, both across aircraft categories and between the volume- and operations-based drivers, and can provide the basis for longer term decisions regarding network structure and fleet mix. The advantages of newer and wide-bodied aircraft in the use of flying operations labor, fuel, maintenance materials and overhead, and maintenance labor are evident (see panel A). When combined, they result in marginal costs ranging from $46 to $51 per 1,000 CSM, as opposed to $63 to $75 for the older regular-bodied models for the representative firm.

The separate estimates for different aircraft categories in panel A, before adjustments for operations-based drivers, are aggregated into a single number by weighting them with the average CSM for their respective categories. The weighted averages of these marginal cost components are presented in the first column of panel B. For the representative carrier, the weighted average incremental cost is approximately $83 per 1,000 CSM (before adjustment for operations-based drivers), but the total operations-based savings are approximately $27, which leaves a net marginal cost of $56. The savings derive largely from concentrating flights through hubs. As may be seen from the descriptive statistics calculated by carrier and quarter (see the lower part of panel B), the potential savings from concentrating flights through hubs average approximately $27 and range from $3 to $139. For carriers dominating hubs, estimated savings range up to $72. The savings associated with increasing ASL are smaller, averaging $2 per 1,000 CSM and ranging up to $8. The savings associated with increasing density are the

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[15] Standard error estimates, under the assumption of no contemporaneous correlation across inputs, were calculated as the square root of the sum of the estimated variances weighted by the squares of their prices.

Table 5
Marginal Costs By Aircraft Category
(Per 1,000 CSM)

Panel A. Volume-Based Components:

		Older Regular-Bodied Aircraft			*Older Wide-Bodied Aircraft*		*New Fuel Efficient Aircraft*		
Input Category y_i	*Input Price* p_i	*DC-9* $p_i\hat{\beta}_{i1}$	*B727–100* $p_i\hat{\beta}_{i2}$	*B727–200* $p_i\hat{\beta}_{i3}$	*DC-10 L1011* $p_i\hat{\beta}_{i4}$	*DC-8 B707, B747* $p_i\hat{\beta}_{i5}$	*B737* $p_i\hat{\beta}_{i6}$	*B757 MD-80* $p_i\hat{\beta}_{i7}$	*B767 A300* $p_i\hat{\beta}_{i8}$
Fuel	$ 1.0041	$22.3000^a	$28.9330^a	$21.2697^a	$17.5356^a	$16.7972^a	$19.3740^a	$16.1240^a	$16.6137^a
Flying Operations Labor	41.1801	9.4669^a	10.3410^a	9.8073^a	5.8683^a	4.3483^a	5.4506^a	3.9467^a	6.9838^a
Passenger Service Labor	14.7975	22.3000^a	3.8750^a	4.7999^a	3.3189^a	2.5687^a	4.0227^a	1.9542^a	5.0371^a
Maintenance Labor	31.6610	11.4965^a	14.0930^a	10.0002^a	6.4908^a	7.8170^a	5.8616	7.0450	7.6197
Maintenance Materials & Overhead	1.0000	2.4396^a	3.1131^a	1.5895^a	1.8899^a	1.3866^a	0.2856	3.9511^a	0.9026
Aircraft & Traffic Servicing Labor	18.1737	9.6037^a	9.6037^a	9.6037^a	9.6037^a	9.6037^a	9.6037^a	9.6037^a	9.6037^a
Promotions and Sales Labor	39.1818	9.2141^a	9.2141^a	9.2141^a	9.2141^a	9.2141^a	9.2141^a	9.2141^a	9.2141^a
General Overhead	1.0000	4.5830^a	4.5830^a	4.5830^a	4.5830^a	4.5830^a	4.5830^a	4.5830^a	4.5830^a
Ground Property & Equipment	1.0000	15.2655^a	15.2655^a	15.2655^a	15.2655^a	15.2655^a	15.2655^a	15.2655^a	15.2655^a
Flight Equipment		2.2407	1.9490	3.2615	0.9171	0.8084	3.8498	2.4254	0.2410
Volume-Based Driver Subtotal		$90.5197	$100.9700	$89.3944	$74.6869	$72.3925	$77.5106	$74.1127	$76.0642
Standard Error of Subtotal		2.7546	5.8959	3.0276	2.4853	2.2049	3.4208	4.6186	3.9922
Operations-Based Driver Subtotal		−26.5084	−26.5084	−26.5084	−26.5084	−26.5084	−26.5084	−26.5084	−26.5084
Volume- and Operations-Based Total		$64.2691	$74.7194	$63.1438	$48.4368	$46.1419	$51.2600	$47.8621	$49.8136
Conversion Factors:									
Mean CSM		537,268	267,443	1,561,244	1,092,739	589,573	382,142	170,596	237,153
Passenger to CSM Ratio	0.00059								
Aircraft to CSM Ratio		0.000036	0.000030	0.000018	0.000009	0.000015	0.000029	0.000017	0.000010

Continued

Table 5—*Continued*

Panel B. Operations-Based Components:

Input Category y_i	Weighted Average Volume-Based Driver Total[b]	Hub Concentration Competitive $p_i\hat{\gamma}_{i1}z_{R1}$	Hub Concentration Dominated $p_i\hat{\gamma}_{i2}z_{R2}$	Density $p_i\hat{\gamma}_{i3}z_{R3}$	Average Stage Length $p_i\hat{\gamma}_{i4}z_{R4}$	Operations-Based Driver Total $p_i\Sigma_k\hat{\gamma}_{ik}z_{Rk}$	Volume- & Operations-Based Driver Total
Calculations for Representative Firm:							
Fuel	\$19.8599				\$−2.4112[a]	\$−2.4112	**\$17.4487**
Flying Operations Labor	7.5550	\$−1.8572[a]	\$ −0.2743[a]	\$−0.3576		−2.4891	5.0658
Passenger Service Labor	3.8934	−0.4749	−0.0951[a]	−0.2841[a]		−0.8541	3.0393
Maintenance Labor	8.7862	−2.0519	−0.5837[a]	−0.6747		−3.3104	0.4758
Maintenance Materials & Overhead	1.7579	−0.4064	0.0161	0.0411		−0.3492	1.4087
Aircraft & Traffic Servicing Labor	9.6037	−3.9745[a]	−0.8488[a]	0.5441		−4.2792	5.3245
Promotions and Sales Labor	9.2141	−3.5045[a]	−1.0310[a]	0.8870[a]		−3.6485	5.5655
General Overhead	4.5830	2.0377[a]	0.3155[a]	−0.0856		2.2676	6.8506
Ground Property & Equipment	15.2655	−9.3856[a]	−1.4054[a]	−0.6432		−11.4343	3.8312
Flight Equipment	2.1161						2.1161
Operations-Based Driver Subtotal	\$82.6347	\$−19.6173	\$−3.9068	\$−0.5730	\$−2.4112	\$−26.5084	\$56.1264
Standard Error of Subtotal		\$4.4776	\$0.7326	\$2.2533	0.4800		
Mean Driver Level		41.58	4.41	777.80	557.35		
Passenger to CSM Ratio	0.0006						
Descriptive Statistics for Calculations for Sample Firms:							
Mean Savings		\$−26.5712	\$−4.6922	\$−0.9235	\$−2.4112	\$−33.2377	
Standard Deviation		27.2099	11.4729	3.7597	1.3004	22.7887	
Minimum		−139.0104	−71.9077	−1.5021	−8.3219	−131.7645	
Maximum		−3.2457	0.0000	20.6472	−0.5104	−9.8156	

[a] Estimates are based on coefficient estimates significant at 0.05 or higher.

[b] Weights corresponding to CSM by aircraft type are used to average original costs for each input in panel A.

least, averaging $1 and ranging up to $1.50. Approximately 38 percent of the observations, however, exhibit net increases in costs with increases in density. The estimated net savings associated with all operations-based drivers average $33 and range from $10 to $132 per 1,000 CSM.

Variance Analysis

The understanding of the cost structure gained in estimating the underlying production function can be useful for planning and in establishing standards for budgeting and variance analyis. Also, *ex post* analysis of variances from industry benchmarks can be useful for performance evaluation and management control. It can be used to evaluate operating strategy choices or, alternatively, to analyze a firm's performance relative to others in its industry. We illustrate such variance analysis between industry benchmarks and actual levels for operations-based drivers, and input prices in terms of their effects on marginal costs.

Variances in marginal costs for firm m and period t (summed over inputs i) may be calculated as:

$$\Delta_{mt} = \sum_{i} (MC_{Rit} - MC_{mit}),$$

where,

$$\mathrm{MC}_{mit} = p_{mit}\left(\hat{\beta}_{i*} + \sum_{k} \hat{\gamma}_{ik} z_{mkt}\right),$$

p_{mit} is the price of input i paid by firm m in period t, the subscript R in place of m denotes industry benchmark values, and β_{i*} is the average of β_{ij} weighted by CSM for aircraft type j. Industry benchmarks are based on weighted averages for the entire sample. The variance is favorable if it is positive, that is, if the marginal cost for firm m is less than the benchmark marginal cost. Δ_{mt} may be factored into input price and operations-based driver variances as follows:

$$\Delta_{mt} = \sum_{i} (p_{Rit} - p_{mit})\left(\hat{\beta}_{i*} + \sum_{k} \hat{\gamma}_{ik} z_{mkt}\right) \qquad \text{(input price variance)}$$

$$+ \sum_{i} \sum_{k} p_{Rit} \hat{\gamma}_{ik} (z_{Rkt} - z_{mkt}) \qquad \text{(operations-based driver variance).}$$

The input price variance captures differences associated with deviations between actual and benchmark input prices. It is favorable if the prices firm m pays for its inputs are collectively less than the benchmark prices. The operations-based driver variance captures differences in marginal costs associated with deviations between firm and benchmark driver levels. Since the coefficients of these drivers are negative, the variance is favorable if the firm's operations-based drivers exceed the benchmark levels.

Table 6 contains variances for the sample firms. We used mean rather than quarterly data for each firm and computed the variances relative to values for the representative firm that reflect industry means for the period 1981–1985. The results show considerable variation in marginal costs that can be attributed to operations-based drivers. The standard deviation of $7.40 in the total operations-based driver variance is large relative to the marginal cost of $56.13 for the representative firm.

Table 6
Variance Analysis of Marginal Costs of 1,000 Weighted Average CSM
(Firm vs. Industry Means)

	Hub Concentration							
Carrier	*Competitive*	*Dominant*	*Total*	*Density*	*Average Stage Length*	*Operations Driver Subtotal*	*Input Price Variance*	*Total Variance*
AirCal	−0.3750	−2.8190	−3.1939	−0.13583	−0.85083	−4.1806	3.3525	−0.8280
Alaskan	0.7868	−1.4970	−0.7103	−0.30198	−0.07192	−1.0842	−13.2413	−14.3255
Aloha	18.7484	−3.9068	14.8416	0.65010	−1.85727	13.6344	1.1112	14.7456
American	1.5258	−3.9068	−2.3810	0.16468	1.28473	−0.9316	0.7381	−0.1935
Arrow	13.2359	−3.9068	9.3291	−0.55363	2.69359	11.4691	1.6064	10.2330
Braniff	4.7649	−3.9068	0.8580	−0.31494	0.79698	1.3401	8.9135	10.2536
Continental	3.2595	−3.9068	−0.6473	−0.13138	0.78361	0.0049	−0.6579	−0.6530
Delta	−3.2750	−3.9068	−7.1818	0.54160	−0.05437	−6.6946	1.4448	−5.2498
Eastern	−4.2371	−3.9068	−8.1439	0.40355	0.10730	−7.6331	3.9579	−3.6752
Frontier	−3.1833	−3.9068	−7.0901	−0.24935	−0.60747	−7.9469	2.8946	−5.0523
Hawaiian	16.3801	−3.4225	12.9576	0.08595	−1.75845	11.2851	−1.5026	9.7825
Midway	−13.0770	29.3323	16.2553	−0.26101	−0.24728	15.7470	2.8216	18.5686
New York Air	12.2313	−3.9068	8.3245	−0.09199	−1.01429	7.2182	−0.0992	7.1191
Northwest	−2.8749	−3.9068	−6.7818	−0.07769	0.31394	−6.5455	−1.4837	−8.0293
Ozark	0.1396	−3.5397	−3.4001	−0.36971	−0.72970	−4.4995	1.6453	−2.8542
Pacific Southwest	5.1677	−3.9068	1.2608	0.21838	−0.86782	0.6114	−1.8211	−1.4236
PanAmerican	0.8392	−3.9068	−3.0676	−0.31997	1.26505	−2.1226	−19.9864	−22.1089
People Express	8.6514	−3.9068	4.7446	0.07883	−0.24050	4.5829	5.9929	10.5759
Piedmont	−12.9911	6.9010	−6.0901	0.02741	−0.98419	−7.0469	3.3921	−3.6548
Republic	−9.3656	−2.3832	−11.7488	−0.01289	−0.78050	−12.5422	1.4727	−11.0695
Southwest	−12.9847	21.3745	8.3909	0.68047	−1.08479	7.9866	1.3244	9.3110
Texas Int'l	1.4422	−3.9068	−2.4647	−0.36613	−0.47389	−3.3047	5.6353	2.3306
Transamerican	2.2960	−3.2672	−0.9712	−0.42241	1.66495	0.2714	−3.2717	−3.0004
Trans World	−1.2415	−3.9068	−5.1483	0.00797	0.90958	−4.2307	−0.6318	−4.8626
United	−1.9976	−3.9068	−5.9044	−0.01876	1.16767	−4.7555	−4.0696	−8.8251
USAir	−16.1562	15.6956	−0.4606	0.17679	−0.84285	−1.1266	−1.8272	−2.9538
Western	−6.0660	4.5546	−1.5115	−0.07977	0.27156	−1.3197	0.4407	−0.8790
World	11.1592	−3.8908	7.2684	−0.45145	4.88726	11.7042	7.5784	19.2283
Descriptive Statistics for Sample Firms:								
Mean	0.4573	−0.1953	0.2619	−0.0401	0.1314	0.3532	0.2046	0.4468
S. D.	8.9357	8.4789	7.3354	0.3253	1.4151	7.4041	5.7265	9.7732
Minimum	−16.1562	−3.9068	−11.7488	−0.5536	−1.8573	−12.5422	−19.9864	−22.1089
Maximum	18.7484	29.3323	16.2553	0.6805	4.8873	15.7470	8.9135	19.2283

USAir and Republic have similar ASL, USAir has a favorable density variance, and Republic has a favorable input price variance. However, the advantage USAir has over Republic because of its higher percentage of flights through dominated hubs is the most important component of a comparison of the two carriers. Because of this advantage, USAir's marginal costs are estimated to be $8.11 less than those of Republic.

United, the largest carrier during the period, has unfavorable hub concentration and density variances that are partially offset by a favorable ASL variance but leave a net unfavorable operations-based driver variance. United also has an unfavorable input price variance. American, its closest competitor, has the same disadvantages in density and ASL, but is better in hub concentration and input prices, which results in a smaller unfavorable total variance. In contrast, the next two largest carriers, Delta and Eastern, have greater disadvantages in concentration through competitive hubs, which results in more unfavorable operations-based driver variances. Delta and Eastern, however, enjoy favorable input price variances, which make their overall variances less unfavorable.

V. Concluding Remarks

Our findings have demonstrated empirically that, while output capacity and volume are important cost drivers, operations-based drivers related to product diversity and production process complexity are also significant in a major service industry. These drivers often directly reflect management strategies to improve productivity and reduce costs or even to increase market share. Our model, with multiple cost categories and drivers, provides a framework for evaluating the cost effects of these strategies, as well as a method for obtaining cost estimates for other management accounting applications. We have demonstrated empirically that several strategies adopted by U.S. airlines during the transition following deregulation had material effects on costs. Specifically, we found that operations-based drivers reflecting strategies to increase batch size (aircraft size and average stage length) and product diversity (flight density), to reconfigure the production process (increase hub concentration), and to control process flow (develop dominated hubs) have material and differential effects on costs.

Academic research in cost accounting has only recently been directed toward identifying important cost drivers. Although Foster and Gupta's (1990) work with one electronics firm suggests that operations-based drivers are generally not strongly correlated with manufacturing overhead costs, our work provides contrary evidence for an industry. As we begin to accumulate statistical evidence of this type, we will be in a better position to decide whether the traditionally used volume-based drivers need to be augmented with strategy-related operations-based cost drivers. This will, in turn, help management obtain more accurate evaluations of the cost effects of operating decisions.

Table A1
Industry Operating Costs and Physical Measures by Input Category

	Input Costs			*Physical Measures*	
Cost Category	*Mean Level*[a]	*Mean Percentage*	*Standard Deviation*	*Mean Level*[b]	*Standard Deviation*
Aircraft and Traffic Servicing Labor	$ 30,311	8.86%	3.24%	1,724,946	1,980,910
Promotions and Sales Labor	30,285	9.03	2.52	813,849	1,068,803
Flying Operations Labor	30,532	8.57	2.78	664,370	746,424
Passenger Service Labor	16,401	4.60	1.22	1,023,253	1,221,969
Maintenance Labor	19,872	6.95	2.82	933,833	1,309,899
Maintenance Materials and Overhead	7,276	2.06	0.93	7,295,603	9,064,265
General Overhead	37,498	14.62	4.97	37,497,917	39,702,527

Continued

Table A1—*Continued*

	Input Costs			*Physical Measures*	
Cost Category	*Mean Level*[a]	*Mean Percentage*	*Standard Deviation*	*Mean Level*[b]	*Standard Deviation*
Ground Property and Equipment	48,007	12.52	6.38	48,115,431	68,906,924
Flight Equipment	21,269	8.42	3.36	21,268,543	21,581,727
Fuel	75,064	24.37	4.39	85,705,214	95,828,418
Total Costs	$317,075	100.00%	—		

[a] In thousands of 1982 dollars.

[b] Labor in hours, fuel in gallons, and other variables as deflated costs.

Table A2
Industry Volume- and Operations-Based Cost Drivers

Variable	*Mean*	*Standard Deviation*
Volume-Based Cost Drivers (in 1,000s):		
Passengers Enplaned	2,823	2,780
Total CSM	4,838,158	5,792,900
CSM (by aircraft categories):		
B737	382,142	655,774
DC-9	537,268	1,009,699
B757, MD-80	170,596	423,401
B767, A300	237,153	698,257
B727-100	267,443	519,333
B727-200	1,561,244	2,119,059
DC-10, L1011	1,092,739	1,799,622
B747	589,573	1,335,023
Operations-Based Cost Drivers:		
Concentration:		
Competitive Hubs	41.58	19.70
Dominated Hubs	5.41	12.56
Density	777.80	453.06
Average Stage Length	557.35	300.59

Note: CSM = capacity seat miles.

Table A3

Input Costs by Category

(Means in Thousands of 1982 Dollars)

Carrier	*Aircraft & Traffic Servicing Labor*	*Promotions & Sales Labor*	*Flying Operations Labor*	*Passenger Service Labor*	*Maintenance Labor*	*Fuel*	*Ground Property & Equipment*	*Aircraft Rental*	*Maintenance Materials & Overhead*	*General Overhead*
AirCal	$ 6,057	$ 5,992	$ 5,204	$ 2,713	$ 3,621	$ 14,838	$ 5,860	$ 7,368	$ 1,634	$ 9,773
Alaska	7,495	6,362	5,947	2,992	3,879	17,498	10,329	4,921	838	9,901
Aloha	2,477	2,737	1,651	729	2,006	4,330	1,866	3,436	285	3,584
American	106,418	112,297	99,098	52,685	63,216	244,203	170,410	64,403	27,298	135,352
Arrow	762	2,038	1,445	902	4,230	8,990	1,083	2,223	408	6,980
Braniff	11,056	10,853	10,841	5,427	8,481	39,800	31,311	4,439	1,110	17,567
Continental	24,284	23,624	20,721	14,163	16,044	72,718	46,286	24,201	5,043	39,847
Delta	113,909	113,633	106,008	51,289	53,164	236,627	146,507	58,914	19,703	95,614
Eastern	98,051	95,837	96,533	47,651	66,854	225,567	122,658	57,693	23,368	103,643
Frontier	18,437	13,329	13,044	5,653	11,076	32,009	14,171	13,356	3,153	19,388
Hawaiian	3,144	3,019	2,419	1,235	2,540	6,074	2,511	2,838	505	4,550
Midway	1,800	5,212	2,098	1,415	3,285	9,326	2,889	3,352	1,424	8,614
New York Air	1,188	3,170	1,152	902	2,218	7,855	4,026	2,757	882	9,280
Northwest	27,844	32,879	30,887	15,744	15,232	96,182	53,146	28,384	11,564	30,370
Ozark	13,544	9,949	10,526	4,706	8,356	25,175	11,473	5,642	2,074	15,214
Pacific Southwest	11,123	9,696	11,307	5,752	7,643	25,346	16,237	12,038	2,190	18,627
Pan American	39,079	21,946	20,587	16,816	9,109	59,324	106,996	27,088	3,923	30,792
People Express	4,772	4,377	3,727	3,341	7,252	26,631	11,285	9,773	2,569	23,224
Piedmont	21,390	19,941	22,507	9,564	14,463	51,585	27,812	23,297	2,841	29,232
Republic	43,589	37,234	39,593	17,296	20,946	96,734	36,081	25,093	12,074	51,526
Southwest	7,699	8,001	7,831	5,185	6,320	29,426	11,676	12,407	1,273	13,152
Texas Intl	10,002	7,086	7,829	3,023	5,205	24,655	10,285	5,496	1,783	15,931
Trans World	47,410	56,045	57,357	40,457	44,232	133,974	106,868	42,212	17,590	59,359
Transamerica	1,671	1,935	8,385	2,956	8,592	16,575	2,645	4,513	1,052	8,502
United	104,150	122,467	141,899	80,965	93,096	307,844	225,501	78,663	28,368	143,744
USAir	36,973	31,499	40,210	16,567	23,889	73,870	39,449	20,740	9,517	44,294
Western	27,892	27,176	26,813	15,265	14,054	71,550	35,380	22,722	7,067	34,331
World	1,401	5,455	2,753	2,928	4,497	18,222	2,889	2,675	908	11,197
Industry Total	$ 30,311	$ 30,285	$ 30,532	$16,401	$ 19,872	$ 75,064	$ 48,007	$21,269	$ 7,276	$ 37,498

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