FURTHER EVIDENCE ON FACTORS INFLUENCING OPERATING COSTS OF U.S. COMMERCIAL AIRLINES

A Cross-Sectional Study for the Years 1967/68 and 1971/72

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1. INTRODUCTION

This paper extends and completes a study reported recently in this journal by two of us [1], in which we analysed 1967/68 data on domestic operations of U.S. trunk carriers and local service carriers (for brevity called Trunks and LSC from here on). The dependent variable was total operating cost per available ton mile, and several network and technology variables were used as explanatory variables. In [1] we used path analysis on the 1967/68 data to test and confirm the hypothesis expressed by the following causal structure:

$$\text{Network} \rightarrow \text{Technology} \rightarrow \text{Unit cost} \tag{1}$$

We found essentially no direct influence of network on Unit cost; that is, the influence of network appears to pass through technology.

Among the various network variables discussed in [1], the one of greatest impact was average stage length ($\bar{s}$). The most important technology variables were average revenue tons per aircraft ($\bar{T}$) and average miles flown per aircraft ($\bar{U}$). The analysis in [1] aimed only at explaining *total* operating cost per unit (*TC*), and may therefore fail to reveal variables that are important for various *components* of TC.

In this paper we report, for 1967/68 data, a path analysis of three components of *TC*, namely, maintenance and depreciation cost per unit (MDC), flying operation cost per unit (FOC), and indirect cost per unit (IC). In addition to $\bar{T}$ and $\bar{U}$, some important new technology predictors emerged: the load factor (LDF) and the proportion of passenger service (PSR). In addition to $\bar{s}$, a new network variable, the coefficient of variation of the stage length distribution ($cv(s)$), shows major impact on *all three* unit costs.

Also, we deemed it essential to replicate the 1967/68 study on data from a more recent period to see how well the conclusions hold up. Thus we analysed 1971/72 data in the hope and expectation that the causal structure (1) would still apply, despite the big changes in network and technology that most airlines have experienced. Except for minor shifts in the importance of individual predictor variables, our expectation was indeed confirmed: that is, the results for the 1971/72 period lend further strong support to the model (1).

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2. THE VARIABLES IN THE STUDY

The reader is referred to [1] for detailed definitions of most of the variables used in this paper; the notation is the same. The variables to be discussed express interesting dimensions of airline operations; some are measures commonly used in the airline industry. The variables were constructed from data in various airline statistics publications [2] to [8].

The dependent variables in this study are the following *unit cost* variables, defined as cost in U.S. dollars divided by number of available ton miles (ATM):

FOC = Flying operation cost per ATM, where flying operation cost is the sum of pilot and crew wages, fuel and oil costs, and taxes and other charges;

MDC = Maintenance and depreciation cost per ATM, where maintenance and depreciation cost is the sum of direct maintenance cost, indirect maintenance cost, and depreciation of flight equipment.

IC = Indirect operating cost per ATM, where indirect operating cost is the sum of all other operating cost items: passenger service, aircraft service, promotion and sales, general and administration cost, amortisation of development and pre-operating expenses, and depreciation other than flight equipment;

TC = Total operating cost per ATM = FOC + MDC + IC.

For all airlines added together in 1967/68, flying operations cost accounts for 28%, maintenance and depreciation cost 26%, and indirect cost 46% of total operating cost. In 1971/72, the percentages were 31%, 24% and 45%, respectively. For both dates the three unit cost variables are strongly correlated. The weakest correlation is 0.82 (MDC with IC) in 1967/68 and 0.85 (MDC with FOC) in 1971/72.

The *network variables* are: $\bar{s}$ = average stage length in miles; $cv(s)$ = coefficient of variation of stage length distribution; $\bar{d}$ = stage density; $\bar{p}$ = average weekly passenger enplanements per city served; m = number of cities served by carrier.

The coefficient of variation $cv(s)$ expresses "stage length variability per average stage mile". In 1967/68, the highest value of $cv(s)$ was 1.32 (Northwest Orient Airlines); in 1971/72, the highest was 1.20 (Braniff and National). "Traffic intensity per station" is measured alternatively by $\bar{d}$ or $\bar{p}$; the former variable is a stronger predictor.

The *Technology Variables* are of two kinds: (a) *aircraft variables* and (b) *service variables*. In the former category we include: $\bar{T}$ = average ton capacity of aircraft; $\bar{U}$ = miles flown per aircraft; $\bar{U}^*$ = airborne hours per aircraft; $\bar{F}$ = average fleet size; L = number of aircraft types in the fleet.

The most important single predictor of unit cost is aircraft capacity, measured here by $\bar{T}$. The variables $\bar{U}$ and $\bar{U}^*$ are two slightly different measures of fleet utilisation. Speed of aircraft will tend to increase $\bar{U}$ but not $\bar{U}^*$. Therefore, the correlation between $\bar{U}$ and $\bar{U}^*$ is higher in 1971/72 (0.882) than in 1967/68 (0.775), because in the earlier period the LSC fleets still contained a considerable portion of piston aircraft.

The service-oriented technology variables were: NSC = percent non-scheduled service = 100 × ATM of non-scheduled service/overall ATM; PSR = proportion of passenger service revenue = passenger service revenue/total operating revenue; LDF = load factor = revenue tonmiles/overall ATM.

Although weakly correlated with the unit cost variables, PSR and LDF turn out to be significant predictors for some of the unit costs, when used in combination with other predictors.

Size of a carrier is measured in this paper by its ATM.

For the 1971/72 analysis, we excluded the variables $\bar{p}$, $\bar{F}$ and L, which turned out to be of limited interest in the 1967/68 analysis. All variables were standardised to zero mean and unit variance. As a consequence, all regressions reported (Tables 1 and 2) are in standardised form.

3. PRELIMINARY CONCLUSIONS FROM THE DATA

The 1967/68 sample consisted of 11 Trunks (American, Eastern, TWA, United, Braniff, Continental, National, Delta, Northeast, Northwest, Western) and 9 LSCs (Hughes' Air West, Alleghany, Frontier, Mohawk, North Central, Ozark, Piedmont, Southern, Texas International). The important Trunk vs. LSC categorisation is clearly reflected in some of the variables defined in Section 2. For example, two Trunks tend to have very similar scores on $\bar{s}$, as do two LSCs; but the $\bar{s}$ score of a Trunk carrier is very different from that of an LSC. The same is true for the variable $\bar{T}$.

However, for most variables listed in Section 2, the most natural dichotomy is not achieved by the distinction between Trunk and LSC. Suppose we formalise the concept "most natural dicotomy" for a given variable X by defining it as that split into two groups which maximises the squared t-statistic,

$$t^2 = (x_1 - x_2)^2/s^2\,(1/n_1 + 1/n_2),$$

where $s^2 = [(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2]/(n_1 + n_2 - 2)$.

For each of the variables $\bar{s}$, $cv(s)$, and $\bar{T}$, the t^2 criterion produces precisely the Trunk vs. LSC dichotomy, with every Trunk carrier scoring higher than every LSC. For the variable $\bar{U}$, the t^2 maximisation gives a first group containing all Trunks except Eastern, which joins the LSCs in the second group. The dichotomy produced by the size variable, ATM, is the "Big Four Carriers" (American, Eastern, TWA, United) vs. the Rest (16 carriers).

As two mergers had taken place (Delta with Northeast and Alleghany with Mohawk), the 1971/72 sample size was reduced to 18, that is, 10 Trunks and 8 LSCs. Prorated adjustments were made for cost figures of a few carriers involved in strikes during part of 1971/72. In terms of ATM, there are five big carriers in 1971/72. Ranking fourth, ahead of Eastern, Delta-Northeast has (through merger) joined the earlier Big Four group. The gap between Trunks and LSCs remains big in 1971/72 on the variables $\bar{s}$ and $\bar{T}$, but no longer on $cv(s)$.

A comparison of 1967/68 and 1971/72 data shows some of the changes that took place in the U.S. airline industry between the two dates:

The *average level* of $\bar{s}$ for the Trunks increased by 23% from 1967/68 to 1971/72, and by 28% for the LSCs. In the case of the variables $cv(s)$, $\bar{T}$ and $\bar{U}$, the average level for Trunks increased by −4%, 24% and 7%, respectively, and the average level for the LSCs by 25%, 47% and 18%, respectively. The only big changes for the Trunks are the increases in $\bar{s}$ and $\bar{T}$. While the LSCs increased on all four dimensions, their tendency towards bigger aircraft ($\bar{T}$) and sprawling networks ($cv(s)$) is particularly noticeable.

The *relative position* of the carriers on such dimensions as $\bar{s}$, $\bar{T}$ and $\bar{U}$ changed little from 1967/68 to 1971/72. On each of the variables $\bar{s}$, $\bar{T}$ and $\bar{U}$, a carrier's score in 1967/68 correlates 0.93 or more with its score in 1967/68. For $\bar{d}$, $cv(s)$, and LDF, the correlation is 0.88, 0.68 and 0.37, respectively. For $cv(s)$ and LDF in particular, this indicates that the airlines rank rather differently on the two occasions. The data on *cv(s)* show that some LSCs rank ahead of several Trunks in 1971/72, whereas in the earlier period *all* LSCs were at the bottom of the list.

Another noticeable change concerns the relation between load factor and size of aircraft. In 1967/68, LDF and $\bar{T}$ correlated 0.13, whereas in 1971/72 the correlation was negative, at −0.42. This is in part explained by a drastic increase in $\bar{T}$ (through the acquisition of jumbo jet aircraft) with accompanying decreased load factors for certain Trunks, notably Northwest and American.

4. ANALYSIS OF 1967/68 DATA

(a) Screening of Technology variables

A stepwise regression was first performed for each of the unit cost variables MDC, FOC, and IC, using the eight technology variables as a set of potential predictors. Step one of the procedure selects, for all three unit costs, the predictor $\bar{T}$, which correlates about 0.93 with each of the unit cost variables. We noted above that $\bar{T}$ gives a striking expression of the difference between Trunks ($\bar{T}$ high) and LSCs ($\bar{T}$ low). From this it is clear that a high correlation will also obtain between unit cost and a simple dummy variable that takes the value 1 for a Trunk carrier and 0 for an LSC. This correlation is in fact about 0.90 for each of the three unit costs. Although little residual variation remains once the strong relationship between the unit costs and $\bar{T}$ has been partialled out, there are additional significant predictors to be revealed in step 2. Significant contribution to R^2 in step 2 is produced by any technology variable X with a significant semi-partial correlation $r_{Y(X \cdot \bar{T})}$. (The semi-partial correlation $r_{Y(X \cdot \bar{T})}$ is the correlation between Y and the residual of X when X has been regressed on $\bar{T}$). When $\bar{T}$ and one additional technology variable have been admitted to the regression, R^2 will be about 0.90 or more. This means that any variable X for which $|r_{Y(X \cdot \bar{T})}| \geqslant 0.13$ is significant at $\alpha = 0.10$ level, by the usual F-test. The variable X actually selected in step two is the one with the highest value of $|r_{Y(X \cdot \bar{T})}|$, , provided it is significant.

The semi-partial correlations $r_{Y(X \cdot \bar{T})}$ are as follows:

X	*1967/68*				*1971/72*			
Y	$\bar{U}$	$\bar{U}$*	*PSR*	*LDF*	$\bar{U}$	$\bar{U}$*	*PSR*	*LDF*
MDC	−0.09	−0.07	0.04	0.24	−0.23	−0.17	0.05	−0.10
FOC	−0.24	−0.19	0.16	0.08	−0.16	−0.14	−0.10	−0.16
IC	−0.08	−0.04	0.21	0.08	−0.06	−0.05	0.09	−0.02
TC	−0.13	−0.09	0.15	0.13	−0.13	−0.11	0.02	−0.08

The patterns for $\bar{U}$ and $\bar{U}^*$ are similar; this is not unexpected, since both measure fleet utilisation. As it turns out, $\bar{U}$ has a somewhat stronger explanatory effect than $\bar{U}^*$. In 1967/68, PSR has significant effects of FOC, IC, and TC. For IC, this is likely to be linked to high levels of passenger and service related items for carriers with high PSR. Increased crew and pilot wages is a likely reason for the tendency of FOC to increase with PSR. In 1967/68, the variable LDF has a significant effect only on MDC.

Only in the case of FOC is there a significant variable in step three, namely, PSR. The regression equations are given in Table 1.

(b) **Screening of Network variables**

Each of the Unit costs, MDC, FOC, and IC, was regressed by stepwise procedure to screen out the most important network predictors. The results are shown in Table 1. For each of the three dependent variables, $\bar{s}$ is picked in step one and $cv(s)$ in step two. Both $\bar{s}$ and $cv(s)$ have negative regression coefficients. In the case of $\bar{s}$ this is easy to accept; it is well-known that carriers with long stage length tend to have lower unit cost. As for $cv(s)$, our expectation, based on [1], was for negative slopes, and this was confirmed. The implication is that lower unit costs are predicted for carriers with a high degree of network heterogeneity, for a given level of $\bar{s}$.

Only MDC shows a third significant variable, namely, $\bar{d}$. When $\bar{s}$ and $cv(s)$ are fixed, an increase in MDC is predicted for carriers with high departure density $\bar{d}$. Three of the Big Four carriers, American, TWA and United, rank at the top in terms of d, and their MDC is also higher than one would expect, considering their size.

(c) **Relation of Network to Technology**

Three network variables, $\bar{s}$, $cv(s)$, and $\bar{d}$, and four technology variables, $\bar{T}$, $\bar{U}$, PSR, and LDF, have been selected so far in our analysis. This selection of network variables was confirmed by stepwise regression of each of the selected technology variables, using the set of five network variables as potential predictors. The results are given in Table 2, except for PSR, which has no significant network predictor. Network heterogeneity, $cv(s)$, is a significant predictor for $\bar{T}$, but not for $\bar{U}$. Both $\bar{T}$ and $\bar{U}$ tend to increase significantly with $\bar{s}$, as would be expected. Table 2 also shows that fleet utilisation $\bar{U}$ will tend to fall, and the load factor LDF will tend to increase, for carriers with high departure density $\bar{d}$. Both conclusions are easy to accept. Delays at high traffic centres are probably responsible for the drop in $\bar{U}$.

(d) **Testing the causal model (1)**

The analysis so far indicates that the variables influencing MDC are $\bar{T}$, LDF, $\bar{s}$, $cv(s)$, and $\bar{d}$. For FOC, the relevant variables are $\bar{T}$, $\bar{U}$, PSR, $\bar{s}$, $cv(s)$, and $\bar{d}$. For IC, finally, the relevant variables are $\bar{T}$, PSR, $\bar{s}$, and $cv(s)$. Testing of the model (1) was done by running the regression of each unit cost variable on the indicated predictors. The model (1) hypothesises an absence of direct effects of network on unit cost. This hypothesis would be confirmed if the regression coefficients were significant for technology predictors but non-significant for network predictors. This turned out to be so. Thus model (1) is supported by the data. Figure 1 shows the path diagram for 1967/68.

TABLE I

Unit cost regressed on Technology and on Network

I = 1967/68; II = 1971/72

Indicated Variables are Significant at α = 10% Level

	Regression of Unit cost on Technology					*Regression of Unit cost on Network*			
	Slope, standardised data (Standard error of slope)					*Slope, standardised data (Standard error of slope)*			
Criterion	$\bar{T}$	$\bar{U}$	*LDF*	*PSR*	R^2	$\bar{s}$	$cv(s)$	$\bar{d}$	R^2
MDC I	−0.967 (0.062)		0.243 (0.062)		0.931	−0.864 (0.174)	−0.461 (0.136)	0.383 (0.153)	0.864
MDC II		−0.892 (0.087)	0.355 (0.087)		0.879	−0.737 (0.108)	−0.316 (0.108)		0.851
FOC I	−0.551 (0.125)	−0.429 (0.125)		0.139 (0.067)	0.924	−0.607 (0.158)	−0.345 (0.158)		0.802
FOC II	−0.719 (0.113)	−0.284 (0.113)			0.931	−0.718 (0.124)	−0.034 (0.124)		0.803
IC I	−0.917 (0.072)			0.213 (0.072)	0.906	−0.502 (0.127)	−0.497 (0.127)		0.872
IC II	−0.961 (0.067)				0.924	−0.710 (0.115)	−0.337 (0.115)		0.832
TC I	−0.793 (0.109)	−0.192 (0.108)	0.101 (0.058)	0.144 (0.057)	0.949	−0.559 (0.126)	−0.440 (0.126)		0.874
TC II	−0.787 (0.074)	−0.232 (0.074)			0.970	−0.743 (0.095)	−0.333 (0.095)		0.884

TABLE 2
Technology Regressed on Network
I = 1967/68; II = 1971/72
Indicated Variables are Significant at α = 10% Level

Criterion		*Slope, standardised data (Standard error of slope)* $\bar{s}$	$cv(s)$	$\bar{d}$	R^2
$\bar{T}$	I	0.651 (0.085)	0.383 (0.085)		0.943
$\bar{T}$	II	0.744 (0.100)	0.322 (0.100)		0.872
$\bar{U}$	I	1.141 (0.197)		−0.368 (0.197)	0.758
$\bar{U}$	II	0.827 (0.136)			0.684
LDF	I	−0.718 (0.327)		0.976 (0.327)	0.335
LDF	II		−0.607 (0.193)		0.369

5. ANALYSIS OF 1971/72 DATA

In the 1971/72 analysis we were interested in seeing how well some of the main 1967/68 conclusions would hold. We expected to find the following confirmations of 1967/68 results: (a) that the causal model (1) also applies to the 1971/72 data, and that the path diagram in 1971/72 is virtually the same as in 1967/68; (b) that $\bar{s}$, $cv(s)$, and $\bar{d}$ are important network variables; (c) that $\bar{T}$, $\bar{U}$, LDF, and PSR are important technology variables; (d) and $\bar{U}$ and $\bar{U}^*$ act as substitute measures for fleet utilisation.

We duplicated step by step the 1967/68 analysis described earlier. The results confirmed in essence all our expectations (a) to (d), except that $\bar{d}$ and PSR were no longer found to be important variables. The equations are summarised in Tables 1 and 2, where 11 indicates 1971/72 data, and the path diagram is given in Figure 2. Comparing the two time periods, we find that the results in Tables 1 and 2 are remarkably consistent, despite big changes in the airline industry (see Section 3). The values of R^2 are very similar, and even the regression coefficients are in most cases close.

A few points deserve to be emphasised in the 1971/72 analysis:

1. For each of the three unit costs, $\bar{T}$ is (as in 1967/68) the best predictor. However, in the case of MDC, the best two-variable explanation involves $\bar{U}$ and LDF, and not $\bar{T}$.

2. The tendency of MDC to increase with LDF is consistent for the two periods. However, LDF is explained differently in terms of the network variables on the two occasions. In 1967/68, low $\bar{s}$ and high $\bar{d}$ tend to produce high LDF. In 1971/72, low $cv(s)$ tends to give high LDF. Both explanations are easy to accept; the later one

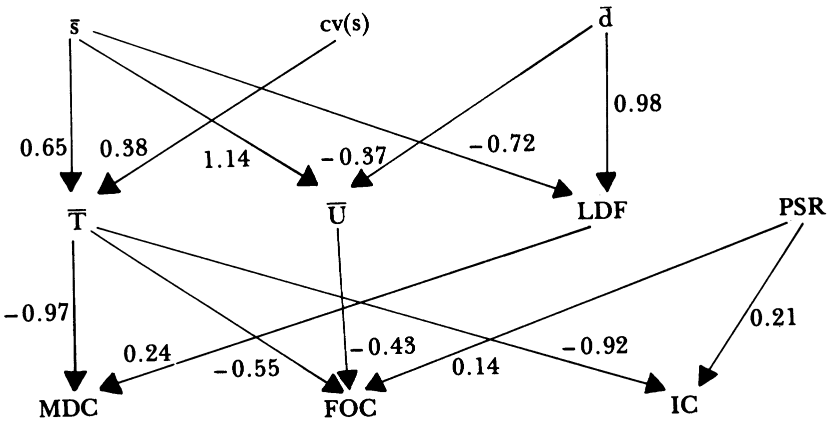

FIGURE 1
Path Diagram, 1967/68 Data

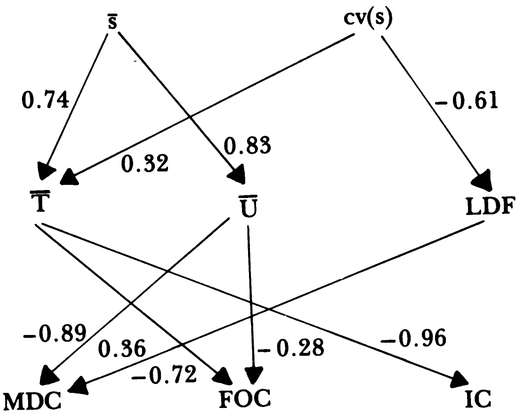

FIGURE 2
Path Diagram, 1971/72 Data

suggests that a favourable situation for a high load factor is frequent runs between a few high traffic centres (that is, a low $cv(s)$-value), rather than the servicing of many stations in a fragmented network (a high $cv(s)$-value). We recall from Section 3 that it is on the dimenstions $cv(s)$, LDF and $\bar{d}$ that the more noticeable shifts in the ranking of the carriers occurred between 1967/68 and 1971/72.

6. SUMMARY

We have in this paper: (1) presented a causal analysis of three unit cost variables (MDC, FOC and IC) for U.S. airlines in 1967/68 and 1971/72; (2) provided important additional support for the causal model (1); (3) shown that, for both time periods, $\bar{s}$ and $cv(s)$ are network variables of major impact on unit costs, and that $\bar{T}$, $\bar{U}$ and LDF are the technology variables of major impact: detailed path diagrams are presented in Figures 1 and 2; (4) outlined the changes (on the dimensions essential to this study) that U.S. airlines have undergone between the two time periods.

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