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A TOTAL FACTOR PRODUCTIVITY BASED STRUCTURE FOR TACTICAL CLUSTER ASSESSMENT: EMPIRICAL INVESTIGATION IN THE AIRLINE INDUSTRY

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ABSTRACT

In this paper we analyze and assess the efficiency of the United States (U.S.) airline industry through the total factor productivity (TFP) method. While airlines use various resources to produce a heterogeneous group of outputs, this article focuses on certain fundamental outputs as final products of selected airlines. The results from this analysis indicate that the national airlines (U.S. domestic carriers) have higher TFP as compared to the major airlines. While major airlines have drastically cut costs in the past few years, they also need to improve efficiency or risk going out of business. In this paper, we investigate the efficiency and productivity of a selection of U.S. airlines for the years 1996 through 2001. These years have been chosen as a good example of years in which the industry experienced normal growth and generally positively returns. Subsequent to 2001 the industry experienced two severe external shocks, namely, the September 11, 2001, terrorist attacks and the Iraq war. These anomalous shocks make the years after 2001 inconsistent with respect to the type of index developed in this article.

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INTRODUCTION

The recent decline in airline profitability and productivity is not unique by historical standards. The magnitude of this decline,[1] however, is significantly greater due, in part, to the confluence of economic recession, SARS, the Iraq war and recent security concerns. Since the terrorist attacks on September 11, 2001 (9/11), certain airlines, such as United and US Airways, have filed for bankruptcy, while others, such as Delta and American, have flirted with the idea repeatedly, but have so far managed to avoid this fate. US Airways received $900 million in federal bailout money in March 2003 as it emerged from bankruptcy protection. However, only two years since its first filing, US Airways was forced again to return to the protection of the bankruptcy courts.

Nonetheless, even in the absence of strong traffic demand, innovative new airlines, such as JetBlue Airways, have been able to enter airline markets and successfully capture market share from incumbent airlines. For the past few years, smaller airlines have prospered as the bigger airlines rushed to bankruptcy courts. On April 25, 2003, JetBlue Airways placed a firm order for 65 Airbus A320 aircraft. Delivery of the new aircraft began in 2004 and will run through to 2011.[2] JetBlue Airways also announced an option for 50 more Airbus planes (Carey, 2003). Among the major U.S. airlines, Southwest is the only airline to remain profitable despite 9/11.[3] To ensure survivability, many airlines, such as Delta, Northwest, American and United, have slashed costs in order to improve financial and operational efficiencies. While efforts to reduce costs are not uncommon during economic recessions, the efforts undertaken by the airline industry may have been extreme. These initiatives have included massive reductions in work force, major changes to service, and significant wage concessions from employee groups. In effect, these airlines have had to substantially

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[1] U.S. airlines have sustained $18 billion in losses in the past two years.
[2] JetBlue has reported a profit each quarter since its public offering in April 2002.
[3] Since the 1978 airline deregulation act, 13 of the largest 20 airlines have gone out of business.

restructure themselves, operationally and financially, whether they sought the protection of the bankruptcy courts or not.

On the other hand, the success of the low cost, low frills airlines relative to their hub-and-spoke counterparts has not been limited to their financial performance. In the most recent update of their annual Airline Quality Rating study, Bowen and Headley (2004) find that the low cost, low frills carriers generally outperform the legacy hub-and-spoke carriers in terms of service measures for on-time performance, denied boardings, mishandled baggage, and customer complaints. The most recent update is based upon 2003 data reported to the U.S. Department of Transportation.

Table 1. 2004 Airline Quality Rating (AQR)

Airline	AQR	Airline	AQR
Jet Blue	(0.64)	Air Tran	(1.05)
Alaska	(0.74)	United	(1.11)
Southwest	(0.89)	ATA	(1.17)
America West	(0.89)	American	(1.24)
U.S. Airways	(0.96)	Delta	(1.24)
Northwest	(1.02)	American Eagle	(2.10)
Continental	(1.04)	Atlantic Southeast	(5.76)

Conversely, the major airlines have substantially reduced the number of flights operated, and have parked thousands of unused aircraft in the desert. American Airlines has restructured its flight schedule in order to eliminate flight banks at its major hubs (i.e., de-hubbing) in order to gain better utilization of employees and operating assets. In-flight services have been scaled-back or eliminated, including meal service on most domestic flights and complimentary cocktails on international flights. US Airways' labor force has dwindled dramatically in recent years; from 46,000 employees before 9/11 to 28,000 in 2004. The airline has gone through a bankruptcy restructuring and successfully cut costs by nearly $2 billion, including about $1 billion in concessions from employees. Further, certain major airlines have attempted to emulate their low-cost competitors with the formation of their own low-cost, no-frills subsidiaries,[4] despite limited historical success at such operations.

[4] For example Delta Air Lines' new low-fare startup airline Song is an attempt to reproduce the success of rivals Southwest and JetBlue Airways. United Airlines has also created a low-cost airline in an attempt to recapture the market share lost to low-cost competitors, including America West, Southwest and JetBlue. United has chosen the name Ted for its low-cost airline venture and it started flying in February 2004. Ted will be based at Denver International

Airlines, however, tend to operate with substantial operating and financial leverage.[5] While these efforts do reduce operating costs, the impact is mitigated by the substantially fixed nature of airline costs. Although parking aircraft in the desert allows airlines to avoid operating costs such as labor, fuel and associated maintenance, the substantial carrying cost of these assets in the form of lease payments and interest expense remains. Further, the substantial costs associated with operating hub structures are not easily reduced. Thus, the major airlines tend to enjoy higher levels of leverage, which can be beneficial in periods of economic expansion, but detrimental in periods of contraction. As the preceding discussion makes clear, not all airlines have been equally affected by 9/11.

Therefore, the question arises as to how these results might be generalized, and how to provide quantitative measures of the factors that have influenced the more successful smaller airlines during this period. If some measure of productivity that accounted for these factors could be determined, then airlines and external analysts could have benchmarks against which they could measure individual airline performance. Such measures might also provide internal indications of problems. It is the purpose of this paper to provide a methodology against which an airline could measure its performance. This methodology involves a comparison between and amongst airlines that ranks them according to productivity and efficiency.

The paper is organized as follows. In the next section, the productivity analysis and methodology are presented. This is followed by a description of the efficiency measurement methodologies. The fourth section discusses data issues and variables used in the models, while the fifth section presents the empirical results. The final section provides a summary and conclusion of the ideas discussed above relating to the TFP of the U.S. commercial aviation industry.

PRODUCTIVITY ANALYSIS AND METHODOLOGY

Despite the fact that many studies of efficiency and productivity have been conducted on airports and other industries, limited work has been completed in evaluating the efficiency of commercial airlines (Hooper &

Airport, the home of discount carrier Frontier. The Ted fleet will begin with four Airbus A320 aircraft and expand to as many as 45.

[5] A high degree of operating leverage implies that a small change in sales will result in a large change in net profit. Therefore, high operating leverage equals high business risk. Financial leverage is the degree to which a business is utilizing borrowed money or fixed assets. Companies that are highly leveraged may be at risk of bankruptcy if they are unable to make payments on their debt; they may also be unable to find new lenders in the future.

Hensher 1997; Oum, Yu, & Fu, 2003).[6] This paper seeks to fill this void by adapting the models and techniques used in these studies of other industries to evaluate the efficiency of U.S. airlines. This is of particular importance given the current concerns over the financial condition of commercial aviation and the financial viability of the industry.

Efficiency and productivity are key to the success of the commercial aviation industry, and, therefore, models that measure efficiency can be extremely useful. The available literature reports the adoption of commonly used techniques such as ratio analysis, data envelopment analysis (DEA), TFP, and stochastic frontier analysis (SFA) each with its own strengths and weaknesses.

DEA measures the relative efficiencies of Decision Making Units (DMUs) based upon a linear programming model. Inferences are drawn from optimal solutions. The critical feature of DEA is the selection of inputs/outputs, as well as the definition of the appropriate DMUs.

The DEA methodology was utilized by Charnes, Cooper and Rhodes (1978) who built on the frontier concept initiated by Farrell (1957). DEA uses linear programming techniques to calculate the Malmquist index of TFP growth, while the SFA calculates both technical efficiency and technical change components of TFP growth.

Farrell (1957) pioneered the primary ideal of the SFA to measure the efficiency of productive units. Since then, many researchers have broadened the SFA in evaluating efficiency. Nonetheless, Farrell's parametric estimation was unable to fully satisfy the particular nature of the large stochastic model. Hence, Aigner, Lovell, and Schmidt (1977), as well as Meeuseu and van den Broeck (1977), brought forth the SFA to measure efficiency.

The SFA was applied to decompose TFP into technological progress and efficiency. This enabled the model to specify the mechanism by which investment affects productivity (Cooper & Tone, 1997). The typical approach with the SFA is to draw inferences from optimizations over all observations (Cooper & Tone, 1997). The word frontier emphasizes the idea of maximally and represents the best practice approach to production.

Nero (1999) explored the extent to which a competitive advantage is secured by airlines operating large hub-and-spoke networks. Specifically, he looked at the relationship that arises among productive efficiencies and profitability when the size of the network expands. Nero found that returns to size are not constant, but rather decreasing. However, while suggesting

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[6] For example, the Air Transport Research Society (ATRS) publishes its annual Global Airport Performance Benchmarking Report. The report measures and compares the performance of three aspects of airport operation: Productivity and Efficiency, Cost Competitiveness and Financial Results, for up to 90 major airports in Asia Pacific, Europe and North America.

that an effective limit to size likely exists, Nero concluded that increasing network size still provides a competitive advantage. Ozment and Morash (1998), in their research to evaluate the relationship between productivity and performance quality in the U.S. domestic airline industry, argued that network density is correlated with productivity and lower output costs, as well as higher subjective measures of quality. On the other hand, Ozment and Morash found no such correlation between input cost efficiency, and lower output costs and quality.

Coelli, Grifell-Tatje and Perelman (2002) examined the inefficiency in profit generation (as well as the contributing components) of a sample of international airlines. Feng and Wang (2000) argued for the inclusion of financial ratios and considerations, in addition to operational measures, in evaluating airline performance. They contended that ignoring these financial considerations provides an incomplete picture of airline performance and survivability. The approach of Feng and Wang divided airline performance into production, marketing and execution efficiencies. Financial statistics are found to be best for measuring execution efficiency, while operational measures are best in measuring production efficiency. Forsyth, Hill and Trengove (1988) found that the North American airlines performed well compared to the European airlines, confirming the results of some earlier studies of airline productivity. In addition, the study discovered substantial differences across some of the European airlines.

Using the DEA methodology, Bazargan and Vasigh (2003) analyzed the performance of 45 U.S. commercial airports selected from the top 15 large, medium, and small hub airports. The results suggest that the relative efficiency of the airports is highest for small and lowest for large hub airports.

Thus, the literature shows numerous attempts to measure various aspects of efficiency. For this study, TFP will be used to measure and compare commercial airlines. The rationale for this is outlined below.

Performance can be measured based on efficiency or effectiveness. Efficiency is related to the supply side, where the technique of transformation of physical inputs (such as pilots, flight attendants, aircraft, fuel, etc.) into physical outputs of service (such as passengers, cargo, operating revenues and profits) can be assessed. Productivity is basically an efficiency measure that shows how well an airline utilizes its resources, and can be expressed in different ways.

TFP measures the productivity of all inputs engaged in the production process. This, in effect, allows us to measure its cost-efficiency and cost-effectiveness (the difference being in the selection of the measure of output).[7] TFP aggregates outputs on the basis of their revenue contribution, and inputs on the basis of their relative importance to total costs, in order to calculate the overall airline productivity as a function of these quantities.

Therefore, TFP allows us to distinguish productivity differences in airlines that arise from economies of scale as opposed to those differences resulting from managerial performance. In this paper, a Malmquist (1953) TFP index is used to investigate the efficiency and productivity of a selection of U.S. airlines for the years 1996 through 2001. The results are then used to compare airline performance.

There are many different ways of measuring productivity. For example, in a factory productivity might be measured based on the number of hours it takes to produce a product, while in the service sector productivity might be measured based on the revenue generated by an employee divided by the number of hours worked. Hence, productivity is concerned with the ratio of outputs over inputs.

Productivity measures can be categorized in two primary methods: first, TFP, which is calculated by dividing total measured outputs by total measured inputs, and second, partial productivity, which is calculated by dividing total outputs by each factor input.

We start by introducing a production function that relates different observable inputs (I_m) to output Q:

$$Q = f(I_1, I_2, \ldots, I_m, t)$$

The above production function contains a time variable t that explains the shift of the production function over time. In this paper we measure productivity by using the index number method. Productivity measures try to capture the ability of inputs to produce output.

Following Tornqvist (1936) the output quantity index is defined as follows:

$$Q_{st}^{T} = \prod_{j=1}^{n} \left(\frac{Q_{jt}}{Q_{js}} \right)^{\left(\frac{1}{2}\right)(Wjs+Wjt)} \qquad (1)$$

The Tornqvist index is the weighted geometric average of the output relatives, with weights given by a simple averaging of the value of the shares

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[7] It is also possible to examine economies of scale and density, as well as investigate the impact of variations of input and output prices on the performance of a DMU (Gillen & Lall, 1997).

in period s and t. In the above equation, Q_{js} represents the quantity of j^{th} output in the s period.

Input quantity indexes are defined in a similar manner:

$$I_t^T = \prod_{i=1}^{m} \left(\frac{I_{it}}{I_{is}} \right)^{\left(\frac{1}{2}\right)(V_{is}+V_{it})} \tag{2}$$

In general a productivity index is defined as the ratio of an output quantity index to input quantity index, that is:

$$TFP_k = \frac{\prod_{j=1}^{n} \left(\frac{Q_{jt}}{Q_{js}} \right)^{\left(\frac{1}{2}\right)(Wjs+Wjt)}}{\prod_{i=1}^{m} \left(\frac{I_{it}}{I_{is}} \right)^{\left(\frac{1}{2}\right)(V_{is}+V_{it})}} \tag{3}$$

The following TFP model, in logarithmic format, is similarly a framework introduced by Caves, Christensen and Diewert (1982). The appropriate input weights in the following equations are the contributions of each input and output in the system (Hooper & Hensher, 1997). Equation 4 represents a pair-wise comparison of two airlines in one year. To form the TFP, it is necessary to divide the output quantity indexes by input quantity indexes:

$$Ln\frac{TFP_k}{TFP_b} = \frac{1}{2}\{\sum_j W_k(LnQ_{kj} - \overline{Ln\,Q_{kj}}) - \sum_i V_i(Ln\,I_{ki} - \overline{Ln\,I_{ki}})\}$$
$$-\frac{1}{2}\{\sum_j W_b(LnQ_{bj} - \overline{LnQ_{bj}}) - \sum_i V_b(Ln\,I_{bi} - \overline{Ln\,I_{bi}})\} \tag{4}$$

Where:

$\overline{Ln\,I_{ik}}$ = geometric average of input over the entire observations in the sample;

$\overline{LnQ_{ik}}$ = geometric average of output over the entire observations in the sample; and

b = base airline.

Likewise, where:

Q_{jk} = is the j x k matrix of all airlines outputs
I_{jk} = is the i x k matrix of all airlines inputs
j = number of outputs, j = 1, ..., J
i = number of inputs, i = 1,...,N
k = number of airlines, k = 1, ..., K
W = weights assigned to each output

The revenue contributions of each output could be used as applicable output weights.

Where:

V = weights assigned to each input;
$\overline{Ln\, I_{ik}}$ = geometric average of input over the entire observations in the sample;
$\overline{Ln\, Q_{ik}}$ = geometric average of output over the entire observations in the sample; and
b = base airline.

EVALUATION OF AIRLINE EFFICIENCY: EMPIRICAL RESULTS

The intent of this study is to analyze and evaluate the efficiencies of major U.S. airlines and to compare them to national airlines (U.S. domestic carriers).[8] This study used the annual statistics (1996-2001) on major and national airlines from the Form 41 (Form 41, 2003).[9] On the input side, the study includes two types of variables: physical units of input, and dollar values. Five input variables were selected:

1. Available seat miles (ASM);
2. Total expense;
3. Cost per available seat mile (CASM);
4. Average number of employees; and
5. Fuel cost.

[8]The FAA groups carriers according to the operating revenue boundaries contained in Section 04 of Part 241. Major airlines have operating revenues of over $1 billion. Airlines with revenues between $100 million and $1 billion in revenues are defined as national airlines.

[9] Large, small, and commuter certificated air carriers are required to complete Form 41 Financial and Traffic Reporting Requirements. The Office of Airline Information (OAI) within the Bureau of Transportation Statistics (BTS) collects data on the Form 41.

A total of five output variables were also selected:

1. Revenue passenger miles (RPM);
2. Yield;
3. Total revenue;
4. Revenue per available seat mile (RASM); and
5. Load factor.

Tables 2, 3 and 4 show the rankings of the major and national airlines in terms of their efficiency scores and the average TFP, for the years 1996 through 2001.

Table 2. Total factor productivity for U.S. major airlines, 1996-2001

Majors	1996	1997	1998	1999	2000	2001
American	0.13	0.13	0.01	0.07	0.17	0.09
American Trans Air	0.54	0.59	0.64	0.95	0.90	0.66
Continental	0.41	0.43	0.42	0.29	0.39	0.36
Delta	0.16	0.25	0.28	0.16	0.29	0.16
Northwest	0.30	0.49	0.17	0.19	0.29	0.25
Southwest	0.46	0.47	0.49	0.46	0.63	0.41
United	0.17	0.14	0.17	0.08	0.12	0.10
US Airways, Inc	0.32	0.36	0.45	0.28	0.24	0.34

Table 3. Total factor productivity for U.S. national airlines, 1996-2001

National	1996	1997	1998	1999	2000	2001
AirTran	0.69	0.76	0.68	0.76	0.73	0.76
Alaska	0.57	0.59	0.69	0.60	0.56	0.61
Aloha	0.85	0.83	0.89	1.00	0.85	0.92
American West	0.53	0.56	0.57	0.56	0.52	0.59
Frontier	0.83	0.64	0.83	0.89	0.84	0.84
Hawaiian	0.84	0.67	0.72	0.64	0.69	0.80
Horizon	0.85	0.84	0.85	0.93	0.81	0.91
Midwest Express	0.83	0.81	0.82	0.89	0.77	0.84
Spirit	0.90	0.86	0.85	0.82	0.87	0.85
World	0.77	0.81	0.82	0.89	0.85	0.71

During the observation period, national airlines have continuously outperformed major airlines. As the tables imply, among the major airlines, American Trans Air and Southwest Airlines have the highest productivity for all 6 years (1996-2001). However, it should be pointed out that subsequent to the period of evaluation, and as a direct result of sluggish demand, resulting from 9/11, ATA imposed a wage freeze for non-contractual personnel, furloughed 300 people and eliminated 400 jobs. It is also of interest to note that Southwest Airlines is the only major U.S. based airline to remain continuously profitable since its maiden voyage in 1971. In 2003, Southwest posted a net income of $442 million (up $78 million from 1999). On the other hand, American, United and Delta Airlines have had the lowest productivity. In 2000, American Airlines' net income was at $813 million (down $172 million from the year before), while in 2001 it reported a net loss of $1,762 Million. Also, in 2000, United Airlines reported net earnings of $50 million (down $1,185 million from 1999) while in 2001 it had a net loss of $1,762 million.[10] US Airways and United have lowered costs through bankruptcy, and American Airlines enjoyed major labor concessions from unions and avoided bankruptcy. While US Airways slashed its costs, they still are the highest in the industry. It is 11.7 cents cost per available seat mile (CASM) is about 20% above the average for the major airlines. The third worst performer, Delta Airlines, has a cost structure that is much higher than those of its competitors.

Table 4. Average total factor productivity for U.S. airlines, 1996-2001

Airline	ATFP	Airline	ATFP
Aloha	0.89	American Trans Air	0.71
Horizon	0.87	American West	0.56
Spirit	0.86	Southwest	0.49
Midwest Express	0.83	Continental	0.38
Frontier	0.81	US Airways	0.33
World	0.81	Northwest	0.28
Airtran	0.73	Delta	0.22
Hawaiian	0.73	United	0.13
Alaska	0.60	American	0.10

While the productivity rankings within the group of major airlines have remained relatively static, the productivity rankings of the national airlines have exhibited considerable variability from year to year. As smaller, less stable enterprises, these operations are subject to considerable variability in both operational and financial performance. The calculated productivity for these individual airlines is influenced by their rising and falling fortunes. However, they have still managed to be more productive than the major airlines. Some reasons for this greater productivity may be attributed to smaller fleet sizes, lower financial leverage, avoidance of congested hub airports, and a less diverse fleet.[11]

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[10] United Airlines filed for Chapter 11 bankruptcy in December 2002. US Airways, the sixth largest domestic airline, had previously filed for bankruptcy protection in August 2002, following the collapse of Midway, Sun Country and Vanguard airlines.

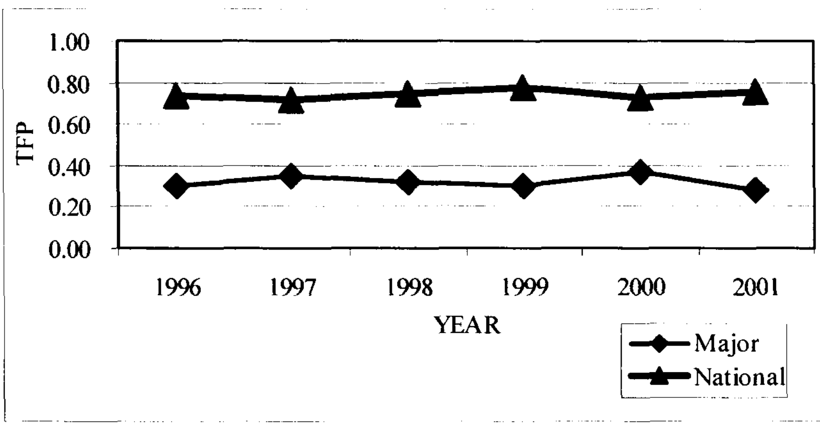
[11] Delta Airlines avoids its hubs using Song (its low-cost carrier) and flies the aircraft, B-757, more hours per day than its mainline operations.

As shown on Table 3, the top three national airlines are Aloha Airlines, Horizon Airlines, and Spirit Airlines, in that order. Alaska Airlines has been the least efficient national carrier during the period of 1996 through 2001.

Founded in 1946, Aloha operates an average of 145 daily flights with a fleet of Boeing 737 jets.[12] In 1999, Aloha improved its first-quarter profit by 10.7 percent despite a 2.7 percent drop in revenues.

This analysis has demonstrated a consistently higher productivity for the national airlines as compared to the major airlines (Figure 1). The peak productivity occurred in 2000 for the national airlines, at which time the major airlines exhibited a relatively significant lower productivity. The major airlines exhibited relatively consistent productivity as compared to the national airlines, which peaked in 1999-2000. The national airlines demonstrated a decline in productivity in 1999, but experienced an immediate recovery after that.

Figure 1. Total factor productivity for major airline and national airline, 1996-2001



These results raise questions with respect to the cost structures of airlines. The stronger productivity of the national airlines as a group, relative to the major airlines, indicates that the major airlines may have exceeded the effective limit to size suggested by Nero (1999). Further, while the hub-and-spoke system, which evolved following deregulation of the industry, has been credited with allowing for the efficient provision of air transportation to smaller markets and routes, the relative productivity rankings of this analysis

[12] The airline's outstanding in-flight service was recently recognized as the first place Diamond Award winner in international competition conducted by Onboard Services magazine.

suggest that perhaps these hub-and-spoke systems decrease TFP. In addition to the national airlines out performing the major airlines, Southwest Airlines, a point-to-point carrier, has significantly outperformed the remaining major carriers. Southwest has been profitable by keeping costs about 20% lower than the industry average. The lower productivity of the major airlines may in fact result from the inefficient use of assets and expenses associated with the operation of hub systems, an issue American Airlines has tried to address with its de-hubbing efforts at O'Hare International Airport and Dallas-Fort Worth International Airport.

Potential explanations for the decline in productivity of the national airlines over the analysis period are less readily apparent. Harraf and Vasigh (1994) suggest a counter-cyclical beneficial impact for low-cost and start-up carriers. These airlines benefit from reduced wage rates and aircraft acquisition costs, as well as demand substitution impacts associated with periods of economic recession. These same influences negatively impact such carriers during economic expansion. Thus, under this proposal, the national airlines would have experienced increasing pressures from these factors as an economic expansion continued through this analysis period and did not wane until late-2000 or early 2001.

In January 2004, America West Airlines reported a fourth quarter net income of $6.8 million or $0.13 diluted earnings per share. This compares to a net loss of $52.0 million or $1.54 per share for the same period last year. The airline's operating expenses in the fourth quarter decreased 1.5 percent to $544.6 million. Continued cost diligence and increased capacity resulted in a 2.5 percent decrease in the airline's CASM in the fourth quarter of 2003. On a fuel exclusive basis, the airline's CASM in the fourth quarter of 2003 declined 4.3 percent to 6.44 cents.

In order to provide a further evaluation of the TFP index developed in this paper, we compared the TFP to some more conventional measures of financial performance for all of the airlines used in this study and also the major and national carriers as a group. The first of these financial measures was a simple measure of return on assets (ROA), defined as total revenue minus total cost divided by total assets, and the second measure was basically a measure of the gross profit margin (GPM), and defined as total revenue minus total cost divided by total revenue. Our hypothesis was that the TFP should track positively (in either the negative or positive direction) with the more conventional measures over the time period evaluated.

The results of this analysis are contained in Table 5. As the table indicates, and as might be expected with the data sample of this size, the results are mixed, but generally supportive of the hypothesis.

More specifically, as far as the major airlines are concerned, for those with a negative *r* value, or no correlation either negative or positive between the TFP and the financial measures, the *t* value is not significant at any meaningful level. The only exception to this is the ROA value for American Airlines, and this measure would require further investigation. The remaining major airlines have positive correlations with varying levels of significance for the two measures used. When the major airlines are aggregated, then the results are much better for both measures. In both cases the aggregated measures of correlation are significant at a better than 95% level of significance, showing a strong correlation between the TFP and the more conventional measures of performance. This may also be a reflection of the generally smaller variation of the performance measures for the major airlines that was mentioned earlier in the paper.

Table 5. Statistical analysis of measures of financial performance, for major and national airlines, 1996-2001

	ROA		GPM		Critial t	
	R	t	R	t	One tail	Two tail
Major Airlines						
American	0.94	-3.74	0.54	-0.90	2.13	2.78
American Trans Air	0.04	-0.06	0.14	0.21	2.13	2.78
Continental	0.11	0.16	0.82	2.00	2.13	2.78
Delta	0.33	-0.50	0.35	-0.52	2.13	2.78
Northwest	**0.85**	**2.27**	0.78	1.75	2.13	2.78
Southwest	0.51	0.84	0.71	1.42	2.13	2.78
United	0.05	-0.06	0.22	0.32	2.13	2.78
US Airways, Inc.	0.66	1.24	**1.00**	**24.48**	2.13	2.78
Major aggregated	0.47	1.98	**0.56**	**3.41**	1.70	2.05
National Airlines						
AirTran	0.39	-0.60	0.15	0.21	2.13	2.78
Alaska	0.73	1.51	0.75	1.62	2.13	2.78
Aloha	0.23	-0.33	0.32	-0.48	2.13	2.78
American West	**0.95**	**4.46**	**0.99**	**11.98**	2.13	2.78
Frontier	**0.98**	**7.46**	**0.93**	**3.68**	2.13	2.78
Hawaiian	0.80	1.89	**0.89**	**2.70**	2.13	2.78
Horizon	**0.85**	**2.29**	**0.84**	**2.18**	2.13	2.78
Midwest Express	0.67	1.26	0.76	1.63	2.13	2.78
Spirit	0.19	-0.28	0.12	-0.17	2.13	2.78
World	0.17	-0.24	0.78	-1.75	2.13	2.78
National aggregated	0.19	1.29	0.04	0.26	1.68	2.02
All	0.05	-0.43	0.21	-1.84	1.68	2.01

The results for the national airlines are again mixed. Just as in the case of the majors, the national airlines that exhibit negative correlations are not significant at any meaningful levels, and this is true for all of the negative values. On the other hand, for those nationals that exhibit positive correlations, the majority of the results are very significant and strong for both conventional measures. The weakest of these is the ROA correlation for Midwest Express that is not significant at conventional levels, but still exhibits a respectable *r* value of .66. All of the other values for the correlation of the financial measures with TFP are significant at a .9 or better level (five airlines and nine *t* values). However, the aggregate measure for the national airlines is not significant at all. Again, and as mentioned earlier, this result probably reflects the inherently larger variation present in all the performance measures for the national airlines.

Overall, the results from this extended analysis of the TFP index are encouraging, although it is obvious that a larger data sample (over time) will be needed to provide a more significant validation of the TFP index.

SUMMARY AND CONCLUSION

This paper espouses an embryonic process, which uses selected literature to explore the applications of different productivity measures and their limitations on the U.S. commercial aviation industry. This study highlights the relatively stronger productivity achieved by the U.S. national airlines as compared to the U.S. major airlines. This analysis did not attempt to examine the relatively poor performance of the major airline group.

It is clear that little work has been completed to date in the area of airline productivity. Yet, this industry is a vitally important element of the U.S. transportation system and exhibits a significant impact on the overall economy. Understanding that differences in productivity do exist is the first step in evaluating these differences.

It is not surprising that differences in performance exist between individual enterprises. However, it is interesting that significant, sustained differences in productivity exist between important segments within this industry. These differences raise important questions with respect to the nature, cost structure, and long-term viability of these segments. Such questions correspond to the performance of the industry as a whole, as well as the relative performances of the various segments in 2001 through the current period.

Important further study of this subject would include the analysis of productivity through the industry recession as that data becomes available. It should be expected that significant erosion in productivity would be followed by an improvement as restructuring efforts take effect. The dynamic nature of demand, with the static nature of supply and cost structure, would dictate that the near-term plunge in demand would cause a decline in productivity since the supply is necessarily slower to adjust. As predicted by these productivity measures, the major airlines have undertaken significant measures to increase productivity and to lower cost. However, these responses have been formulated in the absence of significant academic research into the reasons of the specific causes of these productivity differences. Thus, these results indicate the urgency of further research in order to formulate appropriate responses and structures to insure long-term viability.

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