An Analysis of Labor and Multifactor Productivity in Air Transportation: 1990–2001

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ABSTRACT

The analysis has two main objectives: 1) to examine labor productivity and multifactor productivity (MFP) in U.S. air transportation during the 1990 to 2001 period and to compare these measures to those of two other transportation subsectors and of the U.S. business sector; and 2) to assess the factors that have affected changes of labor productivity and MFP in air transportation over time. The assessment finds that labor productivity and multifactor productivity in air transportation both increased over the analysis period. However, both measures grew at lower rates during the second half of the 1990s. Factors affecting increases in labor productivity include increases in capital intensity and technological advances. Factors affecting multifactor productivity include improvements in the capital input, measures that increase the utilization of air carrier resources, measures that speed up maintenance work and the marketing of air services, and changes in industry structure through mergers, acquisitions, and bankruptcies.

INTRODUCTION

This paper evaluates changes in productivity in the U.S. air transportation subsector during the 1990-2001 period. The analysis has two main objectives: 1) to examine labor productivity and multifactor productivity (MFP) in air transportation over time and to compare these measures to those of two other transportation subsectors and of the U.S. business sector; and 2) to assess the factors that affected changes in labor productivity and multifactor productivity in air transportation.

The analysis examines two primary time periods: 1990 to 2000 and 1990 to 2001. The difference in results between these periods shows the indirect impact of the catastrophic events of September 11, 2001. The analysis also uses the subperiods of 1990 to 1995 and 1995 to 2000 (and 2001) in order to examine changes over time in relevant productivity variables. It compares productivity changes in air transportation to those in line-haul railroads, long-distance general freight trucking, and overall U.S. business.

The paper differs from other studies that assess the productivity—either labor or MFP—of air transportation with regard to the scope, unit of analysis, period of analysis, and methodology used. The present analysis uses annual industry data on labor productivity and MFP in U.S. air transportation; these data were obtained from the Bureau of Labor Statistics, and the MFP data are based on the conventional method of estimation used by federal agencies. By contrast, other studies use data on individual airlines or for different and more distant time periods (Oum and Yu, 1995; Windle and Dresner, 1992).

Still other studies assess only labor productivity in air transportation and for non-U.S. air carriers (Alamdari, 1998). Furthermore, other analyses use other methodologies, such as the Malmquist procedure, to estimate efficiency of individual air carriers (Alam and Sickles, 2000), or they estimate the Fisher index of productivity by using cross-sectional data of individual U.S. air carriers (Ray and Mukherjee, 1996).

LABOR PRODUCTIVITY

Labor productivity is defined as output per unit of labor and is calculated by dividing output by a measure of the labor input (typically labor hours). For air transportation, output is measured in terms of passenger-miles and ton-miles; for rail and truck transportation, output is measured in ton-miles. The derivation of labor productivity can be illustrated through an industry production function: Output = f (labor, capital, intermediate goods). Consequently, labor productivity = output/labor.

Industry data used in this paper are classified under the North America Industry Classification System (NAICS). Labor productivity is evaluated for three transportation industries or subsectors: Air transportation (NAICS industry number 481); Line-haul railroads (NAICS 48211); and General freight trucking, long-distance (NAICS 48412). Comparisons of labor productivity are also made with the U.S. business sector. That sector is based on GDP (gross domestic product) but excludes general government, nonprofit institutions, paid employees of private households, and the rental value of owner-occupied dwellings. The words “industry” and “subsector” are used interchangeably in the paper.

To evaluate labor productivity in air transportation, data on levels of productivity over time are plotted in figure 1. These data indicate that labor productivity increased from 1990 until 1997, when it reached its peak. In 1998, labor productivity declined and stayed at this lower level until 2000. In 2001, it declined again, quite significantly, as industry output and demand experienced a sudden and substantial decline following the catastrophic events of September 11th, 2001.

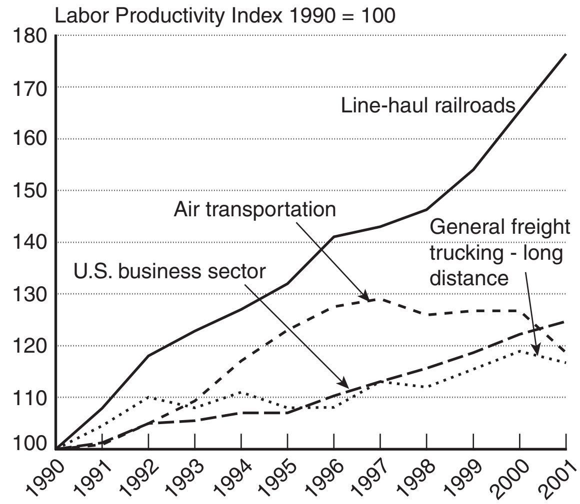
To compare labor productivity in air transportation with the other two transportation industries and the U.S. business sector, relevant data are plotted in figure 2. There, one observes the following:

1. From 1990 to 2000 (and with the exception of 1991 to 1993), labor productivity in air transportation was at higher levels than in long-distance trucking and the U.S. business

FIGURE 1 Labor Productivity in Air Transportation

Source: The data on which this chart is based were obtained from the Bureau of Labor Statistics internet site: ftp://ftp.bls.gov/pub/special.requests/opt/dipts/ipr.aiin.txt

FIGURE 2 Labor Productivity in Transportation and U.S. Business



Sources: The data on which this chart is based were obtained from the Bureau of Labor Statistics internet site. For the three transportation industries: ftp://ftp.bls.gov/pub/special.requests/opt/dipts/ipr.aiin.txt. For Private Business: http://data.bls.gov/PDQ/servlet/SurveyOutputServlet.

sector. In 2001, however, labor productivity in air transportation declined to a lower level than it did in the U.S. business sector.

2. Rail transportation was the one subsector where labor productivity increased faster than in air transportation. Rail transportation had continual increases in labor productivity over time. In fact, labor productivity in this subsector continued to increase in 2001, while it declined in air transportation and trucking.

In order to make comparisons from another perspective, growth rates of labor productivity are presented in table 1. These data indicate a big drop in the annual growth rate of labor productivity in air transportation from 1990 to 2000 (2.4%) as compared to 1990 to 2001 (1.6%). This clearly shows the very significant impact of September 11th on this subsector. After that date, output of air transportation dropped immediately and significantly, while the labor force in air transportation declined, but with a time lag.

With respect to comparisons with the other transportation subsectors and the private business sector, the annual growth rate of labor productivity in air transportation over the 1990 to 2000 period was higher (2.4%) than in trucking (1.7%) and in the U.S. business sector (2.0%). From 1990 to 2001, however, the growth rate for air transportation was lower (1.6%) than that of business sector (2%). In both time periods, rail transportation experienced the highest growth rate of labor productivity.

With regard to the subperiods, the growth rate of labor productivity in air transportation declined significantly from 1995 to 2000—when it grew 0.6% per annum—compared to 1990 to 1995—when it grew 4.2% per annum. Also, the growth of labor productivity in air transportation from 1990 to 1995 was higher than that of long-distance trucking and of U.S. business, though lower than that of rail. By contrast, from 1995 to 2000, the growth of labor productivity in air transportation was the lowest (although positive) of the three transportation subsectors, and lower than that of the business sector. Therefore, these data show that labor productivity in air transportation was declining in the second half of the 1990s, even before the events of September 11th.

TABLE 1 Growth Rates of Labor Productivity in Transportation and U.S. Business
(Growth Rates - annual, percentage)

	1990-2000	1990-2001	1990-1995	1995-2000	1995-2001
Air transportation	2.4	1.6	4.2	0.6	-0.6
Line-haul railroads	5.2	5.3	5.7	4.6	5.0
General freight trucking —long distance	1.7	1.4	1.5	2.0	1.3
U.S. business	2.0	2.0	1.4	2.6	2.5

Source: The data on which these growth rates are based were obtained from the Bureau of Labor Statistics internet site. For the three transportation industries: ftp://ftp.bls.gov/pub/special.requests/opt/dipts/ipr.aiin.txt. For private business: http://data.bls.gov/PDQ/servlet/ SurveyOutputServlet.

FACTORS AFFECTING LABOR PRODUCTIVITY

Increases in labor productivity reflect the joint effect of a number of influences. The basic factors that affect labor productivity in an industry are:

1. increased use of capital in production—which increases the amount of capital per worker; and
2. technological progress, which can include a number of factors and will be examined later in the paper.

Capital per worker in air transportation increased over time, by 22.2% from 1990 to 2001, as indicated by data presented in table 2. This increased capital intensity of service delivery.

However, capital per worker did not increase uniformly during the period of analysis. Relatively higher growth rates from 1990 to 1995 were followed by lower increases from 1995 to 2000 (or 2001). This factor is related to the declining labor productivity, discussed at a later point.

A related factor that accompanied the increased capital input is the improvement in the quality of capital used in the delivery of air transportation services. This relates to the fact that capital input of more recent vintage incorporates advances in technology, as compared to capital input of less recent vintage. In air transportation, such technological advances include the increased use over time of newer aircraft models that required two pilots instead of three. That resulted in increased productivity of labor as fewer pilots served the same number (or higher) of passengers. The reduction in the number of pilots per aircraft took place over time and incrementally in airlines, generally in the 1980s and the 1990s. As older airplanes needing three pilots were retired, airlines would purchase newer airplanes that needed only two. This included the replacement of Boeing-727s with newer Boeing-737s or with Airbus-320 models.

The reduction in airplane pilots was related to new airplane models. Airplanes are part of the capital input of the industry, and these new models would be measured through higher airplane prices and thus higher measured capital intensity (capital per worker). Because these airplanes resulted in a reduction in the number of pilots, thus increasing output per worker, this factor is classified under labor productivity (although it can also relate to MFP).

Also, the average stage length of air travel increased over the period of analysis. This applies to domestic and international travel (data from BTS, Office of Airline Information). With regard to international travel, in the early 1990s, more U.S. carriers began to grow internationally and were flying long-distance trips using larger aircraft. This would have resulted in higher labor productivity in terms of passenger-miles per employee.

In addition, with regard to aircraft scheduling, in recent years, several hub-spoke carriers decided to depeak their schedules. This entails departure times of airplanes that are more spread out instead

TABLE 2 Increases in Capital and Labor in Air Transportation
(Annual Percentage Rates)

Year	Index of labor hours	Index of capital	Index of capital per labor hour	Growth of labor hours	Growth of capital	Growth of capital per labor hour	Period	Growth of capital per labor hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1990	100.0	100.0	100.0					
1991	97.0	103.1	106.3	-3.0	3.1	6.3		
1992	98.9	101.3	102.4	2.0	-1.7	-3.6		
1993	98.0	105.3	107.4	-0.9	3.9	4.9		
1994	97.4	112.2	115.2	-0.6	6.6	7.2		
1995	96.7	113.9	117.8	-0.7	1.5	2.3	1990-1995	3.3
1996	99.7	117.0	117.4	3.1	2.7	-0.4		
1997	102.9	120.5	117.1	3.2	3.0	-0.2		
1998	107.8	125.9	116.8	4.8	4.5	-0.3		
1999	112.4	131.4	116.9	4.3	4.4	0.1		
2000	119.3	139.3	116.8	6.1	6.0	-0.1	1995-2000	-0.2
2001	119.1	145.5	122.2	-0.2	4.5	4.6	1995-2001	0.6

Source: For index numbers of labor hours and capital, Bureau of Labor Statistics internet site: ftp://ftp.bls.gov/pub/special.requests/opt/dipts/indmfp3.txt. The index of capital per per labor hour and the growth rates were computed by the author.

of being concentrated during particular time periods of the day. Depeaking results in the use of fewer gates and aircraft, and it spreads out the demand on the carriers resources. Consequently, there are less manpower needs. The outcomes of such changes are increased labor productivity and multifactor productivity (which is examined in a later section). A reduction in the number of airplanes, from a depeaked schedule, also implies that the previous use of concentrated take-offs at the hub was accompanied by a substantial number of empty seats.

Moreover, there has been increased use of information technology (computer hardware and software) to schedule maintenance checks for airplanes. The utilization of computer-based programs, by air carriers, resulted in productivity improvement, which translated into a 25-percent reduction in the number of people performing maintenance scheduling (Communication with staff of air carriers).

Data presented in figure 1 show that after 1997 the level of labor productivity in air transportation declined, and this was followed by a significant drop in 2001. The decrease in 2001 was the result of a large decline in output (demand for air travel) while the labor force was reduced after a time lag. There was also a recession in that year. The decline in labor productivity after 1997 would appear to have been affected by several factors and they are discussed below.

Increases in capital per worker declined considerably during the 1995 to 2001 period as compared to the previous subperiod. While during the initial subperiod of 1990 to 1995, capital per worker grew at 3.3% per annum (table 2), its growth dropped significantly to only 0.6% per annum from 1995 to 2001. In fact, during the 1995 to 2000 period, the ratio experienced a negative growth rate (-0.2% annually). The considerable slowing down, from 1995 to 2000 (2001), in the increase of capital per worker would have affected decreases in the growth of labor productivity which are observed during the same time period.

The explanation of the declining growth in capital per worker is a challenge. During the second half of the 1990s, the industry was doing well financially; consequently, that would not have impeded investment. One factor that is suggested is a form of competition in the industry that relates to flight frequency.[1] Accordingly, air carriers compete on the basis of frequency of flights and thus attempt to increase their market share, or maintain them if a competitor increases their number of flights. This type of competition could have resulted in significant increases in investment—i.e., airplanes—during the first half of the 1990s. In time, the potential for the number of flights would have reached some saturation point.

The impact of increased size and speed of airplanes diminished over time. Since the 1950s and 1960s, the size and speed of airplanes used in commercial aviation increased. Moreover, in the 1970s, wide-body jets were introduced in commercial service, also increasing airplane size. In addition, aircraft models were "stretched" and were thus able to accommodate more passengers. These factors had a positive effect on labor productivity as bigger and faster airplanes carry more passengers and cargo per day. This increases output (i.e., passenger-miles or ton-miles) of the labor force, thus raising labor productivity. However, the airplanes used in commercial aviation in the United States peaked in size and speed before 1990; consequently, the impact of these factors on productivity diminished over time.

In this regard, one notes that in some cases, the reduction in the number of pilots in the aircraft took place in the late 1980s and 1990s. In such cases, B-727s (with three pilots) were replaced with aircraft that needed two pilots such as the A-320 (Communication with staff of air carrier). Also, the replacement of turbo-props by regional jets, starting in the late 1990s, would have resulted in increasing speeds. However, the positive effects of these two factors on labor productivity were not sufficient to affect the declining trend in labor productivity in the second half of the 1990s.

Work rules, including scope clauses, would appear to have had a negative impact on labor productivity in an indirect way. Scope clauses in labor contracts of pilots require that pilots of regional jets be paid the same salaries as pilots of larger airplanes. This limits the economies available from using regional jets and discourages their use. Moreover, scope clauses limit the size of regional jets that airlines can use. This constrains the potential increases in output (passenger-miles) which, in turn, constrains labor productivity.

MULTIFACTOR PRODUCTIVITY

In the estimation framework for MFP, increases in output are attributed to 1) increases in the quantity of the inputs, and 2) increases in multifactor productivity (MFP). Multifactor productivity refers to the productivity of all the inputs used in production. After the contribution of the amount of inputs to output is estimated, the remaining output growth is attributed to increases in productivity of the inputs—i.e., multifactor productivity, also referred to as technological progress. Multifactor productivity can be affected by improvements in the quality of the inputs. This includes improvements in computers and other equipment used in production and maintenance systems. At the industry level, productivity (efficiency) can also be affected by changes in industry structure brought about by mergers, acquisitions, and bankruptcies.

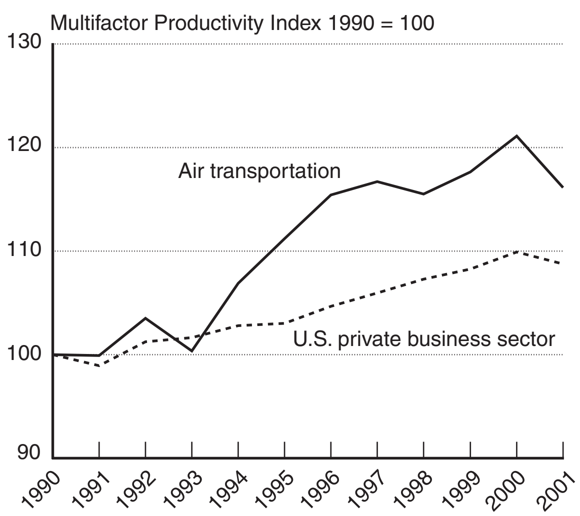
For estimating MFP at the industry level, the output measure used is total output, rather than value added. The inputs used are: labor, capital, and intermediate inputs. The labor input is measured in terms of labor hours; while the capital input includes structures, equipment, inventories, and land (in a broad definition of capital). Intermediate inputs include purchased electricity, fuels, materials, and services. The weights used to estimate the contribution of each input to output are their shares in the total cost of production in the industry.

[1] The use of schedule frequency has been discussed in previous work: "Hubbing and Airline Costs", by Kanafani and Hansen, 1985.

The basic estimating methodology was initially used in studies of economic growth, at the macroeconomic level, such as those by Denison and Kendrick (Denison, 1967; Kendrick, 1961). The methodological framework was enhanced over time and used in the calculation of multifactor productivity at the sectoral and industry levels at the Bureau of Labor Statistics, among others (BLS, 1983; Duke, et al., 1992).

Data presently available from government sources (the BLS) on MFP for the transportation sector, under NAICS, relate only to air transportation. The plots presented in figure 3 indicate that MFP in air transportation increased at faster rates than that of the private business sector over the period of analysis. This sector excludes various activities as the business sector and, in addition, it excludes government enterprises.

FIGURE 3 Multifactor Productivity in Air Transportation and Private Business



Source: Data on which this chart is based were obtained from the Bureau of Labor Statistics internet site. For data oir transportation: ftp://ftp.gov/pub/special.requests/opt/.dipts/indmfp3.txt. For data on Private Business: http://data.bls.gov/PDQ/servlet/SurveyOutputServlet.

In 2001, the growth of MFP in air transportation declined. By contrast, labor productivity in air transportation began to decline in 1997 (figure 1). Thus, the performance of MFP in air transportation was better than labor productivity as MFP continued to increase after labor productivity began to fall. MFP in air transportation grew faster than that of the private business sector in every period examined, except for 2001.

To examine productivity from another perspective, growth rates of MFP are presented in table 3. These data show that over the 1990 to 2001 period, MFP in air transportation grew at a significantly faster annual rate (at 1.4%) than in the U.S. private business sector (0.8%). With regard to subperiods, MFP in air transportation from 1990 to 1995 grew at a higher rate (2.1% per annum) than from 1995 to 2000 (1.7%). This drop in the growth of MFP is substantially less than that observed for labor productivity from 1995 to 2000.

These data indicate that, over the 1990 to 2000 period, air transportation contributed positively and substantially to increases in multifactor productivity in the private business sector and, hence, to the U.S. economy. However, this contribution experienced a relative decline from 1995 to 2000 as compared to 1990 to 1995.

Factors Affecting Multifactor Productivity

A number of factors can affect growth of multifactor productivity (or technological progress) at the industry level. The factors that seem to have affected MFP growth in air transportation include:

1. improvements in the quality of the inputs, particularly capital;
2. increased use of computer technology; and
3. changes in the structure of the industry.

The text below examines these factors over the period of analysis.

There were improvements in the quality of capital—including various types of equipment used in air transportation. According to data in table 2, the capital input used in air transportation increased by 39.3% over the 1990 to 2000

TABLE 3 Growth of Multifactor Productivity in Air Transportation and Private Business
(Annual Percentage Rates)

	1990-2000	1990-2001	1990-1995	1995-2000	1995-2001
Air Transportation	1.9	1.4	2.1	1.7	0.7
Private Business	0.9	0.8	0.6	1.3	0.9

Source: The data on which these growth rates are based were obtained from the Bureau of Labor Statistics internet site. For air transportation: ftp://ftp.bls.gov/pubspecial.requests/opt/dipts/indmfp3.txt. For Private Business: http://data.bls.gov/PDQ/servlet/SurveyOutputServlet.

period (column 2, year 2000). Such increases in the quantity of the capital input would also have been accompanied by improvements in the quality of the capital input, as capital investment of more recent vintage incorporate newer and more efficient technology. [2]

Improvements in the capital input include airplane engines that are more efficient in the utilization of airplane fuel. Data in table 4 indicate that there was a rather steady and continual increase over time in the efficiency with which intermediate inputs were used in air transportation. This efficiency is shown by the ratio of "output per unit of intermediate purchases." The ratio increased in the early 1990s, decreased in 1993, and then increased steadily until 2000. These changes indicate that the efficiency with which intermediate inputs were utilized in air transportation increased over the period of analysis and particularly since 1993 (until 2000).

This shows that as the newer aircraft models were replacing older models, their engines were more fuel-efficient, thus resulting in reductions in the amount of fuel used for an airplane trip. Improvements in the fuel efficiency of airplane engines resulted in reduced use of intermediate inputs. This contributed to the increased efficiency of the industry in using intermediate inputs.[3]

Since 1990, air carriers have become more efficient in driving more traffic through their networks as average loads of airplanes have increased. There has been more effective revenue management and use of new distribution channels, particularly the internet, to sell otherwise empty seats. Revenue management entails the use of information technology to assist air carriers in maximizing revenues through higher load factors and/or yields (Communication with staff of ATA).

In recent years, several hub-spoke air carriers decided to depeak their schedules by changing aircraft scheduling. This resulted in increasing the utilization of hub assets of the air carriers—such as aircraft facilities, labor, etc.—and in decreasing manpower needs. The outcomes of such changes are increases in multifactor productivity as well as labor productivity.

With regard to aircraft maintenance, there has been use of Magneto Optic Imaging (MOI—an electromagnetic device), since the early 1990s, which allows aircraft inspectors to scan parts of the aircraft fuselage for cracks. This technology is in lieu of a pencil probe eddy current (an instrument to test for cracks), and provides a substantially faster inspection (personal communication with FAA Technical Center staff).

There has been use of advanced ultrasonic imaging and analysis to inspect parts of the aircraft for cracks. This ultrasonic scanning method was implemented around 1995 and has been used to inspect for cracks in the wing fuel tank. The previ-

[2] Improvements in the quality of the capital input could be measured in the price indexes used to deflate capital data. However, such a measurement has only been partial in the case of air transportation (per communication with staff of the Bureau of Labor Statistics). Consequently, the impact of improvements in capital would be included in the MFP.

[3] A paper by BEA's R. Yuskavage, using SIC data, found a relative decline in intermediate goods in air transportation, over 1992-1997, and that this decline was affected by a below-average growth in refined petroleum products – which include aviation gas and jet fuel (Yuskavage, 2001).

TABLE 4 Data Relevant for Labor Productivity and MFP in Air Transportation

(Index Numbers, 1990=100)

Year	Output	Labor Hours	Capital	Intermediate Purchases	Output per hour	Output per unit of capital	Output per unit of intermediate purchases
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1991	98.0	97.0	103.1	97.3	101.0	95.1	100.7
1992	103.9	98.9	101.3	101.1	105.1	102.6	102.8
1993	107.2	98.0	105.3	113.9	109.4	101.8	94.1
1994	114.2	97.4	112.2	112.9	117.2	101.8	101.2
1995	119.0	96.7	113.9	113.5	123.1	104.5	104.8
1996	127.2	99.7	117.0	116.7	127.6	108.7	109.0
1997	132.8	102.9	120.5	120.8	129.1	110.2	109.9
1998	135.7	107.8	125.9	122.8	125.9	107.8	110.5
1999	142.5	112.4	131.4	125.0	126.8	108.4	114.0
2000	151.3	119.3	139.3	124.8	126.8	108.6	121.2
2001	141.3	119.1	145.5	117.9	118.6	97.1	119.8

Source: Bureau of Labor Statistics internet site: ftp://ftp.bls.gov/pub/special.requests/ opt/dipts/indmfp3.txt.

ous technology entailed an intrusive visual inspection, in which an inspector had to crawl into the fuel tank and remove sealant in order to do the inspection. The old technology took an estimated 800 man-hours. The ultrasonic scanning method takes about 48 hours, resulting in a savings of about 750 man-hours to do the inspection on one airplane. In addition, the new technology provides better coverage than the internal visual inspection (personal communication with FAA Technical Center staff).

In aircraft maintenance, new technologies have been used to inspect aircraft parts. This includes the use of an automated eddy-current procedure to test engine parts for cracking and corrosion. Prior to the implementation of this technology, it took 6 to 8 hours for an inspector to test an engine disk. With the new technology, the inspector needs 30 minutes to test the engine disk. Moreover, this is a more reliable inspection with a higher level of confidence (Communication with staff of air carriers).

Moreover, there have been improvements in sealants, and particularly their cure time; that resulted in faster maintenance times of aircraft. New and improved sealants—used for the cockpit window, for example—have a cure time of 6 hours, while the older sealants had a cure time of several days (Communication with staff of air carriers). This reduction in cure time decreases the length of time during which an aircraft is out of service, and thus increases utilization of capital assets.

There has been increased use of information technology (computer hardware and software) to schedule maintenance checks for airplanes and to schedule specific maintenance tasks. Also, there has been increased use of computers for keeping maintenance records. The utilization of computer-based programs by air carriers has resulted in productivity improvements. This has made possible (in one case) a 25% reduction in the number of people performing maintenance scheduling (Communication with staff of air carriers).

Also, there has been increased use of computerized maintenance manuals instead of paper manuals. The use of computerized manuals makes it easier to revise and update these manuals, instead of updating paper manuals by hand. The maintenance updates on a computer system change the maintenance instructions at the same time, instead of revising each paper manual by hand. The increased use of computer-based maintenance manuals saves time and labor costs. The computerized system also reduces duplication and distribution costs of the revised maintenance manuals. The savings from reduced publication costs have been estimated at $2.0 million annually for an air carrier (Communication with staff of air carriers).

There has been increased use of automation in the loading and unloading of airplanes. With the former way of doing things, several people would be employed to load baggage to the main storage area (belly) of the airplane. New technology, used for narrow-body aircraft, includes the use of a piece of equipment called a Ramp Snake. This is an electric, self-propelled, semiautomatic loading and unloading system. It replaces conventional belt loaders and, in the plane, the mechanical loading systems. The benefits of the system are:

1. reduced employee injuries;
2. reduced damage to the aircraft; and
3. improvement in loading efficiencies (Communication with staff of air carriers).

Over time and continuing to the present, there has been a continual increase in the use of more sophisticated computerized systems for the buying and selling of air transportation tickets. Presently, consumers with access to computers can go to the internet and purchase a ticket from a computerized system instead of calling the airline. Computerized ticket and invoice systems have facilitated the ticket transactions of more passengers and freight, with the same (or lower) number of staff. The result is higher output (passengers and freight) for the quantity of labor and capital used; thus, increased productivity (labor and MFP). It may be noted that such increases in productivity brought about by computer systems, and their use by consumers, allowed airlines to reduce commissions paid to travel agents.

Changes in Industry Structure

The structure of an industry can change over time as a result of mergers, acquisitions, and bankruptcies. Such changes can affect efficiency (productivity) in an industry and they are examined below for the air transportation industry.

Mergers and Acquisitions

In air transportation, a horizontal merger combines two air carriers into one. Consequently, in the new postmerger firm, there is expected to be merging of certain functions of the two premerger firms; these would include finance, payroll, and advertising. These developments result in the same output being produced but with fewer inputs such as labor, equipment, building space, and materials and services. This results in a reduction in inputs (a reduction in costs) and an increase in multifactor productivity.

Data on mergers and acquisitions, presented in appendix table 1, indicate that a substantial number of mergers took place in air transportation in the second half of the 1980s and in the 1990s. It can take time—probably several years—for the cost-reduction effects of mergers and acquisitions to become operative. It is expected that mergers that occurred in the 1990s affected industry efficiency in that decade. In addition, it is likely that mergers that took place in the late 1980s were also affecting productivity in the early 1990s and beyond.

Bankruptcies

During the 1990s, a number of bankruptcies took place in the air transportation subsector, shown by the data in appendix table 1. Because efficient companies are expected to survive and grow over time, and inefficient companies are less likely to survive, bankruptcies in air transportation generally result in increased efficiency (productivity) in the industry. There was not a general deterioration of demand during the period of analysis. Consequently, it would appear that bankruptcies related rather to efficiency considerations of individual airlines, and the inability of companies' management to successfully deal with problems on the supply side—i.e., labor, capital, or intermediate inputs. A related factor was the increased competition from new industry entrants, typically with lower costs, that followed deregulation in 1978.

CONCLUSIONS

Productivity increases in the U.S. economy over time have contributed significantly to economic growth and to improvements in the standard of living. According to the data and analysis presented in this paper, growth of labor and multifactor productivity in air transportation grew rather significantly over the 1990-2000 period. Thus, the industry contributed positively to the economy's productivity. However, the growth of both labor and multifactor productivity declined in the second half of the 1990s.

Increases in labor productivity in air transportation were declining in the second half of the 1990s, even before the events of September 11th. The growth of labor productivity in air transportation also declined during the 1995 to 2000 period in relation to other industries.

Factors that had a positive impact on labor productivity in air transportation include increases in the capital input. These increases in the capital input were accompanied by improvements in the capital input. This included newer airplane models that needed fewer pilots, and increased use of computer technology in the maintenance of airplanes, such as in the scheduling of maintenance checks. Labor productivity increases were also affected by technological innovations.

Factors that appear to have contributed to the lower growth rate in labor productivity in the second half of the 1990s include:

1. The diminishing benefit of increasing size and speed of airplanes, and
2. The effect of work rules in the industry including scope clauses.

A number of factors affected increases in MFP in air transportation. These factors include:

1. Improvements in the capital input, which incorporate advances in technology; this included more fuel-efficient airplane engines, which contributed to the reduction in the utilization of intermediate goods;
2. In maintenance work, the use of new technology that significantly reduced the time of inspecting and repairing airplanes (and their engines), which contributed to less out-of-service time of airplanes;
3. The use of more automated equipment for the loading of baggage on airplanes;
4. The increasing use of information technology to market airplane tickets; and
5. Changes in the industry structure, through mergers/acquisitions and bankruptcies.

This information indicates that a primary type of technological advances in air transportation have been of the embodied type. This is similar to the situation in other industries. These technological advances were incorporated in capital goods through new investment implemented by air carriers. Consequently, the sources of these technological advances were the industries that make capital goods—including robotics, computers, etc.

It would appear that air transportation is quite amenable to productivity improvements from technological innovations. And a substantial number of such innovations have been developed and implemented in the decade. This portends rather well for future technological developments in the industry.

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APPENDIX TABLE 1 Mergers/Acquisitions in Air Transportation (1985-2001)

Year	Air Carriers
1985	Southwest acquired Muse
1985	Piedmont acquired Empire
1985	People acquired Frontier
1986	Northwest acquired Republic
1986	Texas acquired Eastern
1986	TWA acquired Ozark
1986	Alaska acquired JetAmerica
1986	Delta acquired Western
1986	American acquired Air Cal
1986	Alaska acquired Horizon
1986	USAir acquired Pacific Southwest
1987	USAir acquired Piedmont
1987	Braniff acquired Florida Express
1987	Continental acquired People Express
1994	Southwest acquired Morris Air
1997	AirTran merged with ValueJet
1998	American acquired Reno Air
2001	American acquired TWA
Bankruptcies in Air Transportation (1985-2001)	
1991	Eastern Airlines
1994	Braniff
1997	Carnival
1997	Western Pacific
1998	Kiwi

Note: "Bankruptcies" refer to Chapter 7 liquidation rather than Chapter 11 restructuring.

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