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10 Productivity in the Transportation Sector

Robert J. Gordon

If we are ultimately to gain an understanding of the underlying causes of the worldwide slowdown of productivity growth in the 1970s and 1980s, analysts must probe at the microeconomic level of industries, firms, and establishments. The transportation sector has a special appeal for microeconomists, because of its long history of government regulation, and more recently, the laboratory experiment provided by the virtually complete deregulation of domestic air transport and the substantial deregulation of railroads and intercity trucking. The transportation sector is endowed with a unique and largely public data base, as one beneficial side effect of its history of regulation, helping to explain why microeconomists have expended a disproportionate amount of effort studying an industry that in 1987 accounted for only 3.3 percent of total GNP and 5.9 percent of service GNP.

As shown in table 10.1, the transportation sector illustrates the same general pattern of post-1973 productivity slowdown as the total economy, only more so.[1] The growth rate of average labor productivity (ALP) in the transportation sector exhibited a sharper deceleration during 1973–87 (as compared to

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[1] In what follows the terms "unrevised" and "revised" refer to industry output data for 1977–87 published in the NIPA prior to and after January 1991. Table 10.1 links Kendrick's (1961) estimates for the pre-1948 period with the unrevised NIPA data for the period since 1948; it provides the only long-run view of transportation productivity available to analysts prior to early 1991. Below we shall incorporate the revised NIPA output data for 1977–88.

1948–73) than did the nonfarm private economy, with respective slowdowns of 1.87 and 1.51 annual percentage points. The slowdown is even more serious when 1973–87 is compared with 1909–48, yielding a 3.71 point slowdown for transportation that is *triple* the 1.23 point slowdown for the economy as a whole.[2]

How could the productivity performance in transportation be so lamentable in an era when deregulation was widely perceived as offering management a myriad of opportunities for pursuing operating efficiencies that were formerly prohibited by regulators? This paper explores two complementary hypotheses: First, the data used in table 10.1 on the growth of ALP in transportation may incorporate a downward bias that is particularly large in the most recent decade. Second, productivity growth in the transportation sector is driven by the pace of labor-saving and energy-saving innovation achieved outside that sector by the manufacturing firms that produce transportation equipment. The ALP data in table 10.1 do not take into account either capital or energy inputs and thus do not rule out the possibility that multifactor productivity (MFP) growth slowed down after 1973 by less than labor productivity or even speeded up.

The objectives of this paper are to reconcile conflicting measures of output and employment, to examine aspects of unmeasured changes in the quality of output, to provide improved measures of the quantity and quality of capital input, and to construct a consistent time series of MFP growth for the major transportation subsectors over the entire postwar period. The detailed analysis in this paper is limited to the three most important subsectors, railroads, trucking, and airlines, which constituted 82 percent of nominal transportation output in 1973.[3] The paper differs substantially from most of the literature on transportation productivity that has emerged in the past decade. With few exceptions, recent studies of air and surface transport have estimated cost functions from panel data sets in which individual carriers are observed over time. Although the use of data for individual carriers allows the effects of firm size, network density, and other cross-section issues to be addressed, these studies are limited by the relatively short sample period of the available data. In contrast, this paper attempts to assess the performance of the transportation sector over the entire postwar interval from 1948 to present, while sacrificing the added richness of data on individual carriers that are available for shorter periods. Because the primary focus of this study is to address the measurement of productivity in national economic statistics, a move along the trade-off curve toward a longer sample period and away from firm-specific observations seems appropriate.[4]

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[2] Mansfield (1965), using Kendrick's data, treats the faster rate of productivity growth in transportation than in the aggregate economy as a well-accepted fact of economic history.

[3] The remaining subsectors consist of local transit, water transportation, pipelines, and transportation services.

[4] For a review of the cost-oriented studies of productivity change, see Winston (1985, 66–69). The cost studies for air transport based on individual carrier data, and the sample periods

Table 10.1 **Growth of Output per Hour in Nonfarm Private Economy, Transportation Sector, and of Output per Employee for Subsectors, 1889–1987**

Sector	1889–1909	1909–29	1929–48	1948–73	1973–87	1889–1987
Nonfarm private economy	2.27	2.18	2.12	2.43	0.92	2.07
Transportation*	2.05	3.36	4.75	2.20	0.33	2.63
Railroads[†]	1.88	1.58	2.95	3.66	1.24	2.40
Trucking[†,‡]	. . .	. . .	9.70	3.70	−0.28	. . .
Airlines[†]	. . .	. . .	8.25	5.33	−0.87	. . .
Local transit[†,§]	2.34	3.00	3.96	−3.34	−2.12	0.70

Sources: 1889–1948—Nonfarm private: Kendrick (1961), table A-XXIII, 338–40. Transportation and subsectors: Kendrick (1961), tables G-II, G-III, G-VIII, G-X, and G-IV. 1948–87—Nonfarm Private: *Economic Report of the President* 1990, table C-46, 346. Transportation and subsectors: NIPA table 6.2 divided by table 6.11 for total transportation; divided by table 6.10B for subsectors.

*The transportation sector includes minor subsectors not included here, mainly water, pipeline transportation, and transportation services.

[†] Per employee, not per hour, for all subsectors 1948–87, and for trucking and airlines 1929–48.

[‡] Intercity only 1929–48, trucking and warehousing, 1948–87.

[§] 1889–1948, local railways and bus lines.

The longer sample period provides another benefit. Many of the earlier studies of productivity suffer from their timing; when data terminate in the period 1980–83, they are inevitably influenced by the idiosyncratic confluence of high energy prices and low aggregate demand prevalent during that period. A study that can include data through the late 1980s benefits from the recovery of the economy to a macroeconomic condition comparable to earlier prosperous years, as well as the partial reversal of the 1974 and 1979–80 oil shocks.

Part 10.1 of the paper contains an analysis of measurement issues in the official U.S. government data on output and employment; it shows that the recent revisions of the industry output data in the national income and product accounts (NIPA) (de Leeuw, Mohr, and Parker 1991) resolve some inconsistencies in output data but leave substantial divergences between official agencies in estimates of employment and ALP growth. After a discussion of general conceptual issues in part 10.2, the paper turns to the detailed analysis of the subsectors. Much more attention is devoted to air transportation (part 10.3) than to rail (part 10.4) or trucking (part 10.5). This reflects two important differences: First, because rail and trucking output consists almost entirely of the carriage of freight, these subsectors provide intermediate rather

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covered, include Caves, Christensen, and Tretheway (CCT) (1981), 1972–77; CCT (1983), 1970–80; CCT (1984), 1970–81; CCT and Windle (1987), U.S. and foreign airlines, 1970–83; Sickles (1985), 1970–78; and Good, Nadiri, and Sickles (1989), 1977–81. Estimates of MFP growth based on groups of carriers (domestic, international, etc.) are available for 1948–81 in CCT (1985) and for air transportation as a whole in Jorgenson, Gollop, and Fraumeni (1987) and Jorgenson (1990).

than final goods. Hence any mismeasurement of productivity implies an offsetting adjustment in other industries rather than for the economy as a whole. In contrast, much of the output of air transport is sold directly to consumers, and so revisions to existing NIPA measures carry through to total GNP. Second, the quality of capital input in air transportation has changed much more dramatically over the postwar era than in rail or trucking, explaining our attention to alternative measures of capital input for airlines. We also incorporate changes in nonconventional inputs, including purchased services (e.g., those provided by travel agents) and government expenditures on airports, air traffic control, and highways.

10.1 Conflicts in the Official Data

10.1.1 The Discrepancy between NIPA and BLS

The U.S. official statistical system provides two independent measures of ALP in the transportation sector, but no estimates of MFP.[5] Accordingly in part 10.1 we take a close look at the official output and employment data that enter into estimates of ALP like those already examined in table 10.1. One set of official ALP measures is provided by the NIPA, which contain estimates of real output and employment for total transportation and seven subsectors (see n. *a,* to table 10.1), and of hours for total transportation but not the subsectors. Measures of ALP can be constructed for the years since 1948 as the ratio of output to one of several alternative employment series.[6] Although in principle the NIPA measure of output is gross product originating, that is, value added, in practice value added is calculated by double deflation only since 1977; prior to 1977 value added is calculated only for rail transport. Output in air and truck transportation is based on deflated gross revenue prior to 1977.

Another set of ALP measures is provided by the Bureau of Labor Statistics (BLS) Office of Productivity and Technology over most of the postwar period.[7] The data published by the BLS include gross output, employment, and output per employee for five transportation subsectors (the same as NIPA minus water transportation and transportation services, and with some defini-

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[5] The BLS publishes MFP series only for the total economy (private and private nonfarm) and for the manufacturing sector (see Mark and Waldorf 1983). MFP estimates are published at the disaggregated level for only four industries: tires and inner tubes, steel, footwear, and motor vehicles and equipment (U.S. Bureau of Labor Statistics 1990).

[6] These are full-time and part-time employees (NIPA, table 6.6B), full-time equivalent employees (table 6.7B), and persons engaged (table 6.10B). All NIPA ALP measures in this paper are based on persons engaged. Results would be almost identical for rail and air using full-time equivalent employees, which make up 100 percent of persons engaged for rail and 99 percent for air, but not for trucking, where self-employment is more important.

[7] Published BLS indexes begin in 1958; unpublished estimates for air and rail begin in 1947 and for trucking begin in 1954. See the notes to table 10.2. A general introduction to the BLS methodology for the indexes covering the service sector is provided by Dean and Kunze (chap. 2, in this vol.).

tional differences discussed below). Hours and output per hour are also included for railroads and bus carriers. Output is measured by physical output data reported by regulatory agencies; in the case of railroads raw data on ton-miles are adjusted for changes in the composition of goods carried.[8] Data on employment and hours include the self-employed and come from the BLS establishment survey. An important conceptual difference between the NIPA and BLS series is that the BLS incorporates links when definitional changes occur in source data; the NIPA data do not. Below we find that this helps to explain the difference between NIPA and BLS estimates of airline employment.

Table 10.2 provides our first detailed look at ALP data for the transportation sector and three subsectors. The NIPA data in the top section of table 10.2 duplicate those in table 10.1 for the three subsectors but differ for the total transportation sector by reporting output per employee rather than output per hour and by excluding the four minor transportation sectors.[9] The NIPA output data for 1977–87 are the unrevised series published prior to 1991, presented here in order to highlight the sharp discrepancies between the NIPA and BLS data that in part motivated the recent NIPA revisions (subsequently we examine the revised output data in table 10.4 below). Growth rates are shown for intervals broken in 1958 (the starting year of the published BLS data), 1973, 1979, and 1987. The productivity growth slowdown in the final column compares 1973–87 with 1958–73 (not 1948–73 as in table 10.1). The post-1973 productivity growth slowdown is much larger in table 10.2 than table 10.1, mainly because pre-1973 productivity growth is held down in table 10.1 by the inclusion of local transit (where productivity collapsed, particularly during 1948–58).

The BLS data shown in the middle section of table 10.2 tell a very different story from the unrevised NIPA data shown in the top section, particularly for 1979–87 when the growth rate of BLS ALP for total transportation exceeds that of NIPA ALP by 4.43 points per year.[10] The BLS slowdown occurs entirely for airlines, and there is virtually no slowdown for railroads and trucking. The bottom section of table 10.2 subtracts each NIPA growth rate from the corresponding BLS rate and shows that the discrepancy was large for all three major subsectors over 1973–87.

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[8] This adjustment is based on Interstate Commerce Commission data on unit revenue for 200 commodity lines, see Mark (1988, 146–47). This source indicates that a similar adjustment was formerly made for trucking, but that the disaggregated commodity data from the source agency were discontinued at an unspecified date.

[9] The "minor" sectors included in the transportation total in table 10.1 but excluded in table 10.2 and subsequent tables are local transit, water transportation, pipelines, and transportation services.

[10] The BLS does not publish data for the aggregate transportation industry. In tables 10.2 and table 10.3 we use a quasi-Törnqvist index that takes the shortcut of aggregating over multiyear intervals (using the average shares in the first and last year of each interval), rather than of aggregating each year-to-year change and averaging these. The Törnqvist formula is shown to be one of the class of "superlative" index numbers by Diewert (1976). The same formula is labeled the Törnqvist-Theil-translog index by Caves, Christensen, and Diewert (1982).

Table 10.2 **Growth of Output per Employee, Unrevised NIPA versus BLS, Selected Intervals, 1948–1987**

	1948–58	1958–73	1973–79	1979–87	1948–73	1973–87	Slowdown, 1973–87 – 1958–73
Unrevised NIPA:							
Transportation	2.96	4.15	1.06	−0.63	3.88	0.11	−4.04
Railroads	2.17	4.65	1.37	1.14	3.66	1.24	−3.41
Trucking	3.59	3.78	0.18	−0.62	3.70	−0.28	−4.05
Airlines	7.39	3.96	2.72	−2.13	5.33	−0.87	−4.83
BLS:							
Transportation*	n.a.	4.44	3.03	3.67	n.a.	3.50	−0.94
Railroads	1.75	5.46	1.48	8.17	4.46	5.30	−0.16
Trucking	n.a.	2.86	3.15	2.18	n.a.	2.59	−0.27
Airlines	8.43	6.64	4.66	3.20	6.16	3.83	−2.81
BLS – NIPA:							
Transportation	n.a.	0.29	1.97	4.43	n.a.	3.39	3.10
Railroads	−0.42	0.82	0.11	7.03	0.80	4.06	3.25
Trucking	n.a.	−0.92	2.97	2.80	n.a.	2.87	3.79
Airlines	1.04	2.68	1.94	5.33	0.83	4.70	2.02

Sources: NIPA: Output per employee is calculated as output from table 6.2, as published most recently in the July 1988 *Survey of Current Business*, divided by persons engaged from table 6.10B. BLS: Output, employees, and output per employee for 1958–63 are from BLS bulletin no. 2296, 134–38, and for 1963–87 are from bulletin no. 2349, 142–46. For railroads and air transportation data for 1948–58 are available in unpublished computer printouts, BLS Office of Productivity and Technology, January 16, 1990.

*The transportation aggregate for BLS is obtained by weighting the BLS growth rates of output and of total employment by a quasi-Törnqvist method. Output and employment growth in each subsector is weighted by the NIPA nominal output weight (table 6.1) for the average of the initial and terminal year within each interval, e.g., the average of 1973 and 1979 weights for the 1973–79 interval. Aggregate transportation in NIPA includes railroad transportation, trucking and warehousing, and air transportation. The BLS aggregate includes railroad traffic (revenue traffic), intercity trucking, and air transportation. n.a. indicates "not available."

Because ALP is the ratio of output to employment, the discrepancy between the BLS and NIPA data could result from differences in the treatment of output, employment, or some combination of both. A decomposition is provided in table 10.3, which expresses the difference between the BLS and NIPA annual growth rates of output in the top part of the table and of employment in the bottom part. Here we learn, surprisingly, that the puzzle for total transportation after 1973 lies almost entirely in the differing data on employment, albeit this aggregation disguises very large and offsetting differences for output growth in the four subsectors.

10.1.2 The NIPA Output Revisions and Remaining Discrepancies

In earlier versions of this research, beginning with Baily and Gordon (1988), we showed that the slow growth in the unrevised NIPA output series for railroads and airlines relative to the more rapid growth of the BLS output

Table 10.3 **Difference between BLS and Unrevised NIPA Estimates of Output and Employment, Annual Percentage Growth Rates, Selected Intervals, 1958–1987**

	1958–73	1973–79	1979–87	1973–87	Slowdown, 1973–87 – 1958–73
Output:					
Transportation	0.98	−0.18	1.17	0.67	−0.31
Railroads	1.16	−0.19	6.87	3.84	2.68
Trucking	0.38	−0.56	−2.03	−1.40	−1.78
Airlines	2.36	0.76	3.42	2.28	−0.08
Employment:					
Transportation	0.69	−2.19	−3.13	−2.71	−3.98
Railroads	0.35	−0.30	−0.16	−0.22	−0.57
Trucking	1.30	−3.53	−4.83	−4.27	−5.57
Airlines	−0.31	−1.19	−1.91	−1.60	−1.29

Sources and notes: Same as table 10.2.

series could be traced to overdeflation. In particular, the NIPA price deflators for airline output and for consumer expenditures on airline transportation made little or no allowance for discount fares in the 1977–83 period and thus rose much too quickly, causing deflated gross revenues to increase much too slowly. The same problem appears to have plagued the previous NIPA railroad deflators. Responding to this criticism, the revised NIPA industry gross output estimates have shifted from deflated gross revenue to physical volume measures (as well as shifting to double deflation, i.e., subtracting purchased inputs, for trucking and airlines, as was done previously for railroads). The top section of table 10.4 shows that the revised NIPA indexes for 1977–87 now rise faster than the BLS indexes for all three subsectors; previously this was true only for trucking. The revision for railroads is an astonishing 7.5 percent per annum, and for airlines a smaller but substantial figure of 4 percent per annum.

Nevertheless, as shown in the middle and bottom sections of table 10.4, the BLS series on ALP in total transportation, as well as for the trucking and airline subsectors, rises faster than the NIPA ALP series, despite more rapid growth of NIPA output. This occurs because the BLS registers slower growth in employment in each sector. Although the difference for railroads is not important, that for trucking and airlines makes a substantial difference.

10.1.3 Sources of Employment Discrepancies

By far the most important remaining discrepancy concerns trucking employment. An important definitional difference between NIPA and BLS is that the former includes all trucking (intercity and local), as well as warehousing; BLS includes only a fraction of intercity trucking. Table 10.5 displays the 1979 and 1987 values, and 1987/1979 ratios, for a variety of measures of

Table 10.4 **Growth Rates for Revised NIPA, Unrevised NIPA, BLS, and Differences for Output and Output per Employee, for Interval 1977–1987**

	Unrevised NIPA	Revised NIPA	BLS	BLS-Unrevised NIPA	BLS-Revised NIPA
Output:					
Transportation	0.52	3.67	1.46	0.94	−2.21
Railroads	−4.65	2.80	0.90	5.55	−1.90
Trucking	1.18	2.26	−0.59	−1.77	−2.85
Airlines	3.36	7.42	6.31	2.95	−1.11
Employment:					
Transportation	1.04	1.04	−2.74	−3.78	−3.78
Railroads	−5.76	−5.76	−6.16	−0.40	−0.40
Trucking	2.15	2.15	−3.87	−6.02	−6.02
Airlines	4.39	4.39	2.52	−1.87	−1.87
Output per employee:					
Transportation	−0.52	2.63	4.20	4.75	1.57
Railroad	1.11	8.56	7.06	5.95	−1.50
Trucking	−0.97	0.11	3.28	4.26	3.17
Airlines	−1.03	3.04	3.79	4.82	0.75

Sources: Same as table 10.2, except revised NIPA output from de Leeuw, Mohr, and Parker (1991), table 6, 34.

nominal and real output, price indexes, and employment in the trucking industry. The data include both measures for the comprehensive trucking-warehousing universe partially covered by the NIPA, and the intercity subsector covered by the BLS. To summarize our conclusions in advance, we find that the NIPA data correspond closely to independent measures of the trucking universe, but that the BLS data are badly biased by including only a part of the intercity subsector that has experienced a sharply reduced share of output and employment as a result of deregulation.

The nominal output data in section 1 of table 10.5 show a close correspondence for the 1987/1979 ratio of, respectively, NIPA nominal output and a related measure called "outlays for highway freight transportation" (which includes both intercity and local transportation). A separate series for intercity class I carriers (line 1d) indicates a much slower increase in revenue, resulting from a shift in the composition of intercity freight away from class I carriers.

Three price series are shown in section 2, the NIPA implicit deflator, an implicit price series that results when the intercity outlays series in line 1c is divided by the output series in line 3b, and a direct measure of revenue per ton-mile for class I intercity freight. The implicit intercity price increases at about the same rate as the NIPA deflator; the direct measure of revenue per ton-mile increases less. Because all three deflators in section 2 refer to intercity freight, they should be viewed as different measures of the same con-

Table 10.5 **Comparison of Data on Nominal and Real Output, Price Indexes, and Employment for Total and Intercity Trucking, 1979 and 1987**

	1979	1987	1987/ 1979(%)
1. Nominal output (in billions of dollars):			
a. Revised NIPA (table 6.1)	41.4	65.2	157.5
b. Outlays on highway freight	142.7	220.3	154.4
c. Outlays on intercity freight	90.2	132.8	147.2
d. Operating revenue, class I intercity freight carriers	30.1	35.0	116.3
2. Price indexes:			
a. Revised NIPA implicit deflator for trucking output, 1982 = 100 (1a/3a)	74.7	99.8	133.6
b. Intercity outlays per ton mile (in cents) (1c/3b)	14.8	19.9	134.7
c. Class I intercity revenue per ton mile (in cents)	11.6	14.1	121.6
3. Real output:			
a. NIPA output in 1982 dollars (table 6.2)	55.4	65.3	117.9
b. Intercity freight ton miles (in billions)	608	666	109.5
c. Implicit real revenue (in billions of 1987 dollars), Class I intercity freight carriers	36.4	35.0	96.2
d. BLS output index (1977 = 100)	104.3	94.3	90.4
4. Employment (in thousands)			
a. NIPA (no. of persons engaged)	1498	1674	111.7
b. BLS trucking and warehousing employment	1340	1464	109.2
c. Class I intercity freight carriers	575	519	93.3
d. BLS employment level	571	434	76.0

Sources by line: **(1a,2a,3a)** de Leeuw, Mohr, and Parker (1991), tables 5 and 6, 33–34. **(3d)** Basic BLS source, same as table 10.2. **(1b,1c)** *Statistical Abstract,* 1989, table 998. **(1d,4c)** 1979–80, TRINC Associates, linked for 1980–87 to *Statistical Abstract,* 1990, table 1055, sum of figures given for common carrier general freight, common carrier other than general freight, contract carrier other than general freight, and carriers of household goods. **(2b)** 1c/3b. **(2c)** *National Transportation Statistics,* annual report 1989, U.S. Department of Transportation for 1977–87, 1981 issue for 1969–76, 1972 issue for 1960–68. **(3b)** *Statistical Abstract,* 1989, table 1000. **(3c)** Equals line 1d for 1987. For 1979 equals line 1d for 1979 times 1987/1979 ratio from line 2c. **(4a)** Basic NIPA source, same as table 10.2. **(4b)** *Statistical Abstract,* 1989, table 999, totals given for SIC 421, 422, and 423. **(4d)** Source of BLS employment data provided by Edwin Dean (American Trucking Association, *1987 Motor Carrier Annual Report*), lists total employment in 1987 as 349,842. To this is added 84,000 leased drivers, as stated in a letter from Dean. 1979 employment equals 1987 employment times the 1979/1987 ratio of the BLS trucking employment index.

cept.[11] We view the final measure in line 2c as superior, as it is a direct measure of revenue yield per ton-mile, rather than an implicit ratio of numerator and denominator that may not cover the same universe.

The intercity output series on line 3b rises at about the same rate as the NIPA real output series; a constructed series (line 3c) for the implied real

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[11] The source listing provided by de Leeuw, Mohr, and Parker (1990, table 3) indicates that the nominal value is based on class I motor carriers and real output is based on a physical measure of ton-mile volume, which could only refer to intercity freight, as ton-miles for local traffic are not available.

revenue of class I intercity carriers based on the implicit price series from line 2c declines somewhat slower than the BLS output series for Class I and II intercity carriers (line 3d), as would be consistent with the evidence presented below that the BLS has been measuring a shrinking fraction of the intercity trucking industry.[12] The employment data display the same ranking of 1987/1979 ratios as the output data, except that the BLS employment series shows even more relative shrinkage, contributing to the relatively favorable performance of the BLS productivity series examined previously in table 10.2. To track down the source of the rapid decline in the BLS employment series, we have attempted to reconstruct the absolute level on which the BLS series is based in 1979 and 1987 (see source notes to table 10.5). If these figures are correct, they imply that coverage by the BLS of the NIPA employment total fell sharply from 38.1 percent in 1979 to 25.9 percent in 1987.[13]

In our detailed examination of the trucking industry in part 10.5 below, we learn that there was a huge shift in the composition of firms in the intercity trucking industry as a result of deregulation. The BLS, by choosing to cover a portion of the industry that is declining in importance, has misrepresented employment trends in the industry as a whole. This leaves as a mystery why the segment of the industry covered by the BLS exhibits healthy productivity growth over 1979–87; NIPA productivity growth for the trucking industry as a whole is a barely positive 0.7 percent per annum slightly (line 3a divided by 4a).[14] If both the NIPA and BLS productivity data are correct, they imply a slight *decline* in the absolute level of ALP between 1979 and 1987 for the part of the NIPA trucking universe not covered by the BLS.[15]

Because of its much greater coverage, the NIPA output and employment series are preferable to those of the BLS. There remains a potential measurement error in the NIPA output series, because of the possibility of an overly rapid increase in the implicit deflator. The direct measure of class I revenue per ton-mile rises 1.2 percent per annum less than the NIPA deflator. Support-

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[12] The intercity freight output series on line 3b comes from a source that allows the relative share of railroad and trucking output to be computed; these shares are almost identical to those in data independently collected by Winston et al. (1990, table 1-1).

[13] We were unsuccessful in locating additional independent sources of trucking employment over the full 1979–87 period. In particular the TRINC data used in table 10.5 for 1958–80 are not available after 1983.

[14] Despite its tantalizing title, the recent article by Ying (1990) contains only estimated parameters allowing a calculation of the marginal effect of deregulation on trucking productivity, but no data on the level or rate of change of actual productivity.

[15] If revenue per employee were the same in the BLS and non-BLS part of the total NIPA trucking universe at the 1987 level of $78,876 reported by the BLS source (American Trucking Association, *1987 Motor Carrier Annual Report*, summary table I, col. 7, then the implied 1987 revenue figures are $34.2 billion for BLS, $97.8 billion for non-BLS, and $132.0 billion for the total. Using NIPA real output to extrapolate the total back to a 1979 figure of $124.1 billion real revenue in 1987 dollars for the total, and the BLS output index to obtain a 1979 figure of $37.8 billion for the BLS segment, the implied non-BLS real 1979 revenue is $86.3 billion. Implied non-BLS real revenue per non-BLS employee fell from $93,096 to $78,876, for an implied decline in non-BLS productivity of 15.3 percent.

ing a slower price increase is the contrast of the 33.6 percent 1979–87 increase of the NIPA deflator with the increases in the prices of inputs, 35.8 percent for labor and 28.6 percent for diesel fuel.[16] Output prices should have increased less than input prices if there was an improvement in labor productivity and fuel efficiency; the improvement in fuel efficiency is a solid fact; labor productivity increased even with the NIPA deflator and even more with the alternative deflator.[17] In part 10.5 we explore the consequences of replacing the NIPA output index with an alternative index based on the deflator in line 2c of table 10.5.

In the airline subsector NIPA employment also grows substantially more rapidly than BLS employment, but here the discrepancy is resolved in favor of the BLS series. The most important cause of this difference, also uncovered by Card (1989, table 10.1), is that Federal Express was added to industry output and employment figures in 1986. Because Federal Express carries high-value shipments, it has an extremely low ALP measured as ton-miles per employee, less than one-tenth that of American Airlines in 1989.[18] Thus the introduction of Federal Express into the statistics introduces a spurious downward shift in the ALP of the airline industry that the BLS handles by linking out Federal Express output and employment. A superior approach, but one with more onerous data requirements, would be to follow Caves, Christensen, and Tretheway (1981, 1983, 1984) by constructing a Törnqvist output index that weights different output components by their revenue shares. Because it recognizes the Federal Express problem and makes two other links to improve comparability, we deem the BLS output and employment data to be superior to those in the NIPA and use them in part 10.3 below.[19]

10.1.4 Choice of Series for Further Study

Subsequent sections of this paper develop new measures of MFP for the three transportation subsectors. Our desired output concept is gross rather than value added, because we want to include fuel and materials inputs explicitly in the MFP calculation. The BLS output measures have the double advantage that they explicitly measure gross output and are conceptually consistent over the postwar period; the NIPA output series is inconsistent, measuring

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[16] Labor cost is compensation per full-time equivalent employee, NIPA table 6.4B divided by table 6.7B. The fuel cost is the retail price of diesel fuel, from *American Trucking Trends*.

[17] Average miles per gallon for single-unit trucks increased by 14 percent from 1979 to 1986 (*American Trucking Trends* 1987, 44). The 1979–87 percentage increase in ALP is 5.5 percent for the NIPA deflator (table 10.5, line 3a/4a) and 16 percent for the alternative deflator.

[18] Making the arbitrary assumption that Federal Express shipments travel 700 miles on average, one can calculate from its 1989 annual report an average of 10,233 ton miles per employee, in contrast to American's 115,716 (ton miles per "average equivalent employee," from an American Airlines, annual report).

[19] According to Richard Carnes of the BLS, the two other links occur in the 1979–81 period were made necessary by the elimination of the distinction between certificated and noncertificated carriers, and a major shift in coverage of small carriers.

value added throughout only for railroads, while switching in 1977 from gross output to value added for trucking and airlines. Although it would be desirable to use the BLS indexes throughout for consistency, the above analysis of data discrepancies suggests that a mixed set of sources is superior.

Railroads. The BLS and NIPA employment series are very close, so the choice of the BLS series raises no problem. However, since 1977 the NIPA railroad output series rises almost 2 percent per annum faster than the BLS output series. About half of this difference reflects the BLS practice of weighting several hundred traffic classes by unit revenue weights, which approximates the practice of Törnqvist aggregation advocated by Caves, Christensen, and Tretheway (1981) and is conceptually superior to the Bureau of Economic Analysis (BEA) index that is based on unweighted ton-miles. The remaining half of the difference reflects the distinction between gross output and value added; the latter increases more rapidly as a result of increased fuel efficiency. Both of these differences point to the use of the BLS gross output series for railroads and adjusting explicitly for fuel efficiency.

Trucking. We concluded above that the NIPA output and employment series for trucking are much superior to the BLS series, which cover a shrinking segment of the industry. Because the NIPA output series represents value added since 1977, our MFP index for trucking since 1977 should not adjust for fuel and materials inputs, because this would amount to subtracting these inputs twice.

Airlines. As noted above, the BLS employment series for airlines incorporates adjustments that make it superior to the NIPA series, and for consistency we also use the BLS output series. For 1977–87 the revised NIPA output series grows only about one percent per annum faster than the BLS output series, and much of this may reflect increased fuel efficiency that we take into account separately.

10.2 Conceptual Issues

10.2.1 MFP Growth and the Cost-Function Approach

The production process in transportation is well described by the standard economic theory of production, with a few unique features. Because the formal interpretation of MFP indexes within the cost-function approach has been clearly developed elsewhere, here we limit the discussion to the implications for the MFP indexes that we develop subsequently.[20]

10.2.2 Issues in the Estimation of MFP Growth

The cost-function approach emphasizes that standard measures of MFP growth are equivalent to the shift in the production function and cost function

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[20] See Denny, Fuss, and Waverman (1981, 187–95) and the appendix in Good, Nadiri, and Sickles (1989).

only in the presence of constant returns to scale. With increasing returns, the growth of MFP exaggerates the shift in the production and cost functions by including the contribution of economies of scale to economic growth. Because the proper measurement of returns to scale requires data on outputs and inputs at the level of the firm or establishment, the findings in this paper based on industry-level data must be qualified to the extent that more disaggregated studies have determined that nonconstant returns to scale are important.

Other issues emerging from the cost-function literature include departures from marginal cost pricing and effective rate-of-return regulation. The first of these appears to be most important in industries that practice cross subsidization, as in the case of telephone communications studied by Denny, Fuss, and Waverman (1981), and involves the mismeasurement of output growth because of the application of incorrect weights in aggregating outputs and inputs. We are able to sidestep this issue in studying the transportation sector, because it is of secondary importance. Although airlines and railroads produce multiple outputs, their revenues are overwhelmingly dominated by a single product, scheduled passenger travel in the case of airlines and freight carriage in the case of railroads.

The second issue, rate-of-return regulation, is clearly relevant for transportation. Denny, Fuss, and Waverman (1981, 199) show that, if prices of expensed factors of production and the allowed rate of return are increasing over time, then estimates of technical change that ignore rate-of-return regulation overestimate the true underlying rate of technical change. This finding is important for any investigation that includes the period of deregulation, because it could lead to an erroneous conclusion that the rate of technical change had been decreased as a result of deregulation. Although we make no adjustment for this potential bias in our study of railroads and trucking, we have sufficient data to decompose changes in airline efficiency into changes achieved by aircraft manufacturers and changes in the intensity of use of aircraft, particularly changes in load factors and in the seating density of given aircraft, that may reflect in part the influence of regulation and subsequent deregulation.

Hulten (1986) and Berndt and Fuss (1986) have emphasized a problem in productivity measurement that applies to any industry, not just to the regulated sector. If output is produced by capital services, that is, by the utilized portion of the capital stock, then conventional measures of MFP growth based on data on the capital stock (implicitly assuming constant utilization) err by treating the effect on productivity of changing utilization as a shift in the production function. Below in table 10.15 we address this issue by providing estimates of MFP growth that are adjusted for changes in utilization in the national economy.

10.2.3 Causes of Changes in MFP

We conclude part 10.2 by discussing causes of productivity change that are common to different subsectors of transportation, and reserve for the remaining sections of the paper a detailed consideration of those causes that are specific to particular subsectors.

1. Unmeasured changes in the quality of output. Because it mainly provides a consumer service rather than an intermediate input, air transportation raises more questions of unmeasured quality change than do rail and trucking. Computers, for instance, have produced unmeasured quality deterioration in the form of restrictions and penalties on airline tickets, balanced by advance seat selection and boarding passes, frequent-flyer awards, and the potential welfare gains of price discrimination to price-sensitive travelers. Other dimensions of quality change include the benefits of increased speed made possible by improved aircraft, the effects of congestion, noise, flight frequency, waiting time, and safety. Both noise and pollution are relevant for railroads and trucking, as is the increased speed of rail shipments made possible by deregulation.

2. Quality of inputs, especially capital. In the macrosources-of-growth literature there is a substantial controversy about the effects on MFP of changes in labor quality. Having summarized the issues recently, we say nothing new about this here (Baily and Gordon 1988, 370–76). Here our main emphasis is on changes in the quality of capital. The growing literature on computer prices, recently surveyed by Triplett (1989), has yielded a consensus that the proper measure of utilized capital input that appears in the production function is a vector of input characteristics of capital, defined as any attribute of a capital good that has a positive marginal product, including the horsepower and physical dimensions of a truck, or memory size and speed for a computer. Recently (Gordon 1990a) I have constructed a number of new deflators for investment goods; my approach to price measurement for capital goods emphasizes the need for accurate attribution of quality changes among producers and users of capital goods.[21] Manufacturers should be "credited" not only with improvements in performance, but also with cost-saving innovations in energy efficiency, durability, and maintenance costs.

To make sense in conjunction with my quality-adjusted measures of real capital input, calculations of MFP growth must include fuel or energy as an input. My method credits equipment manufacturers for improvements in fuel economy that are not accompanied by proportional increases in real equipment cost. Thus new technology that improves fuel efficiency enters the calculation of transportation MFP growth as an increase in the growth of capital input (which reduces MFP growth) and is balanced by a decrease in the growth of fuel input (which boosts MFP growth). If the calculation is done properly, the faster capital input growth and slower fuel input growth exactly offset each other and no change occurs in transportation MFP growth. This is the correct conclusion, because by assumption the technical achievement occurs in the manufacturing sector, not in the transportation sector. The many recent detailed studies of productivity growth in transportation have devoted

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[21] A brief summary of the methodology and results of this book-length study is available in Baily and Gordon (1988, 377–84).

remarkably little attention to the issue of capital quality, and hence in this example credits the transportation sector for faster MFP growth that has been achieved elsewhere.[22]

10.3 Air Transportation

10.3.1 The Long-Run Behavior of Productivity and Relative Price

The U.S. airline industry commenced operations in the late 1920s, and by 1935 almost all of today's largest domestic airlines were operating under their present names. Total industry output in 1987 exceeded that in 1935 by a factor of 1650, for an annual growth rate during the intervening years of 14.2 percent. The growth performance since 1935 is summarized in the top half of table 10.6. ALP growth marched along at a rock-solid 7.1 percent throughout the period 1935–69, even though output growth in the two decades after 1948 fell by half compared to 1935–48. This casts doubt on the importance of increasing returns in the long run, because the post-1948 decline in output growth should have reduced ALP growth if scale economies were important. The bottom half of table 10.6 displays the ratio of United Airlines output and productivity to that for the air transport industry as a whole. Although United was the largest airline during 1931–38 and again from 1961 to 1988, there is no evidence that it gained any advantage from its large scale. In fact, its ALP grew slightly slower than that for the industry, 5.73 versus 6.25 annual percentage points, respectively.

If an industry enjoys ALP growth that is more rapid than for the economy as a whole, its real price should decline. The final column of table 10.6 shows that this occurred for the airline industry during 1935–87, although the relationship is not exact, as the relative price of an industry's output depends not only on relative ALP growth but also on changes in relative input costs and in the relative productivity of factors of production other than labor.

Our inference that the airline industry is subject to constant returns in the long run accords with the view originally established by R. Caves (1962) and reinforced by Douglas and Miller (1974) and White (1979). Recently, D. Caves, Christensen, and Tretheway (1984) find economies of scale to "density," adding more flights per city served, but agree with the previous literature that larger firm output accompanied by an increased size of network, holding density constant, is subject to constant returns. We return below to the effects of deregulation on route structure and density.[23]

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[22] Many papers on airline productivity cite the detailed panel data set constructed by Caves, Christensen, and Tretheway (1981) and extended in subsequent papers. These authors carry out a detailed aggregation of major aircraft types, as do we in part 10.3 below, but they weight each aircraft type by its lease cost. If lease cost is proportional to purchase price, then their procedure is equivalent to assuming that the input characteristics of different models of aircraft differ in proportion to their purchase price, which greatly understates the quality of newer models.

[23] Caves, Christensen, and Tretheway (1981) also show that there are systematic differences in managerial efficiency over time that are not related to scale. In reporting these results, they stress their agreement with the results of my first professional paper (1965).

Table 10.6 **Long-Run Behavior of Output, Employment, and Passenger Yield, Airline Industry and United Airlines, 1985–1987**

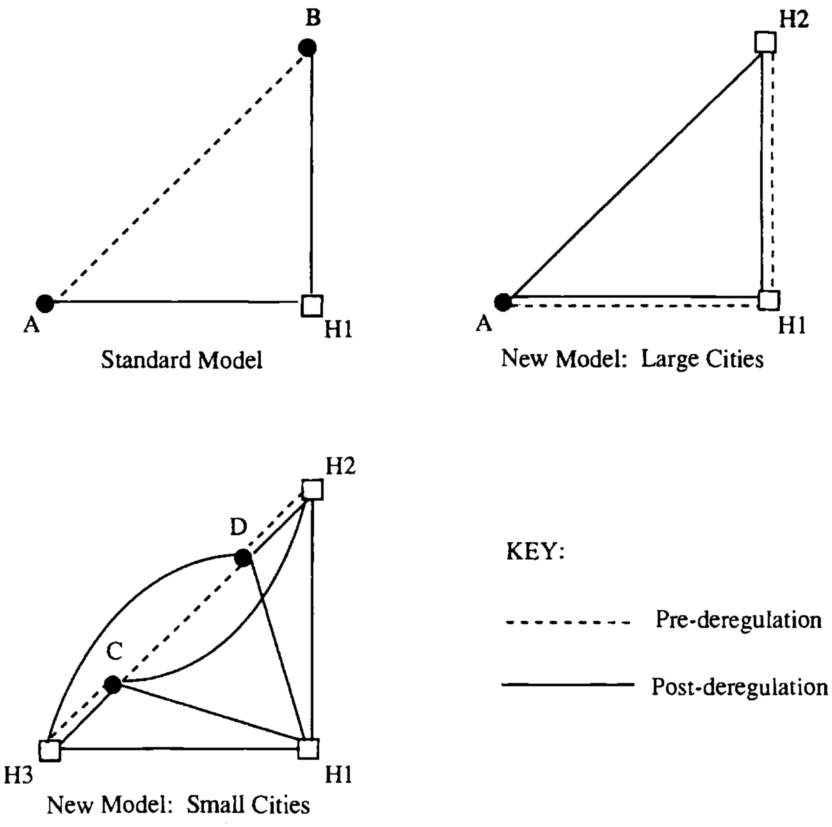
Year	Revenue Ton Miles	Employees	Output per Employee	Real Passenger Yield
Annual Growth Rate, U.S. Domestic & International Scheduled Air Carriers				
1935–41	26.43	19.21	7.07	−4.02
1941–48	24.58	16.61	7.08	−5.52
1948–59	13.58	6.03	7.05	−2.82
1959–69	13.48	6.42	7.06	−2.72
1969–78	6.26	0.60	5.66	−2.57
1978–87	5.81	2.03	3.78	−1.92
Ratio, Index of Each Variable for United Airlines to Index for Air Transport Industry (1978 = 1.0)				
1935	1.48	1.22	1.22	1.15
1941	1.11	0.84	1.32	1.03
1948	0.89	0.81	1.09	1.01
1959	0.84	0.80	1.06	1.08
1969	1.08	1.03	1.05	1.00
1978	1.00	1.00	1.00	1.00
1987	0.95	1.03	0.93	1.00

Sources: For 1948–87, industry output and employment are obtained from the same sources as table 10.4. For 1935–48, data are obtained from the CAB *Handbook of Airline Statistics*. Domestic revenue ton miles were linked to total revenue ton miles prior to 1943. Real passenger yield is passenger revenue divided by revenue passenger miles times the GNP deflator. United Airlines data come from company annual reports, selected issues.

Our treatment of airline productivity treats two main topics, unmeasured changes in output quality and new measures of inputs (especially capital). Improvements in output quality can be achieved both by aircraft manufacturers and by airline operators. The most dramatic changes in quality prior to the 1970s occurred as manufacturers made possible the shift to larger and faster piston planes, and then to jet aircraft; these are treated below in the context of input measurement. First we examine issues in the changing quality of airline output achieved within the airline industry itself, and this concentrates on the period since deregulation in the late 1970s, an interval during which interval the quality of aircraft has been relatively stable.

10.3.2 Output Quality: The Productivity Effects of Hubbing

Airline deregulation is widely believed to have substantially changed the production process by shifting airline service from nonstop point-to-point service to connecting service through hubs, thereby increasing flight mileage to travel between origin and destination. In the upper left-hand of figure 10.1, the dashed line indicates the nonstop flight between origin A and destination B flown prior to deregulation, and the solid lines show the roundabout route through hub H1 flown after deregulation. If correct, this "standard model"



Standard Model

New Model: Large Cities

New Model: Small Cities

Fig. 10.1 Routing effects of airline deregulation: Standard model compared to new model

would have the important implications that official measures of output in the 1980s overstate true output measured from origin to destination and that measures of yield understate the true origin-to-destination price. This standard view is frequently encountered in academic work,[24] and it appears to be universally held by journalists.[25]

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[24] McGowan and Seabright (1989, 326, 329) support verbally the graphical interpretation in the top left frame of figure 10.1: "a traveller from A to B takes off and lands twice instead of once, takes longer to reach the destination, travels further in total and may have to suffer the inconvenience of changing aircraft and an increased risk of baggage loss or missed connections. . . . it is important, therefore, that the true social costs of making indirect rather than direct flights should be borne by carriers." Similarly, Good, Nadiri, and Sickles (1989, 7) state that "increased use of hub-and-spoke and loop type networks . . . allow carriers to increase load factors, but they artifically inflate the level of real production by increasing the air miles between cities and by reducing the likelihood of non-stop service."

[25] Samples include "instead of flying a 'linear' route system, with criss-crossing services between cities, airlines have developed more efficient hub-and-spoke systems" (*The Economist,*

The most widely cited advocate of the standard view is Dempsey (1990), who claims that the hub-and-spoke system has caused passengers to fly between 5 percent and 30 percent additional mileage on a given trip, implying that a portion of productivity gains measured by passenger-miles is illusory. Dempsey uses this finding (1990, 32) sharply to criticize the cost-benefit analysis of deregulation by Morrison and Winston (1986) for failing to take account of the time cost of "greater circuitry attributable to hub and spoking." Although it might seem from Dempsey's critique that the output and price data examined in part 10.1, above, are flawed by failing to adjust for circuitry, in fact the issue is of trivial importance. Borenstein has estimated that, if all domestic air travel were nonstops and there were no connections at all, total domestic flight mileage would be reduced only by about 4 percent, but of course there were plenty of connections before as well as after deregulation, so that the net circuitry effect must have been much less than 4 percent even if the percentage of flights involving connections has increased substantially.[26]

In assessing unmeasured aspects of quality change in airline output, the issue of connections and hub-and-spoke routings is central. Justifying a new assessment is that academic studies by Morrison and Winston (1986, 1989) and others use data for 1983 and earlier years produced by the U.S. Civil Aeronautics Board (CAB) prior to its 1984 "sunset." There is virtually no evidence available for any recent year that takes account of the 1986–87 wave of mergers and the failures of numerous new entrants.[27]

To provide a fresh look at the routing opportunities available to travelers, we have assembled a virtually complete census of routes, and of the daily number of flights per route, flown by the air transportation industry within the 48 continuous states in August 1978 and August 1989. The results, summarized in tables 10.7 and 10.8, unambiguously contradict the standard model and reflect two simple facts. First, surprisingly few nonstop routes involving medium and large cities were discontinued. Second, critics overlook the fact that *millions of people actually live in metropolitan areas where new hubs were established;* the number of new nonstop hub-to-hub and hub-to-spoke routes from these new hubs greatly outnumber the small number of discontinued nonstop routes. This new model is shown in the upper-right frame of figure 10.1; deregulation allows new nonstop service from city A to new hub, H2, thus eliminating the circuitry of detouring via an old hub H1.[28]

March 10, 1990, 73); "They built hub-and-spoke route systems . . . rather than a web of direct, non-stop flights" (*The Economist*, January 26, 1991, 57); there are "far fewer direct flights" (*New York Times*, January 2, 1991, A1); "Many travelers now must fly farther to reach a given destination because of hub-and-spoke systems . . . yield can decline even though passengers are paying more for their tickets" (*Wall Street Journal*, April 19, 1990, B1).

[26] The 4 percent figure is from correspondence to the author from Severin Borenstein, dated May 20, 1991, and is calculated from the Department of Transportation data base for the second quarter of 1986.

[27] An exception is Borenstein (1991), to which we return below.

[28] The ability of deregulation to open up new nonstop routes bypassing traditional hubs was recognized immediately by perceptive observers, whereas previously, for instance, "everyone in

Table 10.7 **Effect of Deregulation on Nonstop Domestic Air Service, Top 500 Origin-Destination Markets, August 1978 and August 1989**

	1978		1989	
	Routes	Flights	Routes	Flights
Flown both years:				
Hub to hub[a]	71	. . .	116	. . .
Hub to nonhub	187	. . .	171	. . .
Nonhub to nonhub	71	. . .	42	. . .
Total	329	. . .	329	. . .
Flown one year, not the other:				
Hub to hub	1	1	6	16
Hub to nonhub	11	19	47	123
Nonhub to nonhub	5	6	8	16
Total	17	26	61	155
Flown neither year:	93	. . .	93	. . .

Source: Official Airline Guide, North American Edition, August 1, 1978, and August 1, 1989.
Note: The 500 top markets are ranked by revenue passenger miles, from Department of Transportation origin and destination survey, table 7, for the 12 months ending December 30, 1986.
[a]The hub airports include both the original hubs and new hubs. See the listing of hubs in the notes to table 10.8.

Some accounts treat hub-to-spoke routings as a byproduct of deregulation. However, on-line connections date back to the dawn of the airline age, and the first hub operations on today's scale began when Chicago's O'Hare airport terminal complex was opened in 1962.[29] By the time deregulation occurred in 1978, United at O'Hare, as well as Delta and Eastern at Atlanta, were *already* operating full-scale hubs, each with roughly 250 departures per day. Prior to deregulation passengers were forced to make connections, just as they are today, but many more of those connections were interline rather than on-line, and more involved double connections. Between 1978 and 1989 interline connections fell by a factor of 10, from 41 percent of all connections to 4 percent (see table 10.10 below, sec. 1d).

When markets are ranked by passenger-miles, there are many long-haul markets that lacked nonstop service in both 1978 and 1989, but many more that gained service than lost service.[30] This contrast is shown in table 10.7, which provides a decomposition of nonstop routes served in the top 500 origin-destination markets (accounting for 60 percent of traffic measured by

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the Carolinas or Virginias had to change planes to get beyond Atlanta or New York" (Baumgarner 1979, 47).

[29] 29. This statement is supported by the American Airlines annual report for 1983, which reports that the opening of Chicago's O'Hare terminal in 1962 represented the initiation of American's first "true hub" (8).

[30] 30. Here it is important that markets be ranked by origin and destination passengers, i.e., the city pairs where people actually want to travel, and not by enplaned passengers on particular city-pair segments, which of course respond to where the flights are actually operated.

Table 10.8 **Effect of Deregulation on Nonstop Domestic Air Service, All Markets, August 1978 and August 1989**

	1978		1989		Change		Frequency*	
	Routes	Flights	Routes	Flights	Routes	Flights	1978	1989
1. Original hubs:								
a. To original hubs[†]	94	815(0)	97	944(0)	3	129(0)	8.7	9.7
b. To new hubs	115	610(10)	166	1068(23)	51	458(33)	5.4	6.6
c. To large nonhubs	391	2018(90)	468	2394(269)	77	376(179)	5.4	5.7
d. To small nonhubs	280	497(630)	358	355(1515)	78	-142(885)	4.0	5.2
e. Total	880	3940(730)	1089	4761(1807)	209	821(1097)	5.3	6.0
2. New hubs:								
a. To new hubs[†]	29	91(18)	55	255(69)	26	164(51)	3.8	6.0
b. To large nonhubs	146	467(39)	350	1263(284)	204	796(245)	3.5	4.4
c. To small nonhubs	63	53(138)	205	187(669)	142	134(531)	3.0	4.2
d. Total	238	611(195)	610	1705(1022)	372	1094(827)	3.4	4.5
3. Large nonhubs:								
To large nonhubs[†]								
a. Served both years	175	653(58)	175	608(368)	0	-45(310)	4.0	5.6
b. Not other year	44	73(3)	61	123(44)	16	50(41)	1.7	2.8
To small nonhubs:								
c. Served both years	118	162(216)	118	118(378)	0	-44(162)	3.2	4.4
d. Not other year	126	108(150)	44	26(120)	-82	-82(-30)	2.0	3.3
e. Total	463	996(427)	398	875(910)	-66	-121(483)	2.6	4.0

4. Between small nonhub:[†,‡]								
a. Served both years	139	132(143)	139	47(353)	0	−85(210)	2.0	2.9
b. Not other year	165	60(282)	50	17(93)	−115	−43(−189)	2.1	2.2
c. Total	304	192(425)	189	64(446)	−115	−128(21)	2.0	2.7
5. Summary:[§]								
a. All hubs	1233	5161(935)	1865	7534(2852)	632	2373(1937)	4.9	5.6
b. Large nonhubs	1000	3479(556)	1215	4532(1051)	215	1053(495)	4.0	4.6
c. Small nonhubs	647	742(1193)	752	606(2630)	105	−136(1437)	3.0	4.3

Source: Official Airline Guide, North American Edition, August 1, 1978, and August 1, 1989.

Notes: First-listed count of flights is for jets, subsequent count in parentheses is for turboprops. The listing of routes and flights in this table includes only airports in the 48 continuous states and excludes all service from these airports to Alaska, Hawaii, or foreign countries. Every route and flight is included, except as indicated in note *c*, and except among cities too small to be classified as "small nonhubs." Flight totals ignore weekend exceptions; a flight is counted as one daily frequency if it operates four or more days per week.

Definitions: (1) *Hubs:* Hub airports include all those in which at least one airline operated a substantial number of on-line connecting flights in 1989. New hubs are those in which one or more airlines performed a hub operation in 1989 but not 1978 and include Baltimore, Charlotte, Chicago Midway, Cincinnati, Dayton, Detroit, Nashville, Newark, Philadelphia, Phoenix, Raleigh-Durham, Salt Lake City, and Washington Dulles. The remaining hubs are classified as original hubs and include Atlanta, Chicago O'Hare, Cleveland, Dallas-Ft. Worth, Denver, Houston, Kansas City, Los Angeles, Memphis, Miami, Minneapolis, Pittsburgh, St. Louis, and Washington National. (2) *Size:* Small nonhubs had nonstop service to no more than two hubs (new or original) in at least one year but had nonstop service to at least one hub in at least one year. Any airport with more than two routes to a hub in one or both years is classified as a large nonhub; airports with no routes to any hub in either year are excluded. Major airports classified as large nonhubs include Boston, Buffalo, Columbus, Oh., Indianapolis, N.Y. LaGuardia, N.Y. Kennedy, Orlando, San Diego, Seattle, and Tampa.

*"Frequency" indicates total flights per route per day, including both jets and turboprops.

[†] Routes and flights between airports within a single category are adjusted to eliminate double counting.

[‡] The listing for flights between small nonhubs is based on a 50 percent sample (all cities with names beginning "A" through "L", which account for 49 percent of the pages listing flights in both the 1978 and 1989 source).

[§] Summary totals are not adjusted to eliminate double counting; hence the total of routes and flights in section 5 is greater than the sum of routes and flights in sections 1–4, inclusive.

passenger-miles). Fully 422 of the 500 top markets show no change in the status of service, in that routes were either served nonstop or not in both years. In the remaining 78 markets, those adding nonstop service outnumbered those losing nonstop service by a margin of 61 to 17. Average frequencies (flights per day) in the discontinued markets were just 1.5, but were 2.5 in the markets adding service. Further, many 1978 nonstop markets were served sparsely, so that many passengers were forced to make stops or connect if they did not want to travel at the time of a single nonstop (e.g., nonstop service from Boston to Dallas increased from a single nonstop in 1978 to 9 per day in 1989). Critics, including Dempsey, imply that nonhub cities on the periphery of the 48 states have suffered particularly severe declines in nonstop service.[31] Taking as examples Boston, San Diego, and Seattle, nonstop routes from these three major cities to the other 24 of the top 25 largest metropolitan areas increased from 44 in 1978 to 56 in 1989 (out of a possible of 72).

The complete census of domestic airline routes and flights appears in table 10.8. Airports are divided among four categories: original hubs, new hubs, large nonhubs, and small nonhubs.[32] The number of routes served increased not only in every category involving hubs but also in routes between large nonhubs. Taking the categories in table 10.8 from line 1a through 3b, which account for 90 percent of flights in 1978,[33] the number of routes served increases by 45 percent, the number of jet flights by 36 percent, and the number of turboprop flights by 229 percent.

The bottom part of table 10.8 (lines 3c–4b) displays a sharp contrast between the 90 percent of flights on major routes and the remaining 10 percent of flights involving service between small nonhubs and other (small and large) nonhubs, where the number of routes flown decreased by 36 percent, and the number of jet flights decreased by 55 percent; the number of turboprop flights increased by 37 percent. A graphical interpretation of this shift is provided in the bottom frame of figure 10.1. Many of the abandoned flights to small cities were along linear routes dictated by regulated routes, as in the abandoned

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[31] Indeed Dempsey's prime example of circuitry involves "the loss of pre-deregulation Boston-San Francisco nonstops" (30). This is one of Dempsey's many factual errors: in no year since 1962 has Boston-San Francisco lacked nonstops, and in the summer of 1991 enjoyed five daily nonstop flights. His fanciful "circuitry" example involves passengers allegedly forced to fly this route via Dallas, rather than more directly through any of the many available hubs, including Chicago, Cleveland, Denver, Detroit, Minneapolis, Newark, or Salt Lake City.

[32] My definition of a hub is based on the absolute volume of connecting flight and traffic activity, not the percentage of total traffic that is connecting vs. local (an alternative criterion suggested to me by Severin Borenstein). For instance, San Francisco and Memphis in 1989:Q3 were ranked 15th and 16th in the absolute volume of connecting passenger enplanements, yet San Francisco boarded only 21 percent of its total domestic traffic as connections (79 percent local traffic); Memphis boarded 63 percent as connections (37 percent local) This contrast does not make San Francisco any less of a hub than Memphis, because the volume of activity is the same, and the dominant connecting airline in San Francisco (United) gains a tremendous advantage in adding flight frequencies that allow it to dominate the local traffic as well.

[33] When a turboprop flight is given a weight equal to 0.25 of a jet flight, the 1978 flights listed in lines 1a through 3b account for 89.3 percent of the total flights listed in lines 1a through 4b.

route between C and D. Because most of these routes were shorter than 200 miles in length, they were valued by relatively few passengers, most of whom used surface transport.[34] More than offsetting the loss of such routes was (1) the large number of new routes to hubs (e.g., from C to H1 and H2), (2) the large number of local passengers served on new routes than abandoned routes (because hubs like H1 and H2 on average have much larger populations than small cities like D), (3) the greatly increased number of connection opportunities from travel beyond hubs, thus allowing many two-connection trips to be reduced to a single connection, and (4) the much greater daily frequency of service on added routes than on abandoned routes.[35]

Overall, it appears that the benefits to small nonhub cities of added flights to hubs outweigh the loss of direct nonstop flights, as the number of routes flown from small nonhubs increased by 16 percent, and the total number of flights increased by 67 percent (table 10.8, line 5c). The only remaining aspect of the indictment of deregulation by Dempsey and others that retains its validity is the shift from jet to turboprop aircraft. Yet even here the discomfort factor is minimal; as most of the flights involved are less than an hour, discomfort is partly offset by increased frequency.[36]

Despite the widespread introduction of new nonstop routes and the virtual elimination of interline connections under deregulation, the fraction of trips involving connections actually rose slightly, from 27 percent in 1978 to 33 percent in 1989 (table 10.10 below, line 1d). Thus, in view of new nonstop route opportunities, the remaining debate over hubbing remains whether passengers were *forced* to take the extra connections or voluntarily *chose* to take the extra connections that accounted for the 1978–89 increase of 6 percentage points in the fraction of trips involving connections.

The forced interpretation argues that the total number of flights involving large nonhubs increased by only 33 percent between 1978 and 1989 (table 10.8, line 5b, weighting turboprops as 0.25 of a jet flight); domestic passenger enplanements increased by 67 percent. The implication is that the unavailability of seats on heavily booked nonstop flights forced demand to spill over to less desirable connections. Denying this interpretation, however, is the fact

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[34] Of the 123 abandoned nonstop routes between large and small nonhubs (table 10.10, line 3d), 62 percent were 200 miles or less.

[35] The average daily frequency on flights from hubs to small nonhubs (table 10.10, lines 1d and 2c) in 1989 was 4.8, as contrasted with 2.1 on the abandoned 1978 routes involving small nonhubs (lines 3d and 4b).

[36] We can tie our study of airline routes back to the findings of CCT (1984) that there are economies of scale to increased density (traffic per number of cities served) but not from an extension of the number of cities served. For the system as a whole, increased traffic between 1978 and 1989 was not accompanied by an increase in the number of points served, and hence density increased. But the CCT results refer to individual carriers, and most carriers increased the number of points served, implying that each airport had more carriers in 1989 than 1978. The CCT results for economies of scale for individual carriers cannot be applied to the system as a whole without a carrier-by-carrier study to determine whether increased traffic offset the increase in the number of points served by each carrier.

that long-haul nonstop flights were not significantly more or less crowded than average flights before or after deregulation.[37]

Instead, the choice interpretation suggests at least four reasons why travelers opted voluntarily for connections instead of same-plane service: The first two reasons take note of a flaw in the data on the percentage of trips involving change of plane—these neither distinguish same-plane flights making no stops, one stop, or multistops, nor do they distinguish single from double connections. Thus the first reason for voluntary choice of connections after deregulation is that a significant fraction of the same-plane 1978 traffic did not operate nonstop but involved one, two, or more stops. Much of this one or multistop traffic has been replaced by connections that are usually as fast and available at much greater frequency. Second, the proliferation of new hubs has greatly reduced not only the number of interline connections as is documented, but also the number of time-consuming double connections.[38] Third, the greatly increased number of long-haul connection opportunities involving satellite airports (e.g., Oakland, Orange County, San Jose, White Plains, Islip) diverted traffic from the traditional nonstop flights (still routed from airports like San Francisco, Los Angeles, and New York Kennedy); passengers chose connections from nearby satellite airports voluntarily to save ground travel time, pay lower parking fees, and reduce congestion delay. Fourth, passengers may choose voluntarily to take the time penalty of a connection in order to build up frequent-flyer credits on a preferred carrier; revealed preference argues that this cost is more than offset by the benefits of frequent-flyer programs. Overall, we conclude that the forced diversion of traffic from overcrowded nonstops to connecting flights was minor compared to the diversion from one-stops to connections (involving a negligible time cost), to the benefits of reduced double connections, to the saving in ground time and congestion when travelers chose alternative smaller airports, and to the perceived benefits of frequent-flyer plans.

10.3.3 Output Quality: Other Aspects

The popular literature on deregulation implies that there has been a widespread and unambiguous decline in the quality of airline service as a result of

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[37] Taking the nine most important transcontinental nonstop routes flown by American, TWA, and United, the weighted average load factor in October, 1977 was 58.1 percent, compared to domestic system load factors for the same three carriers of 60.5 percent. In October, 1989, the figures were 66.5 and 63.3 percent, respectively. The source is the author's calculations from CAB and Department of Transportation market segment data.

[38] Of the hundreds of examples that could be constructed from the sources used in tables 10.7 and 10.8, the first two I looked up will suffice. Travel from Portland, Maine, to Anchorage, Alaska, in July, 1978 involved a single early-morning option to take a double connection involving three airlines; in July, 1989 the same trip could be taken in mid-morning or mid-afternoon through a single connection involving a single airline, with an elapsed time shorter by 2 hours and 45 minutes. Travel from Bakersfield, California, to Savannah, Georgia, could be made twice daily in either year, by double connection involving two airlines in 1978 and by single connection involving a single airline in the other; the time saving in 1989 was only 15 minutes for an early morning trip but 2 hours for a midday trip.

airline deregulation.[39] This section assembles in table 10.9 a variety of indicators to provide a new evaluation.

(1) On-time performance. Since September 1987, the U.S. Department of Transportation (DOT) has compiled a data base of on-time performance by carrier, flight, and airport, and these data are widely publicized. Shown in the second column of table 10.9, line 1, is the average percentage of flights arriving within 15 minutes for the three years ending in August 1990. It is less well known that comparable data (covering only the top 200 markets) were collected prior to 1981, and the 1977–78 average is also displayed on the same line of table 10.9. Perhaps surprisingly, the percentages are almost identical, indicating no deterioration in on-time performance.

(2) Scheduled flight times. How could the airlines have maintained a constant on-time record, in view of the frequent criticism that deregulation-inspired hubbing has increased congestion and led to long conga lines of aircraft waiting to take off? The answer is provided on line 2 of table 10.9, which shows that airlines have extended scheduled times in order to maintain their average on-time percentage. Our sample consists of 60 routes flown in both years, with a representative selection of routes from original hubs, new hubs, and large nonhubs, and most of the heavily congested airports are included. The sample covers roughly 5 percent of the comparable routes in each year and shows that flight times were extended by roughly 10 minutes regardless of distance, implying that ground congestion was the cause.[40] However, the increase in flight times is uniform across airport types and shows no tendency to be greater in hubs than nonhubs. Hence the underlying culprit is more likely to be the growth in air traffic relative to air traffic control capacity rather than any effect of deregulation on route patterns.

(3) Service complaints. Line 3 of table 10.9 shows a surprising decline in airline service complaints, indicating either an improvement in airline service or a reduction in the "propensity to complain." It is unlikely that the source of this change is selection bias resulting from a change in the complaint-receiving agency from the CAB to the Department of Transportation, as the Department of Transportation telephone number has been widely publicized and in fact complaints exhibited a temporary 1987 hump as a result of airline mergers.[41]

(4) Safety. The fatality rate has dropped markedly, and this appears to be the result of coordinated efforts by aircraft manufacturers, airlines, and government safety regulation, rather than a by-product of deregulation. As of early 1991, more passengers had survived than died in the six fatal crashes that occurred over the three previous years. During that period 72 percent of pas-

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[39] A particularly vivid indictment is provided by Charles Kuralt (1990).

[40] In August 1978, the sample includes 249 flights of the 4,727 jet flights (5.3 percent) among the airports other than small nonhubs. In August, the sample includes 296 flights of the 6,655 jet flights (4.5 percent) within the same category.

[41] Complaints fell from 41,560 to 16,668 despite an increase in enplaned passengers of roughly 80 percent.

Table 10.9 **Aspects of Airline Service Quality, Selected Indicators, Averages for 1977–1978 and 1988–1989**

	Average, 1977–78	Average, 1988–89	Change 1988–89 – 1977–78
1. Percentage of flights on time (within 15 minutes)	76.8	77.9	1.1
2. Elapsed scheduled time (hours:minutes):			
1. 20 short-haul routes	1:07	1:15	0:08
b. 20 medium-haul routes	2:05	2:19	0:14
c. 20 long-haul routes	4:08	4:18	0:10
d. Average for 60 routes	2:27	2:37	0:10
3. Complaint rate per 100,000 passengers enplaned	8.03	1.84	−6.19
4. Fatalities per 100,000 passengers enplaned	0.17	0.06	−0.14

Sources by line: (**1**) 1977–78 on-time percentage refers to top 200 markets; 1988–89 on-time percentage for all reported airports is for the 36 months from the beginning of the current data base in September 1987 through August 1990. Source for September 1987 through January 1990 is U.S. Department of Transportation, Office of Consumer Affairs, *Air Travel Consumer Report*, March 1990. Otherwise the source is *Air Transport World*, "facts and figures" page, various issues. (**2**) Times are for August 1978 and August 1989 and the source is the same as for table 10.8. Short-haul routes are 300–400 miles, medium-haul 700–800 miles, and long-haul routes 1500 miles and over. Of the 20 routes in each category, 8 are randomly selected among those from "original hubs" (as defined in the notes to table 10.8), 5 from "new hubs," and 7 from "large nonhubs." Of the most congested airports, Atlanta, O'Hare, Denver, Dallas-Ft. Worth, Los Angeles, and N.Y. Kennedy are all included. (**3**) Same sources as line 1, the average for the years 1977–78, and for the 24 months ending November 1990. (**4**) Fatalities for 1977–78, *Statistical Abstract*, 1982–83, table 1102, 635, and enplanements, table 1099, 633. Fatalities for 1988, *Statistical Abstract*, 1990, table 1066, 622 and for 1989 from *New York Times*, January 19, 1991, A14. 1988–89 enplanements are from *Aviation Daily*, various issues.

sengers in airline accidents survived, as compared to only 10 percent during the period 1980–87 (Phillips 1991). Also suggesting that deregulation had no adverse effect, Rose (1990) shows that the average accident rate was virtually the same in 1976–80 and 1981–86 and that this rate has declined by a factor of five since 1957–60.

(5) Seating density. There is no more obvious source of discontent with air travel than the cramped dimensions of seats in present-day commercial aircraft. Although an increase in seating density has occurred, its timing antedates deregulation. Seats per plane for the Boeing 747 increased by 18 percent between 1972 and 1977 and by 8 percent between 1977 and 1982 (Gordon 1990a, table 4.8). The respective figures for the Boeing 727–200 were 7 percent and 9 percent. Rather than resulting from deregulation, higher seat density resulted from an overexpansion of airline capacity in the late 1960s and the timing of the airline design cycle, which led to the introduction in 1970–72 of overly large wide-bodied aircraft. Both seat density and load factor were temporarily depressed, and both increased as traffic recovered after 1975.

(6) Frequent-flyer benefits. Morrison and Winston (1989, 83n.4) have estimated that frequent-flyer benefits were worth 2.3 cents per passenger-mile in 1983, fully 20 percent of the average fare in that year, and there are good

reasons to view this figure as an underestimate.[42] This represents an unmeasured component of airline output, in the sense that the true price of travel is overstated. Some portion of unmeasured output may be offset by free travel that is counted as part of revenue-passenger-mile output. But apparently such travel is not consistently counted in measured output, leaving a substantial residual of unmeasured output.[43] Further, as long as there is an inventory of unused miles, previous travel has created a consumer asset of substantial present value. To value frequent-flyer benefits, we take the conservative Morrison-Winston estimate of a 20 percent discount and assume that one-third of award miles are claimed, one-third are held for future use, and one-third expire without use. If one-half of claimed miles are counted as revenue traffic, then the remaining unmeasured component of output is one-sixth for claimed miles and one-third for unused miles, or half the 20 percent discount figure. This implies a downward bias in output estimates of about 1 percent per year over the ten years since frequent-flyer programs began in early 1981.

10.3.4 The Value of Time

By far the most important unmeasured quality attribute of airline output is the value of time saved by airline travelers, as compared to alternative means of transportation. However, the invention of aviation, and the increased speed of aircraft from the beginning of the industry through the late 1960s, should be credited to the airframe and engine manufacturers rather than to the airline industry. Unmeasured quality change in airline output refers to changes in elapsed time caused by changes in airline operations with a given fleet of aircraft. Here we focus on such changes between 1978 and 1989 and return at the end of this section to the value of time achieved by the aircraft manufacturing industry.

Morrison and Winston (1989, table 2, 66) have estimated a disaggregated airline carrier choice model that yields dollar values of time saving in three categories for 1983, total travel time ($34), transit time ($74), and schedule delay time ($3). Using these estimates, we calculate in table 10.10 the time

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[42] The existence in the mid-1980s of a broker market for frequent-flyer awards (recently shut down by aggressive airline court actions) provides a market test for valuation. I paid in the range of $0.025 to $0.04 per mile for such awards in the period 1983–86, yet this figure understates the value to the traveler who earned the free mileage, because of innumerable bonuses (double miles, triple miles, loyalty awards, affinity credit cards, etc.). In my case, in the first ten years of frequent-flyer programs I was credited with 1.463 million frequent-flyer miles for only 0.836 million miles actually flown, for a payoff ratio of 1.75, and an estimated value of bonus miles in the range of $0.04 to $0.05 per mile actually flown. For instance, in one example by flying 100,000 miles I earned enough bonuses for a 175,000 certificate, good for two round-trip first class tickets to Australia, with a retail value of $11,000, and which I valued at $4,750 ($2,500 for the cheapest coach fare, $25 per hour per person for 35 hours in the first-class instead of economy cabin, and $500 for the included hotel and car rental certificates), or at $0.0475 per mile flown to win the award.

[43] Severin Borenstein has written me that "frequent flyer plan bonus trips have not been consistently reported as revenue passenger miles by the airlines, though the Department of Transportation is now starting to enforce a consistent reporting method for these trips."

value of shifts in routing patterns, as well as extended travel times on given flights. Because of the low estimated value of schedule delay time, we can neglect the difficult calculation of the value of increased flight frequency on given routes.

All counts of flights in table 10.10 are taken from table 10.8 and are weighted, with respective weights of 1.0 for jet flights and 0.25 for turboprop flights. Line 1c shows that 21 percent of 1989 flights were on new routes. Despite this, line 2 shows that total connecting traffic increased somewhat from 27 percent to 33 percent of total trips, and interline connections almost disappeared. We have argued above that this small shift to connections, despite increased nonstop routings available, mainly reflect consumer choice rather than forced diversion from overcrowded nonstop flights.

To place a time value on these shifts, we use the Morrison-Winston estimates of the value of time, updated from 1983 to 1989 using aggregate compensation per hour, and make plausible estimates of the elapsed times involved in different types of flights. The resulting estimates, shown in section 4 of the table, show that the direct benefits of changes in flight routings add up to a small $1.5 billion, more than offset by the cost of lengthened flight times. The resulting time cost is about 4 percent of domestic airline passenger revenue in 1989, with the implication that measured output growth from 1978 to 1989 is overstated by roughly 0.3 percent per annum.

The estimates in table 10.10 are trivial in size, however, in contrast to plausible estimates of the value of time saving achieved by the aircraft manufacturing industry. Our calculations of standardized seat miles, summarized in table 10.12 below, show that average elapsed block speed increased from 210 miles per hour in 1954 to 433 miles per hour in 1972, and then remained at this level through 1987. This implies that the average 1989 trip of 2:37 hours (table 10.9, line 2d) would have taken 5:24 hours in 1954, neglecting the greater number of enroute stops in 1954. The time saving in 1989 was worth $51.7 billion, or 116 percent of domestic airline passenger revenue.[44]

The value of time saving from faster aircraft is just the tip of the iceberg, because it neglects the value of time saved when traffic shifts from surface to air transport. If we assume that intercity common carrier passenger-miles per dollar of real disposable income remained constant between 1939 and 1989, hypothetical air travel would have been 52 percent of the actual amount.[45] (The remaining 48 percent represents some combination of an income elasticity for travel greater than unity and an increased demand for travel resulting from the new-product aspects of air travel). Taking an average 1989 domestic

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[44] If we take a more conservative approach and use the Morrison-Winston value of elapsed time for the half of air traffic that represents business travel, and use aggregate compensation per hour for the other half, the time saving falls to $35.4 billion.

[45] 1939 intercity traffic from James (1982, table 1-3, xxviii); 1989/1939 real disposable income equals 5.8, from 1990 *Economic Report of the President*, table C-27. 1989 intercity travel includes bus, rail, and air, and the share for air was 92 percent. Resulting hypothetical 1989 intercity traffic is 197.2 billion revenue passenger miles, of which 27.5 actually traveled by surface, leaving 169.7 as the amount shifting from surface to air.

Table 10.10 **Changes in Value of Time in Domestic Air Travel, 1978 to 1989**

	1978	1989
1. Allocation of flights (weighted by aircraft size):		
a. Total flights	6183	8451
b. Flights on new routes		1789
c. Flights on new routes (%)		21
2. Connecting flights (%):	27	33
a. Interline	11	1
b. On-line	16	32
3. Shifts in type of flight (%):		
a. Single interline to single on-line connections		7
b. Double interline to single on-line connections		3
c. One-stop no-plane-change to single on-line connections		3
d. Nonstop flights to single on-line connections		3
4. Value of time saving (in billions of dollars):		
a. Interline to on-line connections		3.3
b. One-stop no-plane-change to single on-line connections		−0.3
c. Nonstop flights to single on-line connections		−1.5
d. Extended flight times		−3.1
e. Total		−1.6
1989 domestic airline passenger revenue (%)		−4

Sources by line: (**1a**) Table 10.8, totals of lines 1a through 4b, with jet flights weighted 1.0 and turboprops weighted 0.25 (**1b**). Flights on new routes are calculated by taking the number of new routes in each category of table 10.8 and estimating the frequency per route as the average of the 1978 and 1989 frequency within that category. Turboprop weights are applied as in line 1a. (**1c**) 1b/1a. (**2, 2a, 2b**) Borenstein (1991, tables 3 and 4), which refers to 1978:Q2 and 1990:Q2. Data for the first period are copied by Borenstein from Bailey-Graham-Kaplan (1985, table 4.6, 86) and for the second period are calculated by Borenstein from the Department of Transportation data base. (**3a, 3b**) Interline to online is divided arbitrarily by a 7-3 ratio between double interline and single-interline connections. (**3c, 3d**) The remaining shift to on-line connections is assumed to have been diverted equally from one-stop and nonstop flights. (**4a–4c**) Domestic passenger enplanements for 1988 from *Statistical Abstract* 1990, table 1065, 628, multiplied by 0.67 to eliminate double counting for connections. Value of time for 1983 from Morrison-Winston (1989, table 2, 66), extrapolated to 1989 by business sector compensation per hour. Respective total travel times and transit travel times saved are, respectively, 2.0 and 1.5 for double interline to single on-line, 0.5 and 0.5 hours for single interline to single on-line, −0.25 and −0.25 for one-stop no change of plane to single on-line connection, and −2.0 and −1.0 for nonstop to single on-line connection. (**4d**) Extra travel time 0.167 hours from table 9, line 2d. Rest of calculation uses same sources as (4a–4c).

airline trip of 791 miles and the elapsed times of 2:37 hours for air (from table 10.9) and 14 hours by surface, the implied time saving for the traffic shifting from surface to air was worth $61.5 billion.[46]

There remains the 48 percent of 1989 air travel that represents a combina-

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[46] The 14-hour surface speed is calculated as 794 miles divided by 65 miles per hour (interstate highway speed), which allows about 1.8 hours for rest and meal stops. By contrast, the fastest 1940 scheduled train between New York and Chicago took 17 hours (James 1982, xxvi).

tion of a nonunitary income elasticity and a new product.[47] If, for instance, the income elasticity of travel demand with respect to real income per capita is 1.5, then this 48 percent can be divided into 16 percent for the income effect and 32 percent for the new-product effect. Usher (1964) interprets an invention as a shift from a one-dimensional to two-dimensional production possibility frontier and evaluates the social welfare created by the extra dimension as the distance between the new frontier and the community indifference curve, but his approach cannot be implemented empirically without knowledge of the slopes and intercepts of the frontier and indifference curve. A more practical approach for estimation is to interpret the demand for the new product of air travel as resulting from a decline in the total cost of travel, consisting of the money price plus the value of time. A demand curve can be drawn through two points: The first is the actual 1989 total cost of an average trip ($185) and the average quantity (416 million passengers). The second is the hypothetical 1989 total cost of the assumed surface speed ($531) and the hypothetical quantity (the actual quantity less the 32 percent new-product demand, or 283 million).[48] The implied consumer surplus trapezoid is $120.9 billion.

Overall, we can sum the value of time saved from shifted traffic ($61.5 billion) to the new-product value ($120.9 billion), to arrive at a total of $182.4 billion, which is 408 percent of 1989 domestic passenger revenue, or, alternatively, 3.5 percent of 1989 GNP. We cannot include the value of the increased speed of aircraft from 1954 to 1989, because this would represent double counting. Our estimate is conservative, because it applies only to the domestic, but not the international, portion of the U.S. airline industry. Balancing this is the likelihood that, in the absence of air travel, surface travel speeds would have increased by investment in an American version of the French high-speed train or Japanese bullet train. Whatever its size, this type saving should be credited to the aircraft manufacturing industry and is about 10 times as large as U.S. commercial aircraft sales in 1988, a number that would be even larger if the saving of time in international travel by U.S. and foreign airlines were included, implying a huge rate of return to research in the aircraft industry, at least through the early 1970s.

10.3.5 Input Quantity and Quality

We have previously in part 10.1 discussed alternative estimates of the quantity of labor input. Our primary concern here is the measurement of capital

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[47] Severin Borenstein (in correspondence) cites a third source, the introduction of price discrimination under the deregulated regime, because he suspects that low discount fares have increased leisure travel by more than high undiscounted fares have reduced business travel. Thus some unknown part of our "new product" measure may be attributable to deregulation.

[48] The 1989 actual cost is the average fare per passenger ($107) plus a time cost of $29.80 (the average of the Morrison-Winston estimate for elapsed travel time and compensation per hour) times 2.6 hours per trip, or a total of $184.50. The 1989 hypothetical surface cost is $184.50 plus $29.80 times the hypothetical extra time of 11.6 hours, or $530.20.

input, although in our MFP calculations we also make allowance for energy and materials input, and expenditures by the government on air traffic control. Our aim here is to develop alternative measures of MFP growth that correspond to different capital goods deflators, in order to determine whether improved measurement of the quality of capital goods can explain some or all of the changes in ALP growth over time in the transportation sector.

Much analysis of transportation productivity treats capital as a fixed factor of production (Good, Nadiri, and Sickles 1989, 3–4). However it would be a mistake to impose too sharply the dichotomy that the manufacturing sector produces aircraft on purely technical considerations and to search for effects of deregulation only in the MFP residual that remains after the effect of capital quantity and quality is subtracted out. The quantity of service that a given aircraft can provide is determined not just by the manufacturer but also by utilization. Airlines can boost the capital services provided by a given aircraft fleet in three ways; by increasing the fraction of seats filled (load factor), by increasing the utilization of the fleet measured in hours per day or year, and by increasing seating density.

In addition to affecting the ratio of capital services to aircraft characteristics, the regulatory regime feeds back to the aircraft design process itself. The mileage-based fares in the regulated era were originally based on competition with first-class rail travel, where the relation of per-mile cost to length of haul was much flatter than for airlines. As a result there was heavy cross subsidization of short-haul by long-haul travel. Gellman (1968) has argued that the highly inefficient DC-7, the last of the piston-era aircraft and the first plane designed to fly coast to coast nonstop, would not have been created without the overpricing of long-haul travel. Similarly, the wide-bodied jet aircraft (B747, DC10, and L1011) introduced in 1970–72 might have taken a different form, or have been ordered in fewer numbers by domestic carriers, had it not been for long-haul overpricing. In turn, the effect of deregulation in sharply increasing short-haul fares relative to long-haul fares, together with the economics of hub operations, have stimulated the demand for short-haul airliners like the B737.

The first concept of capital input is the real stock series developed by the BEA, using the same deflators for structures and equipment as in the NIPA accounts. The BEA capital measurement project provides a breakdown that is perfectly designed for the purpose of this study, including real and nominal investment flows and capital stocks for both structures and equipment in total transportation and in the three subsectors covered in this paper.[49]

For air transport two alternative capital input series are developed for comparison with the BEA. One takes the new aircraft deflator developed in my price measurement project (Gordon 1990a) and combines it with my automo-

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[49] All BEA investment and capital stock data used in this paper are taken from the latest release of the BEA "Wealth Tape."

bile deflator as a proxy for ground equipment to form an alternative series for equipment. Because I have not developed an alternative deflator for structures, the alternative equipment series is combined with the existing BEA deflator for airline structures (which represents 5 percent or less of airline capital). By taking into account improvements in both performance and operating efficiency, my aircraft deflator declines relative to the BEA deflator by a factor of 10 and by somewhat less once ground equipment and structures are included.

In order to assess the relative importance of improvements in performance as compared to improvements in efficiency, a second capital input series measures the standardized available seat mile (ASM) capacity of the industry's aircraft fleet. Each of 35 different aircraft types is described by a standard number of seats, speed, and yearly utilization, and the total is aggregated by the actual number of each aircraft type in the fleet in each year. This measure of capacity differs from actual output in response to any divergence between actual and standard seats, speed, and utilization.

In comparing new models of aircraft with the comparable older models that they replace, the standardized ASM measure always yields a smaller valuation of the quality of the new model compared to the old than is yielded by my estimate of net revenue or by a comparison of used aircraft prices, simply because it adjusts only for the increased size and speed of newer models, but not (as do the net revenue and used price ratios) for improved fuel efficiency and for the reduced number of pilots required by some types of newer aircraft. Table 10.11 shows eight examples of the 15 comparisons used to develop my aircraft price index. These eight examples cover 14 of the 35 aircraft types used to compute standardized ASMs. For each comparison, column (3) lists the ratio of the sales price of the new to the old model (in the overlap year, if any, or else in the first year of production of the new model and last year of production of the old model).[50] Column (4) shows standardized ASMs for each comparison and indicates that the ASM ratio was smaller than the price ratio in six cases of eight, suggesting that airlines would not have purchased the new models if they had offered no attractive attributes other than improved size and speed. The appeal of the newer models becomes clear in column (5), which shows the ratio of the net revenue that could be generated by each model at the fixed input prices of a particular year, and in column (6), which shows the ratio of the prices of the models in the used aircraft market in a particular year.

The distinction between actual and standardized capacity provides an interesting decomposition of the sources of improvement in aircraft performance over time, even if it fails to take into account improvements in the efficiency of labor and fuel use. As shown in the top part of table 10.12, *actual* growth

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[50] These are true "buyers' prices" copied from CAB records that report the price of each aircraft and engine purchased by each airline.

Table 10.11 **Comparisons of Selected New and Old Model Commercial Aircraft**

Old Model (1)	New Model (2)	Sales Price Ratio (3)	Standardized ASM Ratio (4)	Net Revenue Ratio (5)	Used Price Ratio (6)	Year for columns 5 and 6 (7)
DC6-B	L188	1.73	1.47	3.37	2.86	1965
L188	B727-100	2.67	1.82	1.80	4.10	1965
DC7	DC8-50	2.67	2.86	20.57	19.20	1965
CV440	DC9-10	4.00	2.48	10.35	9.33	1965
B707-300B	B747-100	2.99	3.55	4.97	6.00	1977
DC8-61	L1011	1.84	1.28	1.44	3.54	1977
B727-200	MD80	1.70	1.02	3.07	3.01	1982
L1011	B767-200	1.00	0.79	0.78	. . .	1982

Sources: Columns 1–3, 5–7 from Gordon (1990a), table 4.9, 137–39, and table 4.13, 146. Column 4: see notes for table 10.12.

in traffic largely paralleled growth in actual capacity, although there was a minor negative contribution of load factor in 1959–69, which was reversed in 1969–78. The major contribution to capacity growth in the first and last periods was the purchase of additional planes; the most important factors were larger and faster planes in 1959–69, the decade of transition from piston to jet, and larger planes in 1969–78, the decade in which the wide-bodied aircraft were introduced. The pattern for standardized capacity was similar, indicating that most changes in average size and speed were inherent in the products supplied by the manufacturing industry.

Changes in the use of standardized capacity were relatively minor. Actual seats per plane fell relative to standardized seats in the first period and then rose; this reflects in part the use of relatively large low-density first-class sections on the first generation of jets, which were gradually reduced as a fraction of total seats. Once the transition to jets was complete, after 1969, the increase in seat density proceeded steadily, and there was no significant acceleration after deregulation. The only visible effects of deregulation were a minor increase in utilization (line 3d), and a slowdown in the growth of plane size (line 2b) related to the shift to smaller aircraft suitable for hub-and-spoke operations.

10.3.6 Growth in MFP

The new results on changes in capital quality can now be used to compute alternative series of MFP growth for the full period 1948–87. Each of the new MFP series uses the same input data on fuel and materials inputs, and an experimental series is calculated that allows for government input in the form of spending on airports and air traffic control.

Table 10.13 provides growth rates of output and input for four time intervals and begins in section 1 with the two alternative equipment deflators (BEA and

Table 10.12 **Sources of Capacity Growth by Aircraft Characteristic (annual percentage growth rates)**

	1954–59	1959–69	1969–78	1978–87
1. Actual:				
a. Revenue passenger miles	11.37	12.38	6.58	6.42
b. Load factor (1c − 1a)	−0.95	−2.05	2.30	0.15
c. Available seat miles (= 1d + 1e + 1f + 1g)	12.32	14.43	4.28	6.27
d. Number of planes	5.31	2.50	0.54	4.74
e. Seats per plane	3.25	6.24	3.39	1.19
f. Speed (MPH)	1.55	5.65	0.59	0.03
g. Utilization (hours per year)	2.21	0.03	−0.24	0.40
2. Standardized:				
a. Available seat miles	14.74	13.66	3.76	4.78
b. Seats per plane	5.24	3.67	2.47	0.16
c. Speed (MPH)	3.42	5.29	0.31	−0.04
d. Utilization (hours per year)	0.78	2.20	0.45	−0.09
3. Actual − standardized:				
a. Available seat miles	−2.42	0.77	0.52	1.49
b. Seats per plane	−1.99	2.57	0.92	1.02
c. Speed (MPH)	−1.87	0.36	0.28	0.07
d. Utilization (hours per year)	1.43	−2.17	−0.21	0.49

Sources by line: (**1a**) Revenue passenger miles are from *Aerospace Facts and Figures,* various issues, for 1954–83 and from *Air Carrier Traffic Statistics,* December of various years, for the years 1984–88. (**1b**) Equals 1a minus 1c. (**1c**) Available seat miles are from *Aerospace Facts and Figures,* 1984/85 for the years 1969–83 and from *Air Carrier Traffic Statistics,* December of various years for 1954–68 and 1984–88. (**1d**) The number of planes is a constructed series aggregating models over the time period 1954–88. The number of each model in use for each year is from the *FAA Statistical Handbook of Aviation,* various years, and the *World Jet Airplane Inventory at Year-End 1988* (Boeing 1989), sec. 3, table 5. (**1e**) Data for seating density are from the measure of available seats per aircraft mile from *Aerospace Facts and Figures,* 1984–85, for the years 1960–83 and *Air Carrier Traffic Statistics,* various years, for 1954–59 and 1984–88. (**1f**) Average speed was constructed as a weighted average of the speed of U.S. certificated air carriers domestic and international operations, taken from the *FAA Statistical Handbook of Aviation,* various years, and the *Statistical Abstract,* various years. (**1g**) Data for total aircraft hours are revenue aircraft hours from *Air Transport,* various issues, for the years 1960–87 and the CAB *Handbook of Airline Statistics,* 1963 ed. for 1954–59. (**2a–d**) Standardized available seat miles were constructed by aggregating over airplane models using *World Jet Airplane Inventory at Year-End 1988* (Boeing 1989) and *FAA Statistical and Handbook of Aviation,* various years, for the number of planes. The number of seats for each model, annual utilization, and speed for each model come from Gordon (1990a, table 4.8), taking the figure shown for the latest year listed. For models not covered by Gordon, data for similar models were used.

my alternative) and the BEA structures deflator. These are converted in section 2 into two alternative series on total capital input, using the BEA structures deflator in each case and BEA weights for equipment and structures. Because the alternative equipment deflator (line 1b) declines relative to the BEA deflator (1a) throughout, but fastest during 1959–69, the corresponding alternative real capital input measure (2b) grows faster than BEA throughout, but the difference is also greatest in 1959–69. Also shown in section 2 is the capital input measure based on standardized capacity that adjusts for size and speed of aircraft but not for operating efficiency. After 1959 its growth rate

Table 10.13 **Growth in Multifactor Productivity: Air Transportation, 1948–1987 (annual percentage growth rates)**

	1948–59	1959–69	1969–78	1978–87
1. Investment deflators:				
a. BEA equipment	3.05	2.16	6.90	4.79
b. Alternative equipment	−2.89	−8.14	1.89	2.93
c. BEA structures	1.59	2.70	8.10	5.56
2. Real capital input (equipment and structures):				
a. BEA	8.23	10.75	3.48	0.58
b. BEA with alternative equipment deflator	10.73	21.84	9.14	4.71
c. Standardized seat miles*	9.52	13.53	3.86	4.67
3. Output:				
a. Unrevised BEA	13.33	10.66	4.33	2.28
b. Revised BEA	13.33	10.66	5.38	6.16
c. BLS	13.88	13.84	5.43	5.57
4. Other components of MFP growth:				
a. BEA labor input	5.68	6.96	1.49	4.26
b. BLS labor input	5.52	6.66	0.46	2.35
c. Fuel input	13.73	16.16	0.53	3.95
d. Materials input	12.88	11.32	3.15	7.26
e. Government input	. . .	7.61	1.21	4.33
5. MFP growth:				
a. With NIPA unrevised output and input	4.24	0.65	2.22	−2.00
b. With NIPA revised output and labor input	4.24	0.65	2.73	1.73
With BLS output and labor input:				
c. BEA capital input	4.85	3.97	3.69	1.85
d. BEA capital input with alternative equipment deflator	4.48	2.49	2.81	1.26
e. Standardized seat miles	4.68	3.62	3.63	1.14
f. Same as 5c with government input	3.70	3.23	2.93	1.19
g. Line 5d with output smoothing: remove effect of changes in real yield and real GNP	5.52	2.16	2.43	1.27

Sources by line: (**1a, 1c**) BEA wealth tape. (**1b**) The aircraft index comes from Gordon (1990a, table B.9, 620) and the ground equipment index comes from the same source (table B.8, 618), with respective weights of 0.8 and 0.2. (**2a, 2b**) Equipment capital (cumulated with BEA weights from lines 1a and 1b) is combined with structures capital using BEA weights. (**2c**) From table 10.12, line 2a. (**3a, 3b, 3c**) See sources to table 10.2. (**4a, 4b**) See sources to table 10.2 (**4c**) Total gallons of aviation gasoline and jet fuel from *National Transportation Statistics*, various years, and from the CAB *Handbook of Airline Statistics*. The price of both types of fuel is from *National Transportation Statistics*, various years, and from the WPI and producer price index prior to 1970. (**4d**) Nominal materials input for 1969 and 1979 is from James (1982, table 1-4, 10) and for 1989 is from *World Aviation Directory*, winter 1990, table 101, X-17, and is interpolated for other years, and is deflated by the average of the PPI for intermediate supplies and of the revised BEA airline output deflator. (**4e**) Nominal expenditure on airways and airports from *Transportation in America, Historical Compendium*, updated with May 1989 issue, and interpolated between data available at five-year intervals before 1970. Airways deflated by the NIPA deflator for nondefense expenditure and airports by the NIPA deflator for nonresidential structures (deflators implicit before 1959, fixed weight after). (**5**) MFP indexes are Törnqvist indexes, with nominal shares from the sources listed for secs. 3 and 4 of this table. Methodology for output smoothing (line 5g) explained in the text. Smoothed MFP series for 1952–87 in line 5g is linked to actual MFP series for 1948–51 for the calculation of 1948–1959 growth rate.

*Standardized seat miles for 1954–59 are linked to the BEA series for 1948–54.

lies between that of the alternative capital series, indicating that the effect of greater aircraft size and speed are not fully measured by the BEA deflator, but that additional improvements were made in fuel and labor efficiency that are captured by the alternative deflator and not by standardized capacity. Figure 10.2 plots the three capital input measures.

Sections 3 and 4 of table 10.13 display the growth rates of alternative output measures and of the other inputs. We note a substantial reduction in the ratio of energy to output after 1969 but not before and a decline in the ratio of materials input to output before 1978 but not afterward (reflecting in part the greater importance of travel agent commissions in the 1980s). Finally, a series on real government expenditures on airports and air traffic control (line 4e) indicates a decline in the ratio to airline output throughout. Surprisingly, the ratio of government input to airline output declines least rapidly after 1978.

The implied growth rates of alternative MFP indexes appear in section 5. The first (line 5a) combines the BEA unrevised output and employment series with the BEA capital stock series, while line 5b introduces the BEA revised output series and shifts to a value-added concept for calculating MFP growth since 1977.[51] The remaining MFP indexes in section 5 replace the BEA output and employment series with those from the BLS. Line 5c uses the BEA capital input series and differs from the revised all-BEA series in line 5b by growing more rapidly throughout, but particularly in 1959–69. The next two series replace BEA capital with, respectively, that based on my alternative equipment deflator and on the standardized capacity measure of input. The final series (line 5f) introduces government input and appropriately reweighs all input shares.

Annual values of four MFP measures are plotted in figure 10.3, corresponding to table 10.13, lines 5a through 5d. Here we see the importance of choosing reference dates at comparable stages of the business cycle. In particular, all four measures of MFP show a local peak in 1978–79 and a sharp decline through 1981, resulting from the recession and the PATCO strike. Airline MFP performance in the 1980s looks much better measured from the 1981 trough than from the 1978 or 1979 peaks.

The MFP indexes for airlines are unanimous in showing a slowdown after 1978 and implicitly no efficiency gain from deregulation. Some observers, particularly Caves, Christensen, and Trethewey (CCT) (1983, 1984), date de-

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[51] In all the MFP calculations in this paper, the MFP growth rates based on a value added rather than gross concept of output (i.e., for all BEA railroad indexes, for BEA revised airlines and trucking since 1977, and for our alternative trucking index since 1977) are calculated as the value-added share in gross output (α_v) times the growth rate of value-added productivity (θ_v). Thus if total MFP growth is given by

$$\theta = q - (1 - \alpha_v)\, m - \alpha_v i, \text{ then } v = [q - (1 - \alpha_v)m]/\alpha_v,\ \theta_v = v - i,$$

and the desired MFP growth rate can be calculated as $\theta = \alpha_v\,(v - i) = \alpha_v\theta_v$. Here growth rates refer to gross output (q), materials (m), a weighted average of labor and capital inputs (i), and value added (v).

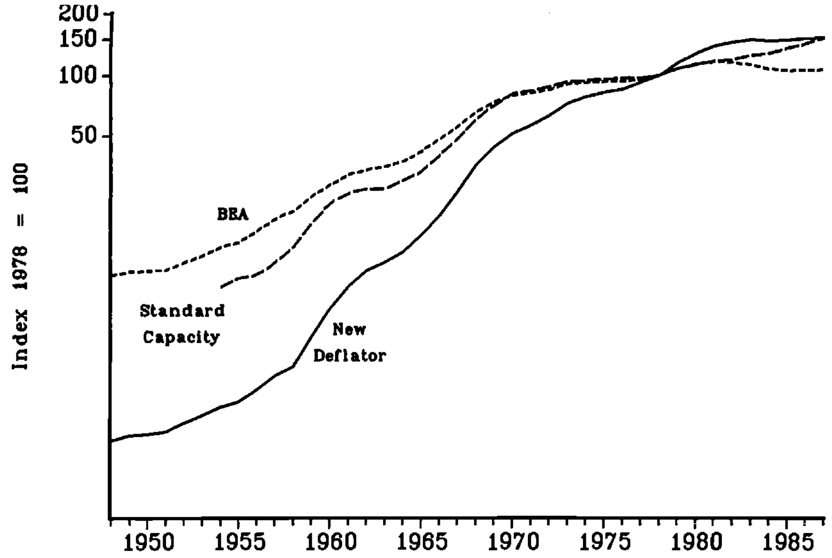

Fig. 10.2 Three versions of capital input: Air transportation industry, 1948–87

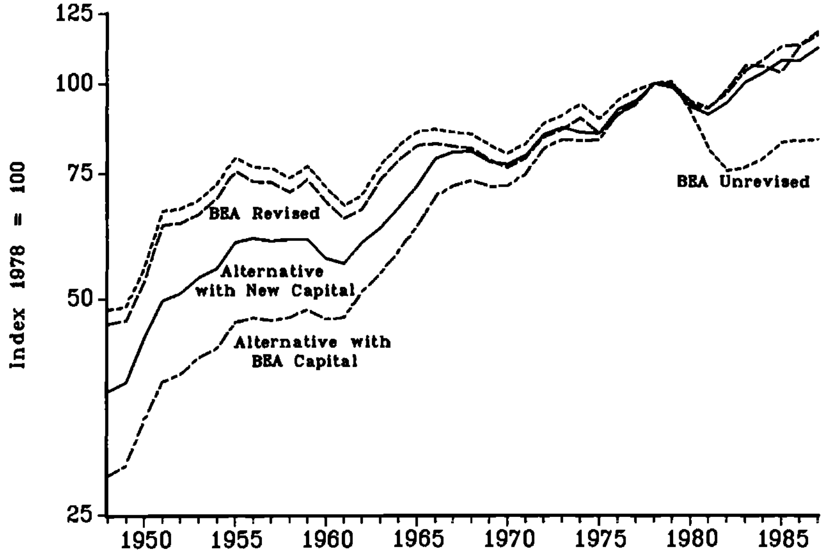

Fig. 10.3 Four versions of multifactor productivity: Air transportation industry, 1948–87

regulation prior to 1978, because fare reductions beginning in 1977 caused a jump in 1978 traffic and load factor. The debate over the date of deregulation can be easily resolved by a statistical decomposition to purge the MFP series for the effects of changing prices and aggregate demand. We first run a regression over 1950–88 of the annual change in airline output on two constants (split at 1969), the annual change in real yield, and the annual change in real GNP (both entered as the current and one-lagged change). The results are highly significant and indicate that fully 73 percent of the variance in annual output can be explained by changes in current and lagged real yield and real GNP during 1950–69 and 86 percent during 1970–88. This allows us to compute the counterfactual growth of airline output on the assumption that real yield, real GNP, or both grew at their mean 1950–69 and 1970–88 rates rather than fluctuating as actually occurred. Next, we run a regression of annual changes in MFP on changes in airline output and use these coefficients to determine the annual growth rate of MFP with the various counterfactual output series.

The results are shown in line 5g of table 10.13. Comparing lines 5d and 5g, the full adjustment reduces the MFP growth slowdown between 1959–78 and 1978–87 by about one quarter, from 1.38 percentage points to 1.02 percentage points, and by a smaller relative amount if the rapid productivity period before 1959 is included. If the break point for deregulation is changed from 1978 to 1976, as CCT would recommend, the slowdown from 1959–76 to 1976–87 is *raised* from 0.65 points to 0.90 points. The similarity of the cyclically corrected slowdown figures, 1.02 points with a 1978 break and 0.90 with a 1976 break, shows that our cyclical and yield corrections almost totally capture the causes of rapid MFP growth in the 1976–78 interval.

To conclude, we find that airline productivity growth slowed after deregulation by every measure and that this conclusion is independent of the chosen borderline date. The remaining unmeasured biases in output indexes are offsetting, with a slight upward bias of about 0.3 percent per annum owing to extended scheduled flight times (table 10.10) offset by a downward bias of perhaps 1.0 percent per annum owing to the unmeasured value of frequent-flyer benefits.

10.4 Railroads

The measurement of railroad ALP and MFP is more straightforward than for airlines. Railroads produce an intermediate good, and so we have less concern with the quality of output than with airlines. The most important potential measurement error for output, the changing mix of shipments of different values and labor requirements, is already taken into account in the BLS output measure that we use throughout this section for the period since 1948. There are probably unmeasured dimensions of output quality, consisting mainly of the benefits of improved computer tracking of shipments, but these are likely to be sufficiently minor that they can be safely ignored here.[52]

There is a common impression that productivity in the railroad industry in the 1980s was revived by a combination of deregulation, relaxation of featherbedding work rules, mergers, and the abandonment of unprofitable track.[53] Indeed, there were pathbreaking changes, particularly a reduction from 65 carriers in 1977 to 15 in 1988, and a dramatic abandonment of unprofitable track, which in turn implied a sharp decline in the capital stock (see table 10.14). However, the appearance of rapid growth in ALP, for example, 8.17 percent per annum since 1979 for the BLS data in table 10.2 may not carry over to MFP. Caves, Christensen, and Swanson (CCS) (1980), show that MFP growth, properly estimated to a modern cost-function framework, is less than half of ALP growth over the period 1951–74. Further, as we shall see, the outstanding MFP growth achieved by railroads in the 1980s is nothing new but rather represents the continuation of a longer historical process; in the late 1980s railroads carried one-third more freight traffic than in the late 1940s with only one-sixth as many workers and much less capital and fuel input.

We learned in part 10.2 that MFP measures are inaccurate in the presence of nonconstant returns to scale. Indeed CCS (1980, 1981) do find significant evidence of increasing returns to scale for railroads, but the departure from constant returns is sufficiently small (about 0.09) that their estimated growth rate of MFP is an identical 1.5 percent per year with and without an allowance for increasing returns (1980, 177–78). Thus in the rest of this section we ignore the returns to scale issue.

The ingredients in our calculation of MFP and value added for railroads are displayed in table 10.14. As an alternative to the BEA data on the capital stock of railroad equipment and structures, we have developed for the equipment component a Törnqvist-weighted index of the aggregate horsepower of railroad locomotives and the ton capacity of railroad freight cars. The growth rates of the BEA and alternative equipment stock indexes are compared in lines 1a and 1b of table 10.14 and are quite consistent. Also, much more than half of railroad capital consists of structures, so MFP estimates are robust to the choice of the two alternative measures of equipment capital.[54]

The implied MFP growth estimates, Törnqvist weighted with actual nominal cost shares of labor and materials, the assumed material share, and a residual share for capital, are shown in lines 4c and 4d. Over the entire 1948–87 period, the respective growth rates of the revised BEA and the two new MFP

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[52] The best recent general discussion of productivity and service quality improvements for railroads is Tully (1991). On the use of computers and advanced train control systems, see Machalaba (1988) and Schwartz (1989).

[53] See Flint (1986) and Kupfer (1989).

[54] We also experimented by varying the weights on equipment vs. structures from the BEA weights but found little sensitivity of the MFP indexes to the weighting choice.

Table 10.14 **Growth in Multifactor Productivity: Railroads, 1948–1987**

	1948–59	1959–69	1969–78	1978–87
1. Real capital input (equipment):				
a. BEA	0.50	0.55	−0.01	−2.41
b. Alternative	−0.84	0.73	1.07	−1.81
2. Real capital input (equipment & structures):				
a. BEA	−1.50	−1.87	−1.78	−2.00
b. Alternative	−1.75	−1.81	−1.50	−1.80
3. Output:				
a. Unrevised BEA	−1.75	2.26	−0.88	−4.94
b. Revised BEA	−1.75	2.26	−0.10	1.96
c. BLS	−0.97	2.25	0.86	0.73
4. Other components:				
b. Labor input	−4.42	−3.54	−1.93	−6.62
c. Fuel	−2.80	1.17	0.16	−2.77
e. Materials	−1.44	0.72	0.68	−1.37
5. MFP growth:				
a. BEA unrevised output & input	1.34	4.45	0.97	−0.68
b. BEA revised output & input	1.34	4.45	1.63	4.90
With BLS output & labor input:				
c. BEA capital input	2.04	4.58	2.38	4.56
d. Alternative capital input	2.13	4.55	2.28	4.50

Sources by line: (**1a**) BEA wealth tape. (**1b**) The number of steam and diesel electric locomotives are from *Railroad Facts* and *Yearbook of Railroad Facts*, various years. Data for the horsepower and the average tractive effort of locomotives in service are from the *Statistical Abstract* as well as *Transport Statistics in the United States* and *Railroad Facts*. Total freight cars in service were taken from *Railroad Facts* and *Yearbook of Railroad Facts*. Data on the tons per car was from the series on average freight carload from *Railroad Facts* and *Yearbook of Railroad Facts*. (**2a–2b**) Both series use BEA structures capital and BEA weights to combine structures and equipment. (**3a–3c**) Same sources as table 10.2 and 10.4. (**4a**) Same source as table 10.2. (**4b**) Total fuel use and the price of the fuel are from *Statistics of Class I Railroads* and *National Transportation Statistics*, various years, as well as *Railroad Facts* and *Yearbook of Railroad Facts*. (**4c**) Nonfuel materials use is assumed to be a fixed 10 percent of total operating revenues and is deflated by the GNP deflator. (**5**) Inputs are combined with nominal expenditure weights, obtained from the above sources.

indexes are quite close—3.03, 3.35, and 3.33 percent per annum. The consistent growth rates displayed by the BEA and alternative MFP indexes are reassuring, because the first are calculated from value added without subtracting materials and fuel, whereas the second are based on gross output. However the payoff from deregulation when MFP growth in 1978–87 is contrasted with 1947–78 is, respectively, 2.44, 1.43, and 1.42, that is, less in the alternative than in the BEA indexes.

For the period of overlap (1951–74) the average growth rate of all our MFP index in line 4c is substantially higher than that constructed by CCS, 3.45 versus 1.52 percentage points. CCS provide a decomposition (1980, 177–80) showing that a similar difference between the conventional method and their results can be attributed entirely to a differing treatment of output and input weights. The essence of the difference is that CCS place greater weight on passenger output (because they take the weight of passenger cost in total cost, not the weight of passenger revenue traffic in total traffic).[55] Thus the more rapid growth of MFP in this study is in part due to the cost savings of the disappearance of rail passenger traffic, which CCS largely subsume within their slow-growing output index.

Overall, we have considerable confidence in our conclusion in table 10.14 that MFP growth did accelerate after 1978, but by much less than ALP growth. Alone among the three major transportation subsectors, railroads exhibited rapid MFP growth in the 1980s and helped to offset the productivity slowdown in the rest of the service sector. However, in light of the strong labor-saving effects of deregulation measured by Berndt et al., (1990), it remains surprising that the railroad industry did as well before 1978 as our alternative MFP indexes indicate.

10.5 Trucking

Trucking shares with railroads the fact that output is almost entirely an intermediate good, and so changes in the quality of output do not directly affect aggregate output and productivity.[56] However, the measurement of trucking output and employment is more prone to error than that for railroads, since (as we learned in part 10.1), alternative indexes cover differing fractions of the total trucking industry experiencing quite different productivity performance. For instance, there was so much entry and exit in the trucking industry in the 1980s that a deflator based on the shrinking part of the industry could overstate price increases for the more efficient (and nonunion) new entrants. Winston et al (1990, 11) report a "huge influx of entry" following the 1980 deregulation of trucking, consisting almost entirely of class III carriers providing truckload (TL) service. The number of class III carriers increased from 14,941 to 43,364; the number of class I and II carriers decreased from 3104 to 2477 (Salgupis 1991). The share of class III carriers increased from 82.8 percent to 94.7 percent over this period. The BLS data source reports only 786 class II carriers in 1987, indicating incomplete coverage. A major shift in the trucking industry occurred in response to deregulation from less-than-truckload (LTL) general freight carriers, the core of the BLS sample, to "advanced TL" firms using nonunion driver teams and relays for service on high-

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[55] The other major difference identified by CCS, the understated capital input weights they attribute to Kendrick, does not apply to this study, where the capital share is determined as a residual and includes all of the items, e.g., rent and property taxes, that CCS advocate for inclusion.

[56] This section contains no comparisons with other academic studies, because there appears to be no study analogous to CCS (1980) that presents a time-series MFP index for trucking on the basis of the cost function or production function method. There is a proliferation of studies, but they all are limited to the estimation of micro structural parameters in panels of firms without examination of time-series properties. See Chiang and Friedlaender (1984, 1985), Friedlaender and Spady (1981), Friedlaender and Chiang (1981), Friedlaender and Bruce (1985), Daughety, Nelson, and Vigdor (1985), and Ying (1990).

density traffic corridors, "thereby ensuring high vehicle use and low costs" (Winston et al. 1990, 13). New entry came also from owner operators, and this could cause a shift in output relative to employment that could be interpreted spuriously as an increase in productivity. The distinction between TL and LTL carriers is highlighted by the estimate of Winston et al. that in the absence of deregulation over the interval 1977–85 TL rates would have increased by 55 percent; LTL rates would have increased by a much larger 116 percent. The actual increases were 51percent and 79 percent, respectively, indicating that deregulation had a much larger effect on LTL carriers.

In this paper we develop MFP indexes based on two alternative measures of capital and two of output. The first capital stock measure is that produced by the BEA by the same procedures as for airlines and railroads, and already used in tables 10.13 and 10.14 to compute the BEA index of MFP for those two industries. The alternative capital input measure developed here is based on the alternative deflator for producers' durable equipment investment in trucks from Gordon (1990a). This deflator combines separate deflators for automobiles (which behave quite similarly to the automobile consumer price index [CPI] after the late 1950s) and for diesel engines. However, this deflator, like the CPI and existing NIPA deflator for automobiles, assumes that the addition of antipollution equipment represents an increase in quality rather than an increase in price. Although such equipment may or may not benefit society in proportion to its cost, it does not represent an increase in quality as viewed by the firm using an automobile (or truck) as a capital input. As Triplett (1983) has emphasized, there are two correct measures of capital input: one for output deflation and one for input deflation. Here we need an input deflator that treats the cost of legislated equipment as an increase in price, not an increase in quantity. Fortunately, it is possible to adjust for this equipment, and the resulting hybrid index is likely to be a more satisfactory capital input deflator than other existing indexes. As shown in the comparison of lines 1a and 1b of table 10.15, and on an annual basis in figure 10.4, the new deflator implies a much more rapid increase in the capital stock in the first half of the postwar, because of a substantial reduction in the relative prices of our automobile and diesel engine deflators relative to the BEA trucking deflator.

We also develop a new output measure in table 10.15, line 2c, to compare with the revised BEA output measure shown in line 2b. This takes nominal BEA output and then deflates it with the "yield" (revenue per ton-mile) index shown above in table 10.5, line 2c. Because the yield measure is only available back in 1960 and appears to agree with the BEA deflator until about 1972, the alternative output measure differs from the BEA series only in the 1970s and 1980s. An interesting aspect of these series is their implied capital-output ratios. The BEA capital and output series (lines 1a and 2b) imply a radical shift between a falling capital-output ratio in 1948–69 to a relatively

Table 10.15 **Growth in Multifactor Productivity: Trucking, 1948–1987**

	1948–59	1959–69	1969–78	1978–87
1. Real capital input (equipment & structures):				
a. BEA	3.79	3.29	4.93	2.33
b. Alternative	5.96	5.65	5.69	2.74
2. Output				
a. BEA unrevised output	7.06	5.56	4.92	0.55
b. BEA revised output	7.06	5.56	4.80	1.87
c. Alternative output	7.06	5.57	5.80	3.02
3. Other components:				
a. BEA labor input	3.49	2.15	2.12	1.64
b. Fuel	4.68	3.26	4.84	−2.72
c. Materials	7.79	6.10	3.47	−0.89
d. Highway capital	. . .	4.30	2.23	1.40
4. MFP growth:				
a. BEA unrevised output & input	2.97	2.51	1.49	−0.75
b. BEA revised output & input	2.97	2.51	1.38	0.00
c. Alternative output & labor input, BEA capital input	2.97	2.52	2.38	0.97
d. Alternative output & input	2.05	1.51	2.06	0.82
e. Alternative output & input, with government capital	. . .	1.47	2.36	0.86

Sources by line: (**1a**) From BEA wealth tape. (**1b**) Computed as in tables 10.13 and 10.14 by substituting a new equipment deflator (Gordon 1990a, table C3, 698) for the BEA deflator, while using BEA nominal equipment investment, BEA structures capital, and BEA weights for equipment and structures. (**2a, 2b**) Same sources as tables 10.2 and 10.4. (**2c**) Deflate nominal, revised BEA output with alternative deflator, source given in notes to table 10.5, line 2c. (**3a**) Same source as table 10.2. (**3b**) Total fuel cost from cost of fuel per mile, total vehicle miles, and price of fuel from *American Trucking Trends*. (**3c**) Materials assumed to be 10 percent of revenue, deflated by the average of the producer price index for intermediate supplies and the revised BEA trucking output deflator. (**3d**) Government highway capital is gross constant-dollar capital stock of federal, state, and local highways, from *Fixed Reproducible Tangible Wealth in the United States, 1925–85*. 1985–87 was extrapolated from 1984–85 growth rate. (**4**) Inputs are combined with nominal expenditure weights, obtained from the above sources. Share of government highway input is taken to be half of the ratio of government expenditure on highways (same source as table 10.15, line 1d) to intercity trucking revenue (same source as table 10.5, line 1c).

stable ratio after 1969. The two new series (lines 1b and 2c) imply that the capital-output ratio was roughly stable throughout.

When we combine the BEA and new capital and output series with a fixed set of labor input, fuel input, and materials input series, we arrive at the MFP indexes shown in section 4 of table 10.15; annual data for the indexes on lines 4a–4d are plotted in figure 10.5.[57] The first in line 4a uses the unrevised BEA

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[57] Recall that since 1977 the revised BEA and alternative output indexes refer to value added, and thus the corresponding MFP indexes in table 10.15, lines 4b through 4e, are calculated as value-added MFP times the share of value added in gross output. See n. 51, above.

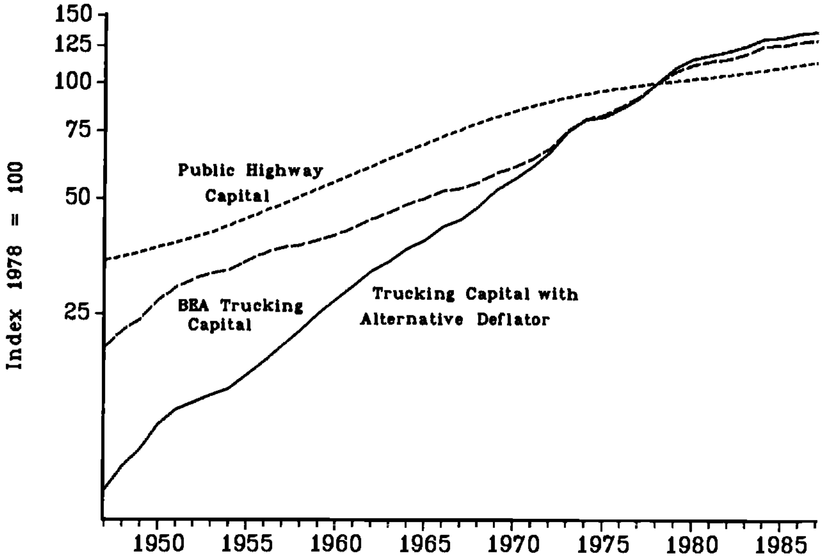

Fig. 10.4 Three versions of capital input: Trucking industry, 1947–87

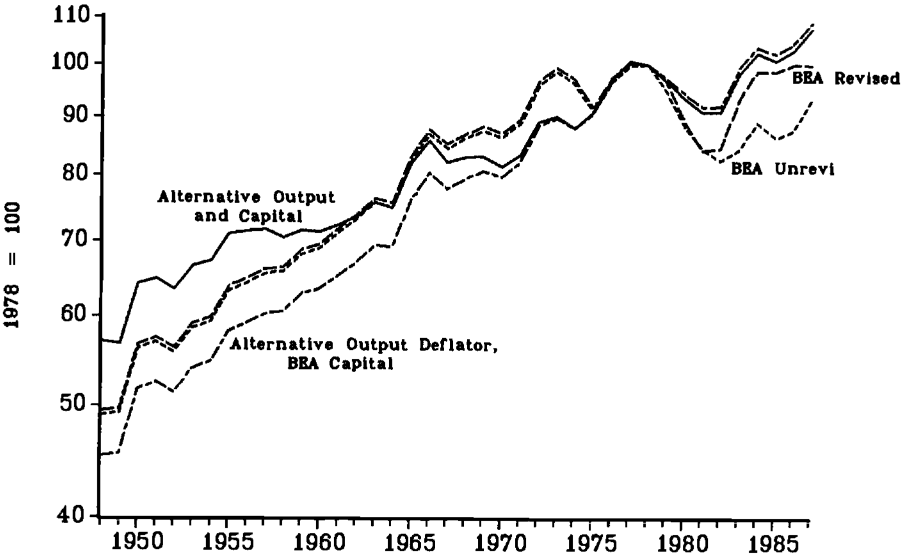

Fig. 10.5 Four versions of multifactor productivity: Trucking industry, 1948–87

series for output and input and exhibits a sharp productivity growth slowdown, especially after 1978. The BEA output revisions make little difference in line 4b; MFP growth slows to zero after 1978. In line 4c we replace the BEA output series with the alternative output series based on the "yield" deflator, while retaining the BEA capital index. This makes a substantial difference but still leaves a post-1978 MFP growth slowdown. The next step in line 4d is to replace the BEA capital input index with the index based on the alternative equipment deflator. By slowing MFP growth before 1978, this reduces but does not eliminate the post-1978 slowdown, and reduces the slowdown to only 0.35 percentage points when 1969–87 is compared to the pre-1969 period. In contrast the two BEA indexes indicate post-1969 slowdowns of 2.38 and 2.06 percentage points, respectively.

A final MFP index is developed in line 4e. This adds to the contribution of input growth the increase in the real gross stock of government "highway capital." To obtain a share, we note that total government expenditures on highways in 1978 were 48 percent of intercity trucking revenues. Arbitrarily allocating half the highway expenditures to cars and half to trucks, we obtain a weight of 24 percent to be applied to the growth rates of highway capital (table 10.15, line 3d). For the resulting MFP index to be significantly different from the other indexes, government capital would have been required to grow at radically different rates than the average for other inputs. However, this did not occur, and the fully inclusive MFP index on line 4e of table 10.15 tells the same story as that on line 4d.

Overall we should have observed some decline in the productivity of the trucking industry after the first oil shock, if only because of a decline in average highway speed.[58] Indeed, this is what is implied by the intermediate series using BEA capital and alternative output. However, the alternative capital series implies that MFP growth in trucking did not actually slow down appreciably in the 1970s and 1980s when the two decades are lumped together. Rather, faster growth in the conventional BEA measure in the early postwar years is attributed largely to the more rapid growth in the quality-adjusted capital stock of trucking equipment in the early postwar period, due in large part to improvements in the efficiency and durability of diesel engines.[59]

10.6 Conclusion

The goals of this paper have been to develop new measures of MFP growth in the three main components of transportation—air, rail, and trucking—that allow for changes in the quality of both output and inputs. The new MFP

[58] Average motor vehicle speed on highways dropped from 63.8 MPH in 1970 to 57.6 MPH in 1974 and then increased gradually to 59.7 MPH in 1986 and 1987 (*Statistical Abstract* 1989, table 1025, and 1990, table 1047).

[59] Gordon (1990a, 505–12) contains a detailed case study of diesel engine prices and quality improvements.

measures are summarized in table 10.16 and compared with the official measure implied by current NIPA (or BEA) data, both before and after the recent NIPA output revisions. Lines 1a and 1b of table 10.16 exhibit MFP growth for transportation, using NIPA data for output (without and with revision) and employment, together with the BEA capital stock estimates and our series on fuel and materials inputs prior to 1977 for airlines and trucking (railroads throughout are based on value added). Here as elsewhere in table 10.16 "total transportation" refers only to the three major subsectors. All MFP series for total transportation are Törnqvist indexes that use annual revised NIPA data on nominal output in the three subsectors as weights. The post-1973 slowdown on line 1a is 2.61 annual percentage points but declines to 0.90 points on line 1b with the recent output revisions.

Line 1c displays the first alternative measure, which switches to BLS measures of airline and railroad output and employment and to our new yield-deflated trucking output measure, as indicated in the notes to table 10.16. This switch boosts MFP growth both before and after 1973, but leaves the post-1973 slowdown almost identical to the revised NIPA index. The second alternative on line 1d substitutes our new capital input measures and reduces MFP growth more before 1973 than after, thus eliminating almost one-third of the post-1973 slowdown on line 1c. However, the second alternative makes a substantial difference in the interpretation of the post-1979 deregulation period, reducing the post-1979 slowdown almost to zero.

As shown in figure 10.6, the annual plot of the four MFP indexes reveals substantial cyclical fluctuations, particularly in the late 1970s and early 1980s. As explained in the notes to table 10.16, the cyclical component of MFP fluctuations due to aggregate real GNP changes is purged, and the cyclically corrected growth rates are displayed in the bottom half of table 10.16. The cyclical correction substantially boosts MFP growth in 1973–79 and cuts it slightly in 1979–87, thus reducing the size of the post-1973 slowdown and slightly increasing the magnitude of the post-1979 slowdown.

The productivity growth story told by the revised NIPA index (line 1b) and our final index (line 1d) are surprisingly similar, given all the differences between them. Our adjustments boost MFP growth by switching to alternative output and employment indexes but then largely offset this by switching to faster-growing capital input indexes. However, these similarities disguise marked differences at the industry level, particularly in the first half of the postwar period. Our alternative output and employment data produce MFP indexes that rise more rapidly for airlines and railroads over 1948–69, but this is largely offset by our alternative capital input data that cut MFP growth for trucking below the rate estimated when conventional capital input indexes are used.

Did deregulation boost productivity in transportation? Surprisingly, the answer is no. The great success story is the railroad industry, but all our indexes for airlines and trucking display a lamentable MFP growth record in the 1980s

Table 10.16 Four Measures of Multifactor Productivity Growth for Transportation, Annual Percentage Growth Rates, 1948–1987 and Selected Intervals, with and without Cyclical Correction

	1948–59 (1)	1959–66 (2)	1966–73 (3)	1973–79 (4)	1979–87 (5)	1948–73 (6)	1973–87 (7)	Slowdown, 1973–87 − 1948–73 (8)	Slowdown, 1979–87 − 1948–79 (9)
1. Raw data:									
a. BEA unrevised output & input	1.90	4.20	1.25	0.39	−0.73	2.36	−0.25	−2.61	−2.70
b. BEA revised output & input	1.90	4.20	1.25	0.99	1.82	2.36	1.46	−0.90	−0.29
c. Alternative output, BEA capital	2.37	4.55	2.32	1.64	2.33	2.97	2.04	−0.93	−0.38
d. Alternative output & capital	2.08	3.96	1.62	1.36	2.15	2.47	1.81	−0.66	−0.11
2. Cyclically corrected data:									
a. BEA unrevised output & input	2.34	3.24	1.63	0.91	−0.80	2.39	−0.07	−2.46	−2.83
b. BEA revised output & input	2.28	3.48	1.55	1.46	1.73	2.41	1.61	−0.80	−0.42
c. Alternative output, BEA capital	2.31	4.25	2.47	1.95	2.23	2.90	2.11	−0.79	−0.52
d. Alternative output & capital	2.02	3.63	1.78	1.67	2.05	2.40	1.89	−0.51	−0.25

Sources by Line: Törnqvist weights (nominal output shares from revised NIPA table 6.1) are used to aggregate MFP growth for airlines, railroads, and trucking. (**1a**) BEA unrevised concept uses NIPA unrevised output, NIPA employment, and BEA real gross capital stock of equipment and structures, together with fuel and materials inputs from tables 10.12–10.14. No allowance is made for the value of time or for government capital. (**1b**) BEA revised concept replaces NIPA unrevised output with NIPA revised output for 1977–87. Because revised NIPA output is a value-added concept, materials and full inputs are not subtracted out. See n. 51 in text. (**1c**) This measure replaced NIPA output and employment with BLS output and employment for airlines and railroads, and uses the revised NIPA output series for trucking with the new deflator, from table 10.15, line 2c. (**1d**) This measure starts from line 1c and replaces BEA capital with the respective capital indexes (see table 10.13, line 5d; table 10.14, line 5d; and table 10.15, line 4d). (**2a–2d**) For the corresponding line of sec. 1, the growth rate of MFP is run on five constants corresponding to the first five columns of this table, and on the current and one lagged change in the ratio of actual to natural GNP, from Gordon (1990b, appendix A, A2–A3). The cyclically corrected growth rate of MFP is the actual growth rate minus the statistical contribution of the GNP change.

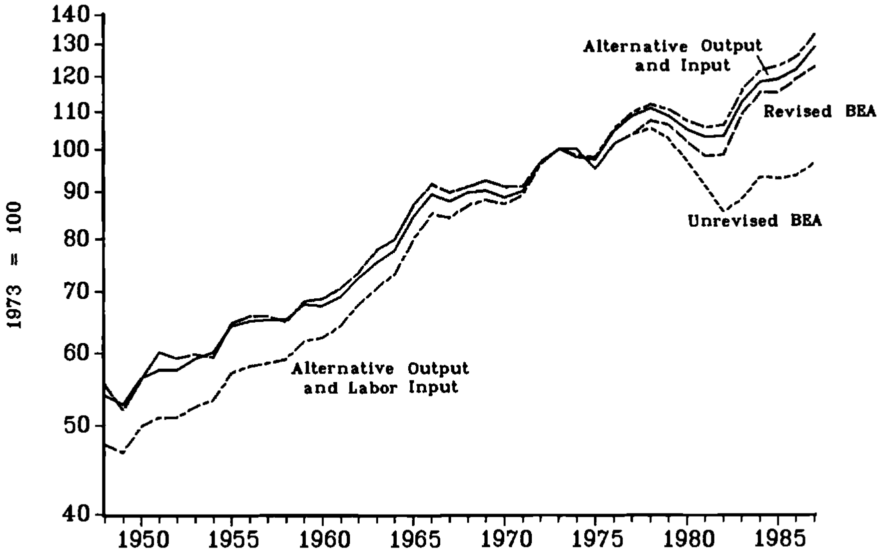

Fig. 10.6 Four versions of multifactor productivity: Transportation, 1948–87

that more than cancels out the railroad success. These conclusions regarding the divergent performances of the three subsectors are extremely robust to alternative dating of deregulation.

In conclusion, this paper has explained much but not all of the large post-1973 productivity growth slowdown in the transportation industry displayed in table 10.1 above and in line 1a of table 10.16, based on the NIPA and BEA data published prior to January, 1991. Much of the reinterpretation involves simple issues of data construction, reviewed in part 10.1, and pre-1991 investigators could have obtained roughly the same conclusion as in this paper by ignoring the old NIPA data and instead using BLS data on output and employment. The NIPA output revisions bring the NIPA and BLS output data much closer together for the period since 1977, and we view the prompt response of the NIPA output revisions to the earlier criticisms contained in Gordon and Baily (1988) as part of the overall contribution of our research.

Our new MFP indexes rely not only on the choice of the "best" output and employment indexes, but also on the development of new capital input measures that adjust more fully for quality changes in transportation equipment than the official measures. The resulting MFP indexes grow substantially slower during the first part of the postwar period than when conventional capital input measures are used; the overall effect on transportation as a whole is limited by the relatively small weight of air transportation in the transportation aggregate during the years when "most of the action" occurred (1958–70).

Several novel elements of our study are not incorporated into the final MFP indexes in table 10.16. We have found that airline deregulation yielded a small time saving from the elimination of interline connections that was more than offset by a small time cost of extended scheduled times (which we interpret as due to inadequate government investment in airports and air traffic control). A much greater contribution was made by the value of time saved through the invention of air transport industry, which should be credited to the manufacturers of airframes and engines. This value (roughly $182 billion in 1989) amounts to a massive ten times U.S. sales of commercial aircraft, four times the domestic passenger revenue of U.S. airlines, and 3.5 percent of GNP.

Our study of MFP growth in transportation has yielded additional findings: Airline deregulation greatly increased the availability of nonstop flights and forced only a negligible number of passengers off of nonstop flights onto connecting flights, contrary to the conventional wisdom. The increased use of travel agents had little effect on MFP growth, as decreases in other purchases of materials offset the increased use by airlines of purchased travel agent services. Finally, the perception that the government has shortchanged infrastructure investment in airports, airways, and highways, although plausible anecdotally in view of extended scheduled flight times, is not supported quantitatively by the government capital and investment data that we have compiled; MFP estimates are little changed when plausible adjustments are made for government inputs.

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Comment

Robin C. Sickles

The paper by Robert J. Gordon follows on the heels of his excellent monograph, *The Measurement of Durable Goods Prices* (1990), and pursues complementary issues in the measurement of factor productivity growth for the transportation sector. The current study is at the industry level and follows the growth in factor productivity in the airline, railroad, and trucking industries for the last 40 years (1948–88). The conceptual and measurement problems that Gordon faced, and in my opinion largely overcame, were substantial. The work addresses a number of important issues on its way to making its key point. It is that the mismeasurement of output and input indexes and the use of partial instead of multifactor productivity (MFP) indexes has lead to erroneous conclusions by some researchers that there was a post-1973 productivity slowdown in transportation mirroring the experience in the total U.S. economy. Gordon points out that this is a somewhat counterintuitive empirical finding because the transportation sector was deregulated in the mid-1970s, and productivity should have benefited from less constrained decision mak-

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Special thanks are given to David Good for his insightful comments and suggestions, which added significantly to the review. The usual caveat applies.

ing. The counterintuition is rendered illusory by Gordon's new data series by which he concludes that there was not a post-1973 slowdown in MFP growth for the transportation sector. Although I am quite sympathetic to Gordon's arguments I do have a number of points to make with regard to the research issues he addresses and with regard to complementary research that addresses these issues somewhat differently.

As I have said, the major point of Gordon's paper is that the measured productivity slowdown in the transportation industry is a measurement problem. Although the topic of the paper is on the transportation sector, Gordon gives disproportionate coverage to the airline industry; so will my comments on his paper. There are a number of convincing reasons why measurement problems plague the evaluation of MFP performance and the attendant national income and product account (NIPA) estimates for average labor productivity (ALP) in the transportation sector in general and the airline industry in particular. One reason has been discussed by a number of researchers and was pointed out by Baily and Gordon (1988). In the airline industry the Bureau of Economic Analysis (BEA) output deflators "fail to adjust properly for the introduction of discount fares." However, Gordon points to a more fundamental reason—that ALP is not an appropriate index to use because a lot has been going on with the other factors such as energy and capital. MFP growth rates are different from ALP as one would expect because there has been a substantial change in relative input prices and relative factor intensities. But doing the right thing inevitably has a cost, and here it is in requiring the capital service flows to be estimated correctly. The measurement of capital service flows and its price and its decomposition into such sources as scale, technical change, and so on can be problematic especially when, for example, the technology (possibly endogenous) is embodied in an airplane's design characteristics (Good, Nadiri, and Sickles 1991). It should be stressed that the transportation data series that Gordon constructs are annual aggregates. There is an acknowledged trade-off between the length of the series and the potential for mismeasurement of MFP and ALP resulting from both temporal and cross-sectional aggregation. Moreover, the motivation for examining aggregated data as opposed to firm level data (which is available for all three major transportation industries) may be misplaced when one considers the substantial changes in industry structure and the menu of new technologies introduced into these industries. The 1948–88 series that Gordon constructs may in fact be nonstationary and chained indexes such as the discrete approximation to the Divisia index used herein may not properly represent shifts in the moments of the underlying data. This concern was in part what lead Sickles (1985), Sickles, Good, and Johnson (1986), and Good, Nadiri, and Sickles (1991) to break up their firm level quarterly series for the airline industry (1968–87) into epochs during which industry structure was more or less stable or to adopt modeling approaches that faced up to temporal and cross-sectional heterogeneity and changes in industry structure and incentives as a result of deregulation. The Gordon and Good-Sickles data do indicate rather remarkable agreement with respect to industry MFP growth rates for overlapping periods. However, the claim in the paper that these aggregate annual data can be used to estimate dynamic effects, effects of the idiosyncratic confluence of high energy prices and low aggregated demand prevalent in the 1970s and 1980s, as well as be able to deliver on the aim to disentangle the contribution of macrodemand, energy prices, deregulation, and microeconomic factors in the determination of the postwar productivity performance of the transportation sector is to my mind overstated.

Continuing with his critique of the input and output series constructed by the BEA and Bureau of Labor Statistics (BLS), Gordon has two specific disclaimers to the veracity of published industry data. An example in the airline industry is the capital and labor supplied to it in the form of airports and their administrative infrastructure (e.g., air traffic controllers and other Federal Aviation Administration personnel) as well as outsourcing personnel in the form of reservations clerks and sales agents at city ticket offices which are not accounted for and thus may bias labor and to some extent the capital input measures. Outsourcing is a problem that is not unique to the airline industry, for example, the U.S. Postal Service USPS outsources to firms in the form of presort discounts. As Walter Oi (chap. 4, in this vol.) has pointed out, failure to properly frame the production process as joint in household time and in formal business inputs can cause serious mismeasurement of the input mix and thus the MFP measures. Thus indirect routing, which presumably requires increased household time, can confound standard growth accounting formulas that do not explicitly recognize the joint production process and can thus distort the measurement of value-added output. Gordon convincingly addresses these points and concludes that indirect routing has indeed increased consumer surplus. Continuing on the problems with BEA and BLS approaches to both ALP and MFP growth calculations, Gordon notes that in the airline industry the two series differ largely because of the aggregation problem, because BLS employment grows less fast than the BEA figures (a fact largely attributable to the inclusion of Federal Express in the industry in 1986), and because NIPA output grows less fast than BLS figures because BEA uses deflated sales and BLS uses physical output and the deflator does not tract passenger yield well. With respect to the inclusion of Federal Express, however, is it not the case that the majority of their employees are really drivers of vans? (Also according to the Department of Transportation figures, roughly one-third of their employees are part-time.) He goes on to argue that measuring the average price of airline service is dicey and that even using yield as a deflator may overstate the growth of airline output relative to true quality-corrected output owing to the introduction of the complex regime of discount fares since 1977.

Gordon makes a number of points about the mismeasurement of transportation service output. First, quality changes may not be important because the deterioration in quality of service and the enhanced quality of service due, for example, to advanced boarding and seat reservations in airlines, are more than likely to cancel each other out. Second, frequent-flyer programs have created a significant upward bias in passenger yield. Third, changes in the efficiency of producing a "quality adjusted ton mile are of independent interest in productivity" because the production process has not been influenced by factors that have influenced quality, such as price discrimination. Here I disagree. Flight frequency and the routes themselves often cater to the business traveler and are influenced substantially by nonneutral quality changes. He concludes by stating that he has found the BLS data to be superior to the NIPA series for output and for employment. The NIPA productivity calculations are clearly suspect, but is this really a surprise in the airline industry? NIPA measures output by revenue and fares have been falling dramatically since 1977. Similarly, using revenue deflators such as the airfare component of the consumer price index does not recognize the extent of discounting of fares that has occurred. The same point could be made about the published tariffs of the LTL trucking industry. They do not adequately reflect the amount of discounting and contract rates after the trucking industry was deregulated. It is not clear that rail rate structures have changed significantly owing to the degree of competitive pressure from private-contract-exempt trucking. It is also unclear why Gordon dismisses the dramatically changing shares of passenger versus freight output for the reason that the NIPA index is so high and that the problem is with the inability of the producer price index to reflect greater pricing flexibility after the rail industry was deregulated. Winston et al. (1990) point out that rate structures, especially the discounted tariff and contract rates, appear to be quite stable before and after deregulation.

The paper goes on to discuss MFP growth and its relation to the cost function. Although all of the analysis is carried in terms of a single output it could have been couched in a multiple-output setting (Denny, Fuss, and Waverman 1981). He imposes long run constant returns to scale. This is a strong assumption but one that does appear to have some empirical support. He goes on to discuss the capacity utilization issue and the mismeasurement of capital services owing to changing utilization rates (Hulten 1986; Berndt and Fuss 1986). At this point I would like to point out an alternative to the conventional view of airline service output. The production function, on which MFP estimates are based, specifies the maximum output produced by a set of inputs. The closest proxy to this is the number of available seats being moved from one place to another. Not unlike agriculture, unused seats are wastage because the distributor (marketer) of those seats has not done the job. In the case of the airlines, the farmer, the wholesaler, and the retailer are the same economic unit and a failure to correctly parcel up MFP growth among the various vertically integrated enterprises distorts measurement of output. Moreover, if revenue ton mile is used, then there are proxies for capacity utilization (other than load factor) that may be superior. In Sickles (1985) I constructed the flying capital series by scaling down the quantity index on the basis of the discrepancy between the average time a plane was in service (ramp to ramp) during a quarter to the maximum that a plane of the same type was in service during the sample period in the entire industry. Also the work by Färe, Grosskopf, Lovell, and Pasurka (1989) and Färe, Grosskopf, Lovell, and Yaisawarng (forthcoming 1993) the producion of "goods" and "bads" could be used to evaluate the shadow prices of the "bad" output of the airlines, specifically indirect routing. Has there been a deterioration in the service provided by the carriers owing to indirect routing? Gordon counters the prevailing wisdom by convincingly pointing out that indirect routing has increased travelers' options. However, the numbers that are cited as interlining of passengers may be systematically misleading because of code sharing. Under code sharing, a commuter carrier, for example, one of the American Eagle affiliates, uses the ticket code of a major airline. This makes it appear that the passenger is staying on the same airline, but its a rather muddy issue about whether or not it really is a different carrier because they are often at different concourses. This behavior results from airlines trying to capitalize on the benefits of feeder traffic. No assumption of increased circuitry is necessary if a cost-based study of productivity were undertaken in which various characteristics of the airline network are controlled for and thus their effects on airline costs estimated (see e.g., Good, Nadiri, and Sickles 1991). The increased options, routes, and so on that travelers face today are in place because of the tremendous economies of networking that characterize communication technologies. However, the coordination problem that exists with AT&T has essentially been resolved with the AR7 switch and more modern digital equipment. The coordination problem in the airline industry has not been resolved so costlessly. In order to assure that average arrival times coordinate in a complex network that is either in place or being pursued by most major carriers, waiting times must be higher, absent the coordination problem. Moreover, Gordon's conclusion that ground congestion was not the cause of the increased scheduled flights times has a counter argument. Consider the following flight itinerary: A → B → C → D. Suppose that airport B is congested. The aircraft leaving at time A (a nonhub) might be held on the ground until it can get a slot for landing at B. The preclearance improves the safety at airport B by reducing the number of planes circling while waiting for a landing slot. Even if C and D are nonhub airports, their scheduled arrival time might be later than the old flight time because the arrival of the plane at C was delayed by the congestion at B. In other words, there are ripple effects of delay. Saying that they must be the results of "in route air traffic control capacity" rather than ground congestion really ignores the network aspects of airline service. With respect to the issue of complaints falling after deregulation, another indication that quality of service improved, it should be pointed out that selectivity problems with the complaints data cannot be dismissed. The filing of complaints is largely driven by expectations about the resolution of complaints. When the Civil

Aeronautics Board existed, there was an agency that could modify rewards and behavior of the carriers. The Department of Transportation merely keeps a tally of the letters. It has no regulatory teeth.

In summary, I think the work by Gordon will stand as a focus of empirical research in the transportation sector for many years to come. I anticipate that the constructed output and input series and conclusions concerning them will remain robust to most changes that economists may argue are sensible, my comments notwithstanding.

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