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PRODUCTIVITY IN THE TRANSPORTATION SECTOR

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ABSTRACT

This is a comprehensive study of measurement and substantive issues that arise in determining the rate of multifactor productivity (MFP) growth in the transportation industry over the postwar period, 1948-87. Official data on output and employment are provided by two government agencies and conflict markedly for railroads, airlines, and trucking. This paper identifies the source of the conflicts and selects the best of the government indexes for further study. It concludes that improved data reduce the magnitude of the post-1973 productivity slowdown in transportation MFP growth from a previously reported 2.5 percent per annum to just 0.5 percent. The effect of deregulation has been mixed; MFP growth accelerated markedly for railroads when 1978-87 is compared to the pre-1978 period, but slowed sharply for airlines and trucking.

New results on output quality are provided for airlines, particularly for the period of deregulation. Contrary to the standard view, deregulation has not substituted circuitous routings through hubs for nonstop flights available previously; instead the establishment of new hubs has greatly increased the number of nonstop routings available, and remarkably few nonstop routes have been discontinued. An estimate is provided of the value of time saved by the improved routings, and of the offsetting time cost of extended scheduled flight times resulting from increased congestion. Such estimates of the value of time are swamped by the huge contribution to welfare provided by the manufacturers of aircraft and engines; the time saving from the "invention of air travel" for 1989 is valued at 400 percent of domestic airline revenue and 3.5 percent of GNP.

Alternative measures of capital input, based on new quality-adjusted equipment deflators, are provided for airlines, railroads, and trucking. These uniformly increase faster in the earlier postwar years than in the last decade and consequently imply a smaller decline in MFP growth than in official data sources. However, new estimates of the input of government expenditures on airports, air traffic control, and highways, do not change appreciably the pattern of postwar MFP growth in transportation.

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I. INTRODUCTION

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 services GNP.

As shown in Table 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 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

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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 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.

[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.

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 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 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 sub-sectors over the entire postwar period. The detailed analysis in this paper is limited to the three most important sub-sectors, railroads, trucking, and airlines, which comprised 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. While the use of data for individual

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

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. Since the primary focus of this study is to address the measurement of productivity in national economic statistics, a move along the tradeoff curve toward a longer sample period and away from firm-specific observations seems appropriate.[4]

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 II 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 (DeLeeuw, Mohr, and Parker, 1991) resolve some inconsistencies in output data but leave substantial divergences

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[4] For a review of the cost-oriented studies of productivity change, see Winston (1985, pp. 66-69). The cost studies for air transport based on individual carrier data, and the sample periods covered, include Caves, Christensen, and Tretheway, hereafter 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 and Fraumeni (forthcoming).

between official agencies in estimates of employment and ALP growth. After a discussion of general conceptual issues in Part III, the paper turns to the detailed analysis of the three sections. Much more attention is devoted to air transportation (Part IV) than to rail (Part V) or trucking (Part VI). This reflects two important differences. First, since rail and trucking output consists almost entirely of the carriage of freight, these sub-sectors provide intermediate rather 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.

II. CONFLICTS IN THE OFFICIAL DATA

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 II we take a close

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[5] The BLS publishes multifactor productivity 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 (see BLS bulletin 2349, February 1990).

look at the official output and employment data that enter into estimates of ALP like those already examined in Table 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 sub-sectors (see *note a* to Table 1), and of hours for total transportation but not the sub-sectors. 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," i.e., value added, in practice value added is calculated by double deflation only since 1977, while 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 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 sub-sectors (the same as NIPA minus water transportation and transportation services, and with some definitional 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

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[6] These are full-time and part-time employees (Table 6.6B), full-time equivalent employees (Table 6.7B), and Persons Engaged (Table 6.10B). All NIPA ALP measures in in this paper are based on persons engaged. Results would be almost identical for rail and air using full-time equivalent employees, which comprise 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, while unpublished estimates for air and rail begin in 1947 and for trucking begin in 1954. See the notes to Table 2. A general introduction to the BLS methodology for the indexes covering the service sector is provided by Dean and Kunze (1991).

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, whereas the NIPA data do not. Below we find that this helps to explain the difference between NIPA and BLS estimates of airline employment.

Table 2 provides our first detailed look at ALP data for the transportation sector and three sub-sectors. The NIPA data in the top section of Table 2 duplicate those in Table 1 for the three sub-sectors 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 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 1). The post-1973 productivity growth slowdown is much larger in Table 2 than Table 1, mainly because pre-1973 productivity growth is held down in Table 1 by the inclusion of local transit (where productivity collapsed, particularly during 1948-58).

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[8] This adjustment is based on ICC data on unit revenue for 200 commodity lines, see Mark (1988, pp. 146-7). 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 1 but excluded in Table 2 and subsequent tables are local transit, water transportation, pipelines, and transportation services.

The BLS data shown in the middle section of Table 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 2 subtracts each NIPA growth rate from the corresponding BLS rate and shows that the discrepancy was large for all three major sub-sectors over 1973-87.

Since 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 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 sub-sectors.

The NIPA Output Revisions and Remaining Discrepancies

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

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[10] The BLS does not publish data for the aggregate transportation industry. In Tables 2 and 3 we use a "quasi-Törnqvist" index that takes the short-cut of aggregating over multi-year 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 labelled the "Törnqvist-Theil-translog" index by Caves, Christensen, and Diewert (1982).

to the more rapid growth of the BLS output 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 4 shows that the revised NIPA indexes for 1977-87 now rise faster than the BLS indexes for all three sub-sectors, whereas 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 4, the BLS series on ALP in total transportation, as well as for the trucking and airline sub-sectors, 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. While the difference for railroads is not important, that for trucking and airlines makes a substantial difference.

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 (inter-city and local), as well as warehousing, whereas BLS includes only a fraction of inter-city trucking. Table 5 displays the 1979 and 1987 values, and 1987/1979 ratios, for a variety of measures of 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 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, due to 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, while the direct measure of revenue per ton-mile increases less. Since all three deflators in section 2 refer to intercity freight, they should be viewed as different measures of the same concept.[11] We view the final measure in line 2c as superior, as it is a direct measure of

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[11] The source listing provided by DeLeeuw, 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 volue, which could only refer to intercity freight, as ton-miles for local traffic are not available.

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, while a constructed series (line 3c) for the implied real 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 1987/79 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 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 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 VI 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

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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 5 for 1958-80 are not available after 1983.

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, while 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, due to the possibility of an overly rapid increase in the implicit deflator. The the direct measure of Class I revenue per ton-mile rises 1.2 percent per annum less than the NIPA deflator. Supporting 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

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[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.

[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*.

input prices if there was an improvement in labor productivity and fuel efficiency; the improvement in fuel efficiency is a solid fact, while labor productivity increased even with the NIPA deflator, and even more with the alternative deflator.[17] In Part VI we will explore the consequences of replacing the NIPA output index with an alternative index based on the deflator in line 2c of Table 5.

In the airline sub-sector 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 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

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[17] Average miles per gallon for single-unit trucks increased by 14 percent from 1979 to 1986 (*American Trucking Trends*, 1987, p. 44). The 1979-87 percentage increase in ALP is 5.5 percent for the NIPA deflator (Table 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 AA annual report).

NIPA and use them in Part IV below.[19]

Choice of Series for Further Study

Subsequent sections of this paper develop new measures of MFP for the three transportation sub-sectors. Our desired output concept is gross rather than value-added, since 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, whereas the NIPA output series is inconsistent, measuring value added throughout only for railroads, while switching in 1977 from gross output to value added for trucking and airlines. While 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 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

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[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 non-certificated carriers, and a major shift in coverage of small carriers.

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. Since the NIPA output series represents value-added since 1977, our MFP index for trucking since 1977 should not adjust for fuel and materials inputs, since 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 will take into account separately.

III. CONCEPTUAL ISSUES

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. Since 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]

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 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. Since 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 non-constant 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 due to the application of incorrect weights in aggregating outputs and inputs. We are able to side-step this issue in studying the transportation sector, since it is of secondary importance. While 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.

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

The second issue, rate-of-return regulation, is clearly relevant for transportation. Denny, Fuss, and Waverman (1981, p. 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 which ignore rate-of-return regulation overestimate the true underlying rate of technical change. This finding is important for any investigation which includes the period of deregulation, as it could lead to an erroneous conclusion that the rate of technical change had been decreased as a result of deregulation. While 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) will err by treating the effect on productivity of changing utilization as a shift in the production function. Below in Table 15 we address this issue by providing estimates of MFP growth that are adjusted for changes in utilization in the national economy.

Causes of Changes in MFP

We conclude Part III by discussing causes of productivity change that are common to different sub-sectors of transportation, and reserve for the remaining sections of the paper a detailed consideration of those causes that are specific to particular sub-sectors.

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 penalities 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 macro sources-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-Gordon, 1988, pp. 370-6). 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, since 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 remarkably little attention to the issue of capital quality, and hence in this example will "credit" the transportation sector for faster MFP growth that has been achieved

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

elsewhere.[22]

IV. AIR TRANSPORTATION

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 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, since the post-1948 decline in output growth should have reduced ALP growth if scale economies were important. The bottom half of Table 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 vs. 6.25 annual percentage points, respectively.

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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 IV 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.

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 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) have found 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]

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

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

been relatively stable.

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 frame of Figure 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" 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 appears to be universally held by journalists.[25]

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 and 30 percent

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[24] McGowan and Seabright (1989, p. 326, 329) support verbally the graphical interpretation in the top left frame of Figure 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, p. 7) state: "... increased use of hub-and-spoke and loop type networks ... allow carriers to increase load factors, but they artificially 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*, March 10, 1990, p. 73); "They built hub-and-spoke route systems ... rather than a web of direct, non-stop flights" (*The Economist*, January 26, 1991, p. 57); there are "far fewer direct flights" (*New York Times*, January 2, 1991, p. 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, p. B1).

additional mileage on a given trip, implying that a portion of productivity gains measured by passenger-miles is illusory. Dempsey uses this finding (1990, p. 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." While it might seem from Dempsey's critique that the output and price data examined in Part II 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" 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 (hereafter 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,

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[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.

flown by the air transportation industry within the 48 contiguous states in August 1978 and August 1989. The results, summarized in Tables 7 and 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 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]

Some accounts treat hub-and-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 inter-line 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 below,

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

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

section 1d).

When markets are ranked by passenger-miles, there are many long-haul markets which lacked non-stop service in both 1978 and 1989, but many more which gained service than lost service.[30] This contrast is shown in Table 7, which provides a decomposition of nonstop routes served in the top 500 origin-destination markets (accounting for 60 percent of traffic measured by 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 non-hub 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

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[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.

[31] Indeed Dempsey's prime example of circuitry (p. 30) involves "the loss of pre-deregulation Boston-San Francisco nonstops." 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.

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The complete census of domestic airline routes and flights appears in Table 8. Airports are divided among four categories, "original hubs," "new hubs," "large non-hubs," and "small non-hubs."[32] The number of routes served increased not only in every category involving hubs, but also in routes between large non-hubs. Taking the categories in Table 8 from line 1a through line 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 8 (lines 3c through 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 non-hubs and other (small and large) non-hubs, where the number of routes flown decreased by 36 percent, and the number of jet flights decreased by 55 percent, while the number of turboprop flights increased by 37 percent. A graphical interpretation of this shift is provided in the bottom frame of Figure 1. Many of the abandoned flights to small cities were along linear routes dictated by regulated routes, as in the abandoned route between "C" and "D." Because most of these routes were less than

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[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), while Memphis boarded 63 percent as connections (37 percent local). This contrast does not make San Francisco any less of a hub than Memphis, since 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.

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 larger number of local passengers served on new routes than abandoned routes (since 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 non-hub cities of added flights to hubs outweigh the loss of direct nonstop flights, as the number of routes flown from small non-hubs increased by 16 percent, and the total number of flights increased by 67 percent (Table 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]

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[34] 34. Of the 123 abandoned nonstop routes between large and small non-hubs (Table 10, line 3d), 62 percent were 200 miles or less.

[35] 35. The average daily frequency on flights from hubs to small nonhubs (Table 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] 36. We can tie our study of airline routes back to the findings of Caves, Christensen, and Tretheway (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.

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 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 six 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 8, line 5b, weighting turboprops as 0.25 of a jet flight) while 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 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 stops, or multi stops, nor do they distinguish single from double connections. Thus the first reason for voluntary choice 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. *Source:* author's calculations from CAB and DoT market segment data.

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 multi-stop traffic has been replaced by connections that are usually as fast and are 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

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[38] Of the hundreds of examples that could be constructed from the sources used in Tables 7 and 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.

smaller airports, and to the perceived benefits of frequent flyer plans.

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 airline deregulation.[39] This section assembles in Table 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 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 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 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 non-hubs, and most of the heavily congested airports are included. The

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

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, showing 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 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 due to a change in the complaint-receiving agency from the CAB to the DOT, as the DOT 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 byproduct 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 passengers 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

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[40] In August, 1978, the sample includes 249 flights of the 4727 jet flights (5.3 percent) among the airports other than small non-hubs. In August, the sample includes 296 flights of the 6655 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.

and 1981-86, and that this rate had 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. While 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 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-Winston (1989, p. 83, footnote 44) have estimated that frequent-flyer benefits (FFB) 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

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[42] The existence in the mid-1980s of a broker market for frequent flyer awards in the mid-1980s (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, due to innumerable bonusses (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 bonusses 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.

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 FFBs, 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 one percent per year over the ten years since frequent flyer programs began in early 1981.

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

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[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."

end of this section to the value of time achieved by the aircraft manufacturing industry.

Morrison and Winston (1989, Table 2, p. 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 the time 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 are taken from Table 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 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 reflects 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 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 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 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 airline trip of 791 miles and the elapsed times of 2:37 hours for air (from Table 9) and 14

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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 I-3, p. 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 RPMs, of which 27.5 actually traveled by surface, leaving 169.7 as the amount shifting from surface to air.

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 combination 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 at the assumed surface speed ($531) and the hypothetical

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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, p. xxvi).

[47] Severin Borenstein cites a third source, the introduction of price discrimination under the deregulated regime, since 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.

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, since 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 TGV or Japanese bullet train. Whatever its size, this time 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 which 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.

Input Quantity and Quality

We have previously in Part II discussed alternative estimates of the quantity of labor input. Our primary concern here is the measurement of capital input, although in our MFP calculations we also make allowance for energy and materials input, and expenditures by the

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[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.

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, Sickles, 1989, pp. 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 services 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 purposes of this study, including real and nominal investment flows and capital stocks for both structures and equipment in total transportation and in the three sub-sectors 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 automobile deflator as a proxy for ground equipment to form an alternative series for equipment. Since 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

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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."

"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 model which 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 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

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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.

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 12, *actual* growth 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, while 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.

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 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 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 two 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 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 2 plots the three capital input measures.

Sections 3 and 4 of Table 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 afterwards (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) is 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 reweights all input shares.

Annual values of four MFP measures are plotted in Figure 3, corresponding to Table 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 1978-1979 and a sharp decline through 1981, due to the recession and the

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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 (that is, 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:
$\theta = q - (1-\alpha_v)m - \alpha_v i$, then $v = [q - (1-\alpha_v)m]/\alpha_v$, $\theta_v = v - i$, and the desired 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).

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 CCT (1983, 1984), date deregulation prior to 1978, since 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 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 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 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 due to extended scheduled flight times (Table 10) offset by a downward bias of perhaps 1.0 percent per annum due to the unmeasured value of frequent flyer benefits.

V. 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, mainly consisting 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]

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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).

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 14). However, the appearance of rapid growth in ALP, e.g., 8.17 percent per annum since 1979 for the BLS data in Table 2, may not carry over to MFP. Caves, Christensen, and Swanson, hereafter CCS (1980), show that MFP growth, properly estimated in 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 III that MFP measures are inaccurate in the presence of non-constant 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, pp. 177-8). 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

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

displayed in Table 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 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 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, since 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 vs. 1.52 percentage points. CCS provide a decomposition (1980, pp. 177-80) showing that a similar difference between the "conventional method" and their results can be attributed entirely to a differing

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[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.

treatment of output and input weights. The essence of the difference is that CCS place greater weight on passenger output (since 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 14 that MFP growth did accelerate after 1978, but by much less than ALP growth. Alone among the three major transportation sub-sectors, 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.*, it remains surprising that the railroad industry did as well before 1978 as our alternative MFP indexes indicate.

VI. 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

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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, based on 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), Friedlander and Bruce (1985), Daughety, Nelson, and Vigdor (1985), and Ying (1990).

prone to error than that for railroads, since (as we learned in Part II), 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 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, p. 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, while 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 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-density traffic corridors, "thereby ensuring high vehicle use and low costs" (Winston *et al.*, 1990, p. 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, while LTL rates would have increased by a much larger 116 percent. The actual increases were 51 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 13 and 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 behaves quite similarly to the automobile 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 anti-pollution equipment represents an increase in quality rather than an increase in price. While 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, and 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 15, and on an annual basis in Figure 6, 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 15, line 2c, to compare with the revised BEA output measure shown in line 2a. This takes nominal BEA output and then deflates it with the "yield" (revenue per ton-mile) index shown above in Table 5, line 2c. Because the yield measure is only available back to 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 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 15; annual data for the indexes on lines 4a-4d are plotted in Figure 5.[57] The first in line 4a uses the unrevised BEA 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

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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 15, lines 4b through 4e, are calculated as value-added MFP times the share of value-added in gross output. See footnote 51 above.

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 of 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 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 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

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[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).

and durability of diesel engines.[59]

VII. 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 measures are summarized in Table 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 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 16 "total transportation" refers only to the three major sub-sectors. All MFP series for total transportation are Törnqvist indexes that use annual revised NIPA data on nominal output in the three sub-sectors 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 16. This switch boosts MFP growth both before and after 1973, but leaves the post-1973 slowdown almost identical to the revised NIPA

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

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. Moreover, 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 6, the annual plot of the four MFP indexes reveals substantial cycical fluctuations, particularly in the late 1970s and early 1980s. As explained in the notes to Table 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 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) tell a surprisingly similar story, 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. 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 cuts 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 that more than cancels out the railroad success. These conclusions regarding the divergent performance of the three sub-sectors are extremely robust to alternative dating of deregulation.

In conclusion, this paper has "explained" most but not all of the large post-1973 productivity growth slowdown in the transportation industry displayed in Table 1 above and in line 1a of Table 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 II, 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 than before for the period since 1977, and we view the NIPA output revisions, which in part amount to a response to the earlier criticisms contained in Gordon-Baily (1988), to represent 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 impact 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 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 the 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 10 times U. S. sales of commercial aircraft, 4 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, while 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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NBER WORKING PAPERS SERIES

APPENDIX

PRODUCTIVITY IN THE TRANSPORTATION SECTOR

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Working Paper No. 3815

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TABLE 1

Growth of Output per Hour in Nonfarm Private Economy, Transportation Sector, and of Output per Employee for Sub-sectors, 1889-1987[a]

	1889-1909	1909-1929	1929-1948	1948-1973	1973-1987	1889-1987
Nonfarm Private Economy	**2.27**	**2.18**	**2.12**	**2.43**	**0.92**	**2.07**
Transportation[a]	**2.05**	**3.36**	4.75	**2.20**	**0.33**	**2.63**
Railroads[b]	1.88	1.58	2.95	3.66	1.24	2.40
Trucking[b,c]	-.--	-.--	9.70	3.70	-0.28	-.--
Airlines[b]	-.--	-.--	8.25	5.33	-0.87	-.--
Local Transit[b,d]	2.34	3.00	3.96	-3.34	-2.12	0.70

Notes:

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

b. Per employee, not per hour, for all sub-sectors 1948-87, and for trucking and airlines 1929-48.

c. Intercity only 1929-48, "Trucking and Warehousing" 1948-87.

d. 1889-1948 "Local Railways and Bus Lines"

Sources:

1889-1948 Nonfarm Private: Kendrick (1961), Table A-XXIII, pp. 338-40. Transportation and sub-sectors: Kendrick (1961), Tables G-II, G-III, G-VIII, G-X, and G-IV.

1948-1987 Nonfarm Private: *Economic Report of the President* 1990, Table C-46, p. 346. Transportation and subsectors: NIPA Table 6.2 divided by Table 6.11 for Total Transportation; divided by Table 6.10B for sub-sectors.

TABLE 2

Growth of Output Per Employee, Unrevised NIPA vs. BLS, Selected Intervals, 1948-87

	1948-1958	1958-1973	1973-1979	1979-1987	1948-1973	1973-1987	Slowdown 1973-87 minus 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[a]	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

Notes to Table 2 on next page

NOTES AND SOURCES FOR TABLE 2

Notes: a. 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 sub-sector 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.

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 2296, pp. 134-38, and for 1963-87 are from Bulletin 2349, pp. 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.

TABLE 3

Difference between BLS and Unrevised NIPA Estimates of Output and Employment, Annual Percentage Growth Rates, Selected Intervals, 1958-87

	1958-1973	1973-1979	1979-1987	1973-1987	Slowdown 1973-87 minus 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

Notes, Sources, and Methods: Same as Table 2.

TABLE 4

Growth Rates for Revised NIPA, Unrevised NIPA, BLS, and Differences for Output and Output per Employee, For Interval 1977-87

	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 2, except revised NIPA output from DeLeeuw, Mohr, and Parker (1991), Table 6, p. 34

TABLE 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 (in percent)
1. Nominal Output ($ billions)			
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 (cents) (1c / 3b)	14.8	19.9	134.7
c. Class I Intercity Revenue per ton mile (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 (billions)	608	666	109.5
c. Implicit real revenue, billion 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 (thousands)			
a. NIPA (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 (see source note)	571	434	76.0

Sources: See next page.

SOURCES FOR TABLE 5

Sources by Line:

1a,2a,3a	DeLeeuw, Mohr, and Parker (1991), Tables 5 and 6, pp. 33-4.
3d	Basic BLS source, same as Table 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 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.

TABLE 6

Long-Run Behavior of Output, Employment, and Passenger Yield, Airline Industry and United Airlines, 1935-87

	Revenue Ton-Miles	Employees	Output per Employee	Real Passenger Yield
Annual Growth Rate, U. S. Domestic and 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 is obtained from the same sources as Table 4. For 1935-48, data are obtained from 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.

TABLE 7

Effect of Deregulation on Nonstop Domestic Air Service, Top 500 Origin-Destination Markets,[a] August 1978 and August 1989

	1978		1989	
	Routes	Flights	Routes	Flights
1. Flown Both Years				
a. Hub-hub[b]	71	--	116	--
b. Hub-nonhub	187	--	171	--
c. Nonhub-nonhub	71	--	42	--
d. Total	**329**	--	**329**	--
2. Flown One Year, not the Other				
a. Hub-hub	1	1	6	16
b. Hub-nonhub	11	19	47	123
c. Nonhub-nonhub	5	6	8	16
d. Total	**17**	**26**	**61**	**155**
c. Flown Neither Year	**93**	--	**93**	--

Note: a. 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.

b. The "hub" airports include both the "original hubs" and "new hubs." See the listing of hubs under "definitions" in the notes to Table 8.

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

TABLE 8

Effect of Deregulation on Nonstop Domestic Air Service, All Markets,[a] August 1978 and August 1989

[first-listed count of flights is for jets, subsequent count in () is for turboprops]

	1978		1989		Change		Frequency[b]	
	Routes	Flights	Routes	Flights	Routes	Flights	1978	1989
1. Original Hubs to:								
a. Original Hubs[c]	94	815(0)	97	944(0)	3	129(0)	8.7	9.7
b. New Hubs	115	610(10)	166	1068(23)	51	458(33)	5.4	6.6
c. Large Nonhubs	391	2018(90)	468	2394(269)	77	376(179)	5.4	5.7
d. 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 to:								
a. New Hubs[c]	29	91(18)	55	255(69)	26	164(51)	3.8	6.0
b. Large Nonhubs	146	467(39)	350	1263(284)	204	796(245)	3.5	4.4
c. 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[c]								
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
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. Betw. Sm. Nonhub[c,d]								
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[e]								
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

NOTES TO TABLE 8

Notes:

a. The listing of routes and flights in this table includes only airports in the 48 continguous 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 d, 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.

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

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

d. 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).

e. "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 through 4, inclusive.

Definitions:

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.

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," while airports with no routes to any hub in either year are excluded. Major airports classified as "large nonhubs" include Boston, Buffalo, Columbus OH, Indianapolis, NY LaGuardia, NY Kennedy, Orlando, San Diego, Seattle, and Tampa.

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

TABLE 9

Aspects of Airline Service Quality, Selected Indicators, Averages for 1977-78 and 1988-89

	Average, 1977-78	Average, 1988-89	Change, 1988-89 minus 1977-78
1. Percentage of flights on-time (within 15 min.)	76.8	77.9	1.1
2. Elapsed scheduled time (hours:minutes)			
a. 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 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 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 New York 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, p. 635, and enplanements, Table 1099, p. 633. Fatalities for 1988, *Statistical Abstract*, 1990, Table 1066, p. 622 and for 1989 from *New York Times*, January 19, 1991, p. A14. 1988-89 enplanements are from *Aviation Daily*, various issues.

TABLE 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. Percent of flights on new routes		21
2. Percent of connecting flights	27	33
a. Interline	11	1
b. Online	16	32
3. Shifts in type of flight (percent)		
a. Single interline to single online connections		7
b. Double interline to single online connections		3
c. Onestop no-plane-change to single online connections		3
d. Nonstop flights to single online connections		3
4. Value of time saving ($ billions)		
a. Interline to online connections		3.3
b. Onestop no-plane-change to single online connections		-0.3
c. Nonstop flights to single online connections		-1.5
d. Extended flight times		-3.1
e. Total		-1.6
(Percent of 1989 domestic airline passenger revenue)		(-4)

TABLE 10 SOURCES

Sources by line:

(1a). Table 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 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, p. 86) and for the second period are calculated by Borenstein from the DoT 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 online connections is assumed to have been diverted equally from onestop and nonstop flights.

(4a-4c). Domestic passenger enplanements for 1988 from *Statistical Abstract* 1990, Table 1065, p. 628, multiplied by 0.67 to eliminate double counting for connections. Value of time for 1983 from Morrison-Winston (1989, Table 2, p. 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 online, 0.5 and 0.5 hours for single interline to single online, -0.25 and -0.25 for onestop no-change-of-plane to single online connection, and -2.0 and --1.0 for nonstop to single online connection. **(4d).** Extra travel time 0.167 hours from Table 9, line 2d. Rest of calculation uses same sources as (4a-4c).

TABLE 11

Comparisons of Selected "New" and "Old" Model Commericial Aircraft

Old Model	New Model	Sales Price Ratio	Stand'ized ASM Ratio	Net Revenue Ratio	Used Price Ratio	Year for cols. (5) and (6)
(1)	(2)	(3)	(4)	(5)	(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 by Column: (1)-(3), (5)-(7) from Gordon (1990), Table 4.9, pp. 137-9, and Table 4.13, p. 146. (4), see notes for Table 12.

TABLE 12

Sources of Capacity Growth by Aircraft Characteristic

	1954-1959	1959-1969	1969-1978	1978-1987
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 (Hrs. per yr.)	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 (Hrs. per yr.)	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 (Hrs. per yr.)	1.43	-2.17	-0.21	0.49

SOURCES FOR TABLE 12

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 Co., 1989), Section 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 edition, 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 Co., 1989) and *FAA Statistical 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 (1990, Table 4.8), taking the figure shown for the latest year listed. For models not covered by Gordon, data for "similar" models were used.

TABLE 13

Growth in Multi-Factor Productivity, Air Transportation, 1948-87 (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 & 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 with:				
a. NIPA Unrevised Output and Input	4.24	0.65	2.22	-2.00
b. 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 4c with govt. input	3.70	3.23	2.93	1.19
Line 5d with output smoothing				
g. Remove effect of changes in real yield and real GNP	5.52	2.16	2.43	1.26

NOTES AND SOURCES FOR TABLE 13

Sources by Line:

(1a and 1c). BEA wealth tape. **(1b).** The aircraft index comes from Gordon (1990, Table B.9, p. 620) and the ground equipment index comes from the same source (Table B.8, p. 618), with respective weights of 0.8 and 0.2.

(2a and 2b). Equipment capital (cumulated with BEA weights from lines 1a and 1b) is combined with structures capital using BEA weights. **(2c).** From Table 12, line 2a.

(3a, 3b, and 3c). See sources to Table 2.

(4a and 4b). See sources to Table 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 PPI prior to 1970. **(4d).** Nominal materials input for 1969 and 1979 is from James (1980, Table 1-4, p. 10) and for 1989 is from *World Aviation Directory*, Winter 1990, Table 101, p. 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 sections 3 and 4 of this table. Methodology for output smoothing (line 5f) 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.

TABLE 14

Growth in Multi-Factor Productivity
Railroads, 1948-87

	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 and 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 and Input	1.34	4.45	0.97	-0.68
b. BEA Revised Output and Input	1.34	4.45	1.63	4.90
With BLS Output and 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 FOR TABLE 14

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 Tables 2 and 4.

(4a). Same source as Table 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)**. Non-fuel 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.

TABLE 15

Growth in Multi-Factor Productivity Trucking, 1948-87

	1948-59	1959-69	1969-78	1978-87
1. Real Capital Input, Equipment and 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 and Input	2.97	2.51	1.49	-0.75
b. BEA Revised Output and Input	2.97	2.51	1.38	0.00
c. Alternative Output and Labor Input, BEA Capital Input	2.97	2.52	2.38	0.97
d. Alternative Output and Input	2.05	1.51	2.06	0.82
e. Line 4d, with government capital	-.--	1.47	2.36	0.86

Sources by line:

(1a). From BEA wealth tape. (1b). Computed as in Tables 13 and 14 by substituting a new equipment deflator (Gordon, 1990, Table C.3, p. 698) for the BEA deflator, while using BEA nominal equipment investment, BEA structures capital, and BEA weights for equipment and structures.

(2a and 2b). Same sources as Tables 2 and 4. (2c). Deflate nominal, revised BEA output with alternative deflator, source given in notes to Table 5, line 2c.

(3a). Same source as Table 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 PPI 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 15, line 2d) to intercity trucking revenue (same source as Table 5, line 1c).

TABLE 16

Four Measures of Multifactor Productivity Growth for Transportation, Annual Percentage Growth Rates, 1948-87 and Selected Intervals, with and without Cyclical Correction

	1948-1959	1959-1966	1966-1973	1973-1979	1979-1987	1948-1973	1973-1987	Slowdown, 1973-87 minus 1948-73	Slowdown, 1979-87 minus 1948-79
1. Raw Data	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
a. BEA Unrevised Output and Input	1.90	4.20	1.25	0.39	-0.73	2.36	-0.25	-2.61	-2.70
b. BEA Revised Output and 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 and Capital	2.08	3.96	1.62	1.36	2.15	2.47	1.81	-0.66	-0.11
2. Cyclically Corrected									
a. BEA Unrevised Output and Input	2.34	3.24	1.63	0.91	-0.80	2.39	-0.07	-2.46	-2.83
b. BEA Revised Output and 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 and Capital	2.02	3.63	1.78	1.67	2.05	2.40	1.89	-0.51	-0.25

SOURCES FOR TABLE 16

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.

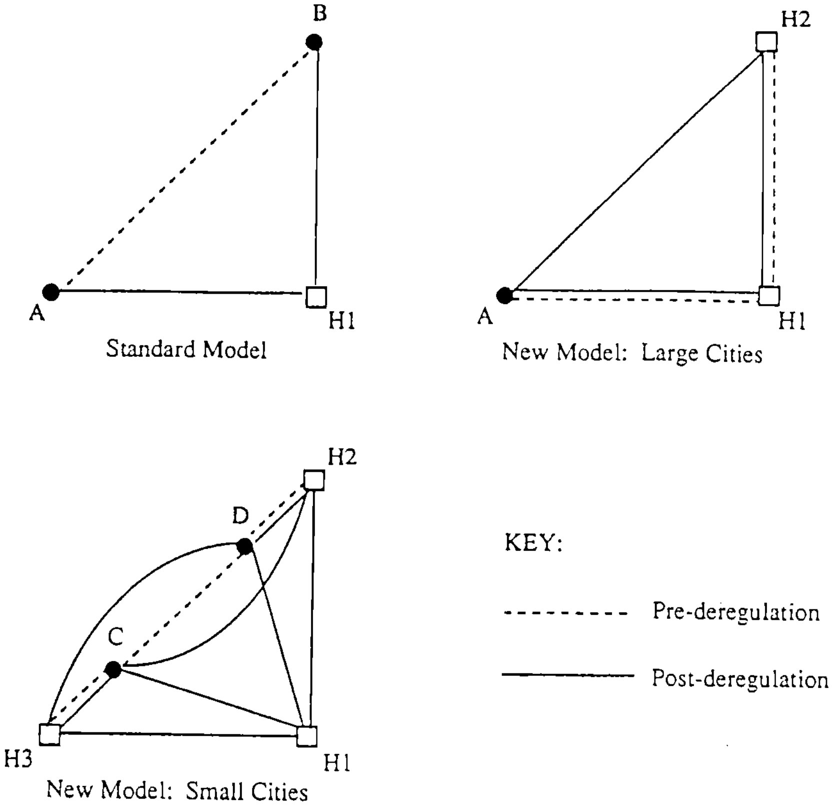
(1a). *BEA* unrevised concept uses NIPA unrevised output, NIPA employment, and BEA real gross capital stock of equipment and structures, together with fuel and materials inputs from Tables 12-14. No allowance is made for the value of time or for government capital.

(1b). BEA revised concept replaces NIPA unrevised output with NIPA revised output for 1977-87. Since revised NIPA output is a value-added concept, materials and full inputs are not subtracted out. See footnote 51 in text.

(1c). This measure replaces 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 15, line 2c.

(1d). This measure starts from line 1c and replaces BEA capital with the respective capital indexes (see Table 13, line 5d; Table 14, line 5d; and Table 15, line 4d).

(2a - 2d). For the corresponding line of section 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, pp. A2-A3). The cyclically corrected growth rate of MFP is the actual growth rate minus the statistical contribution of the GNP change.



Standard Model

New Model: Large Cities

New Model: Small Cities

FIGURE 1

Figure 2

Three Versions of Capital Input, Air Transportation Industry,
1948 - 87

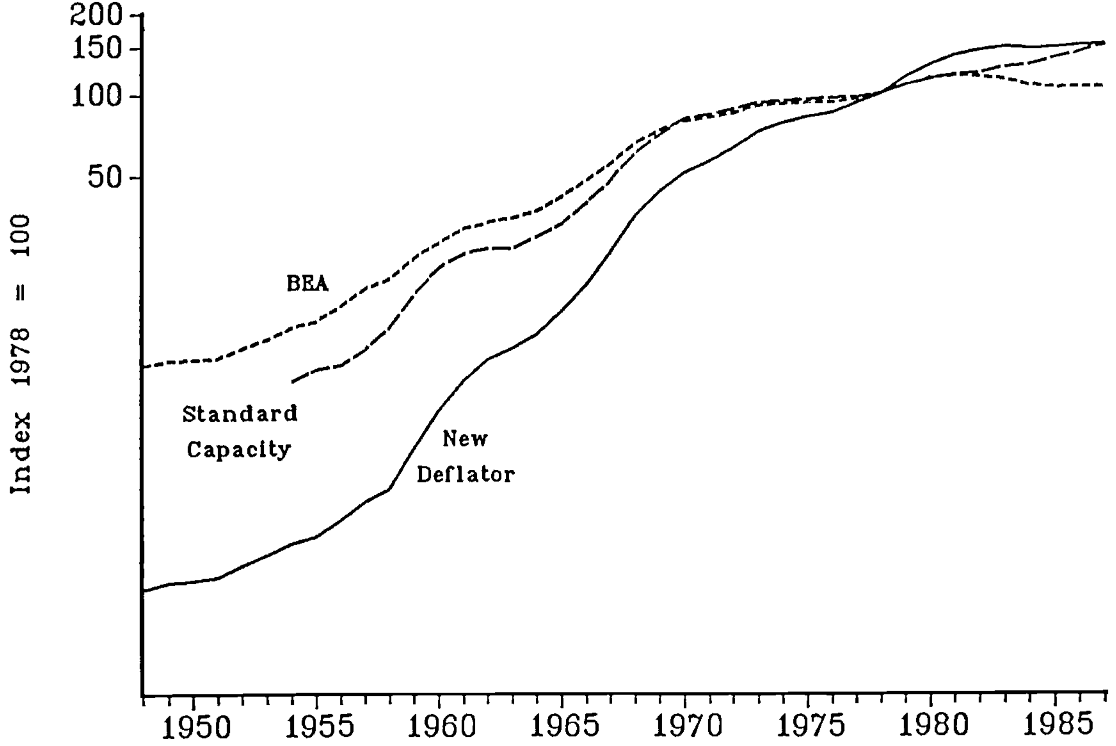


Figure 3
Four Versions of Multifactor Productivity, Air Transportation Industry
1948 - 87

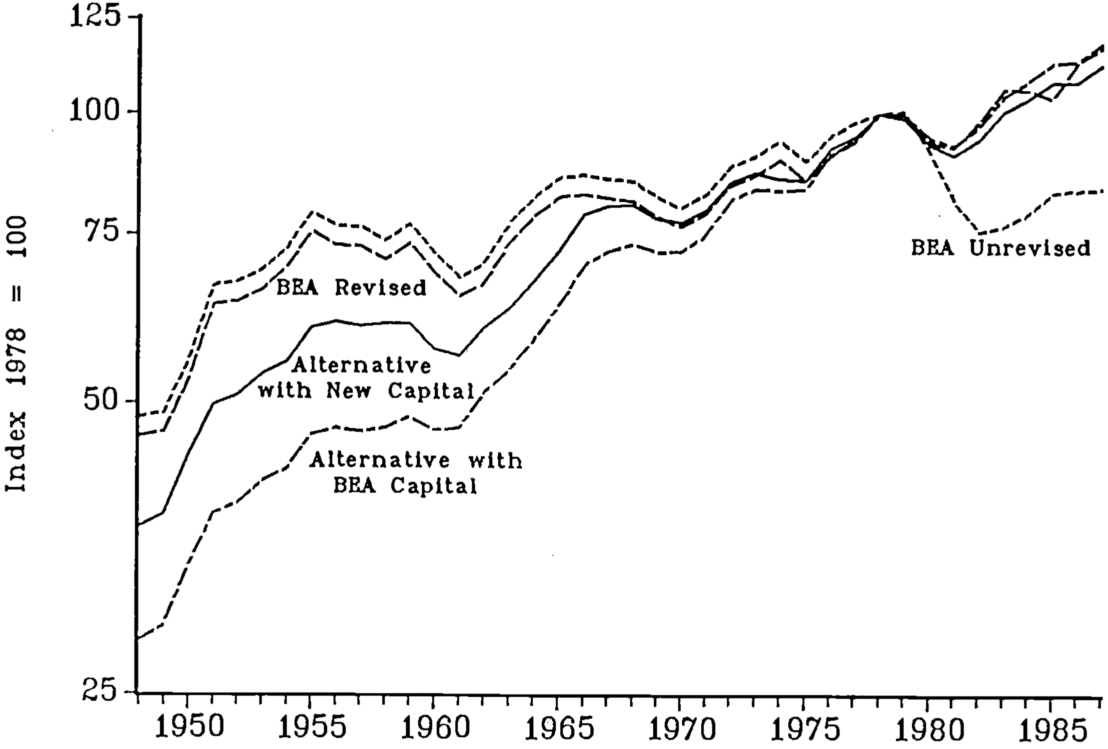


Figure 4

Three Versions of Capital Input, Trucking Industry
1947–87

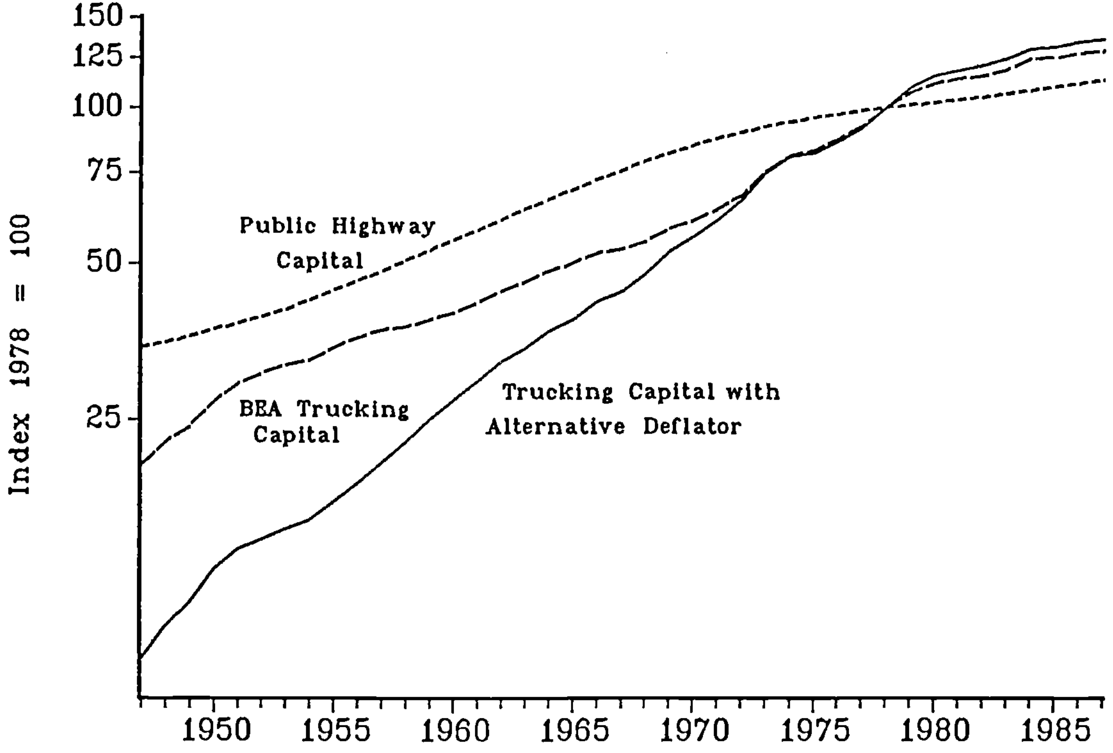


Figure 5
Four Versions of Multifactor Productivity, Trucking Industry
1948 - 87

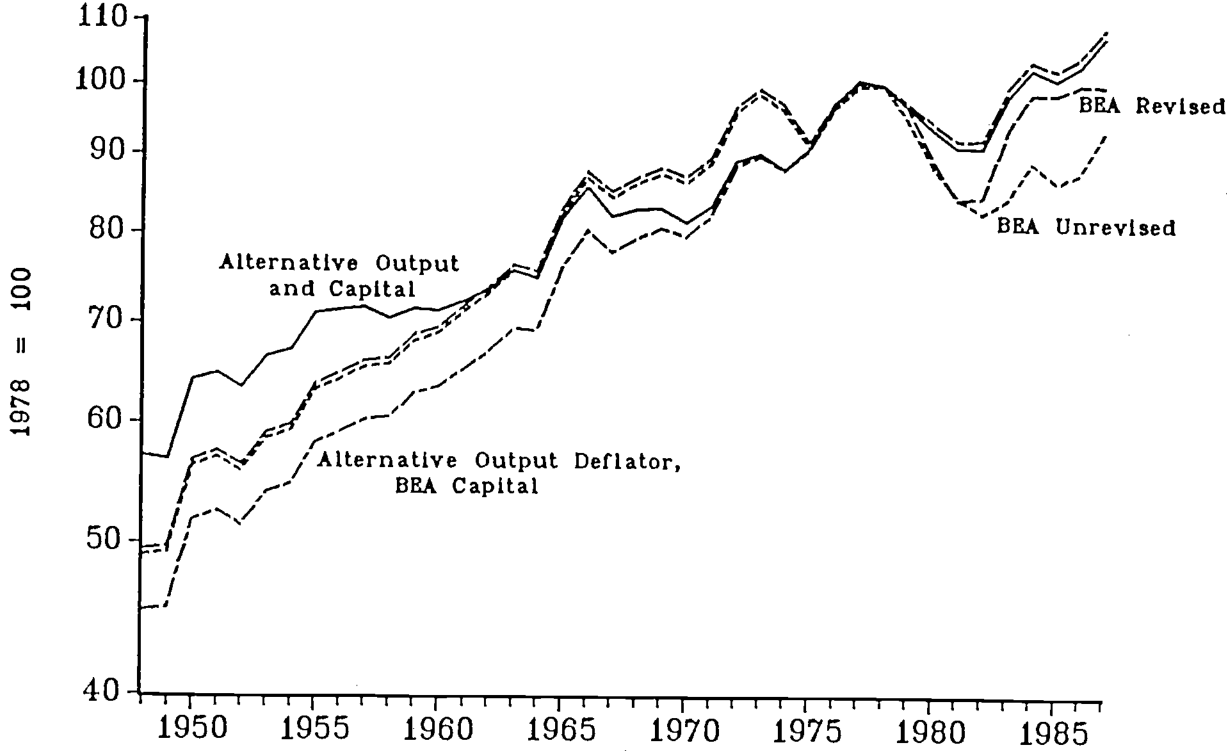
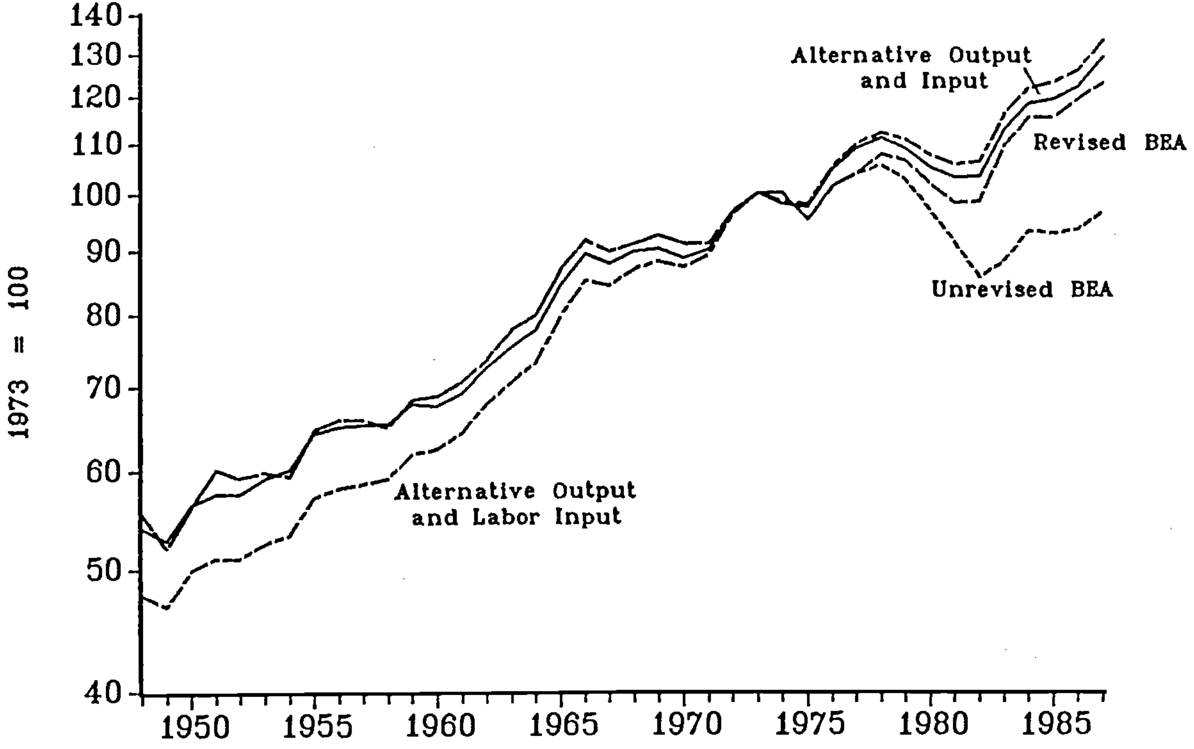


Figure 6
Four Versions of Multifactor Productivity in Transportation
1948 - 87



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