Estimation and Analysis of Multifactor Productivity in Truck Transportation: 1987-2003

ANTHONY D. APOSTOLIDES, Ph.D.
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U.S. Department of Transportation
Research and Innovative Technology Administration
Bureau of Transportation Statistics
Office of Advanced Studies
anthony.apostolides@dot.gov

ABSTRACT

The analysis has three objectives: 1) to estimate multifactor productivity (MFP) in truck transportation during 1987-2003; 2) to examine changes in multifactor productivity in U.S. truck transportation, over time, and to compare these changes to MFP of the U.S. business sector and other transportation subsectors; and 3) to assess the factors that affected changes of MFP in truck transportation over the period of analysis.

With respect to the calculation framework, the analysis estimates annual MFP in truck transportation in the United States over the 1987-2003 period. The data used for the estimations are based on the North American Industrial Classification System (NAICS). The basic data series were obtained from the Bureau of Economic Analysis. The labor data under NAICS were extrapolated from 1998 back to 1987. Data on the land input were estimated using the method of the Bureau of Labor Statistics, with some modifications. In future work, other methods will be used to estimate the land input.

With respect to methodology, use is made of the basic growth-accounting methodology and the methodology using the Tornqvist index number approach. MFP was estimated in three different scenarios. In the first one, the basic growth-accounting methodology was used, without a measurement for land. In the second one, MFP was calculated with the Tornqvist index and without a measurement for land. In the third scenario, MFP was calculated with the Tornqvist method and with a measurement for land.

With respect to MFP results, the calculations indicate a mixed record of multifactor productivity in truck transportation over the period of analysis. Truck MFP increased during the first subperiod—from 1987 to 1995—and decreased during the second subperiod—1995 to 2001. In the last three years of analysis—2001 to 2003—truck MFP again increased.

The outcomes of the calculations indicate that both methodologies (the basic growth-accounting methodology and the one using the Tornqvist index) provide very similar results on multifactor productivity in truck transportation. That implies that either method can be used to provide appropriate estimates of MFP.

A comparison of truck MFP with other transportation industries and the U.S. economy is possible for years in which MPF data are available for the various transportation industries and the economy. These data show that truck MFP over the 1987-2000 period increased faster, at 1.1% per annum, than that of the U.S. private business sector, which grew at 0.9% per annum. Thus, the trucking subsector contributed positively to the growth of multifactor productivity in the U.S. economy over this time period. During 1987-2001, MPF growth in trucking was the same as in the U.S. economy, at 0.8% per annum. After 2001, MFP in trucking grew at a lower rate than in the U.S. private economy. In addition, during 1987-1995, MFP in trucking increased at a faster rate, of 2.0% per annum, than MFP in air transportation, which grew at 1.2% annually.

With respect to factors that affected changes in truck multifactor productivity over the period of analysis, the assessment considers three subperiods of MFP outcomes: 1987-1995, 1995-2001, and 2001-2003. Factors that affected the increases in MFP during the first subperiod (1987-1995) include: 1) the improvement in the capital input—indicated by increases in capital per worker, and the rapid increases in the use of computer hardware and software (information technologies); 2) an improvement in the fuel efficiency of trucks; 3) an increase in the average length of haul; 4) an increasing use of containers; and 5) positive effects on industry efficiency from interstate deregulation taking place over time. Factors that affected *decreases* in MFP during the second subperiod (1995-2001) include: 1) a declining efficiency in utilizing intermediate inputs; 2) a lower growth rate of capital per worker; 3) a lower growth rate of utilizing containers; 4) the decrease in industry output in 2001, as a result of the economic recession that year and the catastrophic events of 9/11/2001; and 5) intrastate deregulation of trucking in 1995; this was followed by a period of adjustments (entry and exit of firms) and uncertainty which appear to have had a negative impact on truck MFP. Factors that affected MFP *increases* during the third subperiod (2001-2003) include: 1) increasing efficiency in the utilization of intermediate inputs; 2) increases in the use of computers; 3) increases in the use of containers; and 4) the adjustment of the industry after intrastate deregulation in 1995, which completed and made comprehensive the deregulation of truck transportation.

SECTION I—INTRODUCTION

In this study, there is an estimation of multifactor productivity and an assessment of changes in multifactor productivity (MFP) in the U.S. truck transportation sub-sector during the 1987-2003 period. The analysis is composed of four sections besides the Introduction (Section I). Section II contains a description of the structure and evolution of the trucking industry, in the U.S., over the period of analysis. In Section III, there is estimation of multifactor productivity in truck transportation during 1987-2003. This estimation is carried out by two approaches: the basic growth-accounting method and the Tornqvist index. In Section IV, there is a comparison of MFP in trucking with MFP in other transportation subsectors and the U.S. business sector. Section V presents an analysis of the factors that affected changes of MFP in truck transportation over the period of analysis. Finally, the Conclusions (Section VI) present the salient points of the estimation and analysis of MFP in truck transportation.

SECTION II—TRUCKING INDUSTRY BACKGROUND AND STRUCTURE

Industry Description and Characteristics

Firms in the truck transportation industry provide a link between manufacturers and consumers. Businesses, and occasionally individuals, contract with trucking companies to pick up and deliver a variety of goods. The trucking industry has two parts: the "for-hire" segment and the "in-house trucking" segment. Within the "for-hire" segment, freight movement is characterized by broad service markets of truckload (TL), less-than-truckload (LTL), and small package delivery. The trucking industry can also be classified into two segments, according to the nature of the freight being transported: general freight trucking and specialized freight trucking. These parts of the trucking industry are described below.

Truckload (TL) carriers specialize in hauling large shipments for long distances. TL shipments are usually defined as those weighing 10,000 pounds or more. In this segment, a driver employed by a TL firm, or a truck owner-operator, will pick up a load from a shipper and carry the load directly to the consignee, without transferring the freight from one trailer to another. Thus, TL carriers do not need a network of terminals. This segment of the industry involves substantial competition and labor is typically not unionized.

Less than truckload (LTL) carriers consolidate, in one truck, several shipments that are going to the same general geographic area. LTL shipments are usually defined as those shipped in amounts that weigh less than 10,000 pounds. The consolidation of freight requires a network of freight terminals. Consequently, LTL carriers are characterized by networks of consolidation centers and satellite terminals. In this framework, a pickup-and-delivery truck typically transports an LTL shipment from the shipper's dock to the trucking firm's local terminal. There, dock workers unload and recombine the shipments with other shipments that are going to similar destinations, typically a destination terminal in another city. This transportation may be accomplished by large trucks or by another transportation mode—e.g., rail or ship—depending on price and service considerations. When the shipment arrives at its destination terminal, the load is processed, moved to a pickup-and-delivery truck, and then transported to the consignee. There are national LTL firms and regional LTL firms.

Besides the TL and LTL service markets, the trucking industry can also be classified into two segments, according to the nature of the freight being transported: general freight trucking and specialized freight trucking. These segments are described below. General freight trucking provides transportation of general commodities; this freight is not specialized. This segment of the industry is further subdivided into local trucking and long-distance trucking. Local trucking establishments carry goods within a single metropolitan area and its adjacent non-urban areas. Local trucking transports a range of items such as produce to different grocery stores, lumber from the lumber yard to construction sites, and debris. Long-distance trucking establishments transport goods between distant areas—e.g., from city to city—and sometimes between the United States and Canada or Mexico. The firms in this segment handle a wide variety of commodities.

Specialized freight trucking provides transportation of freight, which requires specialized equipment because of freight characteristics relating to size, weight, shape, etc. Specialized freight includes petroleum products, refrigerated goods, forest products, and dangerous/hazardous materials. The specialized equipment includes flatbeds, tankers, or refrigerated trailers. This segment also includes the furniture-moving industry, which transports used household, institutional, and commercial furniture. Like general freight trucking, specialized freight trucking is subdivided into local and long-distance.

Deregulation of Trucking and Evolution of the Industry

Legislation affected the trucking industry in the 1980s and in the 1990s. The Motor Carrier Act

(MCA) of 1980 deregulated the interstate portion of the "for-hire" trucking industry. The Act initiated significant changes at the interstate level by allowing easier entry of trucking firms, providing greater pricing flexibility to firms, eliminating restrictions on how many customers a contract carrier could serve, and reducing restrictions on private fleets.

A number of years after the deregulation of *interstate* operations, *intrastate* operations were also deregulated in 1995. Until that year, most States controlled the routes, rates, and services of motor carriers within their borders. One of the outcomes of regulation was empty truck trailers on return trips; this contributed to industry inefficiency. In 1995, the Trucking Industry Regulatory Reform Act (TIRRA) prohibited all states from regulating carriers' routes, rates, or services. However, states were still allowed to regulate such areas as safety, hazardous material movement, and vehicle size and weight.

Thus, the primary deregulation of the trucking industry took place at the interstate level in 1980, while the intrastate deregulation of the industry, in 1995, completed the deregulation of the trucking industry and made it comprehensive. This deregulation resulted in an increase in the entry of new firms and more flexible carrier rates. Consequently, the industry experienced more competition and a significant restructuring.

Following deregulation, adjustments to the industry took place and they included mergers, acquisitions, and bankruptcies. Acquisitions in the industry involved horizontal or vertical combinations of firms. Horizontal mergers involve the combination of two firms that are engaged in the *same industry*. These mergers decrease the number of competitors in the industry and increase their size. Vertical mergers involve mergers of transportation firms that provide complementary services.

Another significant development took place in truck transportation from 1980, with interstate deregulation, and which apparently continued after the intrastate deregulation in 1995. This involved a change in the structure of the industry, resulting in a decrease in the relative importance of less-than-truckload (LTL) trucking and a corresponding increase in the relative importance of truckload trucking (TL).

There are important implications of this change for the structure and performance of the trucking industry. LTL operations were more capital-intensive and labor-intensive than TL operations. They were also more heavily unionized. On the other hand, the TL segment has been characterized by a higher degree of competition and by non-unionized labor. Consequently, the cost of transport (per unit of freight) by LTL operations was higher than for TL operations. The change toward more TL operations indicates a decrease in the capital-intensity and labor-intensity of the trucking industry over the period of analysis. Moreover, this change would lead to a lowering in the cost of truck transport.

SECTION III—ESTIMATING MULTIFACTOR PRODUCTIVITY IN TRUCK TRANSPORTATION, 1987-2003

Introduction

This analysis utilizes two versions of the growth-accounting methodology to calculate multifactor productivity (MFP) in the trucking industry in the United States. The initial methodology used is the basic growth-accounting of sources of economic growth—which includes weighted growth rates of production inputs, with the weights being the share of the input in total industry costs/output. This methodology was initially used in macroeconomic analyses of sources of growth, by analysts such as E. Denison[1] and J.W. Kendrick[2] who also used it to analyze productivity at the sectoral and industry levels. The more recent version of the methodology has been used—in a somewhat different and, what might be called, an enhanced form—by government agencies, such as the Bureau of Labor Statistics (BLS), to estimate multifactor productivity at the sectoral and industry

[1] Denison, 1974 and 1967.
[2] Kendrick, 1973.

levels.[3] This version utilizes the Tornqvist formula in the calculations. The basic growth-accounting methodology is presented in Appendix A, while the enhanced methodology using the Tornqvist index is presented in Appendix B.

The section which follows defines productivity (labor and MFP) and describes its benefits (increases). The subsequent section describes the data used and their characteristics, the calculations, and the results of the calculations by using the two methodological approaches—the basic growth-accounting methodology and the enhanced methodology.

Defining Productivity

Labor productivity is defined as output per unit of labor, and is calculated by dividing output by a measure of the labor input (number of employees or labor hours). Increases in labor productivity reflect the effect of two basic factors: 1) increased use of capital in production—which increases the amount of capital per worker, and 2) technological progress, which can include a number of factors, and is discussed at a later point under multifactor productivity.

Multifactor productivity (MFP) refers to the productivity of all the inputs used in the production process. Multifactor productivity is a more comprehensive measure of productivity than labor productivity, or other single-factor productivity measures. It indicates the overall production efficiency of an industry; it relates to increases in industry output that are not accounted for by increases in the inputs.

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

With regard to the capital input, one notes that reproducible tangible capital and land are two distinct factors of production. There are differences between reproducible capital (structures and equipment) and land. For one, structures and equipment are man-made. They are an output of a production process. Land, on the other hand, is not man-made; it is a natural resource. Moreover, structures and equipment depreciate over time as they are used in production; land does not depreciate over time (at least for practical purposes).

Benefits of Productivity Increases

Productivity, or productivity changes, can affect a company in an industry and a number of companies in the same industry. Thusly, a change in the productivity of the truck transportation industry would affect the productivity of the transportation sector. A change in the productivity of a sector—such as transportation—would, in turn, affect productivity of the U.S. economy.

The initial and basic result of a productivity increase, at the firm or industry level, is a reduction in costs and an increase in profits (total revenues minus total costs). Thus, the productivity increase benefits directly the affected industry. Subsequently, the increase in profits can be followed by lower prices of the industry—particularly when there is competition among the producers of the industry. Competition is affected by the number of producers in the industry, among other things. The higher the number of producers in the industry, the more the expected competition in the industry. Another impact of productivity increases (increase in profits) could be an increase in the labor compensation (wages and fringe benefits) of the workers working for the affected firm/industry, if the company/industry shares part of the productivity gain with the workers.

All three of these impacts of a productivity increase result in higher incomes in the economy. In the case of the business enterprise, there is a direct

[3] Bureau of Labor Statistics, 1983; Duke et al., 1992.

increase in its profit/income. If part of that profit goes to the stockholders of the firm, in the form of higher dividends, their incomes would increase. Moreover, a portion of the higher profit can be kept by the company in the form of retained earnings—with which to finance future investment that can lead to higher levels of productivity. In the case of labor, there could be an increase in the income of workers (labor compensation). In the case of the consumers/users of the services of the industry, if prices of that service decrease, there is an increase in the real incomes of the consumers. These are the basic benefits of productivity increases, and the reasons why productivity increases are desirable from the perspective of the company, industry, and the economy. A recent study has assessed the impact of productivity increases in air transportation.[4]

There can also be second-round effects as when labor uses its higher income to increase its consumption of various goods and services in the economy. This increased consumption stimulates sales of various products/services and subsequent production of other industries, with possible increases in employment and incomes there. Thus, the benefits of an initial productivity increase can have a ripple effect in the industry and affect positively other industries and the economy.

Data

The data used for the analysis were obtained primarily from the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. This source provides most data series needed for the estimation of trucking MFP. The industry analyzed is the Truck Transportation industry, represented by NAICS 484 (North American Industry Classification System). This industry consists of: NAICS 4841—General Freight Trucking and NAICS 4842—Specialized Freight Trucking. In turn, NAICS 4841 includes: 48411 (Local), and 48412 (Long Distance). NAICS 4842 includes: 48421 (Used Household and Office Goods Moving); 48422 (Local); and 48423 (Long-Distance).

[4] Apostolides, 2006.

The data used for the trucking industry refer to "for-hire" trucking, whereby businesses, or households, hire trucking firms to provide transportation of goods. These data do not include "in-house" trucking, whereby a business, such as a grocery chain, engages its own trucks and truck drivers to transport its goods. Presently, sufficient data for in-house trucking are not available to include this segment in the estimation of MFP.[5]

The analysis is initially carried out for the period 1998-2003. The choice of the initial period was affected by data availability. The primary data series, obtained from BEA, include data on gross output, labor, capital, and intermediate inputs. Data on output, capital, and intermediate inputs are available, under NAICS, from 1987. However, labor data under NAICS are available only from 1998. Consequently, estimates of MFP are initially calculated for the 1998-2003 period. Subsequently, labor data under NAICS are extrapolated back to 1987, allowing for calculations on trucking MFP to be carried out for the 1987-2003 period.

In the first phase of calculations, estimates are developed for MFP in truck transportation without land. The second phase of calculations includes a measurement of the land input and its incorporated in the estimation of MFP.

Output

Gross output in trucking is measured in terms of receipts of the industry. Output includes short-haul and long-haul trucking. Data on gross output are available in current prices and in chain-type quantity indexes.

Labor Input

The main data for the labor input are in terms of full-time-equivalent workers (FTE). Part-time workers are converted (by BEA) into full-time equivalents. The labor data do not make a distinction for different types of labor. In this regard, it

[5] BTS has been doing work in estimating the output of in-house trucking. However, other data needed for the estimation of MFP are not available.

is noted that BLS, in its work on productivity (labor and MFP), also considers labor to be homogeneous and additive, with no distinction made between hours of different groups of employees.[6] There are also data available on labor compensation of FTE employees in truck transportation. Thus, the MFP estimates are based on labor data of full-time equivalent employees. In truck transportation, there are also self-employed truckers; these are not included in full-time equivalent employees. The services of self-employed truckers would be included in intermediate inputs, which include purchased services. The services of self-employed truckers are obtained by trucking firms through contractual arrangements.

Capital

Capital stock data refer to structures and equipment (including software). They are available in current prices and in Chain-Type Quantity Indexes for Net Stock. Net capital stock excludes the depreciation of capital from gross capital stock. Capital stock data of BEA do not include land (or inventories of unsold goods).

Intermediate Inputs

Intermediate inputs include purchases of electricity and other energy inputs, purchases of materials, and purchases of services. The latter would include the services of self-employed truckers. Data for intermediate inputs are available, from BEA, in the "GDP-by-Industry" accounts and in the Input-Output accounts. In the "GDP by Industry accounts," intermediate inputs are obtained as the difference between independent estimates of gross output and value added (value of sales minus value of purchases of inputs). In the Input-Output accounts, intermediate inputs are obtained from a combination of source data for industry purchases and indirect techniques, and value added is the residual.[7] The value added of a firm/industry is the value of its sales revenue minus the value of its purchases of intermediate inputs. This analysis uses data from the GDP-by-Industry accounts since that database presents a comprehensive and consistent set of data for variables used in the calculations. A tabulation in Appendix Table C indicates that data on intermediate inputs and gross output, from the two sources, since 1998 are the same for truck transportation. This is consistent with the objective of BEA to create integrated annual I-O and GDP-by-Industry accounts. These integrated accounts are only available starting in 1998. Prior to 1998, there were substantial differences in the measure for intermediate inputs from the two BEA sources (Yuskavage, 2001).

Weights of Inputs

The labor weight was obtained by relating labor compensation (wages and fringe benefits) to industry gross output, in current prices (labor compensation/output). The weight for intermediate inputs was obtained in a similar manner: by relating the cost of these inputs to industry gross output. The weight of the capital input was obtained as a residual, for the first phase of calculations, by subtracting the combined percentage shares of labor and intermediates inputs from one (representing total industry costs).

The annual weights for the inputs used for the calculations with the basic growth-accounting approach are presented in Appendix D.

Land

Land is one of the primary inputs of industry output. Land is non-reproducible capital while structures and equipment are reproducible capital. Data on land are not available from BEA. BEA's estimates of structures (values) are based on data collected by the U.S. Census Bureau. These data pertain to new structures and include the cost of construction and of site preparation for construction projects. "Construction" data for Census exclude land acquisition. Consequently, BEA data on fixed assets include the cost of new structures with site preparation, but do not include the cost of the land on which the structures are built.

The initial sets of estimates of trucking MFP are calculated without a measurement for land. The land input is estimated and incorporated in the

[6] Bureau of Labor Statistics, 1983.
[7] Yuskavage, 2001, p. 7.

MFP calculations in the second set of estimates. Its magnitude is estimated by the approach used by BLS in their estimation of industry MFP (Duke, et. al., 1992). The methodology and data for measuring the land input are discussed in a later section ("MFP Calculations with Land").

Calculations: Basic Growth-Accounting Methodology

Calculations: 1998-2003

Estimates of MFP in trucking, from 1998 to 2003, are shown in Table 1. These estimates are based on the basic growth-accounting methodology, using annual growth rates of inputs, weighted by their share in total industry cost/output. The inputs are labor, capital, and intermediate inputs. Land is not included.[8]

The estimates indicate that for the first three years of the period of analysis, multifactor productivity in truck transportation declined (negative rates), while it grew at positive rates during the last two years.

[8] The weight of land would be included in the weight of capital since the weight of capital is derived as a residual (from 1.00) after accounting for the weight of labor and intermediate inputs.

With regard to changes in output and factor inputs, the data show that over the 1998-2003 period, output in trucking grew at positive rates for the first two years; however, those rates became negative in the last three years of analysis. Changes in employment in trucking were similar to changes in output, with initially positive rates of growth followed by negative ones. Similar patterns can also be observed for capital and intermediate inputs. Changes in the factor inputs over time resulted in a positive combined weighted growth rate during the first two years of the period of analysis; the growth rate turned negative during the last three years of analysis.

Inputs in the trucking industry decreased over the period of analysis and this was accompanied by decreasing output. However, in the last two years of analysis, MFP increased while trucking output continued to decline. This increase of MFP, which accompanied declining output, indicates increasing efficiency in the utilization of industry resources.

Calculations: 1987-2003

It was mentioned previously that data under NAICS are available for the 1987-2003 period for gross output, and for the inputs of capital and

TABLE 1 Growth of Output, Inputs, and Multifactor Productivity in Trucking
Percentage rates of change

	Basic growth accounting methodology, without land input					
Year	Growth of gross output - quantity index	Growth of labor	Growth of capital	Growth of intermediate inputs	Growth of combined weighted inputs	Growth of multifactor productivity
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)
1998	7.3		5.0	10.7		
1999	5.3	3.9	3.3	9.0	6.6	-1.3
2000	2.5	2.1	2.4	3.8	3.1	-0.6
2001	-6.2	1.4	-2.2	-6.9	-3.7	-2.5
2002	-1.7	-3.3	-2.7	-3.2	-3.1	1.4
2003	-6.0	-1.1	-1.6	-11.3	-6.4	0.4

Sources: Bureau of Economic Analysis internet site. For data on gross output, intermediate inputs, and labor: Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm

For data on fixed assets: National\Fixed Assets\All Fixed Asset Tables\Section 3 - Private Fixed Assets by Industry: table 3.2ES and table 3.1ES. http://www.bea.doc/bea/dn/FA2004/SelectTable.asp

Note: Growth rates are computed for variable values between two years. Thus, the growth rate of output shown for 1999 is between the output numbers for 1998 and 1999.

intermediate purchases. However, labor data for trucking, under NAICS, are available only for 1998-2003. This factor defined the time frame for calculations presented in the previous section.

This section uses extrapolated labor data for trucking to expand the analysis to the 1987-2003 period. Labor data are available for trucking under NAICS for 1998-2003, whereas labor data (employment and labor compensation) are available for trucking and warehousing, under SIC 42, for the period 1987-2000.[9] There are three years of data overlap between NAICS and SIC labor data. Consequently, the ratio of labor under NAICS to labor under SIC, in 2000 (the most recent year), was used to extrapolate the NAICS trucking employment and labor compensation back to 1987. These calculations are shown in Appendix E. These labor data were then used to calculate MFP in trucking over 1987-1998.

The results of the calculations are presented in Table 2. They indicate that MFP in trucking experienced a mixed record of performance over the period of analysis. The years in which trucking MFP experienced positive growth rates are observed mostly in the first part of the period of analysis—in the late 1980s and early 1990s. The last two years of analysis (2002, 2003) also show positive growth rates. Negative MFP growth rates are observed during the late 1990s, and 2000 and 2001.

[9] Information on this issue was provided by BEA staff.

TABLE 2 Growth of Output, Inputs, and Multifactor Productivity in Trucking
Percent rates of change

	Basic growth accounting methodology, without land input					
Year	**Growth of gross output - quantity Index**	**Growth of labor**	**Growth of capital**	**Growth of intermediate inputs**	**Growth of combined weighted inputs**	**Multifactor productivity**
	‘(1)	**‘(2)**	**‘(3)**	**‘(4)**	**‘(5)**	**‘(6)**
1988	12.4	(8.3)	3.1	14.7	4.7	7.7
1989	4.8	2.1	0.7	6.0	3.8	1.0
1990	5.7	(1.8)	(3.8)	12.0	5.2	0.6
1991	2.0	(1.1)	(3.8)	(2.1)	(2.1)	4.1
1992	8.3	0.2	(4.5)	9.7	4.5	3.8
1993	4.0	5.6	2.8	2.1	3.3	0.7
1994	9.3	5.6	13.3	9.4	8.8	0.6
1995	2.7	3.9	13.0	3.2	5.0	(2.3)
1996	5.4	2.5	4.7	7.0	5.3	0.2
1997	4.6	2.9	9.3	4.5	4.8	(0.2)
1998	7.3	4.1	5.0	10.7	7.7	(0.4)
1999	5.3	3.9	3.3	9.0	6.6	(1.3)
2000	2.5	2.1	2.4	3.8	3.1	(0.6)
2001	(6.2)	1.4	(2.2)	(6.9)	(3.7)	(2.5)
2002	(1.7)	(3.3)	(2.7)	(3.2)	(3.1)	1.4
2003	(6.0)	(1.1)	(1.6)	(11.3)	(6.4)	0.4

Sources: Bureau of Economic Analysis internet site. For data on gross output, intermediate inputs, and labor: Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm.

For labor data for 1987 - 1997, BEA internet site; see Appendix A. For data on fixed assets: National\Fixed Assets\All Fixed Asset Tables\Section 3 - Private Fixed Assets by Industry: table 3.2ES and table 3.1ES. http://www.bea.doc/bea/dn/FA2004/SelectTable.asp

Note:The growth rate for 1988 is calculated with variable values for 1987 and 1988.
Consequently, there are not growth rates for 1987.

With regard to individual components of the trucking MFP framework, one observes (Table 2) that gross output grew at positive rates during the period of analysis—with the exception of the last three years (2001-2003). Labor also increased at positive rates for most years over time, while during the last two years (2002, 2003), it experienced negative growth rates.

Capital data do not indicate a consistent trend over time: years of positive growth rates are followed by negative growth rates. Years in which capital in the industry had negative growth rates include the last three years of analysis. The intermediate inputs also do not show a consistent trend over time. In most of the years, these purchases experienced a positive growth rate, while in the last three years, they had negative growth rates.

In summary, the data and calculations indicate that the trucking industry was increasing in activity/output and inputs in the first half of the period of analysis—the late 1980s and early 1990s. Multifactor productivity also increased over this period. This situation changed significantly during the late 1990s and in 2000 and 2001. During this period, trucking experienced decreases in output, factor inputs, and multifactor productivity. However, during the last two years of analysis—2002 and 2003—MFP in trucking increased. During the same period, output and factor inputs decreased. This implies increasing efficiency in the utilization of the available inputs in the industry.

Calculations with the Tornqvist Index

Calculations: 1987-2003

Calculations are also carried out by the use of the Tornqvist index methodological framework. In this case, the inputs of labor, capital, and intermediates purchases are aggregated into a chained Tornqvist index (See Appendix B). Data on gross output are available in terms of a chain-type quantity index. Estimates of trucking MFP levels are obtained by relating the combined input index to the quantity output index. Growth rates of MFP are calculated starting with 1989. The results of the calculations are presented in Table 3.

The index numbers in column 3 of the table indicate increases and decreases of trucking MFP levels over time. One does not observe a persistent trend. The growth rates (column 4) provide a picture that is clearer to interpret. These growth rates again indicate that MFP in trucking grew at positive rates during the late 1980s and the first half of the 1990s. This changed in the second half of the 1990s and the first two years of the 2000s, when one observes negative growth rates of MFP. In the last two years of analysis, 2002 and 2003, trucking MFP is again observed to grow at positive rates.

One also observes that these growth rates of trucking MFP are quite similar to those obtained by using the annually-weighted growth rates of inputs (basic growth-accounting methodology), presented in Table 2. The two sets of MFP growth rates are compared in Appendix Table F. For some years, the two sets of growth rates are the same; while for other years, the growth rates differ somewhat. Therefore, the calculations indicate only small differences in the results from the two versions of the estimating methodology. Consequently, it appears that these two methods are relatively good substitutes for each other.

MFP Calculations with Land

This section presents estimates of the quantity and cost share for land used in truck transportation, and includes that factor input in calculating MFP for the industry. The data for output, capital, and intermediate inputs have been described previously. The data for the labor input used refer to FTE employees; and the data for labor compensation were obtained from the BEA's Input-Output accounts. The data on FTEs are compatible with the Input-Output data on labor compensation (for the labor cost share).

The land used by the trucking industry for this study relates to privately owned land; this includes land used for terminals, maintenance facilities, office buildings, parking lots, etc. It does not include land used for public capital, such as highways. This is similar to the measurement of land by BLS

TABLE 3 Multifactor Productivity in Trucking
(Tornqvist methodology, without land input)

Year	Indexes (2000=100)			Growth
	Gross output - chain-type quantity index	Combined inputs index	Multifactor productivity index	MFP growth (percentage rate of change)
	‘(1)	‘(2)	‘(3)	‘(4)
1987	48.704	56.623	86.01	
1988	54.737	58.610	93.39	8.6
1989	57.379	60.812	94.35	1.0
1990	60.676	63.663	95.31	1.0
1991	61.887	62.338	99.28	4.2
1992	67.012	64.977	103.13	3.9
1993	69.712	67.113	103.87	0.7
1994	76.230	73.040	104.37	0.5
1995	78.289	76.714	102.05	-2.2
1996	82.536	80.714	102.26	0.2
1997	86.318	84.544	102.10	-0.2
1998	92.626	91.045	101.74	-0.4
1999	97.515	97.002	100.53	-1.2
2000	100.000	100.000	100.00	-0.5
2001	93.829	96.172	97.56	-2.4
2002	92.202	93.159	98.97	1.4
2003	86.711	86.993	99.68	0.7

Sources: Bureau of Economic Analysis internet site. For data on gross output, intermediate inputs, and labor: Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm

For labor data for 1987 - 1997, BEA internet site; see Appendix A.

For data on fixed assets: National\Fixed Assets\All Fixed Asset Tables\Section 3- Private Fixed Assets by Industry: table 3.2ES and table 3.1ES. http://www.bea.doc/bea/dn/FA2004/SelectTable.asp

for industry studies of multifactor productivity. The land used for public capital, such as highways, in trucking MFP will be assessed in an upcoming study.

This study estimates a land stocks index by using an approach similar to that of BLS, with some modification. In estimating the land input for MFP calculations, that agency uses a result from a study by Manvel (1968). According to that study, the value of industrial land in 1966 accounted for 24% of the total value of industrial land and structures in 1966. Consequently, in BLS industry studies of MFP, an industry's wealth stock of structures in 1966 is multiplied by the ratio 0.24/0.76 (land/structures) to estimate the value of land for the industry in 1966. This estimate is then extrapolated backward and forward, in correspondence with changes in the gross value of structures stocks in constant dollars (of the industry). The gross structures stocks are the capital stocks without deductions for depreciation. In this regard, the position is taken that land does not depreciate, since its service life is (for practical purposes) infinite and its ability to provide services over time does not decline. The resulting land estimate is in constant dollars since the calculation uses the constant dollar value of structures as the extrapolator.[10] One notes that a measurement in constant dollars implies a measurement in quantity terms, since the effect of price changes is taken out.

This study uses the quantity index of the net structures stocks of the trucking industry for extrapolation, instead of the gross structures stocks.

[10] Communications with BLS staff, Office of Productivity and Technology.

This has been affected by two considerations. First, BEA has stopped producing estimates of gross capital stocks; consequently, a NAICS-based gross structure stock index for the trucking industry is not available from that source. In addition, the Manvel estimates of the 1966 values for land and structure were based on data of locally-assessed taxable real estate. Since property assessments are expected to reflect the physical and economic conditions of the properties assessed, the land-to-structures ratio can be interpreted as the relationship between the values of land and depreciated structures. Therefore, the net stock of structures would seem to be appropriate for the estimation of land stock.

A complication in measuring land stocks is that the BLS procedure requires the structures (wealth stock) of the trucking industry, in constant prices, to be available for 1966; however, the BEA structure series (quantity index), under NAICS, is available only from 1987 to 2003. SIC data (value and quantity), however, are available from BEA that go back to 1966.[11] Consequently, this study extrapolates NAICS data for structures by using SIC data for structures for the SIC industry Trucking and Warehousing. Moreover, there are data on structures available for overlapping years between the SIC and NAICS series. Consequently, the ratio between the two series (in current prices) for 1987 and 1988 (the earliest overlapping years) was used to extrapolate the NAIC series backward to 1966. This results in an estimate of the land value, in current prices, used in 1966 by truck transportation. This value is the same as the value of land in 1966 dollars (i.e., constant prices). This value in constant dollars is subsequently extrapolated forward by the movement of the NAICS Structures stock (quantity) for truck transportation.

The estimated land input is then combined with the structures and equipment stock index, by Tornqvist aggregation, and this results in a capital input index of reproducible and non-reproducible capital. The capital input index is approximated by the capital stock index. The results of the calculations on the land input (land index) are shown in Appendix G.

[11] The data were kindly provided to BTS by BEA staff, Fixed Asset Accounts.

Weights of Inputs

The weights of the inputs used in the estimation of industry MFP are the cost of each input (labor, capital, land, and intermediate inputs) in the total costs of the industry. The total costs of the industry are the combined cost of each factor input.

Data on costs for labor and intermediate inputs are available in the BEA "GDP-by-Industry" accounts. Labor compensation is the labor cost, including wages and fringe benefits. The value of total intermediate inputs is the total intermediate input cost. Total industry costs are measured as gross industry output, in terms of revenues, minus indirect business taxes (sales taxes).

The weights for structures, equipment, and land are estimated in this study. These three types of capital assets comprise the capital input of the industry. This study measure *total capital costs* (of the capital assets) in the trucking industry by the industry's *gross operating surplus*. The gross operating surplus consists of pre-tax income and depreciation of fixed capital assets.

To provide a simple description of the concepts:

1. Profit or Income before (corporate income) taxes = Total revenues—Total costs;
2. Depreciation = amount deducted from income for "wear" of fixed capital assets
3. Gross operating surplus = Income (before tax) + Depreciation.

This "gross operating surplus" is taken as the cost of industry capital. This would be the cost of capital for the use of structures, equipment, and land—that is, the total costs of the industry and it would be the overall weight for the industry capital input.

The calculations take structures and equipment as one segment of industry capital (reproducible capital) and land as another segment (non-reproducible capital). Structures-equipment and land are eventually combined into a capital index; consequently, one needs the cost of these asset classes, to be used as weights in the aggregation. In this regard, *total capital costs* (*gross operating surplus*) of truck transportation are allocated between structures-equipment (costs) and land (costs).

This allocation is based on two assumptions, needed for the calculations of land costs: The source data (BEA) provide data on *values*; however, one needs data on *costs* to calculate land costs. The two assumptions are:

1. The share of structures value in the total value of structures and equipment (available BEA data) is the same as the share of structures cost to total costs of structures and equipment.

$$a)\ \frac{\text{Structures value (BEA)}}{\text{Structures \& Equipment value (BEA)}}$$

$$=$$

$$b)\ \frac{\text{Structures cost}}{\text{Structures \& Equipment cost}}$$

2. The ratio of the land cost to the cost of structures (net of depreciation) is the same as the ratio of the land value to the structures value.

$$c)\ \frac{\text{Land value (Manvel)}}{\text{Structures value (Manvel)}}$$

$$=$$

$$d)\ \frac{\text{Land cost}}{\text{Structures cost (net)}}$$

With the above assumptions, the estimation of the land cost is estimated by obtaining values for the relevant variables in the relationships shown above. Initially, the cost of structures is separated from total capital costs (gross operating surplus). The cost of structures is net of depreciation; the structures cost is used to estimate the land cost, and land does not depreciate. The land cost is assumed to be equal to 0.24/0.76 times the cost of structures (net of depreciation). The steps in the estimation of land cost are described in Appendix H. The weights used for the inputs in the calculations that include land are shown in Appendix I.

Results of MFP in Truck Transportation

The estimated levels and growth rates of MFP for truck transportation, with a measurement for land, are calculated for the period of analysis and various subperiods. The results are presented in Table 4. The annual growth rates show that MFP in trucking grew at positive rates during 1988 to 1994, and in 1996. It grew at negative rates in 1995, and during 1997 to 2000. In the last 3 years of analysis, 2001 to 2003, truck MFP again grew at positive rates.

The growth rates for longer periods summarize changes in truck MFP over time. Over the entire period of analysis, truck MFP increased at an annual rate of 0.8%. The period of analysis can be subdivided into three subperiods: 1987-1995, 1995-2001, and 2001-2003. The calculation results indicate that during the first subperiod (1987-1995), truck MFP increased at an average rate of 2.0% per annum. In contrast, during the second subperiod, of 1995-2001, MFP decreased at an annual rate of -0.8%. During the last subperiod (2001–2003), truck MFP again increased, at an annual rate of 1.1%.

In addition, it is possible to compare the MFP results shown in Table 4 with those of a recent study by Triplett and Bosworth (2004). They estimated MFP for the SIC industry Trucking and Warehousing, for a shorter period than of our analysis. Growth rates of those calculations are presented in Table 5 along with BTS-estimated growth rates of the NAICS Truck Transportation industry—for the two periods shown. In comparing the two sets of MFP results, one notes a general consistency between the BTS results and those of Triplett-Bosworth even though there is, at least, a difference in industry coverage. According to both sets of results, the trucking industry shows positive growth rates of MFP during 1987 to 1995; they become negative growth rates during 1995 to 2001.

From another perspective of assessing the MFP results, one also notes that the MFP estimates in Table 3 are quite similar to the results shown in Table 4. The estimates in the former table do not

TABLE 4 Multifactor Productivity in Trucking
(Tornqvist methodology with land input)

Year	Indexes (2000=100) Output index	Combined input index	Multifactor productivity	Growth: MFP growth (percentage)	Time period	Growth of MFP (annual percentage)
1987	48.70	55.8	87.29			
1988	54.74	58.2	94.00	7.69		
1989	57.38	60.4	94.96	1.02		
1990	60.68	63.3	95.83	0.92		
1991	61.89	62.0	99.81	4.15		
1992	67.01	64.7	103.63	3.83		
1993	69.71	66.8	104.41	0.76		
1994	76.23	72.7	104.86	0.43		
1995	78.29	76.4	102.48	-2.27	1987-1995	2.0
1996	82.54	80.4	102.62	0.13		
1997	86.32	84.3	102.37	-0.24		
1998	92.63	90.9	101.91	-0.45		
1999	97.52	96.9	100.60	-1.29		
2000	100.00	100.0	100.00	-0.59		
2001	93.83	96.2	97.50	-2.50	1995-2001	-0.8
2002	92.20	93.3	98.86	1.39	1995-2003	-0.4
2003	86.71	87.1	99.57	0.72	2001-2003	1.1
					1987-2003	0.8

Sources: Data for output, labor, and intermediate inputs were obtained from BEA Industry Accounts at: http://www.bea.gov/bea/dn2/gdpbyind_data.htm. Data for fixed assets, from Fixed Assets Accounts at: http://www.bea.gov/bea/dn/FA2004/Details/Index.html The BTS calculations are described in the text.

TABLE 5 Comparison of Annual Growth Rates of Truck MFP

	BTS		Triplett and Bosworth	
Periods	1987 to 1995	1995 to 2001	1987 to 1995	1995 to 2001
MFP	2.03	-0.83	0.5 to 1.3	-0.2 to -0.5
Industry	NAICS Trucking		SIC Trucking and Warehousing	
Data	BEA		BEA, BLS, Census	

Source: BTS calculations; and Triplett and Bosworth (2004).

include a measure for the land input while the results of the latter table do. Thus, it would appear that the inclusion of the land input does not make a noteworthy difference to the MFP results. This, however, would seem to be related to the methodology used in this study for the measurement of land. The approach used essentially tied the land measurement to the magnitude, and change, in the stock of structures. That is, changes in land followed changes in the structures. This eliminated the effect of actual changes in the land input that might have been substantially different—in some years—from changes in the structures. In future work, it is planned for the measurement of land to be carried out by a different approach.

Two Points

There are two points to note with respect to the estimated MFP for truck transportation. First, as pointed out, the official statistics of trucking output include the output of firms whose primary output is trucking. They do not include data for in-house trucking. Therefore, such data are not available for this analysis.

Second, there is the matter of contracted services. Trucking services are sometimes contracted out by truck carriers to single owner-operators of trucks. That activity would be an intermediate purchase by the trucking firm. Consequently, the activity would be counted in the gross output of truck transportation. On the input side, the activity would be counted as an intermediate input. This measurement would not affect the estimation of MFP, since the activity is measured in both the output and input sides.

SECTION IV—COMPARISONS OF MULTIFACTOR PRODUCTIVITY

Data are available that make it possible to carry out comparisons between MFP in trucking and MFP of other transportation industries as well as of the U.S. private business sector. Such a comparison provides a broader perspective into the truck MFP estimates. Relevant data are shown in Table 6 on levels and growth of MFP. MFP estimates for truck transportation are obtained from Table 4 of this study, and they relate to NAICS data. The other MFP estimates were obtained from BLS calculations. The air transportation MFP relates to NAICS data while rail MFP relates to SIC data. Rail MFP data are available up to 1999 while the other three MFP series go beyond that year.

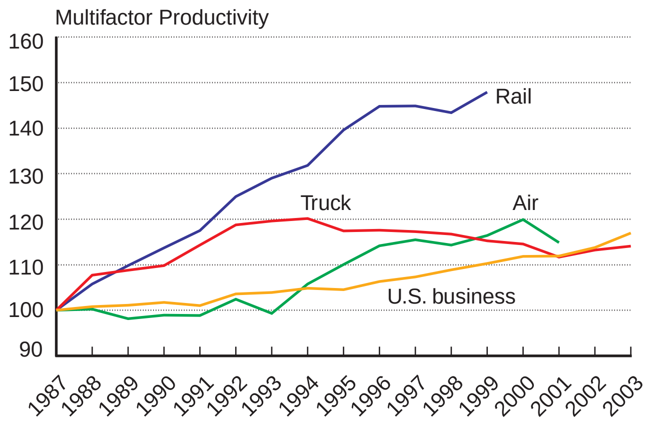
Estimates of MFP for the three transportation industries and the U.S. business sector end at different years; so, it is not possible to compare trucking with the other three series for the entire 1987-2003 period. However, all series do go up to 1999; so, MFP growth rates can be compared for the 1987-1999 period. Over that period, truck and air MFP increased at similar annual rates, of 1.2% and 1.3% respectively; while rail MFP increased at the highest annual rate of 3.3%. All three transportation industries experienced growth rates of MFP that were higher than that of the U.S. business sector of 0.9% per annum.

In addition, during 1987-1995, truck MFP increased at a faster rate, of 2.0% per annum, than MFP in air transportation, which grew at 1.2% annually. During this time period, also, the three transportation industries experienced annual MFP growth which was at substantially higher rates than that of the U.S. economy (of 0.6%).

When one compares truck MFP with the MFP of the U.S. business sector beyond the 1987-1999 period, the data in Table 6 indicate that over 1987-2000, truck MFP increased faster per year (1.1%) than the business sector (0.9%). Consequently, during this time period, truck MFP contributed positively to increases in MFP in the U.S. economy. During 1987-2001, the growth rates of truck MFP and U.S. economy MFP were the same (at 8.0%). During the 1987-2003 period, truck MFP grew at 0.8% per annum, compared to the U.S. private economy of 1.0% per year. After 2001, MFP in trucking grew at a lower rate than in the U.S. private economy.

The decrease in truck MFP during 1995-2001 was affected by a decrease in truck output—observed in Table 4 for the year 2001. This decrease in output was affected by two events in that year:

FIGURE 1 MFP in Transportation Industries and U.S. Private Business Sector (1987=100)



SOURCE: The data on which this chart is based were obtained from Table 6.

TABLE 6 Multifactor Productivity of Rail, Air, Trucking, and the U.S. Private Business Sector

	Indexes (1987=100)					Growth rates (percentage)			
Year	Rail MFP	Air MFP	Truck MFP	U.S. private business sector	Time period	Rail MFP	Air MFP	Truck MFP	U.S. private business sector
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)	'(7)	'(8)	'(9)
1987	100.0	100.0	100.0	100.0					
1988	105.8	100.2	107.7	100.8					
1989	109.8	98.2	108.8	101.1					
1990	113.7	99.0	109.8	101.7	1987-1990	4.4	-0.3	3.2	0.7
1991	117.5	98.8	114.3	101.0					
1992	125.0	102.4	118.7	103.6					
1993	129.0	99.3	119.6	103.9					
1994	131.8	105.8	120.1	104.8					
1995	139.6	110.0	117.4	104.5	1987-1995	4.3	1.2	2.0	0.6
1996	144.8	114.2	117.6	106.3					
1997	144.9	115.5	117.3	107.3					
1998	143.4	114.3	116.7	108.9					
1999	147.9	116.4	115.2	110.3	1995-1999	1.5	1.4	-0.5	1.3
2000		119.9	114.6	111.8					
2001		114.9	111.7	111.9	1995-2001		0.7	-0.8	1.1
2002			113.3	113.8					
2003			114.1	117.0	1987-1999	3.3	1.3	1.2	0.9
					1987-2000			1.1	0.9
					1987-2001			0.8	0.8
					1987-2002			0.8	0.9
					1987-2003			0.8	1.0
					2001-2003			1.1	2.3

Sources: Truck MFP from Table 4. MFP for rail, air, and the private business sector, from the BLS internet site: Productivity\Multifactor Productivity. Rail: ftp://ftp.bls.gov/pub/special,request/opt/dipts/indmfp.txt.
Air: http://www.bls.gov/mfp/mprnaics.htm Private business sector: http://www.bls.gov/news.release/prod3.t01.htm
The MFP numbers for truck, air, and the private business sector were converted to 1987=100.

1) an economic recession, and 2) the catastrophic events of 9/11/01. Subsequently, industry output dropped in 2001 while the inputs decreased but by less.

The MFP levels of Table 6 were then converted into a graphical presentation, as shown in Figure 1. There, it can be observed that truck MFP was at a higher level than that of the U.S. business sector for most of the period of analysis. However, in 2001 to 2003, it fell below that of the U.S. business.

One also observes that truck MFP reached higher levels than air MFP, for most years of the period of analysis. In 1999, however, this situation was reversed and maintained until 2001. It is not possible to make comparisons for 2002 and 2003, during which years truck MFP increased, because of unavailability of air MFP data. Finally, while truck MFP briefly exceeded the level of rail MFP in 1988, the latter increased at faster rates during the rest of the period of analysis.

SECTION V—FACTORS AFFECTING MULTIFACTOR PRODUCTIVITY IN TRUCKING

Introduction

Technology and Advances in Technology

Technology is the recipe, the "know-how," that is used by producers in different industries in order to produce a product or deliver a service. The technology utilized should be the best available technology, in order to produce a product or service at the greatest possible level (and quality), given the available inputs (resources). The production of a product or service at the maximum level (given resources) also implies that it is produced at the lowest possible cost (cost per unit).

The technology of production refers to the mixture, or factor proportions, of the inputs used in production, and the ways (or techniques) by which the inputs are combined—in order to maximize output. For services (as well as for products), the main inputs in production are: labor, capital, land, and intermediate inputs. In practice, there are various types of these main inputs. For example, the capital input includes various type of equipment and structures. The intermediate inputs include purchased materials, services, and energy inputs such as petroleum and electricity.

At a point in time, a firm, or an industry or economy, can maximize its output of a service (or product) by meeting two conditions: 1) full utilization of available resources (labor, capital, land, and intermediate inputs); and 2) by using the best technology that is available for the delivery of a service (or the production of a product). In the case of truck transportation, full utilization of resources means that trucks are full with freight at all times, on originating and return trips. It also means that trucks use roads that minimize any loss of time due to road congestion, construction, or accidents. Full utilization of trucks also implies the minimizing of the out-of-service time of trucks due to maintenance problems. With respect to the second requirement, the use of the best available technology includes the utilization of capital goods (e.g., equipment, machines) that incorporate in them the latest technological advances. This would lead to the highest possible level of output and, consequently, productivity. Capital goods can include equipment such as computers, and software.

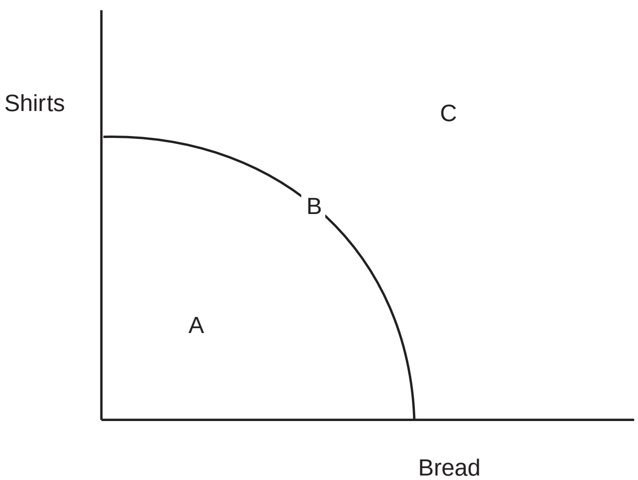
When, and if, the level of maximum output is attained, it can only increase further with additional increases in resources (labor, capital, land, and intermediate inputs) and improvements in technology. Either of these two factors require the passage of time. Over time, labor can increase through population growth, which can lead to higher numbers of labor force in the economy. Moreover, man-made capital, such as machines and structures, requires time to be created. In addition, improvements to the technology used in production can entail improvements in the quality of the inputs or by the discovery of new ways of combining the inputs used in the production process. Improvements such as these are typically the result of research and development activity, which requires time as well as expenditures. That activity may take place outside the industry that may eventually be affected. For example, improvements in computers and software can take place in the computer industry; and, subsequently, these improved capital inputs can be used in truck transportation and lead to production increases.

The above effects can be illustrated with a production possibilities frontier, shown in Figure 2. The discussion will use an economy for illustrative purposes; one could substitute an industry or a firm, and the outcomes shown would still apply. Let us assume that an economy uses its resources and makes two outputs: bread and shirts (i.e., food and clothes). The potential levels of these two outputs are shown on the two axes of the diagram.

In that case, the production relationship can be stated as:

Output = depends on (Labor, Capital, Land, Intermediate Inputs), Technology. The meaning of this relationship is that the level of output depends on the amounts of the inputs used in production—i.e., labor, etc.—and the technology used. “Technology” is outside the parenthesis; it is not a physical input like labor and capital, and it can influence the productivity of the physical inputs. Its effects are generally incorporated in the MFP or residual.

FIGURE 2 Production Possibilities Frontier



SOURCE: The production possibilities frontier is a widely known and used tool in economic courses. For example, see Dolan G. Edwin, 1983.

The production possibilities frontier (Figure 2) represents the various combinations of the two outputs that would result in the maximum level of (total) output. Point B on the curve shows the maximum output, which is possible when the economy is using its resources fully and utilizing the best available technology. Point A, which is below B, indicates an output level lower than the maximum. That level would be attained if the economy’s resources were not fully utilized. That could be the result if there was unemployed labor or capital in the economy due to an economic recession. That point would also be reached if firms in the economy did not use the best available technology and thus did not maximize their output. That level would also be attained if there were monopolies in the economy that restricted output in maximizing their profits.

In order for the economy to move to a higher production possibilities frontier—i.e., at a higher level of output, indicated by point C—there would be need for time to pass. During this passage of time, it would be possible for resources of the economy to increase. This would include population growth and hence growth in labor. Over time, there could also be an increase in capital—buildings and equipment—and land. Technology could also improve over time through the discovery of new ways of producing raw materials, intermediate inputs or final products/services.

The above discussion can be applied to the trucking industry. In that case, the trucking industry could be thought of as making two types of output—e.g., the delivery of bread and shirts. The analysis would follow the same lines as for the economy. The main point is that for the trucking industry to deliver the greatest level of transportation services, there is need to: 1) employ fully the needed inputs, and 2) use the best available technology. Also, for the level of output of the trucking industry to increase, over time, there would be need to employ more resources and/or improved technology (including a more efficient industry structure).

Factors Affecting Changes in MFP of Truck Transportation

A number of factors can affect changes in multifactor productivity at the industry level. In the case of truck transportation, there were increases and decreases in MFP over the period of analysis, and these changes can be divided into three subperiods for assessment: 1) the subperiod of 1987-1995, during which truck MFP increased by an average annual rate of 2.0%; 2) the subperiod of 1995-2001, during which truck MFP declined at an average annual rate of –0.8%; and 3) the most recent subperiod of 2001-2003, during which truck MFP increased at an annual rate of 1.1%. Thus, the analysis has the challenging task of evaluating the factors that resulted in such a changing pattern of truck MFP.

The factors which have affected changes in truck MFP—in a positive or negative manner—include: 1) Improvements in the quality of capital: computers, software, trucks (information technologies); 2) The efficiency of utilizing intermediate inputs; this includes the fuel efficiency/inefficiency of trucks; 3) Average length of haul; 4) Containerization; and 5) Changes in the structure of the industry—particularly following truck deregulation at the interstate and intrastate levels. The text below examines the effect of these factors over the period of analysis.[12]

1) Improvements in the Quality of Capital

There were improvements, over time, in the quality of capital used in truck transportation. Capital includes buildings, equipment—such as trucks and computers—and software. In truck transportation, there were increases in the capital input over time; and newer capital is typically more efficient than older capital, as it incorporates in it improvements in technology (embodied technical progress).

Table 7 present data on two measurements of the capital input in truck transportation: capital and capital per worker. These factors are assessed for the entire period of analysis (1987-2003) and for the three subperiods—1987-1995, 1995-2001, and 2001-2003. According to these calculations, the capital input increased by 43.4% over the entire 1987-2003 period (column 2). This translates into an average annual growth rate of 2.3%. With respect to subperiods, over 1987-1995, capital used in truck transportation increased by 20.6% or an annual rate of 2.4%. Over the following 1995-2001 subperiod, capital increased by a higher annual rate of 3.7%. Then, during the most recent 2001-2003 subperiod, capital decreased by -2.2% per annum.

With regard to capital per worker, this ratio increased by 20.4% over the period of analysis (column 3), or at an average annual rate of 1.2%. With respect to subperiods, capital per worker increased by 1.7% during the 1987-1995 subperiod; this growth rate declined to 0.9% over the next 1995-2001 period. During the most recent 2001-2003 subperiod, capital per worker did not grow.

The increase in capital per worker during 1987-1995 would have affected increases in truck MFP through the availability of technological advances incorporated in new capital goods. As new investment takes place in an industry, capital investment of more recent vintage incorporate newer and more efficient technology as compared to capital investment of an older vintage. These technological advances typically contribute positively to multifactor productivity.

During 1995-2001, there was an increase in capital per worker while truck MFP decreased during this period. The decrease can be attributed to the impact of other factors, which are discussed at a later point and are listed in Table 14. In the last subperiod, 2001-2003, capital per worker did not increase while truck MFP increased. In this case, MFP increases were affected by other factors besides technological advances incorporated in capital.

In order to assess more closely the possible sources of technological advances through changes in the capital stock, an assessment is carried out of more detailed types of capital assets. A channel through which technological advances

[12] Improvements in the labor force could also affect multifactor productivity in the industry. These improvements include the effects of additional training and education of labor. Lack of appropriate data prevent the direct quantification of this factor. Consequently, its impact would be included in the multifactor productivity.

can affect the productivity of truck transportation is through information technologies. This refers to the use of computers and computer software that results in improved delivery of freight. Later text in this section describes the various types of information technology used in trucking over the period of analysis. Consequently, in carrying out the assessment, data were obtained for these two variables in truck transportation, as well as data on capital stock in the form of trucks. These data are presented in Table 8; they are in the form of quantity indexes.

These data show the very rapid increases in the stock of both computers and software used in truck transportation, over the period of analysis. Over time, computers grew more than software. For computers and peripheral equipment, the index increased significantly from 100 in 1987 to 76023 in 2003. For software, the index also increased significantly from 100 in 1987 to 44,232 in 2003. In terms of growth rates, the stock of computers grew at an annual rate of 51.4% over the period of analysis. They increased at a higher annual rate of 82.5% during the first subperiod of 1987-1995. This rate declined to an impressive 30.5% per annum during the second subperiod of 1995-2001. During the most recent 2001-2003 subperiod, computers grew at a still slower rate of 11.8% per annum.

TABLE 7 Increases in Capital and Labor in Truck Transportation

	Indexes (1987=100)			Percentage rates of change			Annual percentage rates		
Year	Labor - index	Capital - index	Capital per worker - index	Growth of labor	Growth of capital	Growth of capital per worker	Period	Growth of capital	Growth of capital per worker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1987	100.0	100.0	100.0						
1988	91.7	103.1	112.4	-8.3	3.1	12.4			
1989	93.6	103.8	110.9	2.1	0.7	-1.4			
1990	91.9	99.8	108.6	-1.8	-3.8	-2.1			
1991	90.9	96.0	105.6	-1.1	-3.8	-2.7			
1992	91.0	91.6	100.7	0.2	-4.5	-4.7			
1993	96.1	94.2	98.0	5.6	2.8	-2.7			
1994	101.5	106.7	105.0	5.6	13.3	7.2			
1995	105.5	120.6	114.3	3.9	13.0	8.8	1987-1995	2.4	1.7
1996	108.1	126.2	116.7	2.5	4.7	2.2			
1997	111.2	138.0	124.1	2.9	9.3	6.3			
1998	115.7	144.8	125.1	4.1	5.0	0.9			
1999	120.3	149.6	124.3	3.9	3.3	-0.6			
2000	122.8	153.1	124.7	2.1	2.4	0.3			
2001	124.5	149.8	120.4	1.4	-2.2	-3.5	1995-2001	3.7	0.9
2002	120.4	145.7	121.1	-3.3	-2.7	0.6			
2003	119.1	143.4	120.4	-1.1	-1.6	-0.6	2001-2003	-2.2	0.0
							1995-2003	2.2	0.7
							1987-2003	2.3	1.2

Sources: The data on which these indexes and growth rates are based were obtained from the BEA internet site. For data on labor: Annual Industry Accounts; http://www.bea.doc/bea/dn2/gdpbyind_data.htm
For data on fixed assets: National\Fixed Assets\All Fixed Asset Tables\Section 3 Private fixed assets by Industry: Table 3.2ES and Table 3.1ES: http://www.bea.doc/bea/dn/FA2004/Select/Table.asp.

TABLE 8 Chain-Type Quantity Indexes for Net Capital Stock of Selected Private Nonresidential Fixed Assets

	Index numbers, 1987=100				Growth rates (annual percentage rates)				Growth rates for periods (annual)				
Year	Computers and peripheral equipment	Software	Light trucks (including utility vehicles)	Other trucks, buses and truck trailers	Computers and peripheral equipment	Software	Light trucks (including utility vehicles)	Other trucks, buses and truck trailers	Time period	Computers and peripheral equipment	Software	Light trucks (including utility vehicles)	Other trucks, buses and truck trailers
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)	'(7)	'(8)	'(9)	'(10)	'(11)	'(12)	'(13)
1987	100.0	100.0	100.0	100.0									
1988	209.6	305.6	104.4	101.6	109.6	205.6	4.4	1.6					
1989	395.5	676.2	101.9	101.2	88.7	121.3	-2.5	-0.4					
1990	552.5	1104.7	94.7	94.9	39.7	63.4	-7.1	-6.3					
1991	724.3	1621.0	87.5	88.7	31.1	46.7	-7.6	-6.6					
1992	1322.0	2866.4	76.0	82.7	82.5	76.8	-13.2	-6.7					
1993	3047.5	6484.6	71.1	84.0	130.5	126.2	-6.5	1.6					
1994	6987.6	14271.0	79.3	92.9	129.3	120.1	11.6	10.7					
1995	12326.0	19711.2	91.5	103.0	76.4	38.1	15.4	10.8	1987-1995	82.5	93.6	-1.1	0.4
1996	17530.5	22080.8	101.4	103.1	42.2	12.0	10.8	0.1					
1997	30719.2	30209.3	123.8	105.1	75.2	36.8	22.1	2.0					
1998	38498.3	35930.4	130.8	105.9	25.3	18.9	5.6	0.8					
1999	45451.4	40222.4	133.5	105.3	18.1	11.9	2.1	-0.6					
2000	56497.2	46729.0	133.1	102.5	24.3	16.2	-0.3	-2.6					
2001	60875.1	46207.5	126.5	94.2	7.7	-1.1	-5.0	-8.1	1995-2001	30.5	15.3	5.5	-1.5
2002	65339.5	44700.5	120.4	87.7	7.3	-3.3	-4.8	-6.9					
2003	76022.6	44232.7	117.8	82.7	16.4	-1.0	-2.2	-5.8	2001-2003	11.8	-2.2	-3.5	-6.3
									1987-2003	51.4	46.3	1.0	-1.2

Sources: For data on fixed assets: National\Fixed Assets\All Fixed Asset Tables\Section 3 -
Private fixed assets by Industry: Table 3.2ES and Table 3.1ES: http://www.bea.doc/bea/dn/FA2004/Select/Table.asp.

With regard to software, their stock increased steadily and significantly over time, up to 2000; it subsequently declined, but was still maintained at high levels. The pattern for software stock over time is similar to that of computers. During the first subperiod, of 1987-1995, the software stock increased at an annual rate of 93.6%. This was even higher than the rate of increase for computers. However, during the second subperiod, 1995-2001, software grew at a substantially slower, although still impressive, rate of 15.3%. This rate declined further to –2.2% during 2001-2003.

A very different picture is obtained for the stock of trucks. Light trucks (column 3) increased much slower over the period of analysis than computers or software; they increased by 17.8% over the entire 1987-2003 period. In fact, during the first subperiod (1987-1995), they experienced a decrease—from 100.0 to 91.5, or about -8.5%. In terms of growth rates, light trucks increased at an annual rate of 1.0% over 1987-2003. During the first subperiod (1987-1995), they actually declined by –1.1% per annum; during the next 1995-2003 subperiod, they increased at 5.5% per year, while during the most recent 2001-2003 subperiod, they decreased at –3.5% per year.

The capital stock of "Other trucks, buses, and truck trailers" experienced a decline over the entire 1987-2003 period (from 100.0 to 82.7). In terms of growth rates, during the entire period of analysis, the capital stock of "Other trucks, etc." decreased at an annual rate of -1.2%. During the first subperiod (1987-1995), their stock increased by 0.4% per annum. However, this changed to an annual decline of –1.5% during the 1995-2001 subperiod; the decline continued at the higher rate of –6.3% during the most recent 2001-2003 subperiod.

In summary, these data indicate the rapid growth, over the period of analysis, of the two IT-related capital assets—computers and software. By contrast, the capital stock of trucks either increased very little or declined over the same period. Consequently, changes in technology in computers and software would have been instrumental in affecting increases in truck MFP during 1987-1995. Increases in computers during the most recent 2001-2003 subperiod are also consistent with an increasing truck MFP during that subperiod. Since computers and software were increasing during 1995-2001 while MFP declined, it would appear that other factors contributed to the decreases in truck MFP during the 1995-2001 subperiod. Such factors are examined in other parts of this study.

2) Information Technologies: Hardware, Software, and Communications

Technological advances used in truck transportation include information technologies. These technologies include the use of computers and software as well as various channels of communication such as satellite communications and the internet. These technologies have affected all aspects of truck transportation services, including the operation of the truck, the selection of routes, truck maintenance, and the marketing of truck services. These technologies can be used by themselves or in combination with other IT technologies; the latter framework seems more typical.

The various information technologies that affected motor carrier operations include the following: a) On-board computers (OBC); b) Electronic data interchange (EDI); c) Automatic vehicle location (AVL); d). Satellite communications (SATCOM): e) Computer-aided dispatching (CAD), and Computer aided routing (CAR); f) Truck maintenance; and g) Transactions of truck services (marketing, operations). These technologies and their impact on trucking productivity are discussed below.

On-Board Computers (OBCs)

On-board computers are truck-based or handheld computers, used to obtain information on truck performance. These computers collect and process data received from sensors, and other devices, located on trucks. They keep records of readings and provide the fleet operator with performance information on the trucks and drivers. OBCs can be used as trip recorders and to monitor drivers' hours of service and vehicle performance measures, such as speed and fuel consumption. OBCs are also used in conjunction with computer-aided routing and dispatching systems and with maintenance-scheduling software. On-board computers also become involved in the Automatic Vehicle Location system, described below.

On-board computers can contribute to increased productivity in the following ways:

Business Transactions. The computer on the truck registers delivery times of freight and customer signatures for proof-of-delivery. This has reduced paperwork and thus labor time to do such paperwork.

Driver Log. With OBC, drivers can input records of hours of service and fuel consumption. Such data make possible an assessment of fuel utilization, leading to truck speeds that minimize the use of fuel. Increased efficiency in the use of fuel, an intermediate input, would increase MFP. A reduction of total intermediate inputs, in relation to output, is not observed in trucking over the period of analysis—except for the last 2 to 3 years. It will be shown that the fuel efficiency in trucking decreased over the period of analysis.

Data Collection on Vehicle Performance. On-board-computers provide information on various parts of truck performance. These include: engine idling, braking, and patterns of shifting and acceleration. The computer also provides data, from diagnostic systems, on ancillary equipment on the truck such as refrigeration units. Consequently, OBCs allow for remote diagnostics prior to a malfunction of the truck; this can be followed by preventive maintenance. Prompt preventive maintenance and repair improve the performance of trucks and reduce their out-of-service time. This results in higher levels of output and MFP.

Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) systems include computers and software that are used to send and receive electronic messages and data transmission between computers of two parties. The transmission can occur between trucking companies and shippers (or between any two trading partners). This technology enables the transmission of information, including electronic transactions, between companies in an easier, more accurate, and timely manner. EDI allows for efficient *billing* and receipt of freight-delivery acknowledgement.

The use of computers for financial transactions reduces paperwork and related labor costs, and thus reduces costs of business transactions. This increase multifactor productivity.

Automatic Vehicle Location (AVL) and Satellite Communications (SATCOM)

Automatic vehicle location (AVL) refers to a broad category of ground-based or satellite technologies, with which it is possible to track the location of trucks. Dispatchers, drivers, shippers, and receivers can track a truck from pickup to delivery of freight; coordinate inter-modal shipments; and perform just-in-time deliveries. In addition to vehicle tracking, SATCOM technologies provide communication between the dispatchers and the truck drivers; this allows for real time coordination of fleet routing and dispatching activities. With an on-board computer, two-way text or voice communications can allow for routing and dispatching of trucks in current time/real time, as well as the (real-time) monitoring of vehicle operating parameters such as speed, etc. With this system, the motor carrier can also locate a truck in case of a breakdown. This results in less out-of-service time, and thus higher levels of output (freight delivered) and MFP.

Computer-Aided Routing (CAR) and Dispatching (CAD)

These technologies involve computer hardware and specific software that are used for dispatching, routing, and decision support for route selection of trucks. Good route selection can contribute to minimizing the time and cost of moving freight. These systems are used to schedule drivers and trucks subject to parameters, such as allowable driving hours, size of load, and origin and destination. The basic systems allow for the planning and scheduling of truck activities prior to the dispatch of a truck. In addition, more sophisticated systems allow for routing and dispatch decisions based on real-time truck locations; estimate delivery times and distances; help improve cost estimates; and generate route maps.

The technologies of computer-aided dispatching (CAD) and computer-aided routing (CAR) lead to improved fleet routing and dispatching. This results in an increased utilization of trucks. This includes a reduction in the number, and extent, of empty trucks, particularly on back hauls. This increases trucking output and, consequently, raises truck productivity and MFP.

Computer-aided dispatching and routing provide for improved dispatcher productivity. This technology results in less time needed for truck carriers' staff to complete routing procedures as compared to previous manual systems. These technologies also improve communication efficiency. With a computerized system, information to drivers can be relayed instantaneously. Consequently, information on a pick-up of freight can be transacted by the truck carrier and the information relayed quickly to an appropriate truck driver, who is close to the freight. This results in increased output (load) for that particular truck, and greater output for the trucking firm—and for the trucking industry.

Truck Maintenance

Technological advances have affected positively truck maintenance through the increased use of maintenance-tracking software (MTS). These software improve the maintenance of trucks by tracking and reordering parts for the repair department of a truck fleet. These software also carry out real-time diagnostics of trucks. As information becomes promptly available on the performance of trucks, maintenance tracking software is used to schedule preventive and emergency repairs, as needed, in the most cost-effective manner. Preventive maintenance reduces maintenance costs as potential problems are repaired before they become bigger and more expensive jobs. This also reduces the out-of-service time of trucks.

Marketing of Truck Services

There has been an increase in the use of computerized systems for the buying and selling of truck transportation services. These include hardware, software, the internet, and satellite communications. The result is higher delivered freight output for the quantity of labor and capital used; this increases production efficiency/MFP.

In summary, information technology contributed to productivity in truck transportation in a number of ways:

On the *operations* side, computers have been used for communications between the truck carrier and the truck drivers. These communications helped carriers increase vehicle utilization through increased monitoring and reducing unnecessary out-of-route miles by drivers. Information availability on road work or the closing of roads (as a result of accidents) enables the driver to avoid the affected roads and choose other routes. These computers have also been used to schedule trips by trucks, including which freight to deliver and which roads to take. Information technologies would also contribute to lower fuel costs through improved routing. Improved routing would entail the choice of the quickest (and lower cost) route between two points.

On the *maintenance* side, computers have been used to schedule regular maintenance checks for trucks. Computers have also been used to check for problems developing in trucks. This can prevent a breakdown of a truck on the road with the accompanying negative effects of the truck being out-of-service.

On the *administrative* side, the use of computers would include personnel transactions and records. Personnel information would relate to the keeping of records for full-time truck drivers and those on a contractual basis. Since the trucking industry has had substantial turnover of drivers, the keeping of correct and updated personnel records would be of particular importance. On the sales side, computers have been used to obtain receipts when the freight is delivered. This entailed electronic transactions and the electronic dissemination of such information. Administrative costs fell as new technologies were adopted that involved paperless transactions.

Finally, it is noted that the data on computers and software would not include information technology equipment utilized on the trucks themselves. The latter would be part of the truck and they would have been included in the measurement of the capital stock for trucks.

3) Intermediate Inputs

An industry's MFP can also be affected by its efficiency in utilizing intermediate inputs. In examining this point, the ratio was calculated of intermediate inputs to gross output of the trucking industry, and the results are shown in Table 9. These results indicate that in terms of current prices, intermediate inputs accounted for about 50% of gross output over the period of analysis (column 3). Moreover, over time, there was an increase in the ratio of intermediate inputs to gross output. Intermediate inputs were 47% of gross industry output in 1987; in subsequent years, the ratio increased and reached a high of 56% in 2000. However, from 2001 to 2003, the ratio declined (from 55% to 51%).

Since the ratio in current prices could be affected by increases in the relative price of intermediate inputs (including fuel), tabulations were also carried out in quantity terms. These tabulations are in terms of growth rates, and are shown in Table 9, particularly columns 7 and 8. They support the results of calculations in current price.

The growth rates in quantity terms indicate that over the period of analysis, the quantity of intermediate inputs increased faster than output of the trucking industry. This is also observed for the two subperiods of 1987-1995 and 1995-2001. However, this trend was reversed in 2001, and over the most recent 2001-2003 period, both the quantity of output and intermediate inputs decreases. During that period, intermediate inputs decreased at a substantially faster rate annual rate (-7.3%) than output (-3.9%).

Thus, these numbers, in current dollars and in quantity terms, indicate that there was a decline in the efficiency with which intermediate inputs were utilized in trucking, over 1987-1995 and 1995-2001. However, there was an increase in the efficiency of utilizing intermediate inputs over the most recent period 2001-2003. The decrease in the efficiency of utilizing intermediate inputs, during 1995-2001, was a contributory factor to the declining truck MFP during that period. Also, the efficiency of utilizing intermediate inputs in truck transportation was increasing over the last three years of the period of analysis. This would have contributed to the increasing MFP during those years.

In attempting to explain the decrease in efficiency of utilizing intermediate inputs over most years of the period of analysis, one notes that a major intermediate input in truck transportation is fuel. Therefore, an examination is carried out of fuel efficiency in trucking.

One would expect that improvements in the capital input of truck transportation would include the use of newer trucks that incorporate in them the results of new technologies. These new technologies would include truck engines that are more fuel-efficient than older engines. Improvements in fuel efficiency are expected to result in reduced use of fuels and consequently of intermediate inputs. This would contribute to increased efficiency of the industry in using intermediate inputs, which would have contributed positively to truck MFP.

In evaluating such a possibility, data on fuel efficiency are presented in Tables 10 and 11. Data in Table 10 are for heavy single-unit trucks; they indicate that there was a rather steady increase in the fuel efficiency of these trucks over the 1987-2002 period. Their fuel efficiency increased over time from 6.4 miles per gallon (mpg) in 1987 to 7.5 in 2001; it declined slightly to 7.4 mpg in 2002. Calculations with growth rates (in the same table) show a similar development. Fuel efficiency of these trucks increased at an annual rate of 0.8% during 1987-1995; it increased rather substan-

TABLE 9 Intermediate Inputs to Output in Truck Transportation

Year	Current prices			Quantity indexes		Growth rates (percentage)		
	Gross output (current $ billions)	Intermediate inputs (current $ billions)	Interm. inputs to gross output [(2)/(1)]	Output index (2000=100)	Interm. input index (2000=100)	Time period	Output	Intermediate inputs
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)	'(7)	'(8)
1987	$82.5	$38.6	0.47	48.70	42.398			
1988	$92.9	$45.0	0.48	54.74	48.613			
1989	$101.0	$49.9	0.49	57.38	51.553			
1990	$111.6	$59.0	0.53	60.68	57.752	1987-1990	7.6	10.9
1991	$111.9	$57.8	0.52	61.89	56.016			
1992	$121.1	$64.0	0.53	67.01	62.016			
1993	$127.9	$66.2	0.52	69.71	63.298			
1994	$141.8	$73.4	0.52	76.23	69.218			
1995	$148.0	$77.9	0.53	78.29	71.421	1987-1995	6.1	6.7
1996	$157.0	$85.0	0.54	82.54	76.409			
1997	$168.2	$89.8	0.53	86.32	79.823			
1998	$184.1	$97.9	0.53	92.63	88.337			
1999	$198.7	$108.8	0.55	97.52	96.326			
2000	$213.2	$120.4	0.56	100.00	100.000			
2001	$205.7	$112.4	0.55	93.83	93.128	1995-2001	3.1	4.5
2002	$204.1	$108.7	0.53	92.20	90.166	1987-2001	4.8	5.8
2003	$196.8	$99.6	0.51	86.71	79.979	2001-2003	-3.9	-7.3
						1987-2003	3.7	4.0

Sources: BEA internet site. Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm.

tially at 1.6% per annum during the 1995-2001 subperiod.

Table 11 presents data on the fuel efficiency of combination trucks. These trucks use one or more trailers. Consequently, they would carry greater and heavier freight than single unit trucks. The data presented indicate, for one, that these trucks had lower fuel efficiency than single unit trucks. In 1987, the combination trucks obtained 5.7 miles per gallon compared to 6.4 miles per gallon for the single unit trucks. Moreover, the fuel efficiency of the combination trucks decreased over the period of analysis, from 5.7 mpg in 1987 to 5.2 mpg in 2002. That implies a decline of –0.6% per year. Consequently in 2002, these trucks were even less fuel-efficient (at 5.2 mpg) than in 1987 (5.7 mpg); they were also considerably less fuel-efficient than the single-unit trucks which obtained 7.4 mpg in 2002.

With respect to subperiods, the fuel efficiency of combination trucks increased by 0.2% annually, during 1987-1995. However, during the subsequent subperiod of 1995-2001, their fuel-efficiency declined significantly at an annual rate of -1.2%. This decline in fuel efficiency would have contributed to the decline in the efficiency of utilizing intermediate inputs during 1995-2001 (shown in Table 9); it would also have been a contributory factor in the declining truck MFP during 1995-2001.

Moreover, the number of miles traveled by the less fuel-efficient combination trucks have been greater than those traveled by the single-unit trucks, by rather substantial magnitudes (column 2 of Tables 10 and 11). Consequently, the fuel efficiency of the truck transportation industry, in total, declined over the period of analysis—and particularly over the last several years of the period. A declining fuel efficiency is consistent with, and contributes to, the decrease in the industry's efficiency in the utilization of intermediate inputs observed previously. This, in turn, is consistent with a declining MFP observed over the 1995-2001 subperiod.

4) Average Length of Haul

Changes in the average length of haul (ALOH) can affect multifactor productivity in trucking. An increase in the average length of haul—affected by longer truck trips (distance from origin to destination)—can contribute to better fuel efficiency and an improved utilization of other intermediate inputs such as engine oil, etc. This would affect positively the efficiency of utilizing intermediate inputs which, in turn, affects MFP.

It has already been observed that truck transportation experienced a decline in the efficiency of utilizing intermediate inputs, with the exception of the more recent 2001-2003 period. An objective of analyzing the average length of haul will be to assess whether this factor contributed to the decline in fuel efficiency of the industry or whether it served as an offsetting factor to that decline.

Table 12 presents data on the average length of haul (ALOH) of trucks. These numbers in-

TABLE 10 Fuel Efficiency of Heavy Single-Unit Trucks, 1980–2002

Year	Registrations (thousands)	Vehicle travel (million miles)	Fuel use (million gallons)	Fuel efficiency (miles per gallon) [(2)/(3)]
	'(1)	'(2)	'(3)	(4)
1980	4,374	39,813	6,923	5.8
1981	4,455	39,568	6,867	5.8
1982	4,325	40,658	6,803	6.0
1983	4,204	42,546	6,965	6.1
1984	4,061	44,419	7,240	6.1
1985	4,593	45,441	7,399	6.1
1986	4,313	45,637	7,386	6.2
1987	4,188	48,022	7,523	6.4
1988	4,470	49,434	7,701	6.4
1989	4,519	50,870	7,779	6.5
1990	4,487	51,901	8,357	6.2
1991	4,481	52,898	8,172	6.5
1992	4,370	53,874	8,237	6.5
1993	4,408	56,772	8,488	6.7
1994	4,906	61,284	9,032	6.8
1995	5,024	62,705	9,216	6.8
1996	5,266	64,072	9,409	6.8
1997	5,293	66,893	9,576	7.0
1998	5,414	67,894	9,741	7.0
1999	5,763	70,304	9,372	7.5
2000	5,926	70,500	9,563	7.4
2001	5,704	72,448	9,667	7.5
2002	5,651	75,887	10,305	7.4
Growth rates—average annual percentage rates				
1987–2002	2	3.1	2.1	1
1987-1995	2.3	3.4	2.6	0.8
1995-2001	2.1	2.4	0.8	1.6
2001-2002	-0.9	4.7	6.6	-1.3

Source: U. S. Department of Transportation, Federal Highway Administration, Highway Statistics 2002, Washington, DC, 2003, Table VM1 and annual. (Additional resources: www.fhwa.dot.gov).

Note: Heavy single-unit trucks include all single-unit trucks which have more than two axles or more than four tires. Most of these trucks would be used for business or for individuals with heavy hauling or towing needs.

TABLE 11 Fuel Efficiency of Combination Trucks, 1980–2002

Year	Registrations (thousands)	Vehicle travel (million miles)	Fuel use (million gallons)	Fuel efficiency (miles per gallon) [(2)/(3)]
	‘(1)	‘(2)	‘(3)	‘(4)
1980	1,417	68,678	13,037	5.3
1981	1,261	69,134	13,509	5.1
1982	1,265	70,765	13,583	5.2
1983	1,304	73,586	13,796	5.3
1984	1,340	77,377	14,188	5.5
1985	1,403	78,063	14,005	5.6
1986	1,408	81,038	14,475	5.6
1987	1,530	85,495	14,990	5.7
1988	1,667	88,551	15,224	5.8
1989	1,707	91,879	15,733	5.8
1990	1,709	94,341	16,133	5.8
1991	1,691	96,645	16,809	5.7
1992	1,675	99,510	17,216	5.8
1993	1,680	103,116	17,748	5.8
1994	1,681	108,932	18,653	5.8
1995	1,696	115,451	19,777	5.8
1996	1,747	118,899	20,192	5.9
1997	1,790	124,584	20,302	6.1
1998	1,831	128,159	21,100	6.1
1999	2,029	132,384	24,537	5.4
2000	2,097	135,020	25,666	5.3
2001	2,154	136,584	25,512	5.4
2002	2,277	138,643	26,451	5.2
Growth rates—average annual percentage rates				
1987-2002	2.7	3.3	3.9	-0.6
1987-1995	1.3	3.8	3.5	0.2
1995-2001	4.1	2.8	4.3	-1.2
2001-2002	5.7	1.5	3.7	-3.7

Source: U. S. Department of Transportation, Federal Highway Administration, Highway Statistics 2002, Washington, DC, 2003, Table VM1 and annual. (Additional resources: www.fhwa.dot.gov).

Note: The Federal Highway Administration changed the combination truck travel methodology in 1993. Combination trucks include all trucks designed to be used in combination with one or more trailers. The average vehicle travel of these trucks (on a per truck basis) far surpasses the travel of other trucks due to long-haul freight movement.

dicate that the average length of haul increased over the 1985 to 2001 period. This increase took place steadily over time—so that while in 1985, the ALOH was 589 kilometers, by 1995, it had risen to 669 kilometers. By 2001, it had increased still further to 781 kilometers. In terms of rates of increase, the average length of haul increased faster during the more recent 1995-2001 period (2.6% per year) as compared to the 1985-95 period (1.3% per year).

The data indicate that increases in the average length of haul would have contributed positively to the overall efficiency/MFP of the trucking industry. With regard to subperiods, the increase in the ALOH over 1985-1995 would have contributed to the increase in truck MFP during that time. During the second subperiod, 1995-2001, the ALOH of trucks is shown to have increased while truck MFP declined. During this time, the ALOH acted to offset the negative impact of other factors on the declining truck MFP.

5) Containerization

Containerization refers to the movement of commodities in (large) containers rather than in smaller units. The use of containers in transportation includes rail-truck and truck-water transport, and has become more widespread over time. Within the continental United States, containers are used to transport cargo by truck from a point of origin to a particular destination. They are also used in the intermodal market, which includes the transportation of freight by truck to, and from, a train or a ship. Intermodal firms link different forms of transportation for ultimate delivery to the customer. Containers have become an integral component of intermodal transportation, which has been expanding over time.

Containers are part of the capital input of the truck transportation industry. They represent a technological improvement over previous ways of transporting freight (use of smaller boxes, etc.) and are thus an improvement in the quality of the capital input. The technological advances are incorporated into the capital input. Thus, the impact of the use of containers would be measured in the MFP of the industry.

The use of containers resulted in an increased use of automation in the loading and unloading of trucks. Because commodities are in containers, cargo is moved by crane or forklift; this procedure requires less manual labor than the handling of smaller packages. Consequently, the utilization of this mode of handling freight reduces the time required to transfer cargo; this increases productivity and reduces handling costs. The use of containers also tends to reduce the cost of damage or theft of freight. The benefits of using containers include: reduced employee injuries; reduced damage to the truck; and improvement in loading efficiencies. Thus, containerization contributes to increased productivity/MFP.

In order to examine the impact of this factor, data on containers were collected and tabulated. It is difficult to find a central source of such data with a comprehensive data base, for the years that cover the period of analysis. Consequently, the basic tabulation uses data on containers from the railroads, and these data are supplemented with data from other sources.

Data on containers are presented in Table 13, for the period 1990-2004. They refer to containers used in truck-rail intermodal transportation.

TABLE 12 Average Length of Haul of Trucks, 1985–2001

Year	Average length of haul (kilometers)	Time period	Growth rates (annual percentage rate)
1985	589		
1990	629		
1991	641		
1992	660		
1993	655	1985-1995	1.3
1994	631		
1995	669	1990-1995	1.2
1996	686		
1997	700		
1998	711		
1999	737		
2000	761		
2001	781	1995--2001	2.6
		1985-2001	1.8

Source: Bureau of Transportation Statistics; website: http://www.bts.gov/cgi-bin/breadcrumbs/PrintVersion.cgi?date=20102416.

TABLE 13 Use of Containters in U.S. Railroads

Year	Containers	Time period	Growth rates (annual percentage)
1990	2,754,829		
1991	3,044,574		
1992	3,363,244		
1993	3,692,502		
1994	4,375,726		
1995	4,443,709	1990-1995	10.0
1996	4,841,130		
1997	5,244,401		
1998	5,419,631		
1999	5,700,219		
2000	6,288,260		
2001	6,332,021	1995-2001	6.1
2002	6,781,022		
2003	7,329,768	2001-2003	7.6
2004	8,065,539	2001-2004	8.4
		1990-2003	7.8

Source: AAR “Railroad Facts,” 2005 edition, p. 26.

Note: Data for 2004 are preliminary.

These data indicate that the number of containers used increased by 7.8% per annum over the 1990-2003 period. Moreover, the first subperiod, 1990-1995, has the highest annual growth rate, at 10.0%. This subperiod is similar to the initial subperiod for truck MFP (1987-1995). The following subperiod, of 1995-2001, has a substantially lower growth rate for containers, at 6.1% per annum. The most recent subperiod, of 2001-2003, has a growth rate that is higher that the previous subperiod, at 7.6%.

The rates of increase in the number of containers used correspond well to the changes in truck MFP. Truck MFP was increasing during 1987-1995, while the number of containers used increased at the highest rate (over 1990-2003) during 1990-1995. Truck MFP decreased during the following subperiod, 1995-2001, and the numbers of container used increased at the lowest rate during that subperiod. Finally, truck MFP was increasing again during 2001-2003, and the use of containers was also increasing during that subperiod.

Additional data on containers are presented in two appendix tables. These data are consistent with, and reinforce, the findings based on data in Table 13. First, Appendix J presents data on containers used in waterborne trade of the U.S. That is another segment of the container market and relates to truck-ship (or ship-truck) transportation. Although these data cover fewer years than the rail data, they show similar trends. They indicate that the increase of shipping containers during the most recent subperiod, of 2001-2003, was greater than during the previous subperiod of 1998-2001. One notes that truck MFP increased during 2001-2003, while it decreased during 1995-2001.

Finally, another set of data are presented in Appendix K. These data refer to containers used in trucks that crossed the border of the United States for Canada or Mexico. These data indicate a rather steady increase in the use of containers over the 1996-2002 period (with a decline in 2003). They also show a pattern similar to that which has been observed. During the most recent 2001-2003 subperiod, the use of containers increased substantially more (at 16.4% annually) than during the previous 1996-2001 subperiod (0.6%). And truck MFP also decreased during 1995-2001, while it increased during 2001-2003.

The data on containers indicate that the use of containers was a factor that affected efficiency in truck delivery and truck MFP. The data indicate high growth of containers use during the 1990-1995 subperiod (or parts of that period) and during 2001-2003. By contrast, low increases of containers use are observed during the 1995-2001 subperiod. Changes in truck MFP corresponds quite well to changes in containers use: During the 1990 (1987) to 1995 period, and the 2001-2003 period, truck MFP increased; while during 1995-2001, truck MFP declined.

6) Changes in Industry Structure—Deregulation

The structure of an industry can change over time as a result of deregulation, mergers/acquisitions, and bankruptcies. Such changes can affect efficiency (productivity) in an industry. With respect to mergers, the acquisition of one firm by another implies that the more efficient firm acquires a less efficient firm. In that case, the more efficient firm has typically grown faster (sales), has gained significant amounts of revenues and profits, and is able to secure financial resources. All of these characteristics enable it to acquire another, less efficient firm. Two types of mergers are relevant to the analysis: horizontal and vertical. A horizontal merger combines two firms in the same industry into one firm. Consequently, in the new post-merger firm, there is expected to be merging of certain functions of the two pre-merger firms; these would include finance, payroll, and advertising. These developments result in the same output being produced but with fewer inputs such as labor, equipment, building space, and materials/services. This results in a reduction in inputs, and thus costs, and an increase in multifactor productivity. Vertical mergers involve mergers of transportation firms that provide complementary services. The provision of complementary services within the same trucking company can increase efficiency.

The structure of the trucking industry changed considerably over the period of analysis—following deregulation at the interstate level in 1980, and at the intrastate level in 1995. The latter completed deregulation in the trucking industry and made it comprehensive. The Motor Carrier Act of 1980 did not affect restrictions on intrastate commerce; and as time passed, the cost of shipping across state borders widened significantly from the cost of shipping within state borders. In 1994, 41 states still maintained some type of economic regulation over intrastate trucking, and intrastate rates were, on the average, 40 percent higher than rates for interstate freight delivery of the same distance.[13] In 1995 the Interstate Commerce Commission Termination Act was passed and it lifted economic regulation from intrastate trucking.

Deregulation—interstate and intrastate—of the trucking industry resulted in significant changes. There was a notable amount of entry in, as well as exit from, trucking. The entry side included the appearance of new truckload (TL) firms, the expansion of less-than-truckload (LTL) firms into new markets, and the emergence of third parties such as brokers. Truckload carriers were no longer restricted to predetermined routes and commodities; some of them merged and consolidated with others to provide national coverage.

The change in truck transportation from interstate deregulation, and which apparently continued after the intrastate deregulation in 1995, resulted in a decrease in the relative importance of less-than-truckload trucking and a corresponding increase in the relative importance of truckload trucking. Data on shipments, in Appendix L, show that in 1989 and early 1990s, the LTL segment of the trucking industry accounted for 39% of total shipments (LTL and TL). In 1998 and subsequent years up to 2003, the relative importance of the LTL segment decreased to 29% of total industry shipments.

While few carriers specializing solely in LTL trucking were formed since 1980, there was significant geographic expansion by existing LTL firms into each other's territories, and entry by other carriers, including carriers from other modes (e.g. rail). These new entrants included newly formed subsidiaries of existing LTL firms, and the expanded operations of truckload, small package, package express, and air cargo carriers.[14]

A comparison of the status of the 100 largest motor carriers (of property) between 1979 and 1991 shows that[15] : 1) Forty-nine carriers were operating, 37 of which were still among the 100 largest; and 2) Fifty carriers had ceased operations since 1979. At least 35 of these carriers were identified as having filed for bankruptcy.

Structural changes in the trucking industry included trucking companies diversifying out of the traditional LTL market. For example, Roadway Services, Inc. was an LTL firm, and it created a subsidiary (Roberts Transportation Services) that performed almost no standard LTL business. The subsidiary was in the business of handling rush shipments, of rather high value. Much of its revenues came from shipments that were smaller than 10,000 lbs. (i.e., technically LTL), but these shipments were not routed through traditional LTL sort terminals. Rather, most of these shipments were picked up within 90 minutes of a customer request and were dispatched directly to their destination.[16]

During the period of analysis, the LTL segment experienced significant decreases in the number of firms, accompanied by an increase in the size of the average firm. In 1975, this segment consisted of about 528 firms (generating $10.6 billion in revenues). By 1989, the segment had shrunk to 159 firms which had $13.4 billion in revenues; and by the end of 1993, there were only 108 firms, generating $16.7 billion in revenues.[17] These data indicate that over the period 1976-1993, there was a substantial change in the structure of the LTL segment of the industry and, thus, in the entire trucking industry.

[13] Federal Highway Administration. "Regulation: From Economic Deregulation to Safety Reregulation," p. 5.

[14] Interstate Commerce Commission, 1992, p. 38.
[15] Ibid., p. 52.
[16] Ibid., pp. 89-91.
[17] Feitler, Corsi, and Grimm, 1998, p. 5.

After interstate deregulation, the LTL firms experienced mergers and bankruptcies. At the same time, a number of LTL carriers, particularly, smaller ones, were able to succeed. From the largest 50 LTL carriers in 1979, twelve companies survived as of 1994 (controlled by 10 corporate parents). Of the top 50 firms, a number of firms merged with others that later closed, while a number of firms shut down operations. Moreover, more closures occurred to firms that were relatively smaller in the group of the top 50 firms. Conversely, more of the relatively larger firms in the top 50 firms were able to survive in the post-regulatory environment (of interstate deregulation).[18]

With respect to bankruptcies, a number of bankruptcies took place in the truck transportation sub-sector. Since efficient companies are expected to survive and grow over time, and inefficient companies are less likely to survive, bankruptcies in truck transportation would tend to result in increased efficiency (productivity) in the industry. It would appear that bankruptcies related, for one, to increased competition from new industry entrants, typically with lower costs, that followed deregulation in 1980 and 1995.

It takes several years for the impacts of deregulation to show in the industry structure and performance. The positive impacts of deregulation would include the expansion of efficient firms in the industry, the entry of new firms that would need to be competitive—i.e., efficient—and the exit of inefficient firms from the industry. It appears that the efficiency of the industry was affected positively by the comprehensive deregulation completed in 1995. It would have taken several years for industry adjustments to take place—through mergers/acquisitions, etc.—that would result in increased efficiency in the trucking industry. It would seem that the impact on higher efficiency began to be shown during 2001-2003, during which period truck MFP was increasing again.

[18] Rakowski, 1994.

There were adjustments in the industry after the interstate and intrastate deregulation of trucking. These two periods of deregulation were probably a shock to the industry, with existing firms attempting to expand while new firms were attempting to enter the industry. One outcome of the new entrants in the industry was more competition, which eventually resulted in a number of (less efficient) firms leaving the industry. In such circumstances, there is typically need for a period of time to pass, in order for adjustments to take place, before the industry reaches some equilibrium between supply of truck services and demand for truck services (the former being affected by the number and type of firms in the industry). It would seem that industry adjustments had taken place to a sufficient degree by 2001, and production efficiency in the industry subsequently began to increase—as shown by an increase in trucking MFP.

In conclusion, it appears that changes in the structure of the (for-hire) trucking industry, as a result of mergers/acquisitions and bankruptcies, over 1987-2003, resulted, in general, in increases of industry efficiency. This would have affected truck MFP increases, during 1987-1995—after interstate deregulation—and truck MFP increases during 2001-2003, after intrastate deregulation.

SECTION VI—CONCLUSIONS

This study estimates MFP in truck transportation, over 1987-2003; compares truck MFP to that of other transportation industries and the U.S. private business sector; and assesses the factors that affected changes in truck MFP over time.

With regard to estimation, the calculations are based on two methodological approaches to estimate MFP: 1) the methodology using the basic growth-accounting approach; and 2) the more complex Tornqvist index approach. With respect to the results, the MFP calculations based on the basic growth accounting methodology, and without land, can be divided into three time subperiods: 1987-1995, 1995-2001, and 2001-2003.

During the first subperiod (1987-1995), truck MFP increased; during the second subperiod, truck MFP decreased; and during the third subperiod, (2001-2003), truck MFP again increased. With respect to MFP calculations using the Tornqvist methodology, and without land, the MFP growth numbers are very similar to, and the trend is the same as, those of the basic growth accounting methodology. That implies that either method can be used to provide appropriate estimates of MFP.

When MFP calculations use the Tornqvist index and include a measurement for the land input (similar to the method of BLS), the results of truck MFP are very similar to those noted above (obtained by either the basic growth-accounting methodology or the Tornqvist index). However, the measurement of land was not direct; it was related to changes of the stock of structures. In future work of BTS, land will be measured by other methods.

According to the MFP results, truck MFP increased at an annual rate of 0.8% over the whole period of analysis. With regard to the subperiods, truck MFP increased at an annual rate of 2.0% during 1987-1995; it decreased at –0.8% annually during 1995-2001; and it increased again during the most recent 2001-2003 period, at 1.1% per annum.

With regard to MFP comparisons, MFP in trucking is compared with that of the U.S. private business sector and the air transportation and train transportation subsectors. All series cover the period 1987 to 1999; so, MFP growth rates can be compared over that period. During that period, truck MFP and air MFP increased at similar annual rates each, of 1.2% and 1.3% respectively, while rail MFP increased at the highest annual rate of 3.3%. All three transportation industries experienced growth rates of MFP that were higher than those of the U.S. business sector of 0.9% per annum.

In addition, during 1987-1995, truck MFP increased at a faster rate, of 2.0% per annum, than air MFP, which grew at 1.2% annually. During this time period, truck MFP also grew at a substantially higher rate than that of the U.S. economy (of 0.6%). Also, truck MFP reached higher levels than air MFP for most years of the period of analysis. In 1999, however, this situation was reversed and maintained until 2001.

Truck MFP was at a higher level than that of the U.S. business sector for virtually every year over the period of 1987-2002. Consequently, over this time period, truck MFP contributed positively to increases in multifactor productivity of the U.S. economy. Only during 2001 and 2002 did the level of truck MFP fall slightly below that of the U.S. business sector.

With regard to factors affecting truck MFP, the analysis of truck MFP was also segmented into three periods: 1987-1995, 1995-2001, and 2001-2003. During the first period—1987 to 1995—truck MFP increased; during the second period—1995 to 2001—truck MFP decreased; and during the third period—2002 to 2003—truck MFP increased again.

Table 14 presents the various factors which affected truck MFP and indicates the directional impact of these factors on truck MFP, by a plus (+) or minus (-) sign. For example, a plus sign would mean that the factor impacts MFP in a positive way during that period, whereas, a minus sign impacts the MFP in a negative way.

The increase in truck MFP during 1987-1995 would seem to have been affected by the following factors: 1) The relatively high increase in capital per worker, including a rapid increase in the use of computers and computer software; this would have contributed to improvements in the quality of capital; 2) An improvement in the fuel efficiency of truck engines that was a result of improvement in the quality of capital; 3) An increase in the average length of haul; 4) An increasing use of containers in truck transportation; and 5) The positive impacts on industry efficiency as a result of interstate deregulation in 1980, including the increase in the TL segment of the industry.

In the second subperiod, 1995-2001, there was a decrease in truck MFP. This would seem to have been affected by the following factors: 1) The declining efficiency of utilizing intermediate inputs; 2) A lower growth rate of capital per worker; 3) A lower growth rate of utilizing containers; 4) The decrease in industry output in 2001, as a result of the economic recession that year, and the catastrophic events of 9/11/2001; 5) State deregulation of trucking in 1995; this was followed by a period of adjustment and uncertainty, which appear to have had a negative impact on truck MFP.

The increasing MFP during the last subperiod (2001-2003) seems to have been affected by the following factors: 1) Increased use of computers; 2) Increases in the efficiency of using intermediate inputs; 3) Increases in the use of containers; and 4) The adjustment of the industry following intrastate deregulation in 1995, which completed and made comprehensive the deregulation of truck transportation.

With regard to the contribution of trucking to the economy's multifactor productivity, data show that over 1978-2000, truck MFP increased at a higher annual rate than the U.S. business sector. Consequently, during this period of time, trucking MFP contributed positively and significantly to economy MFP increases. Productivity increases in the U.S. economy over time have contributed significantly to economic growth and to improvements in the standard of living in the country.

TABLE 14 Factors Affecting Truck MFP in Three Time Periods
(Directional Impacts)

	Time period		
	1987-1995	1995-2001	2001-2003
MFP movement	+	_	+
Factors affecting MFP			
1. Increase in capital per worker; improved quality of capital.	+	_	0
2. Increased use of:			
a. computers	+	+	+
b. software	+	+	_
3. Efficiency of using intermediate inputs.	_	_	+
4. Improved fuel efficiency.			
a. Single-unit trucks	+	+	_
b. Combinaton trucks	+	_	_
5. Average length of haul.	+	+	NA
6. Containerization	+	_	+
7. Interstate deregulation	+	+	+
8. Intrastate deregulation		_	+
9. Mergers/acquisitions			+
10. Recesssion\9-11-2001		_	

SOURCE: The information is obtained from the analysis presented in the paper

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APPENDIX A. BASIC GROWTH-ACCOUNTING METHODOLOGY

The empirical relationship used to estimate growth of multifactor productivity by the basic growth-accounting methodology is shown below:

$$\frac{\Delta T}{T} = \frac{\Delta Q}{Q} - \left[\left(\alpha * \frac{\Delta \text{Labor}}{\text{Labor}}\right) + \left(\beta * \frac{\Delta \text{Capital}}{\text{Capital}}\right) + \left(\gamma * \frac{\Delta \text{Intermediate Inputs}}{\text{Intermediate Inputs}}\right)\right]$$

Where:

$\frac{\Delta T}{T}$ = Growth of MFP

$\frac{\Delta Q}{Q}$ = Growth of gross output

$\frac{\Delta \text{Labor}}{\text{Labor}}$ = Growth of labor

$\frac{\Delta \text{Capital}}{\text{Capital}}$ = Growth of capital

$\frac{\Delta \text{Intermediate Inputs}}{\text{Intermediate Inputs}}$ = Growth of intermediate inputs

α = Share of labor cost in output

β = Share of capital cost in output

γ = Share of intermediate inputs cost in output.

APPENDIX B. METHODOLOGY WITH THE TORNQVIST INDEX

Multifactor productivity is the ratio of the output index to a weighted average of input indexes. A Tornqvist formula expresses the change in multifactor productivity as the difference between the rate of change in output and the weighted average of the rates of change in various inputs.

Let

Ln = the natural logarithm of a variable

A = multifactor productivity

Q = output

I = combined input

K = capital input

L = labor input

M = intermediate input

W_k = the average share of capital cost in total cost in two adjacent periods

W_l = the average share of labor cost in total cost in two adjacent periods

W_m = the average share of intermediate input cost in total cost in two adjacent periods,

The change in the multifactor productivity is then:

$$(1) \quad \Delta LnA = Ln\left(\frac{A_t}{A_{t-1}}\right) = Ln\left(\frac{Q_t}{Q_{t-1}}\right) - \left[W_k\left(Ln\frac{K_t}{K_{t-1}}\right) + W_l\left(Ln\frac{L_t}{L_{t-1}}\right) + W_m\left(Ln\frac{M_t}{M_{t-1}}\right)\right]$$

Or

$$(2) \quad \Delta LnA = Ln\left(\frac{A_t}{A_{t-1}}\right) = Ln\left(\frac{Q_t}{Q_{t-1}}\right) - Ln\left(\frac{I_t}{I_{t-1}}\right)$$

A multifactor productivity index can be further developed by calculating the antilog of ΔLnA, chaining up the resulting annual rates of change, and expressing the resulting series as a percentage of a selected base year. Equivalently, the change in the multifactor productivity can be directly expressed as $A_t/A_{t-1} = (Q_t/Q_{t-1}) / (I_t/I_{t-1})$. Again, A_t/A_{t-1} can be chained over time and converted into an index number.

All variables, except for cost shares, are in the form of a constant dollar quantity index. The output quantity index is usually derived by deflating the industry output in current dollars by an appropriate price index when the industry output is a single measure. When an industry produces multiple products and the output measure of each individual product is available, such individual outputs may be deflated separately by more detailed price indexes. In that case, the total output quantity index can be derived through a Tornqvist aggregation such as:

$$(3) \quad \sum_1^n w_i \Delta LnQ_i \quad ,$$

where Q_i is the output of the ith product, and

w_i is the average share of the ith product in the total output.

APPENDIX C DATA ON GROSS OUPUT AND INTERMEDIATE INPUTS FOR TRUCK TRANSPORTATION, FROM THE GDP BY-INDUSTRY ACCOUNTS AND THE INPUT - OUTPUT ACCOUNTS.

GDP BY INDUSTRY ACCOUNTS

Year	Gross output ($ millions)	Intermediate inputs ($ millions)
1998	$184,085	$97,889
1999	$198,687	$108,849
2000	$213,173	$120,352
2001	$205,674	$112,359
2002	$205,587	$109,936
2003	$204,278	$105,917

INPUT-OUTPUT ACCOUNTS

Year	Gross output ($ millions) - producers' prices	Intermediate inputs ($ millions) - producers' prices
1998	$184,085	$97,889
1999	$198,687	$108,849
2000	$213,173	$120,352
2001	$205,674	$112,359
2002	$205,587	$109,936
2003	$204,278	$105,917

NOTE: The number for I-O gross output, for 2002, came from the annual I-O data.

SOURCES: BEA websites. For GDP-by-Industry data: http://www.bea.gov/industry/gdpbyind_data.htm.
For Input-Output data: http://www.bea.gov/industry/io_annual.htm.

APPENDIX D COST SHARES OF THE FACTOR INPUTS IN TRUCKING
(basic growth accounting, without land)

Year	Labor weight: share of labor costs in industry output '(1)	Capital weight (residual) '(2)	Weight of intermediate inputs '(3)	Total [(1)+(2)+(3)] '(4)
1987	0.414	0.118	0.468	1.00
1988	0.353	0.163	0.484	1.00
1989	0.337	0.169	0.494	1.00
1990	0.317	0.154	0.529	1.00
1991	0.322	0.164	0.517	1.00
1992	0.313	0.158	0.528	1.00
1993	0.314	0.164	0.518	1.00
1994	0.307	0.175	0.518	1.00
1995	0.309	0.162	0.526	1.00
1996	0.302	0.157	0.541	1.00
1997	0.299	0.164	0.534	1.00
1998	0.292	0.177	0.532	1.00
1999	0.286	0.167	0.548	1.00
2000	0.283	0.152	0.565	1.00
2001	0.296	0.158	0.546	1.00
2002	0.293	0.174	0.533	1.00
2003	0.309	0.185	0.506	1.00

SOURCES: Data on labor and intermediate purchases: BEA, Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm.

NOTE: The share of capital was calculated as a residual.

Appendix E BEA LABOR DATA FOR TRUCK TRANSPORTATION—NAICS AND SIC (including self-employed truckers)

	NAICS (BEA internet site)				SIC (87) (BEA internet site)			Extrapolating NAICS data from SIC data					
Year	Persons engaged in production (thousands) ‘(1)	Full-time equivalent employees (thousands) ‘(2)	Compensation of FTE employees ($ millions) ‘(3)	Compensation of FTE employees ($ billions) ‘(4)	Persons engaged in production (thousands) ‘(5)	Full-time equivalents (thousands) ‘(6)	Labor compena-tion, FTEs ($ millions) ‘(7)	Persons engaged in production (thousands) (NAICS) ‘(8)	Full-time equivalent employees (thousands) (NAICS) ‘(9)	Compensation of FTE employees ($ millions) (NAICS) ‘(10)	Compensation of FTE employees ($ billions) (NAICS) ‘(11)	Compensation of FTE employees ($ thousands) (NAICS) ‘(12)	Compensaton per FTE employee (NAICS) ‘(13)
1987					1,671	1,426	$42,806	1,282	1,077	$34,146	$34.1	$34,145,674	$31,691
1988					1,544	1,308	$41,138	1,184	988	$32,815	$32.8	$32,815,137	$33,204
1989					1,546	1,335	$42,699	1,186	1,009	$34,060	$34.1	$34,060,322	$33,767
1990					1,498	1,311	$44,302	1,149	991	$35,339	$35.3	$35,339,010	$35,676
1991					1,503	1,296	$45,203	1,153	979	$36,058	$36.1	$36,057,723	$36,823
1992					1,523	1,298	$47,572	1,168	981	$37,947	$37.9	$37,947,438	$38,693
1993					1,600	1,371	$50,368	1,227	1,036	$40,178	$40.2	$40,177,763	$38,786
1994					1,705	1,448	$54,608	1,308	1,094	$43,560	$43.6	$43,559,944	$39,815
1995					1,766	1,505	$57,376	1,355	1,137	$45,768	$45.8	$45,767,934	$40,249
1996					1,844	1,542	$59,348	1,415	1,165	$47,341	$47.3	$47,340,968	$40,633
1997					1,869	1,586	$62,963	1,434	1,198	$50,225	$50.2	$50,224,597	$41,912
1998	1,491	1,247	$53,663	$53.7	1,944	1,650	$67,221	1,491	1,247	$53,621		$53,621,136	$43,011
1999	1,536	1,296	$56,780	$56.8	2,009	1,715	$71,687	1,541	1,296	$57,184		$57,183,594	$44,130
2000	1,565	1,323	$60,281	$60.3	2,040	1,751	$75,570	1,565	1,323	$60,281		$60,281,003	$45,564
2001	1,572	1,341	$60,867	$60.9									
2002	1,546	1,297	$59,866	$59.9									
2003	1,517	1,283	$60,789	$60.8									

SOURCES: Labor data under NAICS were obtained from table 6.5D at the BEA internet site: http://www.bea.gov/bea/dn/nipaweb/TableView.asp?SelectedTable=186&FirstYear=2002&last year=2003&Freq=Year
Labor data under SIC (1987) were obtained from table 6.5C (full-time equivalent employees) at the BEA internet site: http://www.bea.gov/bea/dn/nipaweb/TableViewasp?SelectedTable=185&FirstYear=1999&last year=2000&Freq=Year

NOTE: Data reflect the reclassification of air couriers, from trucking and warehousing to transportation by air.

APPENDIX F GROWTH OF TRUCKING MFP, ESTIMATED BY THE TWO METHODS (without land)

Year	Percentage Rate of Change		Difference [(1)-(2)]
	Basic growth accounting methodology ‘(1)	Tornqvist methodology ‘(2)	‘(3)
1988	7.7	8.6	(0.9)
1989	1.0	1.0	(0.0)
1990	0.6	1.0	(0.4)
1991	4.1	4.2	(0.1)
1992	3.8	3.9	(0.1)
1993	0.7	0.7	0.0
1994	0.6	0.5	0.1
1995	(2.3)	-2.2	(0.1)
1996	0.2	0.2	(0.0)
1997	(0.2)	-0.2	(0.0)
1998	(0.4)	-0.4	(0.1)
1999	(1.3)	-1.2	(0.2)
2000	(0.6)	-0.5	(0.0)
2001	(2.5)	-2.4	(0.0)
2002	1.4	1.4	(0.0)
2003	0.4	0.7	(0.3)

NOTES AND SOURCES: The MFP numbers in column 1 are from Table 2, and are based on the basic growth-accounting methodology, without land. The MFP estimates in column 2 are from Table 3, and are based on the Tornqvist methodology, without land.

APPENDIX G CAPITAL INPUT INDEX

	Indexes (2000=100)		Cost shares (%)		
Year	Structures and equipment index ‘(1)	Land index ‘(2)	Structures and equipment cost share ‘(3)	Land cost share ‘(4)	Combined capital input index ‘(5)
1987	65.31	33.36	0.974	0.026	63.64
1988	67.34	34.10	0.975	0.025	65.61
1989	67.80	35.28	0.973	0.027	66.09
1990	65.19	37.10	0.971	0.029	63.72
1991	62.69	39.57	0.968	0.032	61.46
1992	59.84	41.84	0.965	0.035	58.87
1993	61.51	43.60	0.965	0.035	60.54
1994	69.66	47.33	0.966	0.034	68.46
1995	78.75	54.78	0.966	0.034	77.46
1996	82.45	60.22	0.963	0.037	81.24
1997	90.11	70.02	0.958	0.042	89.00
1998	94.58	80.72	0.953	0.047	93.80
1999	97.67	90.68	0.948	0.052	97.28
2000	100.00	100.00	0.942	0.058	100.00
2001	97.84	106.69	0.934	0.066	98.36
2002	95.18	109.54	0.930	0.070	96.04
2003	93.63	111.68	0.927	0.073	94.72

SOURCES: Calculations are by consultant. For data on structures and equipment: BEA Fixed Asets Accounts at: http://www.bea.gov/bea/dn/FA2004/Detail/Index.html. Other data were calculated by BTS (consultants); the calcuations are described in the text - section “Calculations with the Tornqvist Index” and “MFP Calculations with Land”.

NOTE: Column 5 is the result of combining the indexes for Structures/Equipment and Land (columns 1 and 2) by using their cost shares (columns 3 and 4), through a Tornqvist aggregation.

APPENDIX H – ESTIMATION OF LAND COST

With the assumptions provided in the text, the estimation of the land cost is as follows:

1) Calculate ratio (a) by using data for Structures value, divided by Structures & Equipment value (BEA data).

2) Calculate ratio (b) (Structures cost/Structures + Equipment cost) by assuming that it is equivalent to ratio (a). Structures & Equipment cost is the gross operating surplus of the industry.

3) Calculate ratio (c) by using the ratio of Land value/Structures value (Manvel study, 1966) and data for Structures value (BEA). Non-availability of structures (value) data (from BEA) for the earlier years of analysis led to the extrapolation of NAICS structures stock (value) data by using SIC structures stock (value) data.

This calculation provides <u>Land value</u> for a specific year.

4) For ratio (d), use the cost of structures net of depreciation. Land is not depreciated. By using the estimate for structures cost and ratio (d), calculate <u>Land cost</u>. This number is used for the weight of land in the calculations.

APPENDIX I COST SHARES OF THE FACTOR INPUTS IN TRUCKING (percentage)

Year	Intermediate inputs ‘(1)	Capital ‘(2)	Labor ‘(3)	Total [(1)+(2)+(3)] ‘(4)
1987	0.474	0.188	0.339	1.000
1988	0.490	0.181	0.329	1.000
1989	0.499	0.183	0.317	1.000
1990	0.534	0.165	0.301	1.000
1991	0.522	0.174	0.304	1.000
1992	0.534	0.169	0.296	1.000
1993	0.524	0.179	0.297	1.000
1994	0.524	0.180	0.296	1.000
1995	0.532	0.170	0.298	1.000
1996	0.547	0.164	0.289	1.000
1997	0.540	0.172	0.288	1.000
1998	0.537	0.168	0.294	1.000
1999	0.553	0.158	0.289	1.000
2000	0.570	0.145	0.285	1.000
2001	0.552	0.149	0.299	1.000
2002	0.538	0.165	0.297	1.000
2003	0.512	0.176	0.312	1.000

SOURCES: Calculations are by consultants. The calculations are explained in the text, in section “Weights of Inputs”. Data for output, labor, and intermediate inputs were obtained from BEA Industry Accounts at: http://www.bea.gov/bea/dn2/gdpbyind_data.htm.
Data for fixed assets, from Fixed Asset Accounts at: http://www.bea.gov/bea/dn/FA2004/Details/Index.html.

NOTE: The weights of the three inputs indicate their relative share in total industry costs. They add up to 1.00 (total industry costs).

APPENDIX J U.S. WATERBORNE FOREIGN TRADE—CONTAINERIZED CARGO

Year	Containers - TEUs	Metric tons	Time period	Growth of containers - TEU's (%)	Growth of metric tons (%)
1998	15,556,255	128,363,847			
1999	16,563,789	135,903,002			
2000	17,937,670	144,825,512			
2001	18,116,582	144,573,085	1998-2001	5.2	4.0
2002	19,729,422	144,573,085			
2003	21,288,545	154,266,192	2001-2003	8.4	3.3
			1998-2003	6.5	3.7

SOURCE: U.S. Department of Transportation, Maritime Administration, Containerized Statistics, on the web: http://www.marad.dot.gov/MARAD_statistics/index.html.

NOTE: Container capacity is measured in twenty-foot equvalent units (TEU or teu). That is equal to one standard 20 ft. (length) x 8 ft. (width) x 8'6" ft.(height) container.

APPENDIX K USE OF CONTAINERS IN TRUCK TRANSPORTATION
(border crossing data)

Year	Loaded truck containers (thousands)	Time period	Growth - percentage
1996	5,935		
1997	3,709		
1998	6,223		
1999	7,641		
2000	7,685		
2001	6,110	1996-2001	0.6
2002	8,341		
2003	8,273	2001-2003	16.4
		1996-2003	4.9

SOURCE: Bureau of Transportation Statistics website: www.transtats.bts.gov/Fields/asp?Table_ID=1358.

APPENDIX L SHIPMENTS BY TRUCKLOAD AND LESS-THAN-TRUCKLOAD FIRMS
(millions of dollars)

Year	Less-than-truckload	Truckload	Total	LTL/total (percent)
1989	41,740	65,905	107,645	0.39
1990	45,710	71,412	117,122	0.39
1991	46,626	71,106	117,732	0.40
1992	49,119	77,930	127,049	0.39
1993	51,604	83,396	135,000	0.38
1998	40,298	99,424	139,722	0.29
1999	41,468	104,780	146,248	0.28
2000	44,318	110,086	154,404	0.29
2001	44,207	108,411	152,618	0.29
2002	45,117	108,757	153,874	0.29
2003	45,613	112,724	158,337	0.29

SOURCE: Data for 1989-1993, from U.S. Census Bureau, Transportation Annual Survey, 1998, Table 4, pl 11. Data for 1998-2003, from U.S. Census Bureau, website: http://www.census.gov/svsd/www/ services/sas/sas_data/48/sas48_rpt_2004/pdf