Estimating Multifactor Productivity in Truck Transportation, 1987–2003

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ABSTRACT

This paper estimates annual multifactor productivity (MFP) in truck transportation in the United States over the 1987 to 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 land input were estimated using the method of the Bureau of Labor Statistics, with some modifications. In the future, other methods will be evaluated for estimating 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 scenarios. In the first, the basic growth-accounting methodology was used, without a measurement for land. In the second, 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 of land.

With respect to results, the calculations indicate a mixed record of multifactor productivity in truck transportation over the analysis period. During the first several years—late 1980s up to 1994—MFP in truck transportation was increasing. This development changed, however, and during the late 1990s and up to 2001 MFP decreased. In the

last 2 years of analysis—2002 and 2003—MFP in truck transportation again increased.

It is noted 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. This implies that either method can be used to provide appropriate estimates of MFP.

Future work on truck transportation will include an assessment of factors that affected changes in multifactor productivity over the analysis period. These factors would pertain to technological advances—that may include the use of computer hardware and software. They may also include the effects of structural changes in the industry brought about by mergers and acquisitions.

INTRODUCTION—METHODOLOGY

This analysis utilizes two versions of the growth-accounting methodology to calculate multifactor productivity (MFP) in the U.S. trucking industry. 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 who also used it to analyze productivity at the sectoral and industry levels.[2] 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 levels.[3] That version utilizes the Tornqvist formula in the calculations. The basic growth-accounting methodology is presented in Appendix A, while the methodology using the Tornqvist index is presented in Appendix B.

This paper 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. The paper does not assess the factors that affected MFP changes in trucking over time. That is the topic of another, future analysis.

DATA

For this assessment, the data used were obtained primarily from the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. The basic data for output, intermediate inputs, and labor (for 1998 to 2003) were obtained from the Annual Industry Accounts, GDP by Industry. The data on fixed assets were obtained from the Fixed Assets data series. The analysis is of 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).

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.[4]

The analysis is initially carried out for the period 1998 to 2003. Subsequently, it is extended to the 1987 to 2003 period. The choice of the initial pe-

1 Denison, 1974 and 1967.

2 Kendrick, 1973.

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

4 BTS has been doing work in estimating the output of in-house trucking. These data are available in the Transportation Satellite Accounts. However, other data needed for the estimation of MFP are not available.

riod is 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 to 2003 period. Subsequently, labor data under NAICS are extrapolated back to 1987, and calculations on trucking MFP are carried out for the 1987 to 2003 period.

In the first phase of calculations, estimates are developed for MFP in truck transportation without land. The second phase of calculations includes the land input 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 data for the labor input are in terms of full-time-equivalent workers. Part-time workers are converted (by BEA) into full-time equivalents. These labor data do not make a distinction for different types of labor. In this regard, it 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.[5]

Capital Stock

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 amount for the depreciation of capital from gross capital stock. Capital stock data of BEA do not include land (or inventories of unsold goods).

Intermediate Inputs

Data for intermediate inputs are available, from BEA, in the "GDP-by-Industry" accounts and in the Input-Output accounts. There is a difference in the derivation of these data from the two sources. In the GDP by Industry accounts, intermediate inputs are obtained as the difference between independent estimates of gross output and value added. 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.[6] This analysis uses data from the GDP-by-Industry accounts because that database presents a comprehensive and consistent set of data for variables used in the calculations.

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 used for the calculations with the basic growth-accounting approach are presented in Appendix C.

Land

Land is one of the primary inputs of industry output. Land is nonreproducible 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

[5] Bureau of Labor Statistics, 1983.

[6] Yuskavage, "Issues in the Measurement of Transportation Output: The Perspective of the BEA Industry Accounts," p. 7.

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, in this paper, are calculated without a measurement for land. The land input is incorporated in the MFP calculations in the second section of this paper. Its magnitude, for the second section, will be estimated by the approach used by BLS in their estimation of industry MFP.

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.[7]

The estimates indicate that for the first 3 years of the analysis period multifactor productivity in truck transportation declined (negative rates), while it grew at positive rates during the last 2 years.

With regard to changes in output and factor inputs, the data show that over the 1998 to 2003 period output in trucking grew at positive rates for the first 3 years; however, those rates became negative in the last 3 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 2 years of the analysis period; the growth rate turned negative during the last 3 years of analysis.

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

TABLE 1 Growth of MFP

Percentage Rates of Change
(Basic growth accounting methodology without land input)

Year	Growth of Gross Output - Quantity Index (2000=100)	Growth of Labor	Growth of Capital	Growth of Intermediate Inputs	Growth of Combined Weighted Inputs	MFP
	'(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

Source: BEA 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

Inputs in the trucking industry decreased over the analysis period, and this was accompanied by decreasing output. However, in the last 2 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 to 2003 period for gross output and for the inputs of capital and intermediate purchases. However, labor data for trucking, under NAICS, are available only for 1998 to 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 to 2003 period. While labor data are available for trucking under NAICS for 1998 to 2003, labor data (employment and labor compensation) are available for trucking and warehousing, under SIC 42, for the period 1987 to 2000.[8] There are 3 years of data overlap between NAICS and SIC labor data. Consequently, the ratio of labor under NAICS to labor under SIC, in 2000, was used to extrapolate the NAICS trucking employment and labor compensation back to 1987. These calculations are shown in Appendix D. These labor data were then used to calculate MFP in trucking over 1987 to 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 analysis period. There were periods with positive growth rates of MFP, followed by years of negative growth rates, and the reverse. However, one does observe that MFP in trucking grew at positive rates during most years over the period of analysis, including during the last 2 years.

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 2 years of analysis (2002, 2003) also show positive growth rates. Negative MFP growth rates are observed during the late 1990s, and 2000 and 2001.

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 3 years (2001 – 2003). Labor also increased at positive rates for most years over time, while during the last 2 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 3 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 3 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 2 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, and the results are shown in table 3. In this case, the in-

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

TABLE 2 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 (2000=100)	Growth of Labor	Growth of Capital	Growth of Intermediate Inputs	Growth of Combined Weighted Inputs	Growth of MFP
	‘(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

Source: BEA 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.

puts of labor, capital, and intermediates purchases are aggregated into a chained Tornqvist index. 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 subsequently calculated.

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 2 years of the 2000s, when one observes negative growth rates of MFP. In the last 2 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), in table 2. For some years, the growth rates between the two tables 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

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

Year	Gross Output - Chain-Type Quantity Index (2000=100)	Combined Inputs (2000=100}	Multifactor Productivity	MFP Growth
	'(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

Source: BEA 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.

two methods are relatively good substitutes for each other.

MFP CALCULATIONS WITH LAND

This section estimates the quantity and cost share for land used in truck transportation and includes that factor input in calculating MFP for the industry.[9] 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 for highways. This is similar to the measurement of land by BLS for industry studies of multifactor productivity.

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 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 assuming no depreciation. In this regard, the position is taken

9 The data and calculations for this section were provided by MacroSys Research and Technology.

that land does not depreciate because 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 because 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 because 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. 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. Second, the Manvel estimates of the 1966 values for land and structures were based on data of locally assessed taxable real estate. Because 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) for the trucking industry, in constant prices, to be available for 1966; however, the BEA structure series (quantity index), under NAICS, is available from 1987 to 2003. Consequently, this study extrapolates NAICS data for structures by using data for structures for the SIC industry Trucking and Warehousing. SIC data (value and quantity) are available from BEA.[11] Moreover, there are structures data 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). The value in constant dollars is subsequently extrapolated forward by the movement of the NAICS Structures stock (quantity).

The estimated land input is combined with the structures and equipment stock index, by Tornqvist aggregation, and this results in a capital input index of reproducible and nonreproducible capital. The capital input index is approximated by the capital stock index.

The results of the calculations on the land input are shown in Appendix E.

Weights of Inputs

For the estimation of weights (cost shares) of the factor inputs, data are needed on costs of the individual factor inputs and for total costs of the industry. Data for the estimation of cost shares of labor and intermediate input 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 minus indirect business taxes.

With regard to capital costs (weight of capital), this study first measures *total capital costs* (of all fixed assets) in the trucking industry through the industry's gross operating surplus. The gross operating surplus consists of pre-tax capital income and depreciation of fixed assets.

Because structures and equipment and land are eventually combined into a capital stock index, one needs cost shares for these asset types. In this regard, the total capital costs are allocated between land and structures/equipment. This allocation is based on two assumptions:

1. the share of structures cost in the capital cost of structures and equipment is the same as the share of structures *value* in the total value of structures and equipment, and

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

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

2. the ratio of the land *cost* to the nondepreciation cost of structures is the same as the ratio of the land *value* to the value of structures.

These assumptions are needed because the source data do not provide details on structures costs, which are needed to estimate the land cost.

Based on these two assumptions, the cost of structures is separated from total capital costs. Subsequently, the depreciation cost of structures is taken out of the cost of structures because the cost of structures is used to estimate the land cost, and land does not depreciate. Consequently, the land cost is estimated as 0.24/0.76 (noted previously) times the cost of structures (net of depreciation).

The weights used for the calculations that include land are shown in Appendix F.

Results of MFP

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, and the results are presented in table 4. The annual growth rates show that MFP in trucking grew at positive rates from 1988 to 1994. It grew at negative rates from 1997 to 2000. In the last 2 years of analysis (2002 and 2003), MFP again grew at positive rates.

The growth rates for longer periods summarize changes in truck MFP over time. They indicate that over the entire period of analysis, truck MFP increased at an annual rate of 0.8%. The data also indicate that during the first subperiod of 1987 to 1995, truck MFP increased at an average rate of 2.0% per annum. In contrast, during the second subperiod, of 1995 to 2003, MFP decreased at an

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

Year	Output Index	Combined Input Index	Multifactor Productivity	MFP Growth (percentage)	Time Period	Growth of MFP (annual percentage)
1987	48.7	55.8	87.3			
1988	54.7	58.2	94.0	7.7		
1989	57.4	60.4	95.0	1.0		
1990	60.7	63.3	95.8	0.9	1987-1990	3.2
1991	61.9	62.0	99.8	4.1		
1992	67.0	64.7	103.6	3.8		
1993	69.7	66.8	104.4	0.8		
1994	76.2	72.7	104.9	0.4		
1995	78.3	76.4	102.5	-2.3	1987-1995	2.0
1996	82.5	80.4	102.6	0.1		
1997	86.3	84.3	102.4	-0.2		
1998	92.6	90.9	101.9	-0.5		
1999	97.5	96.9	100.6	-1.3		
2000	100.0	100.0	100.0	-0.6		
2001	93.8	96.2	97.5	-2.5		
2002	92.2	93.3	98.9	1.4	1995-2003	-0.4
2003	86.7	87.1	99.6	0.7	2001-2003	1.1

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 Account at: http://www.bea.gov/bea/dn/FA2004/Details/Index.html. The BTS calculations are described in the text.

annual rate of 0.4%. However, during the last 2 years of analysis, truck MFP again increased at an annual rate of 1.1%.

It is possible to compare the results of table 4 with those of previous work by Triplett and Bosworth (2004). They estimated MFP for the SIC industry Trucking and Warehousing. 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 time periods shown. 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.

One also notes that the MFP results in table 3 are quite similar to the results shown in table 4. The results in the former table do not include a measure for the land input, while the results of the latter table do. Thus, at this stage, 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 for the measurement of land. The approach used essentially tied the land measurement to the magnitude, or change, in the structures. That is, changes in land followed changes in the structures. This eliminated the effect of (actual) changes in the land input—in some years—that might have been substantially different from changes in the structures. In future work, it is planned for the measurement of land to be carried out by a different approach.

Comparisons of MFP

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

Estimates of MFP for the four series end at different years; so, it is not possible to compare trucking with the other three series for 1987 to 2003. All series go up to 1999; so, MFP growth rates can be compared for the 1987 to 1999 period. These tabulations show that over that period, rail MFP increased at the highest annual rate of 3.3% while air and truck MFP grew at similar annual rates each of 1.3% and 1.2%, respectively. 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 the 1987 to 1995 period, truck MFP increased at a faster rate at 2.0% per annum than MFP in air transportation, which grew at 1.2% annually. During this time period, the three transportation industries experienced MFP growth at substantially higher rates than that of the U.S. economy (0.6%).

TABLE 5 Comparison of Annual Average Growth Rates of MFP

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

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

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

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

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.

The MFP levels of table 5 are converted into a graphical presentation shown in figure 1. It can be observed that truck MFP was at a higher level than that of the U.S. business sector for most of the analysis period. During 2001 to 2003, it fell below the U.S. business.

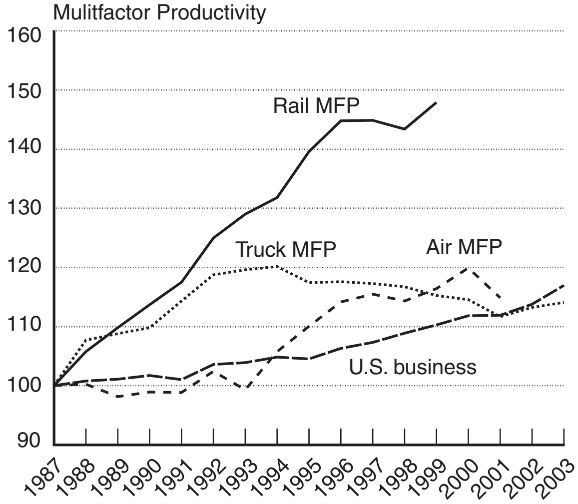
One also observes that truck MFP reached higher levels than air MFP for most years of the analysis period. In 1999, this situation was reversed and maintained until 2001. Due to unavailability of air MFP data, it is not possible to make comparisons for 2002 and 2003, during which years truck MFP increased.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

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 in-house trucking. Such data are not available to be included in the analysis.

Second, there is the matter of contracted services. Trucking services are sometimes contracted out by truck carriers to single owner-operators of

FIGURE 1 MFP in Transportation Industries and U.S. Private Business Sector



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

trucks. That activity would get counted as 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 because the activity is measured in both the output and input sides.

Possible Factors Affecting MFP

Changes in MFP are affected by a number of factors. These factors include improvements in the quality of the inputs, such as improvements of capital goods, for example, machines used in production. These factors can also include changes in the ways in which the inputs are combined in the production of output—that is, the proportion between labor, capital, land, and intermediate inputs. In addition, MFP can be affected by structural changes in the industry brought about by mergers and acquisitions. It is expected that mergers would eliminate the less efficient firms in the industry, leading to an increase in the overall industry efficiency. That would have an impact on the MFP measure.

CONCLUSIONS

This paper was divided into two sections. The first section used the methodologies of basic growth accounting and the Tornqvist index for MFP calculations, and did not include the land input. The second section used the methodology of the Tornqvist index and incorporated the land input in MFP calculations. Land was measured by using the methodological approach of the Bureau of Labor Statistics, with some modifications.

With respect to section one results and using the basic growth-accounting methodology, the MFP calculations indicate a positive growth of MFP from 1988 to 1994. From 1997 to 2001, the MFP growth was negative. During the 2002 to 2003 period, MFP in truck transportation again grew at positive rates. With respect to MFP calculations using the Tornqvist methodology, 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.

In section two, which uses the Tornqvist index and includes the land input, the MFP calculations are very similar to those of section one. The MFP growth is positive from 1988 to 1994, and from 1997 to 2001, it is negative. During the 2002 to 2003 period, MFP again grew at positive rates.

Future research will examine possible factors that contributed to changes in trucking MFP over the analysis period. Multifactor productivity in an industry can be affected by changes in technology. In trucking, MFP could also have been affected by deregulation of the industry, which may affect structural changes in the industry such as mergers and acquisitions. Future work will also include the measurement of land by other methods and the use of the rental price of capital in the calculation of capital weight.

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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:

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

Where:

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

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

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

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

$\frac{\Delta Intermediate\ Inputs}{Intermediate\ Inputs}$ = 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 antilogs of LnA, 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 At/At-1 = (Qt/Qt-1) / (It/It-1). Again, At/At-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:

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

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 Cost Shares of the Factor Inputs in Trucking
(Basic growth accounting without land)

Year	Labor Weight: Share of labor costs in industry output	Capital Weight (Residual)	Weight of Intermediate Inputs
	‘(1)	‘(2)	‘(3)
1987	0.414	0.185	0.468
1988	0.353	0.178	0.484
1989	0.337	0.174	0.494
1990	0.317	0.160	0.529
1991	0.322	0.164	0.517
1992	0.313	0.158	0.528
1993	0.314	0.164	0.518
1994	0.307	0.165	0.518
1995	0.309	0.162	0.526
1996	0.302	0.157	0.541
1997	0.299	0.164	0.534
1998	0.292	0.177	0.532
1999	0.286	0.167	0.548
2000	0.283	0.152	0.565
2001	0.296	0.158	0.546
2002	0.293	0.174	0.533
2003	0.309	0.185	0.506

NOTE and SOURCES: Data on labor and intermediate purchases: BEA, Annual Industry Accounts: http://www.bea.doc.gov/bea/dn2/gdpbyind_data.htm. The share of capital was calculated as a residual.

APPENDIX D BEA Labor Data for Truck Transportation—NAICS and SIC

	NAICS: BEA Internet Site			SIC (87): BEA Internet Site		Extrapolating NAICS Data from SIC Data		
Year	Full-Time Equivalent Employees (thousands)	Compen-sation of employees ($ millions)	Compen-sation of employees ($ billions)	Full-Time Equivalents (thousands)	Labor Compe-nation ($ millions)	Full-Time Equivalent Employees (thousands)	Compen-sation of employees ($ millions)	Compen-sation of employees ($ billions)
	‘(1)	‘(2)	‘(3)	‘(4)	‘(5)	‘(6)	‘(7)	‘(8)
1987				1,426	$42,806	1,077	$34,146	$34.1
1988				1,308	$41,138	988	$32,815	$32.8
1989				1,335	$42,699	1,009	$34,060	$34.1
1990				1,311	$44,302	991	$35,339	$35.3
1991				1,296	$45,203	979	$36,058	$36.1
1992				1,298	$47,572	981	$37,947	$37.9
1993				1,371	$50,368	1,036	$40,178	$40.2
1994				1,448	$54,608	1,094	$43,560	$43.6
1995				1,505	$57,376	1,137	$45,768	$45.8
1996				1,542	$59,348	1,165	$47,341	$47.3
1997				1,586	$62,963	1,198	$50,225	$50.2
1998	1,247	$53,663	$53.7	1,650	$67,221	1,247	$53,621	
1999	1,296	$56,780	$56.8	1,715	$71,687	1,296	$57,184	
2000	1,323	$60,281	$60.3	1,751	$75,570	1,323	$60,281	
2001	1,341	$60,867	$60.9					
2002	1,297	$59,866	$59.9					
2003	1,283	$60,789	$60.8					

NOTE: The data in columns 4 and 5 reflect the reclassification of air couriers from trucking and warehousing to transportation by air.

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.

APPENDIX E Capital Input Index

Year	Structures and Equipment Index	Land Index	Structures and Equipment Cost Share	Land Cost Share	Combined Capital Input Index
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: For data on structures and equipment: BEA Fixed Assets Accounts at: http://www.bea.gov/bea/dn/FA2004/Detail/Index.html. Other data were calculated by BTS as described in the text.

APPENDIX F Cost Shares of the Factor Inputs in Trucking
(Tornqvist methodology with land input)

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

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