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Services Productivity in the United States
Griliches's Services Volume Revisited

Barry P. Bosworth and Jack E. Triplett

14.1 Introduction

In the introduction to his Conference on Research in Income and Wealth (CRIW) volume on services, Zvi Griliches (1992) reviewed services-sector productivity trends, as well as issues in measuring services productivity, as these matters stood in the early 1990s (see also his American Economic Association presidential address; Griliches 1994). In this paper, we analyze the rapid post-1995 productivity growth in services industries, which as we show have contributed greatly to the strength of U.S. productivity growth in recent years. We also review some of the major measurement issues that Griliches addressed, from roughly a dozen years on.

The contexts of the early 1990s and early 2000s are very different yet, at the same time, similar. Griliches wrote in the context of the post-1973 U.S. productivity slowdown, which was the big puzzle of that day. He pointed out that services were crucial to the post-1973 slowdown because productivity in services industries grew much more slowly than productivity in goods-producing industries. Services, therefore, acted as a brake on U.S. productivity growth, a conclusion that was unsettling because services have represented an increasing share of U.S. economic activity, a pattern that is also evident in Europe and other advanced economies.

The post-1973 puzzle was never resolved, just abandoned by economists when they were confronted with a new problem—the acceleration of U.S.

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productivity growth after about 1995. We find, in this paper and in our previous one (Triplett and Bosworth 2006), that accelerating productivity in services industries played a crucial part in post-1995 U.S. productivity growth. Indeed, in recent years services-industry labor productivity has grown as fast as labor productivity in the rest of the economy, which is why we have previously said that "Baumol's disease has been cured."[1] In this, our findings are a mirror image of the conclusions emphasized by Griliches: both the post-1973 slowdown and the post-1995 acceleration in U.S. productivity growth—both labor productivity and multifactor productivity (MFP)—are located disproportionately, though not entirely, in services. Services MFP growth has not been emphasized in other research on the post-1995 resurgence in productivity, which has perhaps too strongly emphasized high productivity growth in electronics-producing industries.

In Griliches' time and now, services industries are the industries that are the most intensive users of information technology (IT) and communication technology capital equipment. But unlike Griliches, who complained that the IT effect on services productivity was invisible in the data of his day, we find that IT investments now make a substantial contribution to labor productivity growth in services-producing industries. This, of course, is another change from the early 1990s, when lagging services productivity seemed a stifling problem for economic growth.

As in most of his writing on productivity, Griliches (1992, 1994) emphasized measurement issues. He was perhaps the foremost of his generation to insist that measurement is part of the science of economics (as it is in all other quantitative sciences) and not just a low-order task to be left to statistical agencies. Data collecting may not itself be part of the science of economics, but specifying what should be gathered and what is needed for economic analysis certainly is. In this regard, Griliches noted the inadequate state of U.S. services-productivity statistics around 1990, which included (but was not limited to) a major deficiency in the conceptual design of the Bureau of Economic Analysis (BEA) industry database, as it then existed:

> The double-deflation procedure (the subtraction of deflated intermediate purchases from deflated gross output to arrive at a real value-added concept) is itself troublesome, as is also the GNP by industry construction, which is based on a value-added measure of an industry's output. . . . For productivity measurement purposes we would be much better off with explicit and separate series on gross output and intermediate inputs in constant prices. (Griliches, 1992, 8–9)

1. See Triplett and Bosworth (2006). Baumol's disease is the presumption, or perhaps the consequence of the presumption, that it is inherently more difficult to increase services productivity than goods-producing productivity—see Baumol (1967).

The measurement of services-sector productivity has advanced hugely since the early 1990s. The best indicator of the improvement that has taken place is displayed in our paper: we calculate MFP for two-digit services industries based on gross output (not value added, as in most previous industry-level studies), using a combination of government databases from the BEA and the Bureau of Labor Statistics (BLS)—and implicitly the Census Bureau, as the other two agencies' compilations rest heavily on data collected by the "economic directorate" part of the Census Bureau. These industry measures incorporate as inputs capital services from different kinds of assets, including separate measures for capital services from IT equipment, and deflated intermediate inputs, exactly along the lines that Griliches recommended.

With the new database, we can compare productivity trends in goods-producing and services-producing industries, we can calculate contributions to growth at the industry level using the well-known Solow framework, and we can aggregate the industry productivity estimates to be consistent with the aggregate productivity estimates that have appeared in "macro" studies such as Oliner and Sichel (2000, 2002), Baily and Lawrence (2001), Gordon (2000, 2002), and Jorgenson and Stiroh (2000). None of this was possible a dozen years ago when Griliches wrote. It has become possible largely because government agencies have implemented some of the recommendations of Griliches and have also taken notice of the substantial contributions to economic accounting of Dale Jorgenson and his collaborators (for example, Jorgenson, Gollop, and Fraumeni 1987). With these great improvements to the government industry database, we can ask and answer questions about post-1995 productivity growth that were nearly impossible to confront for the post-1973 productivity slowdown.

The BEA industry accounts are constructed to be fully consistent with the estimates of aggregate gross domestic product (GDP). They exist for sixty-six industries, published annually, at roughly the two-digit industry level of the old Standard Industrial Classification (SIC) system. After excluding government and the farm sector and combining some industries for which the BLS does not estimate separate information on capital services, we have fifty-four industries (twenty-five in goods-producing, and twenty-nine in service-producing) within the private nonfarm business sector, spanning the period of 1987–2001.[2]

The new database is described more fully in Triplett and Bosworth

2. The BEA-BLS industry data set is an alternative to that developed by Dale Jorgenson and his various coauthors. While they share many of the same sources, the BEA data offer more disaggregation of the service-producing industries. On the other hand, the Jorgenson data are available for a longer time period, and they include measures of labor quality. There are often considerable differences between the two data sets in the growth rates of output at the level of individual industries.

(2004). The database improvements are documented in Yuskavage (1996) and in Lum, Moyer, and Yuskavage (2000). An evaluation of the current data set and plans for its extension are outlined in Yuskavage (2001), and more recent updates are Moyer et al. (2004) and Lawson et al. (2006).

14.2 Summary and Overview

It is now well known that aggregate U.S. labor productivity and MFP accelerated after 1995, with the amount of the acceleration understandably depending on the end period. Using 2002, for example, labor productivity rose at a 2.8 percent annual rate since 1995, compared to 2.4 percent over the 1995–2001 period (2001 was a recession year). In order to reduce the sensitivity of our results to these end-point issues, we present mainly least-squares trend rates of change, which give 2.5 percent per year for trend labor productivity growth for the 1995–2001 interval (table 14.1), compared with 1.0 percent for 1987–1995.

It is also well known that the sources of recent U.S. productivity advance include capital deepening from increased investment in IT (information and communications technology) and an acceleration in MFP growth. At the macro level, these results for the United States have been presented in Oliner and Sichel (2000, 2002), Baily and Lawrence (2001), Gordon (2000, 2002), and Jorgenson and Stiroh (2000); O'Mahoney and van Ark (2003) review the international evidence.

We add to the evidence on recent U.S. productivity growth by computing labor productivity, MFP, and a contributions to growth model at roughly the two-digit SIC level. Three reasons suggest the value of doing productivity research at the industry level.

Table 14.1 Labor productivity and multifactor productivity growth in goods-producing and service-producing industries (trend rates of growth, value added per worker, BEA industry accounts)

	1987–1995	1995–2001	Change
	Labor productivity		
Private nonfarm business	1.0	2.5	1.5
Goods-producing industries	1.8	2.3	0.5
Service-producing industries	0.7	2.6	1.8
	Multifactor productivity		
Private nonfarm business	0.6	1.4	0.9
Goods-producing industries	1.2	1.3	0.1
Service-producing industries	0.3	1.5	1.1

Source: Table A2-2 in Triplett and Bosworth (2004). As explained there, the aggregate productivity numbers differ from those published by BLS (see also footnote 5 in section 14.3 of this paper).

14.2.1 Aggregation

The Solow (1957) productivity paradigm concerns a production function. The empirical application of the production function to any aggregation of producing units always presents problems, but the production function framework fits an industry level of analysis better than the aggregate level.

Fisher (2003, 228) summarized extensive results on aggregation theory by stating: "The question of . . . what meaning can be attached to aggregate production functions . . . [is equivalent to asking] whether there is any system of aggregation over diverse firms that results in some measure of efficiently produced aggregate output being a function of a capital aggregate and a labor aggregate." As Fisher has documented, the aggregation conditions are stringent. They are undoubtedly not met even for industry data, but they are less violently rejected for industry data. For example, one aggregation condition requires that all firms must produce the same vector of outputs. This is nonsense if aggregation proceeds over barber shops and computer factories, but the output vectors of various barber shops must contain more correspondence than those of barber shops and computer factories, whether the aggregation conditions are exactly satisfied at the level of the barber shop industry. From this, it is reasonable to suppose that aggregation at the industry level must perforce do less quantitative damage to the analysis (though it is also true that one cannot prove this proposition).

Against this, one might contend that measurement errors are more severe at the industry level. Grundfeld and Griliches (1960) pointed out long ago that at the aggregate level some measurement errors offset.

14.2.2 Sectoral Sources

A major issue surrounding recent U.S. productivity growth is whether the United States has experienced any productivity growth outside the electronics-manufacturing sector. Gordon (2000, 2002) has promoted the view that most if not all of the U.S. productivity advance originates in computer and semiconductor manufacturing.

Obviously, the way to resolve this question is to compute productivity growth at the industry level, which we do. Our industry productivity growth results show that the "only in electronics manufacturing" contention is false—more than three-quarters of *net* labor productivity and MFP growth since 1995 is in the services industries. Moreover, most of the acceleration in labor productivity growth after 1995, and *all* of the acceleration in MFP growth, took place in the services industries. The goods-producing industries made no net contribution to the acceleration of U.S. MFP growth after 1995. Though productivity growth is very rapid in electronics, the unprecedented productivity growth of the services industries (both labor productivity and MFP growth) is the most striking attribute of the recent advance in U.S. productivity.

14.2.3 IT Contribution to Growth

The contribution of IT to aggregate U.S. labor productivity growth is another major research issue that is best approached at the industry level of analysis. We estimate the overall contribution of IT by examining its contribution in the industries and sectors where the IT is located—predominantly, in the services industries. We find that 80 percent of the total contribution of IT to aggregate U.S. labor productivity growth after 1995 arises from IT's contribution in the services industries.

14.3 Method

We construct measures of labor and multifactor productivity for each of the fifty-four industries and various aggregates.

Labor productivity growth is the output index divided by a simple index of the labor input. Multifactor productivity growth is the ratio of the output index to a weighted average of the inputs, K, L, and M (capital and labor services and intermediate inputs), so the rate of change in gross output MFP is defined:

$$(1) \qquad d\ln \text{MFP} = d\ln Q - [(1 - v)(s_l d\ln L + s_k d\ln K) + v d\ln M],$$

where $d\ln$ MFP designates the rate of growth of MFP (and similarly for the other variables). Inputs include combined energy, materials, and purchased services intermediate inputs (M) in addition to labor (L) and capital services (K), v equals the two-period average share of intermediate purchases in gross output, and s_1 and s_k are the two-period averages of the share of capital and labor income in value added. We compute a Törnqvist chain index of the weighted annual changes in the inputs.[3]

We also estimate growth accounting equations for each of these industries in order to analyze the contributions of capital and materials deepening and MFP to the growth and acceleration of labor productivity:

$$(2) \quad d\ln LP = w_{K_{\text{IT}}} d\ln\left(\frac{K_{\text{IT}}}{L}\right) + w_{K_N} d\ln\left(\frac{K_N}{L}\right) + w_M d\ln\left(\frac{M}{L}\right) + d\ln \text{MFP}$$

In both equations, we disaggregate capital services, K, into IT capital (K_{IT}) and non-IT capital (K_N).

14.4 Trends in Labor Productivity and MFP at the Industry Level

In this section, we report our estimates of labor productivity and MFP for the industries in the BEA industry database.[4]

3. The output data of the BEA are aggregated using Fisher indexes. We switched to Törnqvist indexes only to take advantage of a slightly simpler algorithm.

4. This section and the following one summarize empirical work that is presented more fully in Triplett and Bosworth (2004).

Although we emphasize productivity estimates at the detailed level, the outline of our major findings also emerges from direct sector-level estimates, where industry value added and inputs are aggregated to the sector level.[5] As table 14.1 demonstrates, services-sector labor productivity advanced at a 2.6 percent trend rate in 1995 to 2001, compared with 2.3 percent per year for the goods-producing sector. The post-1995 acceleration in the services sector (at 1.8 percentage points) also far exceeds the acceleration of labor productivity growth in the goods-producing sector (0.5 points)—see table 14.1.

Similarly, MFP growth in the services sector exceeded MFP growth in the goods-producing sector, post-1995 (1.5 percent per year, compared with 1.3 percent). The services-producing sector accounts for all of the acceleration in U.S. MFP growth because there was minimal acceleration in MFP growth in the goods-producing sector, taken as a whole (only 0.1 percentage point). As we said in our previous paper (Triplett and Bosworth 2006, 34), "Baumol's disease has been cured."

The aggregations conceal much heterogeneity among the industries. We compute industry labor productivity and MFP for twenty-five goods-producing industries and twenty-nine services-producing industries.[6] In both goods-producing and services-producing sectors, some industries experienced very high labor productivity growth, such as electronics in goods-producing and brokerage/finance among services industries. Labor productivity growth in the goods-producing sector is restrained by low productivity growth in mining and negative productivity growth in construction. A number of services sectors also had negative productivity growth. These industries include hotels, entertainment and recreation, and education. It is important to recognize that the *net change* in sector productivity reflects the behavior of productivity in the individual industries within the sector, and within both services- and goods-producing sectors, there are industries with negative as well as positive productivity growth.

Tables 14.2 and 14.3 provide a detailed view of the changes in labor and MFP for the twenty-nine services-producing industries. We focus on the services-producing industries because they play such a dominant role in the post-1995 productivity resurgence, and it is in this sector that the industry analysis offers a different interpretation of the resurgence compared

5. As explained in Triplett and Bosworth (2004), these aggregations of BEA industry data do not yield precisely the BLS published productivity numbers. Though the differences arise from a number of respects in which BEA and BLS databases differ, the major cause is the fact that the BEA industry database is consistent with the income side of the accounts, where the BLS productivity estimates are based on the expenditure side. This means that the rate of growth in our aggregations is larger than in the BLS published numbers, but this is not a major limitation on our results, partly because in the recently released benchmark revision of GDP, the product side was revised more than the income side.

6. As noted earlier, our productivity estimates use a measure of gross output, rather than value added, as in some past industry-level studies.

Table 14.2 **Growth in labor productivity in 29 service industries, 1987–2001 (annual trend rates of change based on gross output)**

		Trend growth in output per worker		
Industry	Value added weight	1987–1995	1995–2001	Change
Railroad transportation	0.4	6.2	2.1	–4.1
Local and interurban passenger transit	0.2	–1.7	–0.6	1.1
Trucking and warehousing	1.6	3.4	0.8	–2.7
Water transportation	0.2	1.7	1.0	–0.7
Transportation by air	1.1	0.0	0.4	0.4
Pipelines, except natural gas	0.1	–0.7	1.2	1.8
Transportation services	0.4	2.0	3.5	1.5
Telephone and telegraph	2.6	5.5	7.9	2.5
Radio and television	0.7	0.0	1.8	1.8
Electric, gas, and sanitary services	3.4	2.1	2.0	–0.1
Wholesale trade	8.5	3.4	4.2	0.8
Retail trade	11.3	1.3	3.4	2.2
Depository institutions	4.0	2.9	3.1	0.2
Nondepository institutions	0.6	2.4	1.9	–0.6
Security and commodity brokers	1.4	7.2	10.3	3.2
Insurance carriers	1.9	–0.6	–1.7	–1.0
Insurance agents, brokers, and service	0.8	–3.3	2.8	6.1
Real estate (excluding owner-occupied housing)	6.6	2.7	1.7	–1.0
Hotels and other lodging places	1.0	1.0	–0.6	–1.6
Personal services	0.8	1.0	1.5	0.5
Business Services	5.2	2.9	3.6	0.7
Auto repair, services, and parking	1.1	0.9	1.5	0.6
Miscellaneous repair services	0.4	1.9	1.8	–0.1
Motion pictures	0.4	0.1	0.3	0.1
Amusement and recreation services	0.9	1.6	–0.4	–2.0
Health services	7.1	–0.7	0.9	1.6
Legal services	1.7	0.0	1.5	1.5
Educational services	0.9	0.2	–1.0	–1.1
Other services	4.9	–0.4	2.0	2.4

Source: Appendix table A-1 (Triplett and Bosworth 2004).

to the macroeconomic analysis. The results for all fifty-four industries are provided in Triplett and Bosworth (2004).

In the services-producing sector, the overall growth in labor productivity and MFP camouflages a wide disparity of trends within the individual two-digit industries. Advancing labor productivity in four large services industries—telephone, wholesale trade, retail trade, finance (both brokerage and depository institutions)—drove the overall sector improvement. Labor productivity gains in these industries ranged from 3 to over 10 percent per year after 1995, in all cases representing acceleration over the corresponding rate before 1995 (table 14.2). These four industries represent over a quarter of total value added in the private nonfarm business sector.

However, services-sector labor productivity growth is not just a story of

Table 14.3 **Growth in multifactor productivity in 29 service industries, 1987–2001 (annual trend rates of change based on gross output)**

		Trend growth in multifactor productivity		
Industry	Domar weight	1987–1995	1995–2001	Change
Railroad transportation	0.7	3.4	1.5	–1.9
Local and interurban passenger transit	0.4	–1.0	1.3	2.3
Trucking and warehousing	3.4	0.9	–0.1	–1.0
Water transportation	0.6	1.6	0.2	–1.4
Transportation by air	1.9	2.5	–0.5	–2.9
Pipelines, except natural gas	0.1	–2.8	1.6	4.4
Transportation services	0.6	–0.3	0.2	0.5
Telephone and telegraph	4.3	1.7	1.2	–0.5
Radio and television	1.2	1.6	–4.5	–6.2
Electric, gas, and sanitary services	5.6	0.5	–0.6	–1.1
Whole trade	12.4	1.5	3.1	1.6
Retail trade	17.4	0.2	2.9	2.7
Depository institutions	5.6	0.2	1.5	1.3
Nondepository institutions	1.4	–0.2	2.1	2.4
Security and commodity brokers	2.4	3.1	6.6	3.5
Insurance carriers	4.1	–0.1	0.0	0.2
Insurance agents, brokers, and service	1.3	–3.6	–0.1	3.5
Real estate (excluding owner-occupied housing)	11.2	0.4	1.4	1.0
Hotels and other lodging places	1.7	0.0	–1.3	–1.3
Personal services	1.4	–0.9	0.4	1.3
Business Services	7.8	0.9	–0.6	–1.5
Auto repair, services, and parking	1.9	–1.4	1.4	2.8
Miscellaneous repair services	0.7	–1.1	–1.6	–0.5
Motion pictures	0.9	–1.2	0.2	1.4
Amusement and recreation services	1.6	0.1	–1.1	–1.2
Health services	10.7	–1.7	–0.5	1.2
Legal services	2.2	–0.8	0.9	1.7
Educational services	1.6	–0.2	–0.8	–0.5
Other services	8.5	–0.3	–0.1	0.2

Source: Appendix table A-1 (Triplett and Bosworth 2004).

a small number of large industries. Of the twenty-nine detailed services industries, twenty-four experienced labor productivity growth after 1995 and, of the positive growth industries, seventeen experienced acceleration.[7] In two industries, accelerations or decelerations were marginal (only 0.1 percentage point), so they might better be set as zero acceleration industries. Negative labor productivity growth occurred after 1995 in five indus-

7. This contrasts with the goods-producing sector, where post-1995 labor productivity growth was positive in twenty-four out of twenty-five industries, but accelerated in only fourteen of the twenty-four.

tries (two fewer than before 1995), but in one of them (local transit) labor productivity actually accelerated, that is, the negative productivity growth became less negative.

Multifactor productivity growth shows a more mixed picture in services industries (table 14.3). The 2001 recession is not a factor in this as a similar mix was found in our previous paper, for which the post-1995 period ended with 2000.

Strong MFP growth in a number of large industries—telephone, retail and wholesale trade, and finance—was sufficient to offset negative productivity growth in other large industries, including hotels, health, education, entertainment/recreation, and the "other services" (which is a combination of several two-digit SICs). Multifactor productivity growth was actually negative in twelve of the twenty-nine industries after 1995 (three marginally so).

More than half of the services industries experienced accelerating MFP after 1995. Acceleration after 1995 is associated with large swings from negative to positive MFP growth in several industries (see, for example, local transit, pipelines, auto repair, and legal services) and strong MFP growth in the big industries of trade and finance. However, the acceleration of MFP growth in medical care (though growth is still negative!) is one area where the result is influenced by a methodological break in the index of real output because new producer price index (PPI) measures of price changes begin in 1991. Methodological breaks also occur in other industries, such as miscellaneous services.

In summary, post-1995 productivity growth in the United States—both productivity and MFP—was a product of strong and widespread productivity growth in the services industries. Because services industries by and large did not exhibit strong productivity growth in the previous period, the acceleration of U.S. productivity growth after 1995 is also a product of developments in the services industries.

14.5 The Aggregation of Industry Productivity Measures

The fifty-four industries in the data set vary widely in size. Thus, while tables 14.2 and 14.3 report changes in labor productivity and MFP at the industry level, those tables do not show which of the industries made the largest contributions to the post-1995 surge of aggregate productivity growth. Additionally, we need to make sure that our industry productivity results are consistent with the macro-level results that have appeared in other studies, such as Oliner and Sichel (2000, 2002) and Jorgenson and Stiroh (2000).[8]

In this section, we aggregate our industry productivity measures and

8. This responds to a point raised in oral discussion of our previous paper, a point that could not be answered until data for all fifty-four industries were analyzed.

show the contributions of individual industry productivities to aggregate- and sector-level productivity measures. We find that the industries within the services sector account for the bulk of U.S. productivity growth after 1995, both labor productivity and MFP. Services industries account for all of the post-1995 acceleration. The goods-producing industries, taken together, make no net contribution to the recent acceleration of U.S. productivity growth.

14.5.1 Industry and Aggregate Productivity Relations

We presented, in table 14.1, sector-level productivity estimates formed by aggregating industry outputs and inputs and then computing productivity at the aggregate level. We call such measures "direct" aggregate-level productivity measures, or direct sector-level measures, such as the goods-producing and services-producing sectors, manufacturing durables production, and so forth.

Direct aggregate or sector productivity growth is not just the aggregation of productivity changes within the individual industries contained in the sector. Aggregate productivity can also change because of reallocations across industries. As we (and others, including Stiroh [2002] and Jorgenson, Ho, and Stiroh [2006]) show, aggregated industry productivity estimates generally exceed direct aggregate-level productivity change because of reallocation of resources across industries. These reallocation effects are an important and interesting part of the productivity resurgence story that has been overlooked in macro productivity studies.

We rely on Stiroh's (2002) formula that relates the industry measures of gross output labor productivity to aggregate value added per worker:

$$d \ln LP^V = \left(\sum_i w_i d \ln LP_i^Q \right) + \left(\sum_i w_i d \ln L_i - d \ln L \right) - \left[\sum_i m_i (d \ln M_i - d \ln Q_i) \right], \tag{3}$$

where

LP^V = aggregate value added per worker,
LP_i^Q = gross output per worker in industry i,
w_i = the two-period average of the share of industry i's nominal value added in aggregate value-added, and
m_i = the two-period average of the ratio of industry i's nominal purchased inputs to aggregate value added, and,
K, L, and M are the standard notations for capital, labor, and intermediate inputs.

In this formulation, we can think of $d \ln LP^V$ as the direct aggregate-level labor productivity growth discussed earlier and displayed in table 14.1.

Equation (3) shows that the direct aggregate-level labor productivity estimate is a combination of (a) an industry productivity effect equal to the weighted sum of the growth in the industry productivities, where the weights are the industry shares of total value added; and (b) two reallocation terms that capture the shift of output among industries with variations in their levels of labor productivity and intermediate input intensity.[9]

As an intuitive example, suppose industry A contracts out a portion of its activities to industry B. This intermediate deepening ($d \ln M_i > d \ln Q_i$) may raise labor productivity in industry A (presuming that industry A rids itself of labor employed in its own less productive activities), because less labor is required per unit of output in industry A. But contracting out cannot by itself raise aggregate labor productivity; it will only cause aggregate labor productivity to rise if industry B is more productive in the contracted activities than was industry A. The reallocation terms capture this effect. They will be positive when shifts in economic activity go from less-productive to more-productive industries and will be negative in the opposite case.

Domar (1961) expressed the rate of aggregate MFP growth as a weighted average of the industry (gross output) MFP growth rates, with weights equal to the ratios of industry gross output to aggregate value added. That framework was generalized and developed more fully in Hulten (1978) and Gollop (1979). The important point is that productivity improvements at the industry level contribute to the aggregate economy in two ways—first, through direct cost reductions for the industries' outputs that are part of final demand and, second, through reductions in the cost of intermediate inputs for other industries.

For the aggregation of MFP, we have relied on the generalization of the Domar weights given in Jorgenson, Gollop, and Fraumeni (1987):

$$(4) \quad d \ln \text{MFP}^V = \left(\sum_i v_i d \ln \text{MFP}_i^Q \right) + \left(\sum_i v_i s_i^k \, d \ln K_i - \bar{s}^k \, d \ln K \right) + \left(\sum_i v_i s_i^l d \ln L_i - \bar{s}^l \, d \ln L \right)$$

where

v_i = two-period average of the ratio of industry i's gross output to aggregate value added (Domar weights), and

s_i = the two-period average share in industry i of the designated factor's (K or L) income in nominal gross output.

9. This formulation differs from that of Nordhaus (2002) because it uses chain index weights (the v_i terms), and it adds an additional source of reallocation by measuring labor productivity at the industry level with gross output instead of value added.

Table 14.4 **Aggregation of industry contributions to labor and multifactor productivity growth, nonfarm business sector, 1987–2001 (trend growth rates, except where noted)**

	Growth rate		
	1987–1995	1995–2001	Change
Labor productivity			
Direct aggregate level[a]	1.01	2.46	1.45
Intermediate inputs recallocation(–)	–0.48	0.14	0.62
Labor reallocation	–0.44	–0.31	0.13
Value-added weighted industry aggregate	1.93	2.63	0.70
Multifactor productivity			
Direct aggregate level	0.56	1.44	0.88
Input reallocation	–0.09	–0.14	–0.04
Domar weighted industry aggregate	0.66	1.58	0.92

Source: Equations (3) and (4) of text, and appendix tables A-5 and A-6 (Triplett and Bosworth 2004).

[a]Differs from table 14.2 because it is a trend rate of change.

Our aggregations of both labor productivity and MFP use Törnqvist chain indexes; that is, the weights are averages of adjacent periods, not single-period or base-period weights.[10] The Domar weights (the first element of equation [4]) can best be thought of as the product of two steps in the aggregation: (a) the scaling up of the change in MFP at the industry level by the ratio of gross output to value added at the industry level, and (b) the aggregation using value added weights.[11]

14.5.2 Sector Aggregation of Industry Productivity

Using equations (3) and (4), a summary of the industry contributions to the growth in the direct aggregate (value added) measures of labor productivity and MFP are shown in table 14.4.

Because the contributions of industry productivity changes are offset by resource reallocations (the among industries effects) that reduce the aggregate gain, the aggregation of industry labor productivity estimates more than accounts for the growth of aggregate productivity in both periods. For example, in 1987 to 1995, the aggregation of industry labor productivity improvements (the within industry effects, shown in italics in table 14.4) yields 1.93 percent growth per year, which is nearly twice as much productivity growth as is recorded at the aggregate level (1.01 percent).

10. Domar (1961) assumed a Cobb-Douglas function, which implies base-period weights in a logarithmic index.

11. At the level of individual industries, MFP computed from the gross output framework will always be less than MFP computed from the value added data; however, the contribution to the aggregate MFP is the same for both concepts.

On the other hand, because the reallocation terms have had a less negative influence in recent years, more of post-1995 labor productivity growth within the industries feeds through to the aggregate level—the weighted industry productivity changes (2.63 percent per year) total only 0.17 points higher than the direct aggregate estimate (2.46 percent). Put another way, the aggregate post-1995 acceleration of 1.45 (2.46 – 1.01) percentage points per year in labor productivity growth is boosted by changes in (i.e., less negative) reallocation terms. For this reason, the acceleration (1.45 points) in aggregate productivity growth is roughly twice as large as is evident from a straight aggregation of the fifty-four individual industries (0.70 points per year).[12]

The lower part of table 14.4 indicates that the reallocation terms are less important in the aggregation of the (gross output) industry measures of MFP growth. The aggregation of industry MFP is formed using Domar weights, as indicated in equation (4). The aggregation of industry MFPs is larger than direct aggregate-level MFP for both periods, but the reallocation term is small (only –0.14, for 1995–2001). Moreover, the acceleration in MFP is the same (about 0.9 points), whether calculated from the direct aggregate or by aggregating industry MFPs.

14.5.3 Industry Contributions to Aggregate Productivity Growth

The contributions of individual industries to aggregate productivity growth are shown, for all twenty-nine services industries and for the major aggregates, in table 14.5. The industry contributions in table 14.5 sum to the totals that are given by the first terms in equations (3) and (4), that is, to the bottom line of table 14.4. This aggregation of the industry productivities is repeated as the top line in table 14.5. As we have already noted, the total industry productivity contribution is larger than the direct aggregate-level productivity change shown in table 14.4 for the nonfarm business aggregate because the direct industry contributions include reallocation effects.

Similarly, the sector aggregations in table 14.5 (indicated in italic type) are the sums of the industry contributions within the sector. Accordingly, one should interpret industry (and sector) contributions in table 14.5 in the following way: they show the contribution of industry *i* (or the industries in sector *j*) to the total of all industry contributions to productivity change. For example, table 14.5 shows that the two machinery industries (within which are located computer and semiconductor manufacturing) contribute about 17.5 percent of the total increase in industry labor productivity

12. This variation between the aggregate and the industry results is largely due to changes in the relationship between gross output and value added—what we have labeled reallocation of the intermediate inputs. If labor productivity is measured at the industry level using value added, the reallocation term is limited to changes in the distribution of labor among the industries, which does not change very much before and after 1995.

Table 14.5 **Industry contributions to labor and multifactor productivity growth, nonfarm business sector, 1987–2001 (trend growth rates)**

			Labor productivity				Multifactor productivity			
SIC code	Industry name	Aggregate	Value-added weight	1987–95	Contribution (1995–2001)	Change	Domar weight	1987–95	Contribution (1995–2001)	Change
	Private nonfarm business	Yes	*100.0*	1.93	2.63	0.70	*186.9*	0.66	1.58	0.92
GD	**Goods-producing industries**	Yes	*29.6*	*0.77*	*0.71*	*–0.06*	*73.1*	*0.39*	*0.38*	*–0.01*
	Agricultural services, forestry, and fishing	No	*0.6*	0.0	0.01	0.01	*0.9*	–0.1	0.00	0.01
	Mining	Yes	*1.9*	0.7	0.01	–0.06	*3.1*	0.04	–0.03	–0.06
15–17	*Construction*	No	*5.3*	–0.01	–0.06	–0.05	*9.3*	0.02	–0.05	–0.07
	Manufacturing	Yes	*21.7*	0.72	0.76	0.04	*59.7*	0.34	0.45	0.11
	Durable goods	Yes	12.3	0.58	0.60	0.02	31.7	0.35	0.59	0.23
35	Industrial machinery and equipment	No	2.32	0.15	0.15	0.00	5.54	0.10	0.22	0.12
36,38	Electronic equipment and instruments	No	3.25	0.28	0.31	0.04	7.19	0.20	0.29	0.09
	Nondurable goods	Yes	*9.4*	0.14	0.16	0.02	*28.1*	–0.01	–0.13	–0.12
SER	**Service-producing industries**	Yes	*70.4*	*1.16*	*1.92*	*0.76*	*113.8*	*0.27*	*1.20*	*0.93*
	Transportation	Yes	*4.0*	*0.08*	*0.04*	*–0.04*	*7.8*	0.10	0.01	–0.10
48	*Communications*	Yes	*3.4*	0.15	0.22	0.07	*5.6*	0.09	0.00	–0.09
	Telephone and telegraph	No	*2.6*	0.15	0.21	0.05	*4.3*	0.07	0.06	–0.01
483–484	Radio and television	No	*0.7*	0.00	0.02	0.01	*1.2*	0.02	–0.06	–0.08
49	*Electric, gas, and sanitary services*	No	*3.4*	*0.07*	*0.06*	*–0.01*	*5.6*	0.03	–0.03	–0.07
50–51	*Wholesale trade*	No	*8.5*	*0.31*	*0.36*	*0.05*	*12.4*	0.18	0.38	0.20

(*continued*)

Table 14.5 (continued)

SIC code	Industry name	Aggregate	Labor productivity: Value-added weight	1987–95	Contribution (1995–2001)	Change	Multifactor productivity: Domar weight	1987–95	Contribution (1995–2001)	Change
52–59	*Retail trade*	No	*11.3*	*0.15*	*0.38*	*0.23*	*17.4*	0.04	0.50	0.46
	Finance and insurance	Yes	*8.7*	0.18	0.31	0.13	*14.8*	0.01	0.34	0.32
60	Depository institutions	No	*4.0*	0.12	0.13	0.01	*5.6*	0.01	0.09	0.08
61	Nondepository institutions	No	*0.6*	0.01	0.01	0.00	*1.4*	–0.01	0.04	0.05
62	Security and commodity brokers	No	*1.4*	0.09	0.18	0.10	*2.4*	0.06	0.21	0.15
63	Insurance carriers	No	*1.9*	–0.01	–0.04	–0.02	*4.1*	0.00	0.00	0.00
64	Insurance agents, brokers, and service	No	*0.8*	–0.02	0.02	0.05	*1.3*	–0.04	0.00	0.04
65	*Real estate (excluding owner-occupied housing)*	No	*6.6*	0.16	0.11	–0.05	*11.2*	0.05	0.16	0.11
	Other services industries	Yes	*24.6*	0.05	0.43	0.38	*39.1*	–0.23	–0.15	0.08
70	Hotels and other lodging places	No	*1.0*	0.02	–0.01	–0.02	*1.7*	0.00	–0.02	–0.02
72	Personal services	No	*0.8*	0.00	0.01	0.01	*1.4*	–0.01	0.01	0.02
73	Business Services	No	*5.2*	0.11	0.22	0.11	*7.8*	0.06	–0.07	–0.12
75	Auto repair, services, and parking	No	*1.1*	0.01	0.02	0.01	*1.9*	–0.03	0.03	0.05
76	Miscellaneous repair services	No	*0.4*	0.01	0.01	0.00	*0.7*	–0.01	–0.01	0.00
78	Motion pictures	No	*0.4*	0.00	0.00	0.00	*0.9*	–0.01	0.00	0.01
79	Amusement and recreation services	No	*0.9*	0.01	0.00	–0.02	*1.6*	0.00	–0.02	–0.02
80	Health services	No	*7.1*	–0.07	0.06	0.14	*10.7*	–0.18	–0.06	0.13
81	Legal services	No	*1.7*	–0.01	0.02	0.03	*2.2*	–0.02	0.02	0.04
82	Educational services	No	*0.9*	0.00	–0.01	–0.01	*1.6*	0.00	–0.01	–0.01
83–87	Other services	No	*4.9*	–0.02	0.10	0.13	*8.5*	–0.03	–0.01	0.01

Source: Appendix tables A-5 and A-6 (Triplett and Bosworth 2004).

([0.15 + 0.31]/2.63) between 1995 and 2001 and 32 percent ([0.22 + 0.29]/1.58) of the total industry MFP growth.

In contrast, the post-1995 resurgence in labor productivity can be traced largely to productivity growth in the services-producing industries. Of the total labor productivity growth of 2.63 percent per year after 1995, services industries account for 73 percent of the total (1.72/2.63), while goods-producing industries account for the rest (27 percent, or 0.71/2.63). Improvements within durables manufacturing are more than offset by slow productivity growth in mining and continued outright declines in construction.

Of the fifty-four industries, thirty industries show an increased contribution after 1995, and nineteen of those are in services. Within services, the largest contributors to post-1995 labor productivity growth are retail and wholesale trade, finance (specifically, brokerage firms), business services, and a miscellaneous grouping of other services.[13] Each of the first three of these large services subsectors contributes as much or more to aggregate post-1995 productivity growth as either industrial machinery or electrical machinery, which have received so much attention because of their electronics components. These five services industries represent 70 percentage points of the post-1995 aggregate acceleration in labor productivity (see the "changes" column of table 14.5), and the next ten most important contributors to the acceleration (all of which are in services) add only 30 percentage points.

Many of the industries that made the largest contributions to the resurgence of growth in labor productivity also play a large role in the acceleration of MFP growth. Again, the improvements are dominated by the gains in the services-producing industries, which contribute three quarters (1.20/1.58) of the MFP growth, post-1995, and 0.92 points of the net 0.88 points of acceleration (that is, more than the total). The top contributors to the post-1995 MFP acceleration (retail trade, wholesale trade, brokerage firms, and health) are all in services, closely followed by industrial machinery, which includes computers.[14] As shown in the table, the contribution of durable-goods manufacturing to the improvement is large, but it is offset by declines in other goods-producing industries, including nondurables manufacturing.

Twenty-seven of the fifty-four industries show a post-1995 acceleration of the trend growth in MFP, and seventeen are services-producing industries. Despite the similarity of the large contributing industries, the cross-

13. As mentioned previously, we believe that the productivity improvements recorded in other services are partly due to changes in the methodology for measuring the price deflators for output.

14. The large positive contribution of health arises because the MFP change is less negative after 1995.

industry correlation between the post-1995 acceleration of labor productivity and MFP is a surprisingly low 0.33.

There is also a large change in the role of business services, which was a major source of the rise of labor productivity, but it makes a negative contribution to the improvement in overall MFP growth. Its positive contribution to labor productivity is largely the result of a rapid increase in its weight; labor productivity growth was high but not accelerating after 1995. However, a large increase in purchases of intermediate inputs results in a post-1995 decline in MFP.

14.6 The Role of IT Capital

A number of studies have reported that increasing use of IT capital contributed to the acceleration of labor productivity after 1995, in the standard paradigm of capital deepening, but that non-IT capital per worker did not accelerate after 1995 (see, for example, Oliner and Sichel 2002). Using the labor productivity decomposition in equation (1) and applying it to the nonfarm value added data, we find the same result: overall, increasing IT capital per worker contributed 0.85 points to labor productivity (value added per worker) growth after 1995, and 0.49 percentage points to acceleration (line 1 of table 14.6). Non-IT capital services contributed positively

Table 14.6 Contributions of IT capital to labor productivity growth, by industry, 1987–2001 (trend rates of change)

	Contribution to industry		
Industry	1987–1995	1995–2001	Change
Private nonfarm business	0.36	0.85	0.49
Goods-producing industries	0.12	0.19	0.07
Mining	0.09	0.24	0.15
Construction	0.06	0.09	0.03
Manufacturing	0.11	0.18	0.07
Durable goods	0.12	0.24	0.12
Nondurable goods	0.15	0.23	0.08
Service-producing industries	0.23	0.59	0.37
Transportation	0.13	0.31	0.17
Communications	0.86	1.29	0.43
Electric, gas, and sanitary services	0.25	0.25	0.00
Wholesale trade	0.49	1.42	0.93
Retail trade	0.11	0.26	0.15
Finance and insurance	0.62	1.09	0.48
Real estate (excluding owner-occupied housing)	–0.01	0.02	0.04
Other service industries	0.14	0.47	0.33

Source: The direct estimates of the contribution to labor productivity in individual industries are from the gross-output estimates of table A-1, except for the nonfarm aggregates which are value added estimates from table A-2 (Triplett and Bosworth 2004).

to growth, but only a little less than 0.1 point to acceleration (estimate not shown in the table, but incorporated into appendix table A1 of Triplett and Bosworth [2004]).

Again, as with so many aspects of recent U.S. productivity performance, most of the IT capital deepening effect on U.S. labor productivity growth in recent years originates in the services industries. As shown in the left-hand side of table 14.6, the increased use of IT contributed 0.59 percentage points of labor productivity growth in the services-producing industries after 1995, which was 0.4 points more than the contribution of IT capital in these industries in the previous period (0.23). In contrast, IT contributed less than a tenth of a point (0.07) to labor productivity acceleration in the goods-producing industries. Triplett and Bosworth (2006) show that the service-producing industries are also more intensive users of IT than the goods-producing industries. It is thus not surprising that in such IT-intensive industries as communications, wholesale trade, and finance and insurance, IT contributes substantially to their post-1995 labor productivity growth—1.29, 1.42, and 1.09 points, respectively (left-hand side of table 14.6).

Table 14.6 shows the contributions of IT to the change in labor productivity within each industry. In table 14.7, we use the Domar weights to compute the IT contribution in individual industries to the total IT contribu-

Table 14.7 Contributions of IT capital to aggregate labor productivity growth, nonfarm business sector, 1987–2001 (trend rates of change)

		Contribution to aggregate		
Industry	Domar weight	1987–1995	1995–2001	Change
Private nonfarm business	186.9	0.38	0.77	0.39
Goods-producing industries	73.1	0.09	0.15	0.06
Mining	3.1	0.00	0.01	0.00
Construction	9.3	0.01	0.01	0.00
Manufacturing	59.7	0.09	0.13	0.05
Durable goods	31.7	0.04	0.08	0.04
Nondurable goods	28.1	0.04	0.06	0.01
Service-producing industries	113.8	0.28	0.62	0.34
Transportation	7.8	0.01	0.02	0.01
Communications	5.6	0.05	0.07	0.02
Electric, gas, and sanitary services	5.6	0.01	0.01	0.00
Wholesale trade	12.4	0.06	0.18	0.12
Retail trade	17.4	0.02	0.05	0.03
Finance and insurance	14.8	0.08	0.13	0.05
Real estate (excluding owner-occupied housing)	11.2	0.00	0.00	0.00
Other service industries	39.1	0.05	0.16	0.11

Note: The contributions to the aggregate are computed using Domar weights and gross output at the industry level and aggregating up to the subsector and sector level.

tion.[15] The services-producing industries are responsible for 80 percent (0.62/0.77) of the contribution of IT capital to post-1995 productivity growth in the nonfarm economy. The contributions were particularly large from wholesale trade, finance, and other services (primarily business services and health).

We have shown that the IT contribution to labor productivity growth and also the MFP contribution are both located largely in services industries. It is perhaps tempting to link these two results to infer that in some way acceleration in MFP growth in the services industries is linked to their increased use of IT capital. Both the productivity model and the evidence, however, are inconsistent with this hypothesis.

In the growth accounting framework, MFP is a residual; it shows the productivity growth that is not attributable to growth in inputs (including growth in IT capital inputs). Thus, IT usage should not, in principle, be associated with MFP growth because the influence of IT on productivity growth is already estimated. However, IT and MFP growth could be related in the data for at least three reasons:

1. In the growth accounting framework, one assumes that inputs, including IT inputs, earn normal returns. If IT in fact earns a larger net return than other capital, which is sometimes asserted, then IT's contribution to output growth would be understated, the error would inappropriately inflate MFP, and IT and (mismeasured) MFP would be correlated.
2. It is often asserted that IT investment involves "coinvestments." Many of the coinvestments are probably not counted in the national accounts investment data (software is capitalized and included, so software is not a factor in the coinvestment that is omitted). If coinvestments are missed, then the total investment associated with IT is understated by the amount of the uncounted coinvestment, IT's contribution is also understated, the error inappropriately inflates MFP, and the error is correlated with IT.
3. IT may facilitate entrepreneurial innovation. Investment in innovative resources and innovative activity may not be counted directly in national accounts, so again there is an understatement of inputs, a consequent mismeasurement of MFP, and the measurement error is correlated with IT.

We tested the IT-MFP hypothesis in the following manner. First, we constructed measures of IT intensity by industry (Triplett and Bosworth

15. As in other parts of this paper, the aggregation of the industry contributions (shown in table 14.7) does not equal the IT contribution to the direct productivity measure because of reallocation effects discussed earlier. For that reason, the top line of table 14.7 does not equal the top line of table 14.6. Note that reallocation effects reduced the total contribution of IT before 1995, but added to it after 1995.

2006). Then we regressed the change in MFP post-1995 on the level of IT capital intensity in 1995 (we used the proportion of capital services arising from IT for this purpose). The correlation coefficient was only 0.05 and was not significant.[16] From this, we conclude that there is no association between IT investment and MFP growth (which is what the growth accounting model suggests) and no evidence that IT is "special." Information technology can be analyzed like any other productive input.

14.7 Consistency with Other Studies: IT-producing and Services Industries

Studies using macro approaches, including Oliner and Sichel (2000) and Gordon (2000, 2002), find MFP acceleration in the United States after 1995, but also estimate (in somewhat indirect ways) that two-thirds to all of the aggregate acceleration is accounted for by MFP acceleration in the industries that produce IT investment goods. For example, Gordon (2002, 65) concludes: "There has been no acceleration of MFP growth outside of computer production and the rest of durable manufacturing."

The view that all recent MFP growth is in the IT-producing industries suggests that the post-1995 productivity acceleration is fragile because it rests entirely in a single set of goods-producing industries. Additionally, it suggests that recent U.S. productivity performance differs from that of Europe mainly because the United States has a larger IT-producing sector. In contrast, our finding that MFP acceleration is broadly—though not universally—based in services industries leads to the view that something significant did change in the U.S. economy. Moreover, changes in IT-using industries probably explained a good amount of the recent productivity differences between the United States and Western Europe. Thus, reconciling the apparently conflicting findings has considerable importance.

Before considering the research results, we address an essential methodological point.

14.7.1 A Note on "Exhausting" Total MFP

The macro studies "back off" estimates of MFP in IT-producing industries from the growth of *direct aggregate-level MFP.* Doing so seems to exhaust or nearly exhaust total MFP growth and to leave little room for MFP growth in the rest of the economy. For example, backing off Oliner and Sichel's IT MFP estimate (0.77 percent per year) from the trend BLS MFP growth estimate (1.17 percent per year) appears to leave only 0.40 percent per year MFP growth outside the IT producing industries (see the first col-

16. The same correlation on labor productivity produced a significant coefficient, as expected. See Triplett and Bosworth (2004, 31).

Table 14.8 **Alternative "backing out" exercises for comparisons of IT-producing and other industries multifactor productivity (MFP), 1995–2001 (trend rates of change)**

		BEA data set		
	BLS MFP	Direct MFP estimate	Sum (industry MFPs)	Sum (positive industry MFPs)
1. Nonfarm business MFP (table 14.5)	1.17	1.44	1.58	2.09[a]
Contribution of:				
2. Machinery industries MFP (table 14.6)	0.51	0.51	0.51	0.51
3. Oliner and Sichel (2002) IT-industry MFP	0.77	0.77	0.77	0.77
4. Remainder (row 1 – row 2 = MFP outside IT)	0.66	0.93	1.07	1.58
5. Remainder (row 1 – row 3 = MFP outside IT)	0.40	0.67	0.87	1.32

Source: Authors' computations as explained in text.
[a]Sum of positive (only) industry MFP growth, from tables 14.2–14.6.

umn of table 14.8, row 5).[17] This calculation is the basis for Gordon's statement, quoted previously. If one backs the same IT estimate from the growth in the direct aggregate-level MFP measure from BEA data (which is greater, for the reasons discussed in section 14.4), MFP growth outside IT appears a little greater because the overall MFP growth estimate is larger in the BEA database, as explained earlier (refer to the second column of table 14.8).

However, we showed in section 14.5 that the sum of all industries' MFP growth exceeds growth in the direct MFP measure because of reallocations. If one wants to determine whether non-IT industries contribute to MFP growth, clearly the starting point is the *aggregation of industry MFP growth rates,* not the direct aggregate-level measure that includes reallocations. As the third column of table 14.8 shows, that backing off exercise leaves more room for non-IT MFP. For illustration, backing off our industry IT MFP measure (0.51) from the net industry MFP change leaves 1.07 percent per year contribution to net MFP growth from industries outside the IT-producing sector, more than twice the amount that originates inside the IT-producing sector.

One might think of column three as the answer to the question: "Has there been any *net* MFP growth outside the IT sector?" But if one really wants to determine whether there has been *any* MFP growth outside the IT sector, then the starting point should be the sum of all the industries having positive MFP growth. This is shown in the last column of table 14.8.

17. For comparability, we show trend rates of MFP growth in table 14.8. Using Oliner and Sichel's (2002) average annual rate of MFP growth to the 2001 recession year (0.99) yields only 0.23 for the non-IT growth rate.

Positive MFP growth in industries outside the IT-producing sector contributes three times as much MFP growth as do the IT-producing industries, using our measure of IT MFP growth, and twice the IT-industry contribution, using Oliner and Sichel's IT estimate. By any measure of MFP in IT production, MFP growth outside IT production is substantial and greatly exceeds the MFP contribution from IT production.

There is no necessary conflict between our finding of substantial MFP growth in services industries and the finding of high MFP growth in the IT-producing industries. The misinterpretation arises because some researchers, observing a large MFP contribution from the production of IT, have concluded incorrectly that there can be no other similar contributions of equal size from other industries. Jorgenson, Ho, and Stiroh (2005, 462) make the same point: The "conclusion . . . that all productivity growth originates in these two IT-producing industries . . . would be highly misleading, since the sum of the contributions of . . . agriculture and wholesale trade . . . also exhaust productivity growth for the economy as a whole."

14.7.2 Reconciliation

Our estimates, however, are different from those of other studies.

Two major alternatives to our study are the macro study by Oliner and Sichel (2002) and the industry study by Jorgenson, Ho, and Stiroh (2006). With respect to the contributions of IT capital deepening and of MFP in the IT-producing industries, Gordon's (2002) influential study relies on Oliner and Sichel's estimates, though he also buttresses them with independent calculations of his own. Accordingly, we focus on the Oliner and Sichel and Jorgenson, Ho, and Stiroh studies.

Our study differs from the others in its output measure and its labor input measure, both of which are tied to our use of the BEA industry database. The Oliner and Sichel (2002) study relies on the BLS output measure (from the expenditure side of the accounts), which means that their output measure grows less rapidly after 1995 than our income-side measure because the statistical discrepancy (the difference between the two sides of the accounts) grew after 1995. Other things equal, the income-side measure we use gives more labor productivity after 1995 and more MFP growth. The benchmark revision to GDP that was released in December 2003 raised the product-side estimate more than the income side, which implies that our product-side productivity measure hold up.

Jorgenson, Ho, and Stiroh (2006) use a wider definition of output (it includes both government and the household sectors) than employed in our study or in Oliner and Sichel (2002). The wider measure grows somewhat more slowly, implying less MFP growth, other things equal (partly because the way government output is measured assures low productivity growth in the government sector).

Additionally, the labor input in our study does not include a labor quality adjustment, and it is based on employment, rather than hours. When labor quality is growing, this means that we have too much MFP growth because the contribution of the mismeasured input falls into MFP.

All studies estimate capital deepening and distinguish IT capital deepening from improvements in the non-IT capital-labor ratio. Jorgenson, Ho, and Stiroh (2006) estimates of capital deepening and IT capital deepening are by far the largest, mainly because of their different output concept (the growth in IT capital services in the household "industry" after 1995 is the largest of any industry). Our estimate of IT capital deepening is slightly smaller (by 0.17 points) than that of Oliner and Sichel (2002). We do not know why, but this is not a major factor in the comparisons. Less capital deepening, of course, increases our aggregate MFP estimate, relative to Oliner and Sichel.

Putting all this together, these three factors—difference in output measure, difference in estimates of IT capital deepening, and our omission of labor quality—cause our aggregate non-IT MFP estimate to exceed that of Oliner and Sichel (2002) by around 0.4–0.5 points after 1995.[18] Our MFP estimate is more than twice that of Jorgenson, Ho, and Stiroh (2006), mostly because of the effects of including the household and government sectors in their estimates.

14.8 Measurement Issues

The BEA industry data set has been substantially improved in recent years. The situation has changed significantly since Baily and Gordon (1988) and the Griliches (1992) volume on services drew attention to some of the measurement problems. As discussed previously, the most notable change has been the inclusion of measures of gross output and intermediate purchases in a system that previously relied exclusively on value added (GDP originating) measures of output.[19] At the industry level, gross output provides a measure that is much more closely aligned with the microeconomic concept of a production function and imposes fewer restrictions on the nature of the substitutions among factor inputs and technical change.

18. Triplett and Bosworth (2004, chapter 2) consider this matter at greater length, but a definitive answer awaits publication of Capital, Labor, Energy, Materials, and Services (KLEMS) data on the new North American Industry Classification System (NAICS) "Electronics and Computers" sector, which is the appropriate industry grouping for the purpose. Previous analyses have been conducted at the level of the total-machinery industries, which makes it difficult to extract the contribution of electronics manufacturing from the non-high-tech sectors.

19. The expansion was made possible by the increased information on services provided by the Census Bureau surveys and the expansion of the Producer Price Index program of the BLS to cover a larger number of service industries.

At the same time, the expanded usefulness of the data set has highlighted some of the remaining important problems. In the following sections we address four aspects: inconsistent data sources, a comparison of alternative output data sets, negative productivity growth industries, and shortcomings in the labor input data.

14.8.1 Inconsistent Data Sources

At present, the BEA constructs the industry measures of value added and its components from sources that correspond to those used to measure the income side of the national accounts—that is, the Internal Revenue Services (IRS) for profits and the BLS for wages and salaries. Those data that are derived from company reports must be converted to an establishment basis. In contrast, the measures of gross output are constructed from the sources used to construct the input-output (I-O) accounts, primarily the Census Bureau business censuses and surveys, which focus directly on establishments. Intermediate purchases are then estimated residually as gross output minus value added. This contrasts with the I-O accounts that provide direct estimates of both gross output and purchased inputs, with value added being the residual.

The industry estimates of value added (GDP originating) can differ substantially from those of the I-O accounts (see the detailed comparisons in Triplett and Bosworth [2004, chapter 2]). As noted by Yuskavage (2000), the differences are larger at the industry level with some offset within industry groups. Somewhat surprising, the percentage differences are larger and more volatile for the goods-producing industries, but that is partially a reflection of the more detailed division of the goods-producing industries.

The quantity (constant price) measures of gross output are computed at the four-digit SIC level largely using price indexes from the BLS price programs and aggregated as chained indexes to the two-digit industry level. Information about the composition of purchased inputs is taken from the I-O accounts, but it must be interpolated for non-I-O years. Thus, purchased inputs lack the compositional detail needed to compute high-quality chain indexes. The volume measure of value added is effectively computed as the difference between the quantity values of gross output and purchased inputs.

While one expects measures of labor productivity growth to vary between gross output and value added, the magnitudes are often very large and volatile over time. For our group of fifty-four industries, the standard deviation of the difference between the two growth rates is 3.6 percentage points even though the average growth is 2 percent in each case. It is unlikely that the volatility could result solely from changing patterns of outsourcing. Instead, all of the inconsistencies between the income and I-O data sources are concentrated in the residual calculations of each industry's intermediate purchases. Purchased inputs matter less for MFP as the computation of MFP using either gross output or value added yields essentially the same estimates of its contribution to aggregate (value added) MFP.

In the long run, the objective is to fully integrate the GDP by industry and the I-O accounts. The integration is currently incomplete because of insufficient source information, and the problem is particularly severe for services. Census Bureau sources cover about 90 percent of gross output but only 30 percent of purchased inputs. The business surveys of the Census Bureau are being expanded to provide more detail, and the BEA is planning to achieve a partial integration of its GDP by industry and the annual I-O accounts over the next several years.

14.8.2 Alternative Data Sets

The BEA is not the only source of industry-level data. Two different programs of the BLS—its productivity program and its employment projections program—also produce industry data that can be used for productivity analysis.

The BLS Productivity Office produces detailed industry output and productivity estimates within manufacturing. The manufacturing-output series of the BLS and the BEA are both gross output, and they both rely on Census Bureau shipments data. However, the BLS constructs its own measures of output and excludes an estimate of intramanufacturing shipments. At the level of two-digit SIC industries, the difference in output growth can be quite substantial, ranging from –0.8 percent to +1.0 percent per year over the 1995 to 2000 period. The differences seem too large to explain by changes in the amount of intramanufacturing shipments, but we do not know the sources. A recent very thorough and enlightening analysis of output trends as measured by the BEA and the BLS Productivity Office data is Fraumeni et al. (2006).

More relevant for our focus on services, the employment projections program of the BLS produces detailed industry measures of output and employment over the period of 1972 to 2000, covering both goods-producing and services-producing industries. This is a basic data source for the productivity studies of Dale Jorgenson and his colleagues. The data set includes output measures for a considerable number of the services-producing industries that we have used in our analysis. Table 14.9 provides a comparison of the output growth rates over the 1987 to 2000 period for twenty-eight of our twenty-nine industries, where it appears that the coverage by SIC codes is the same.[20]

It is evident from the table that growth rates for individual industries

20. The BLS projections office data set was not, unfortunately, considered in the otherwise valuable paper by Fraumeni et al. (2006); we gather because of internal bureaucratic reasons.

Table 14.9 **Differences in growth rates of industry output, BEA industry accounts and BLS Office of Employment projections, 1987–2000 (average annual rates of change)**

	1987–1995			1995–2000			Change		
Industry	BEA	BLS	Difference	BEA	BLS	Difference	BEA	BLS	Difference
Railroad transportation	3.6	1.0	–2.5	0.7	–0.6	–1.3	–2.9	–1.6	1.2
Local and interurban passenger transit	1.5	1.6	0.2	2.4	1.2	–1.1	0.9	–0.4	–1.3
Trucking and warehousing	5.7	4.0	–1.7	4.1	4.6	0.6	–1.7	0.6	2.2
Water transportation	2.7	1.4	–1.3	4.7	–0.5	–5.2	2.0	–1.9	–3.9
Transportation by air	3.6	4.8	1.3	5.4	1.5	–3.9	1.8	–3.3	–5.2
Pipelines, except natural gas	–1.6	–0.4	1.2	0.1	–3.0	–3.2	1.7	–2.6	–4.3
Transportation services	6.2	5.7	–0.5	6.2	5.7	–0.5	0.0	0.0	0.1
Telephone and telegraph	5.4	4.5	–0.9	13.4	7.6	–5.8	8.0	3.1	–4.9
Radio and television	2.3	1.9	–0.4	4.7	2.7	–2.0	2.4	0.7	–1.6
Electric, gas, and sanitary services	2.5	0.4	–2.1	1.5	1.6	0.1	–1.0	1.2	2.2
Wholesale trade	4.4	4.0	–0.3	6.0	4.3	–1.8	1.7	0.2	–1.5
Retail trade	2.9	1.9	–1.1	5.5	4.3	–1.3	2.6	2.4	–0.2
Depository institutions	1.5	3.4	1.9	2.9	6.4	3.5	1.4	3.1	1.6
Nondepository institutions[a]	8.2	1.0	–7.2	12.3	9.5	–2.8	4.1	8.4	4.4
Security and commodity brokers	9.5	7.2	–2.3	23.4	22.0	–1.3	13.8	14.8	1.0
Insurance carriers	0.7	1.3	0.6	–1.5	0.6	2.2	–2.3	–0.7	1.6
Insurance agents, brokers, and service	–1.8	1.2	3.0	4.1	4.0	–0.1	5.9	2.8	–3.0
Real estate	4.0	2.1	–1.8	3.5	2.1	–1.3	–0.5	0.0	0.5
Hotels and other lodging places	2.4	2.0	–0.4	3.2	2.7	–0.5	0.8	0.7	–0.1
Personal services	3.2	2.8	–0.4	2.7	3.9	1.2	–0.5	1.1	1.6
Business services	8.6	6.8	–1.8	11.1	9.5	–1.6	2.5	2.7	0.2
Auto repair, services, and parking	3.2	3.8	0.6	4.1	5.2	1.1	0.9	1.4	0.5
Miscellaneous repair services	3.7	2.3	–1.4	1.0	1.7	0.8	–2.7	–0.6	2.2
Motion pictures	4.4	5.7	1.3	3.0	6.6	3.6	–1.5	0.8	2.3
Amusement and recreation services	7.4	5.6	–1.8	3.9	6.7	2.8	–3.5	1.1	4.6
Health services	3.2	3.0	–0.1	2.6	2.8	0.2	–0.6	–0.3	0.3
Legal services	1.4	1.4	0.0	2.9	2.0	–0.9	1.5	0.6	–0.9
Educational services	3.3	2.2	–1.1	2.7	2.9	0.2	–0.6	0.7	1.3
Value-added weighted sum	2.5	2.1	–0.5	3.5	3.0	–0.5	1.0	1.0	0.0

Source: Gross output measures from the BEA industry data set and the employment projections program of BLS at http://www.bls.gov/emp/hojme.htm.

[a]The BLS measure includes SIC 67 (Holding and other investment offices).

often differ substantially between the BEA- and BLS-projections data sets. The differences are large even for industries, such as transportation, communications, and utilities, where we would believe that the quality of the source data is quite high. For example, the BLS-projections data report a substantial slowdown in airline output growth (comparing 1995–2000 with the previous period), where the BEA data indicate acceleration. The BLS measures also report less growth in the large retail- and wholesale-trade sectors, where we found a large acceleration of growth in both labor productivity and MFP. On the other hand, the BLS-projections data show more output growth acceleration in depository banking, insurance, and the amusement and recreation industry (the latter is one of our negative productivity industries).

Using value added weights, we find that the BEA data imply a slightly faster growth of output in the services-producing industries as a whole in both 1987–1995 and 1995–2000; but the magnitude of overall post-1995 acceleration is the same. Thus, despite the large differences at the level of individual industries, the two data sets are in surprisingly close agreement about the overall acceleration of output growth in the services-producing sector. As it has been our experience that the two agencies produce very similar employment estimates at the industry level, the BLS projections programs' output measures seem to offer strong support for the finding in the BEA industry data of a large improvement of productivity growth in overall services, even though they conflict greatly with BEA output measures at the detailed level.

We have been surprised by the degree of overlap between the industry programs and the BEA and the BLS Projections Office, yet it appears that there has been very little effort to compare and contrast their sources and methods. It seems evident that there would be substantial benefit to tracing down the sources of differences in the alternative output measures. It is confusing for the statistical agencies to publish such contradictory measures, particularly when the sources of variation are not documented. While we are unlikely to see movement toward an integrated U.S. statistical system (where such redundancies would be eliminated by consolidation of these statistical programs, thereby melding resources to improve the data), this is one area where there would be significant gains from greater coordination of research efforts between the two agencies.[21]

14.8.3 The Negative Productivity Growth Industries

Negative productivity growth always attracts skepticism, and well it should. In our estimates, the following industries have negative labor productivity growth over the 1995 to 2001 interval:

21. Such a comparison is an obvious extension to the work reported in Fraumeni et al. (2006).

- Education –0.95 percent
- Amusement and recreation –0.41 percent
- Hotels –0.57 percent
- Insurance carriers –1.66 percent
- Local transit –0.61 percent
- Construction –1.12 percent

Analyses of the negative productivity issue include Corrado and Slifman (1999) and Gullickson and Harper (2002). Both studies set the negative-productivity industries (a larger number in their studies than in our results) equal to zero and recomputed aggregate productivity growth. There is no doubt some value to this procedure as a "what if?" exercise. However, we see little reason for supposing that cutting off the left tail of the distribution of productivity changes improves the estimate of the mean.

Instead of mechanical "lopping off the tail" exercises, we believe that the statistical agencies should seek to identify the sources of the negative bias—that is, to take negative productivity growth as an indicator for allocating resources to improve measurement. From our experience with the Brookings economic measurement workshops and from other information and research, we offer the following hypotheses.

Education

Educational output was the subject of a Brookings workshop in which two conclusions emerged. (a) No agreed on measure of the output of the educational function itself exists, and (b) universities, and to an extent perhaps secondary education as well, are classic multioutput firms, in the sense that the cost function for their different activities is not separable on the inputs. For universities, joint outputs include, in addition to education of students, research, lodging and meal services, and entertainment (sports). These outputs interact with educational decision making (Ehrenberg [2000] provides numerous examples from his tenure as dean at a major university), but the output of these other activities is not normally included in the "industry's" output, which is usually deflated only with an index of tuition. Interestingly, two of the joint products of universities (lodging and entertainment) also exhibit negative labor productivity growth (see our table 14.2), even when located in specialized firms. We suspect that these relationships are neither coincidental nor insignificant, even after allowing for the fact that universities do not pay even the minimum wage to many workers in their entertainment activity. Moreover, at least in some universities, the employment figures may be suspect if faculty members devote an increasing amount of time to outside pursuits that do not directly contribute to the output of their employers.

One concludes from this that there are all kinds of measurement problems in computing productivity of the educational sector, covering the definitions of current price output, the deflators, and counting the labor input. Jorgenson and Fraumeni (1992) and also O'Mahoney and Stevens (2004) estimate the output of education by assessing its contribution to human capital and, therefore, to lifetime earnings streams of graduates. Their estimates are far larger than the output that is presently recorded in national accounts, a result that is consistent with the hypothesis that educational productivity is biased downward because of mismeasurement of educational output.

Amusement and Recreation

We know of no recent research on the output of the amusement and recreation industries.

Hotels

For hotels, the McKinsey Global Institute (2001) found the poor labor productivity performance of hotels consistent with other evidence, including information from McKinsey's own consulting practice. Some of the quality improvements in hotel services, notably computerized reservation services, are unpriced outputs that have clearly created benefits to the customer but are not captured in the output measures used in national accounts. Thus, properly measured hotel productivity might not have negative growth.

Insurance

We suspect that negative productivity for insurance carriers is the result of an inadequate and unworkable definition of insurance output in the National Income and Product Accounts (NIPA) and the System of National Accounts (SNA). The long international debate on this topic is reviewed in Triplett (2001). In the national accounts, insurance output is defined as "premiums minus claims," which means that the insurance company is depicted as administering the policy on the behalf of the policy holders and not as absorbing and managing risk. However, Triplett points out that because no contract exists for the "service" of managing the claims pool on behalf of the policy holders, no such service can be priced. Thus, the concepts underlying the PPI price index for insurance (they price the premiums, which we think makes economic sense—see Sherwood 1999) are inconsistent with the national accounts view of insurance output.

Insofar as insurance companies have improved their management of risk—which ought, other things equal, to reduce the margin of premiums minis claims—these improvements are outside the scope of the national accounts' output measure. As additional evidence on this score, we note the peculiar behavior of the data for insurance carriers and insurance agents, considered together: at least one of them is almost always negative, but it is not always the same one, and improvements in the performance of one (or GDP revisions to one) are usually reflected in deterioration of the measured performance of the other.

In Triplett and Bosworth (2004, chapter 7), we show that the national accounts convention for measuring insurance carrier output accounts for the industry's negative measured productivity in the BEA industry accounts data. Using BEA data, we reestimate output and labor productivity growth using a premiums-plus-investment-income concept for current-price output, with appropriate adjustments to the deflators. The alternative output concept produces positive labor productivity growth in the insurance industry, not negative growth as does the current BEA output concept. The exercise suggests where at least one measurement problem lies. However, the industry's rate of productivity growth remains small, on the order of +0.5 percent (half of 1 percent) per year. We speculate that better allowance for insurance companies' handling of risk and better accounting for the value of its new products would increase the measured rate of insurance productivity even more.

Local Transit

Although we are not sure the data are correct, on its face the negative productivity growth in local transit is consistent with substituting its own internal labor for previously purchased inputs. Presumably, this would be the result of regulation, union contracts, and the general climate under which these services operate. The industry's multifactor productivity growth in the recent period is quite respectable (1.29 percent per year) and goes in the opposite direction from its labor productivity. It is also possible that the industry is an example of inconsistency in the source data.

Construction

Construction is an industry whose productivity performance has puzzled many economists (see Baily and Gordon 1988; Pieper 1990). Ours is a paper on services, not on goods-producing industries, but we think that research on measuring the output of construction deserves high priority. Though major parts of construction output are deflated with hedonic price indexes and have been for many years, deflators for other parts are clearly inadequate. We understand that the producer price index program has turned attention to producing deflators for this industry. The BEA is introducing hedonic indexes for commercial construction in the 2003 benchmark revision, but these indexes rise more rapidly than the deflators they replace, which would make the negative productivity in construction even more negative.[22]

22. Based on conversations with Bruce Grimm of the BEA.

14.8.4 Labor Hours and Input by Industry

The labor input in our study is persons engaged in production, and not hours, which are the labor input in the BLS productivity reports and in Jorgenson, Ho, and Stiroh (2006); in addition, we do not apply a labor-quality adjustment. Neither of these aspects is included in the BEA industry data set, and we lacked the resources to estimate an index of labor quality at the industry level. Our analysis indicates that omission of labor quality creates problems for measuring industry MFP.

The reliance on employment, rather than hours, is an equally serious problem. We have, however, little confidence in the estimates of hours across industries. The major source of industry hours is the BLS monthly establishment survey, known as the "Current Employment Survey." The objective of this survey can only be described as archaic, for it persists in collecting hours and earnings information *only* for what it calls "production workers" in manufacturing and "nonsupervisory workers" in the rest of the economy.

The BLS productivity program estimates the hours of nonproduction and supervisory workers, using whatever information it can find. Hours of self-employed and salaried workers are obtained from the BLS-Census monthly household survey, the Current Population Survey (CPS).

Why the BLS emphasizes production and nonsupervisory workers for its establishment employment surveys defies understanding. Even on statistical grounds, the decision is questionable. With the huge changes in workplace organization and management in recent years, the boundary between what is a "production" and a "nonproduction" worker has become so blurred that it has lost its meaning. The same statement applies to "supervisory" and "nonsupervisory" workers outside manufacturing, except there the distinction has always been unclear. This should not be news to a government statistical agency, for the line between what is a supervisory and a nonsupervisory worker within government has also provoked great controversy.

But even if the boundaries between what the BLS does and does not collect were sharply defined, devoting the huge amount of resources that are put into the BLS establishment program[23] to collecting hours and earnings data on only a fraction of the workers shows a profound disregard for the data that are important for economic analysis. Surely we want to know employment, earnings, and hours for all workers, not just for some fairly arbitrarily defined subset of them.

As we understand it, the BLS reasoning behind holding onto the "production worker/nonsupervisory worker" definition for its establishment surveys rests on preserving time series comparability. Although we, too,

23. In both budgetary and sample size (so in resplendent burden), this is one of the largest collections in the U.S. statistical system. Significantly, other countries seem to collect the same information at far less expense, Canada being one example.

value time series continuity, it should not be at the cost of a failure to collect the information that is most relevant for analysis. In any event, blurring of the boundaries means that a constant definition does not produce time series comparability.

When "measurement problems" come up in the analysis of productivity, most economists immediately think about deflators. For industry productivity, the lack of a well-measured labor input is an equally serious problem and more inexplicable because measuring worker hours in services industries is nowhere nearly so complicated as measuring services industries' output prices—an area where the BLS (in its PPI program) has made exemplary progress in recent years.

14.9 Conclusions

Using the relatively new BEA-BLS industry database, our study shows that the post-1995 growth in U.S. productivity is largely a story of developments in the services industries. For both labor productivity and MFP, productivity growth has been faster in services-producing industries than in goods-producing industries in recent years. Because this was not the case before 1995, services industries account for most of the acceleration in labor productivity and all of the acceleration of MFP after 1995. We emphasize that this is not just a story of growth in a small number of large services industries—twenty-four of twenty-nine services industries show labor productivity growth after 1995, and in seventeen of them, labor productivity growth accelerated. In more than half of the services industries, MFP accelerated after 1995.

In terms of contributions, services industries account for nearly three-quarters of total industry labor productivity growth and more than three quarters of total industry MFP growth in the period after 1995. Moreover, capital deepening from IT investment in services industries accounts for 80 percent of the total IT effect in the U.S. nonfarm sector after 1995.

The services productivity story in recent years is a striking change from the past, and strikingly different as well from the stereotypical view that services industries are stagnant and without potential for technical changes or rapid productivity improvement. In recent years, services industries have become an engine of economic growth.

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