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**Services Productivity in the United States:
Griliches' Services Volume Revisited**

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I. Introduction and Overview.¹

Zvi Griliches (1992) reviewed services sector productivity trends, as well as issues in measuring services productivity, as these matters stood in the early 1990's (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 1990's and early 2000's 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 after the late 1960s. Services, therefore, acted as a brake on U.S. productivity growth, a conclusion that was particularly 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. productivity after about 1995. We find, in this paper and in our previous one (Triplett and Bosworth, 2002), 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.”² In this, our findings are a mirror

¹ We are very indebted to David Gunter and Kristin Wilson for their superb research assistance.

² Triplett and Bosworth (2002). 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).

image of the conclusions emphasized by Griliches: Both the post-1973 slowdown and the post-1995 acceleration in U.S. productivity growth is located disproportionately, though not entirely, in services.³

In Griliches' time and now, services industries are the industries that are the most intensive users of information and communication technology (IT) 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 account for a large part of labor productivity growth in services-producing industries. This, of course, is another change from the early 1990's, 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, pages 8-9).

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 multifactor productivity (MFP) for all two-digit services industries based on gross output, using a combination of government data bases from the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics

³ Services MFP growth has not been emphasized in other research on the post-1995 resurgence in productivity,

(BLS)—and implicitly the Census Bureau, since the other two agencies’ compilations rest heavily on data ultimately collected by the “economic directorate” part of the Census Bureau. These industry measures also 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 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 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.

Our results are rich and complex, and our conclusions conflict, to an extent, with interpretations of some previous research. Accordingly, it is appropriate to start with a summary of our findings.

It is now well known that aggregate U.S. labor productivity and multifactor productivity (MFP) accelerated after 1995, with the amount of the acceleration understandably depending on the end period. For this paper, we use 2001 because it is the last for which industry accounts are available. However, because 2001 was a recession year, using it as an end point gives a lower estimate of post-1995 trend productivity growth than using either 2000 or 2002. Using the most recent year (2002), for example, labor productivity rose at a 2.8 percent annual rate since 1995, compared to 2.4 percent over the 1995-

which has perhaps too strongly emphasized high productivity growth in electronics producing industries.

2001 period. In order to reduce the sensitivity of our results to these end-point issues, we present mainly least-squares trend rates of change, 1987-1995 and 1995-2001.

Our first major finding is that, over the post-1995 period, labor productivity in the services-producing sector has advanced more rapidly than labor productivity in the goods-producing sector. Table 1 presents a sector-level summary, in which aggregated value added (for private nonfarm, goods-producing and services-producing sectors, taken from the BEA industry accounts) is used to calculate the growth in labor productivity and MFP from aggregated inputs at the corresponding sector level.⁴ Services labor productivity advanced at a 2.6 percent trend rate in 1995-2001, 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 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). Net, 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). With respect to the services industries, our major conclusions are broadly the same as in our previous paper (Triplett and Bosworth, 2002), though the addition of another year's data, the most recent GDP revisions, and our use of least-squares trends in this paper, rather than end points, all cause small differences.

The aggregations conceal much heterogeneity among the industries. We compute industry labor productivity and MFP for 25 goods-producing industries and 29 services-producing industries. In these lower-level industries, productivity is computed using a measure of gross output, rather than value-added. 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, a combination of motion pictures, 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.

Our conclusions about services industry productivity conflict with a widely cited *interpretation* of previous macro-level studies. In the macro studies, researchers have “backed out” of the macro productivity change the contribution of IT producing industries. They concluded that the MFP contribution of IT-producing industries accounted for all or nearly all of the post-1995 acceleration of U.S. MFP growth and have said (or have been interpreted as saying) that no improvement in MFP growth took place in the other industries.

We show in this paper that post-1995 MFP growth resurgence is evident in many non-IT-producing industries, and was especially evident in a number of services industries. We do not disagree that MFP in the IT-producing industries was very high, as emphasized by other studies. It contributed greatly to the tremendous fall in IT prices and thus to the surge in IT investment (and in turn therefore to labor productivity growth through the standard channel of capital deepening). However, as we show in section V, there is no inconsistency in finding strong MFP contributions from both IT production and from services industries, because the total contributions of industries that have growing productivity are greater than the *net productivity growth* in the aggregate or sector (because of the offsets from industries that make negative contributions and because of reallocations across industries).

As a second major strand of our research, we estimate the contributions of IT capital to labor productivity growth. We confirm the finding of others about the strong contribution of IT capital deepening. We add to the previous research results in finding strong contributions of IT to labor

⁴ As explained in section II of this paper, these aggregations do not agree precisely with BLS published productivity

productivity growth in the services industries, which are the industries where IT intensity is greatest. This helps resolve a rather confused debate about whether the effects of IT can be found in the IT-using sectors

Finally, we evaluate in our last section the U.S. industry database, as it now stands. Although it has been improved greatly over the past dozen years, it is hardly fully adequate. As we detail in this paper, results for some industries seem anomalous. Putting the database through the crucible of productivity estimation points to where, by exposing anomalous results, efforts toward improving the data would have their highest payoffs. In some of these cases, we have hypothesis about where the weaknesses in the data lie, and these are discussed briefly in the last part of the paper. We contend that weaknesses in the industry labor input measures urgently need attention; labor measurement is a neglected problem in estimating and understanding productivity change at the industry level.

II. The Industry Database and Aggregate Nonfarm Business Productivity Estimates

We use for this paper the recently expanded industry accounts of BEA, and combine them with data on capital service flows from the Bureau of Labor Statistics (BLS). The BEA industry data set has been improved substantially in recent years in ways that make it more suitable for productivity analysis. The data set now includes measures of output and purchased inputs to go with the prior measures of value added (formerly somewhat confusingly called “gross product”) by industry. The industry-specific price indexes have been improved, particularly for the services-producing industries, because of expansion of price measures for services industries in the BLS Producer Price Index program. 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).⁵

numbers.

⁵ The BEA industry data set is an alternative to that developed by Dale Jorgenson and his various co-authors. 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.

The BEA industry accounts are constructed to be fully consistent with the estimates of aggregate GDP. They exist for 66 industries, published annually, at roughly the 2-digit industry level of the old SIC classification system. After excluding government and the farm sector, and combining some industries for which we lack separate information on capital services, we have 54 industries (25 in goods-producing, and 29 in service-producing) within the private nonfarm business sector, spanning the period of 1987-2001.

We construct measures of labor and multi-factor productivity plus a growth accounting equation for each of these 54 industries and various sub-aggregates. The results for all 54 individual industries are shown in appendix tables A1 and A2.

In addition to the industry results, we need to create summary statistics, and we need to fit the detailed industry results into aggregate-level productivity estimates regularly published by BLS and analyzed in the macro-level studies cited above. Integrating industry and aggregate productivity estimates is not a simple matter. As we show, if one were to estimate labor productivity and MFP at the aggregate level *using the data from the BEA industry accounts* the results would differ from the corresponding aggregate productivity numbers published by BLS. Understanding why requires a somewhat lengthy review of issues that are both technical and, because they are inter-related, a bit confusing. The details are in Appendix B, but following sections provide the essence of the differences.

The Private Nonfarm Business Aggregate. Published BLS labor productivity and MFP refer to the private nonfarm business sector. For a number of reasons, presented in Appendix B, the BLS measure differs from the aggregation of BEA industry accounts to the same level. Most importantly, BLS begins with aggregate GDP as measured from the *expenditure side* of the national accounts and excludes several sectors. In contrast, our measure of private nonfarm business value added is the result of adding up the value added of individual industries as measured by the *income side* of the national accounts. The difference between the income and expenditure sides is the statistical discrepancy, which has grown in recent years. The statistical discrepancy adds an average of 0.3 percentage points annually to the growth of nonfarm business output over the 1995-2001 period, measured from the income-side, which means that

our productivity measures for the aggregate nonfarm sector grow faster, compared with the BLS labor productivity and MFP measures. Additionally, differences in deflation procedures (explained in Appendix B) add another 0.1 point to the annual growth of the BEA nonfarm aggregate.

A summary comparison of the two nonfarm business sector measures is shown in table 2.⁶ The industry-based measure of aggregate nonfarm value added grows considerably more after 1995, 4.3 compared with 3.8 percent per year (second column of table 2) for the BLS measure. It also shows more post-1995 acceleration, 1.4 versus 0.9 percent points per year, because 1987-95 income side and product side growth are the same.⁷

Because reliable measures of hours of work are not available for many of the services industries, we use the labor input in the BEA dataset—the number of persons engaged in production, which equals full-time equivalent employees plus the self-employed.⁸ This is an incomplete adjustment for variations in hours of work; at the level of total nonfarm business, it results in an index of labor services that grows slightly faster than that of the BLS—1.8 percent per year over the 1987-2001 period, compared to 1.5 percent (table 2, column 3), and it accelerates slightly, where the BLS measure shows the same rate of growth before and after 1995. This implies that hours have been falling, relative to employment growth.

The measures of capital services are obtained directly from the BLS. Thus, the small discrepancies between the two aggregates (table 2, column 4) is due solely to the minor differences in the industries that are included in the aggregate measures

Columns 5 and 6 of table 2 quantify the labor productivity implications of differences in the data. The upper panel presents the published BLS figures for the nonfarm business sector. The lower panel

⁶ This comparison table uses actual changes, as opposed to least-squares trend, so as not to confuse the comparison of the basic data.

⁷ We also show the growth rate of the aggregation of industry gross output (first column of the lower panel of table 2): Although aggregated industry gross output may not be appropriate for computing aggregate productivity, it is useful to note that its overall growth (3.9 percent after 1995) is actually closer to the BLS value added measure after 1995 than is aggregated industry value added.

⁸ The adjustment for full-time equivalents is done by multiplying total employment by the ratio of hours for all employees to hours for those on full-time schedules. This differs from the treatment in Stiroh (2001) where the labor measure is restricted to FTEs.

presents the nonfarm business LP and MFP one gets when the output aggregate is formed from the BEA industry accounts, and the labor input is employment, rather than hours.

Labor productivity growth based on aggregating the BEA industry accounts is significantly lower than that of BLS prior to 1995 because of faster growth in the labor input in our data (the two output measures being the same). However, the two series are very similar after 1995 (both at 2.3 percent per year), when the higher rate of growth in aggregated industry value added is offset by more rapid growth in the labor input. Thus, the aggregated BEA industry accounts produce a significantly larger estimate of the post-1995 acceleration, 1.2 versus 0.9 percent per year (column 5 of table 2). This result complements research of Baily and Lawrence (2001), and Baily (2002), who estimated productivity from an average of income and product sides of the accounts.

A comparison of alternative aggregate MFP estimates is also presented in table 2. In addition to the other differences in output and labor input already discussed, the published BLS measure of MFP incorporates an adjustment for improvement in the quality of the workforce. Improvements in labor quality account for about 0.4 percentage points of the increase in labor productivity over the 1987-2001 period, with an offsetting reduction in the residual estimate of MFP.

However, we did not have the information required to distribute those labor quality improvements among the 52 industries. We chose instead to adjust the published BLS MFP measure of labor inputs to exclude the effect of improvements in workforce quality. On this adjusted basis, growth in the BLS measure of MFP is virtually the same overall (1987-2001) as that using the aggregated BEA industry data, as table 2 shows. But, as with labor productivity, differences between the two sub-periods result in a larger MFP acceleration after 1995 in the industry-based aggregate than in the published BLS numbers.

Manufacturing Productivity. The BLS also publishes estimates of labor productivity and multi-factor productivity growth for durable and nondurable manufacturing. Because several studies (Oliner and Sichel, 2002, and Gordon, 2002) have contended that large portions of the productivity acceleration are within manufacturing (particularly semiconductors and computers), it is important to assess the comparability of BLS and BEA manufacturing measures.

Table 3 compares growth rates for output and labor productivity (BLS measures of manufacturing MFP are currently available only through 2000). Both BLS and BEA measures of manufacturing output are based on a concept of gross output, not value added, so the statistical discrepancy is not an issue. As shown in table 3, BLS estimates substantially greater output growth acceleration after 1995 in durables manufacturing (1.0 percentage points, compared with 0.4 points). The pattern of change is different for nondurables; here, the BLS output measure records a larger deceleration after 1995. We do not know why the output measures differ, since BLS relies on the same basic Census Bureau source data as BEA (see Appendix B).

Consistent with the differences in output measures, BLS reports labor productivity acceleration of 1.6 percentage points per annum for durables manufacturing, compared to only 0.2 percentage points of acceleration for the measure based on BEA output data (right hand side of table 3). This reflects not only differences in the output measures, but also the BLS measure of hours, compared with our reliance on full-time equivalent workers. Though labor productivity measures for nondurables manufacturing also differ, BLS and BEA databases yield nearly identical estimates of the acceleration of labor productivity (0.8 and 0.7, respectively). Taking durables and nondurables together, the BLS measures imply a slightly faster growth rate for output and labor productivity for total manufacturing over the whole period and substantially more acceleration after 1995.

In summary, the BEA industry data set implies a substantially greater acceleration after 1995 of nonfarm sector productivity growth—both labor and MFP growth—than shown in the published labor productivity and MFP of the BLS. At the nonfarm level, the BEA-BLS difference is the result of basing the estimates of nonfarm business sector value added on the income side of the national accounts in the BEA data, and on the product side in BLS, plus methodological differences that result in a lower rate of overall price inflation in the industry data set, plus the difference in labor input. On the other hand, the BEA data suggest weaker acceleration of (gross output) productivity in manufacturing.

The finding of greater acceleration in the aggregate nonfarm productivity measures—and less acceleration in manufacturing—in the BEA data is an important consideration in the evaluation of the

detailed industry productivity measures that are reported in the following sections. It is also a factor in our comparison with other studies that are based on the aggregate nonfarm measures (section V). For our subsequent discussion of industry contributions and sources of productivity growth, and for comparing our results with other studies, the aggregated LP and MFP numbers in the lower panels of table 2 are our “target,” that is, the aggregation of BEA industry data that correspond to the income side of the national accounts.

III. Trends in Labor Productivity and MFP at the Industry Level

In this section, we report our estimates of labor productivity and MFP for the 54 industries in the BEA industry database. We have constructed industry productivity measures using both gross output and value added, but we emphasize the results based on gross output at the industry level.⁹

Measures of gross output are often preferred for production analysis at the industry level because they require the least restrictions on the relationship between intermediate inputs and output. The construction of a production relationship based on value added requires that the components of value added be separable from that of purchased inputs.¹⁰ The value-added construct also implies a specific way that productivity or technical change affects economies in the use of capital and labor, on the one hand, and of savings in intermediate inputs on the other.

Yet, value added is the appropriate focus at the level of the aggregate economy. As Gollop (1979) put it, the objective is to maximize society’s deliveries to final demand—which corresponds with aggregate value added for a closed economy—subject to the constraint of limited supplies of the primary

⁹ Estimates of gross output back to 1977 are incomplete for services industries, largely because early economic censuses and surveys collected very limited information from service-producing firms. See our earlier paper (Triplett and Bosworth, 2002), which carried out separate analyses for the services industries for which data extend to 1977. The information on industry value added extends back to 1947.

¹⁰ Gross output at the industry level can be represented as

$$Q = f[K, L, M, t],$$

where Q is output, and K , L , and M are capital, labor, and purchased inputs, respectively. Excluding purchased inputs and focusing on value-added is equivalent to assuming

$$Q = f[g(K, L, t), M],$$

where g is separable from M , and t_1 and t_2 represent (different) shift factors.

inputs. At this level of consideration, intermediate purchases net out (except for imports), and the aggregation of the industry outputs would involve repeated double-counting. Thus, a full consideration of the implications of productivity developments at the level of individual industries requires a means of linking gross output productivity at the industry level to the value-added concept of the aggregate.

Labor productivity is the output index divided by a simple index of the labor input. Multi-factor productivity is the ratio of the output index divided by a weighted average of the inputs, K, L, and M (capital and labor services and intermediate inputs). For the multi-factor measures we compute a Tornqvist chain index of the annual changes in the inputs where the weight of each input, s_j , is its share of total costs averaged over the two adjacent periods.¹¹

For gross output, MFP is defined as:

$$(2) \quad d \ln MFP = d \ln Q - \left\{ (1 - \nu) [s_l d \ln L + s_k d \ln K] + \nu d \ln M \right\},$$

where inputs include intermediate purchases (M) in addition to labor (L) and capital services (K), ν equals the two-period average share of intermediate purchases in gross output, and s_l and s_k are two-period average labor and capital shares, respectively.

We adjusted the labor income data to include the compensation of the self-employed. One approach is to simply assume that the self-employed earn a wage equal to that of employees in the industry. However, that adjustment produces a negative residual estimate of capital income in several industries. The BLS makes a proportionate adjustment based on the average of two algorithms: equal rates of labor compensation and a rate of return on non-corporate capital equal to that for corporations in the same industry—eliminating the possibility of a negative return to either factor. We adopted the BLS estimate of the factor shares.

Table 4 provides a detailed view of the changes in labor and multi-factor productivity for the services-producing industries and a sector level summary for goods-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 to the macroeconomic analysis. The result for all the industries are provided in the appendix.

In interpreting table 4, note that we compute sector level productivity directly—that is, manufacturing labor productivity, as an example, equals gross output of manufacturing divided by persons employed in manufacturing. These **direct sector-level** estimates are indicated in bold. Sector-level productivity estimates are not aggregations of the industry-level productivity estimates within the sector (the relations among individual industry productivity estimates and aggregate or sector level productivity are explained more fully in the following section IV). Sector-level productivity estimates are included in table 4 more as reference totals for examining the detailed industry productivity data.

For both labor productivity and MFP growth rates, the sector-level estimates for the goods-producing sector are the same before and after 1995, 2.1 percent per year for labor productivity, 0.5 percent for MFP). The lack of improvement in the goods-producing sector as a whole can be explained by a deceleration of productivity growth in mining and construction that offsets the improvements in manufacturing. In the case of construction, the oft-documented decline in labor productivity appears to have intensified recently. There are notable gains in both labor productivity and MFP growth for durable goods, as suggested in other studies. For nondurables, on the other hand, the one percentage point of acceleration in labor productivity is due to increased outsourcing and greater capital intensity; MFP growth in nondurables was actually negative after 1995. For goods-producing industries, only durable manufacturing shows acceleration in MFP at the sector level, in the BEA data.

In the services-producing industries, the overall growth in labor productivity and MFP at the sector level camouflages a wide disparity of trends. Of the 29 detailed services industries, 16 experienced labor productivity acceleration after 1995, but labor productivity decelerated for 9 industries and the

¹¹ The output data of the BEA are assembled using Fisher indexes. We switched to Tornquist indexes only to take advantage of a slightly simpler algorithm.

change was either negligible or indeterminate in 4 industries.¹² 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. These four industries represent over a quarter of total value added in the private nonfarm business sector.

Multi-factor productivity growth shows a more mixed picture in services industries. Only about half of them experienced accelerating MFP after 1995, and MFP growth was actually negative in 12 industries after 1995 (two marginally so). 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. Improvements in services sector MFP after 1995 are associated with large swings from negative to positive MFP growth in several industries (for example, local transit, pipelines, auto repair and legal services) and strong MFP growth in the big industries of trade and finance. Moreover, 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 PPI measures of price changes begin in 1991. Methodological breaks also occur in other industries, such as miscellaneous services.

IV. The Aggregation of Industry Productivity Measures.

In the introductory section of this paper, we discussed aggregating industry outputs and inputs and then computing productivity at the aggregate level (table 1). In table 4, parallel direct sector-level productivity estimates were presented that used sector-level gross output and inputs.

Computing industry productivity first and then aggregating the results raises a completely different set of issues that we need to confront in order to compare our industry productivity figures with the direct aggregate-level productivity numbers. As we (and others, including Stiroh, 2000, and Jorgenson, Ho, and Stiroh, 2002) show, aggregating industry productivity estimates generally exceeds the

¹² The latter is local transit, where labor productivity growth, though negative in both periods, advanced after 1995

estimate of direct sector-level, or direct aggregate-level, productivity 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 some macro productivity studies. In this section, it is important to bear in mind that the aggregate productivity numbers to which our industry productivity numbers correspond are those “targets” in the lower panel of table 2, that is, the direct aggregate-level productivity estimates formed from aggregating inputs and outputs in the BEA industry accounts, not the published BLS aggregate numbers in the top panel.

We also need to link gross output productivity at the industry level with value added productivity at the aggregate level. Domar (1961) provided the link to aggregating industry gross output MFP by expressing the rate of aggregate MFP growth as a weighted average of the industry 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.

Additionally, changes in aggregate productivity are related to productivity at the industry level through a combination of developments within the individual industries and changes in their relative sizes. Aggregation formulas have been developed for labor productivity and MFP, and for each of these in the situation where the underlying industry concept of output is based on gross output or value added. Recent discussions of the aggregation of labor productivity are provided by Nordhaus (2002) and Stiroh (2002). We rely on Stiroh’s formula that relates the industry measures of gross output labor productivity to aggregate value added per worker:

$$(3) \quad d \ln LP^V = \left[\sum_i w_i d \ln LP_i^O \right] + \left[\sum_i w_i d \ln L_i - d \ln L \right] - \left[\sum_i m_i (d \ln M_i - d \ln Q_i) \right];$$

to a less negative number.

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 of course, 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 in section III. Equation (3) shows that the direct aggregate-level estimate is a combination of: (1) 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 (2) reallocation terms that capture the shift of output among industries with variations in their levels of labor productivity and intermediate input intensity.¹³

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.

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

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

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.

The framework differs from that of Domar because it does not net out the intra-industry shipments, and in the case of labor, the total is simply the sum of employment at the industry level rather than being weighted by the industry share of total compensation. Our aggregations of both labor productivity and MFP use Tornqvist chain indexes, that is, the weights are averages of adjacent periods, not single period or base-period weights, as in earlier formulations.¹⁴

Using these formulas, a summary of the industry contributions to the growth in the direct aggregate (shown in bold) value-added measures of labor productivity and MFP are shown in table 5. A more complete accounting is in an appendix table. We also show for comparison direct aggregate productivity measures published by BLS.

With respect to labor productivity, the aggregation of industry productivity estimates (the within industry effects, shown in italics in table 5) more than accounts for the growth of aggregate productivity in both periods. The contributions of industry productivity changes are offset by resource reallocations (the among industries effects) that reduce the aggregate gain. For example, in 1987-1995, the aggregation of industry labor productivity 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).

¹³ This formulation differs from that of Nordhaus (2002) because it uses chain index weights (the v_i terms), eliminating what Nordhaus labeled the Baumol effect, and it adds an additional source of reallocation by measuring labor productivity at the industry level with gross output instead of value added.

¹⁴ Domar (1961) assumed a Cobb-Douglas function, which implies base period weights in a logarithmic index.

On the other hand, the post-1995 resurgence of labor productivity growth within the industries is more evident at the aggregate level because the reallocation terms have had a less negative influence in recent years—the weighted industry productivity changes (2.63 percent per year) total only 0.3 points higher than the direct aggregate estimate. Put another way, the aggregate post-1995 resurgence of 1.4 (1.46 – 1.01) percentage points per year is boosted by changes in (i.e., less negative) reallocation terms. For this reason, the aggregate acceleration (1.45 points) is roughly twice as large as is evident from a straight aggregation of the 54 individual industries (.70 points per year).¹⁵

The lower part of table 5 indicates that the reallocation terms are less important in the aggregation of the industry measures of MFP growth. Though the aggregation of industry MFP's is larger than direct aggregate-level MFP for both periods, the reallocation term is small and thus the acceleration in MFP is the same in both calculations (about 0.9 points).

We can now turn to the contributions of individual industries to aggregate productivity growth. These are shown, for all 29 services industries and for the major aggregates, in table 6.

In table 6, the industry contributions sum to the totals that are given by the first terms in equations (3) and (4), that is, to the bottom line of table 5, which is repeated as the top line in table 6. As we have already noted, this total industry productivity contribution is larger than the direct aggregate-level productivity change shown in table 5 for the nonfarm business aggregate, because the direct industry contributions are gross of reallocation effects. Similarly, the sector aggregations in table 6 (indicated in italic type) are the sums of the industry contributions within the sector; they are not formed from the direct sector-level productivity calculations presented in earlier tables.

Accordingly, one should interpret industry (and sector) contributions in table 6 in the following way: They show the contribution of industry *i* (or the industries in sector *j*) to the total industry contributions to productivity change. They therefore provide the metric for judging the contribution of

¹⁵ 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.

any industry's (or set of industries') contribution to aggregate productivity growth. For example, table 6 shows that the two machinery industries (within which are located computer and semiconductor manufacturing) contribute only about 17 ½ percent of the total industry increase in labor productivity $((0.15 + 0.31) / 2.63)$ between 1995 and 2001, and 32 percent $((0.22 + 0.29) / 1.58)$ of the total industry MFP growth.

In contrast, as table 6 shows, 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 $(1.92 / 2.63)$, while goods-producing industries account for the rest (27 percent, or $0.71 / 2.63$). Improvements within durables manufacturing are more than offset by a slowing of productivity growth in mining and continued outright declines in construction.

Of the 54 industries, 30 industries show an increased contribution after 1995, and 19 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.¹⁶ 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 6), 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 0.91 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. As shown in the table, the contribution of durable goods manufacturing is large, but it is offset by declines in other goods-producing industries, including nondurables manufacturing.

Twenty-seven of the industries show a post-1995 acceleration of the trend growth in MFP, and 17 are services-producing industries. Despite the similarity of the large contributing industries, the cross-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 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.

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). We find the same result: Overall, increasing IT capital per worker contributed 0.8 points to labor productivity (value added per worker) growth after 1995, and 0.5 percentage points to acceleration. Non-IT capital services contributed positively to growth, but only a little less than 0.1 point to acceleration.

As shown in appendix table 1, we find that the service-producing industries are more intensive users of IT capital than the goods producing industries. Breaking down the IT-deepening contribution into sectoral changes shows that most of it was in the services industries.

¹⁶ As mentioned in the prior section, we believe that the improvements in health services and other services are partly due to changes in the methodology for measuring the price deflators for output.

In services industries, increased use of IT contributed 1.0 point of labor productivity growth after 1995, which was 0.6 points more than the previous contribution of IT capital in those industries (that is, IT contributed 0.6 points to labor productivity acceleration. after 1995). Though IT contributed 0.5 to labor productivity growth in goods-producing industries, it only contributed 0.2 points to the acceleration.

Most of the effect of IT capital deepening in the U.S. economy in recent years shows up in its contribution to labor productivity growth in the services industries. Again, as with so many aspects of recent U.S. productivity growth, most of the action is in the services industries.

The contributions data are also useful for exploring the role of IT capital in the productivity revival. Following Stiroh (2002), we rank industries by the proportion of capital services that are derived from IT capital.¹⁷ We use the values for 1995, but they are essentially the same as the 1987-95 average, a correlation coefficient of 0.96. We can then relate IT capital services intensity to the growth of productivity after 1995.

Using the cross-industry averages of trend labor productivity growth from 1995-2001, we obtain a statistically significant correlation of 0.26 with the intensity of IT use. This is very much in line with the results reported by Stiroh, and it is essentially the same if we use the actual changes over the 1995-2001 period. It suggests, as we should expect, that the contribution to overall labor productivity growth has been more rapid in those industries that made extensive use of IT capital.

However, if we now apply the same analysis to the post-1995 growth of MFP, the evidence of a correlation with IT capital vanishes and the correlation coefficient declines to 0.05. This too is as expected. If IT capital investments earn a normal return and there are no substantial externalities associated with such investments, then IT capital should not be associated with MFP, which is after all the residual after taking account of all other inputs (including IT inputs).

Growth accounting analyses of productivity change (of the type we apply to industry productivity analysis) apply the assumption that IT capital earns normal returns. This has often been criticized on

various “IT capital is special” grounds. The lack of correlation between IT and MFP is evidence supporting the view that that IT can be analyzed in the same way as any other capital good.

V. Consistency With Other Studies: IT-producing and Services Industries.

Studies using macro approaches, including Oliner and Sichel (2000), Jorgenson and Stiroh (2000), and Gordon (2000, 2002), find MFP acceleration in the U.S. 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. Table 7 summarizes some selected results.

The macro studies have been interpreted as finding that IT “exhausts” or nearly exhausts the total MFP change. For example, Gordon (2002, page 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 has been taken to indicate that the post-1995 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 U.S. has a larger IT-producing sector. In contrast, our view 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 U.S. and Western Europe. Thus, reconciling the apparently conflicting findings has considerable importance.

A Note on “Exhausting” Total MFP. Before turning to the details of the reconciliation, however, we need to emphasize points that have sometimes been overlooked. The macro studies “back off” estimates of MFP in IT-producing industries from the growth of aggregate MFP. The size of our

¹⁷ For our earlier paper, we computed several different measures of IT capital intensity, using alternative definitions of IT. The industry rankings are not invariant to IT definition or to intensity measure, but many of the same industries (especially in services) appear on all the lists.

estimate of MFP in the industries that produce IT is an issue (which we explore below). But the aggregate from which the “backing off” starts also needs consideration. Table 8 illustrates.

If one backs off MFP in the IT-producing industries (whether our estimate or the somewhat larger one of Oliner and Sichel (2002)) from *direct aggregate-level MFP*, it seems to leave little “room” for MFP growth in the rest of the economy, whether one starts from the BLS published MFP estimates or from our direct aggregate-level estimate from the BEA industry accounts. This is apparent the first two columns and bottom two rows of table 8.

However, we showed in section IV that the sum of all industries’ MFP growth exceeds growth in the direct measure because of reallocations. If one wants to determine whether there is growth in non-IT industries, clearly the starting point is the aggregation of industry MFP, not the direct aggregate-level measure that includes reallocations. As the third column of table 8 shows, that “backing off” exercise leaves more room for non-IT MFP; indeed, non-IT MFP growth is larger than IT MFP growth, with either measure of IT MFP.

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 8. By either measure, MFP growth outside IT production is substantial, and exceeds the MFP contribution of 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 (2002) make the same point (on page 43): 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.”

Reconciliation. The major methodological alternative to ours is the macro study by Oliner and Sichel (2002). With respect to the factors considered here (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, as indicated in table 7, though he also buttresses them with independent calculations of his own.

Our study differs from the others in table 7 in its output measure and its labor input measure, both of which are tied to our use of the BEA industry database. Their effects have already been discussed in previous sections. We do not know why O&S's IT capital deepening contribution exceeds ours by 0.17 points.¹⁸ More capital deepening, of course, diminishes their aggregate MFP estimate, relative to ours. The total of these three factors—difference in output measure, difference in estimates of IT capital deepening and our omission of labor quality—accounts for almost all of the 0.45 difference in our two MFP estimates.

Thus, the crucial point to consider is our smaller estimates of MFP in the IT-producing industries (see table 7).

MFP in High Tech. We do not actually estimate MFP at the level of the computer, communications equipment and semiconductor industries (which are four-digit SIC) because we work with 2-digit industry detail. Is the finding by others of rapid MFP acceleration in IT-producing industries consistent with our industry estimates?

In the old U.S. industry classification system (SIC 1987) computer production was located in SIC 35 (industrial machinery) and semiconductors and communications equipment were located in SIC 36 (electronic and electrical machinery). As we have noted before, in the old SIC system computers were combined with drill bits, and semiconductors with Christmas tree lights. This means that the electronics producing industries, which are of major interest in analyzing the post-1995 economy, are buried within broad industrial categories that have little to do with electronics, the new economy, or high tech. The BEA industry database is still constructed around SIC 1987, which is actually much more than 15 years

out of date (the reason is that BLS, the laggard among the statistical agencies, is just beginning to convert its statistical series to the new NAICS classification system, which has an electronics sector).

Jorgenson, Ho, and Stiroh (2002)—hereafter, JHS—have extracted the four-digit IT-producing industries from their concealment within the non high tech sectors. We have aggregated their estimates to produce two-digit machinery industry estimates comparable with our own (table 9).

As table 9 shows, the JHS implied MFP for industrial machinery industry (4.4% per year) is two-tenths of a point greater than ours for the same 1995-2000 interval. The Census shipments data that underlie the BEA industry accounts indicate that all the growth in industrial machinery between 1995 and 2001 was in computers; the output of the remainder of industrial machinery was lower in 2001 than in 1995. Indeed, JHS record negative MFP growth for non-computer industrial machinery. Our estimate for industrial machinery thus appears comparable to what we would get from decomposition of this industry, and our contribution to MFP from this 2-digit industry (in table 7) is consistent with JHS.

JHS's implied electrical machinery industry MFP, at 5.7%, is about a point higher than ours (4.7%). However, JHS combined instruments (SIC 38) with miscellaneous manufacturing; we combined instruments with electrical machinery, on the grounds that instruments are increasingly electronics manufacturing. The inclusion of instruments probably reduces the MFP of our sector, because the Census shipments data show that the output of the Instruments SIC grew more slowly than did the output of the Electrical machinery. Semiconductor output, of course, far outstripped output growth in the other types of electrical equipment.

Thus, the JHS MFP estimates for 2-digit high tech goods-producing industries are somewhat larger than our estimates, but not by a great amount. From this, even though we do not estimate MFP directly for the four-digit electronics manufacturing industries, we conclude that our industry estimate for the MFP contribution of industrial and electrical machinery (0.51 in table 7) is consistent with the very

¹⁸ We are both using the data on capital services from BLS, and our two non-IT capital deepening estimates are the same.

rapid MFP growth in IT production estimated by JHS, and probably as well with their estimates of IT's contributions (0.41 points) to total MFP growth.¹⁹

We next need to ask whether our (and JHS) industry MFP estimates for IT production are consistent with the indirect IT estimates of more macro-oriented studies. Three indirect approaches have been used.

Baily-Lawrence (2001—see Baily, 2002) recalculated constant-price GDP with IT deflators set to the same rate of price change as the other components of GDP (rather than falling 20-30 percent per year, as do the national accounts IT deflators) and compared the results with constant-price GDP as estimated by BEA. This is equivalent to estimating IT MFP by the ratio of the decline in IT prices to other prices. Oliner and Sichel (2002) do this more explicitly: They infer relative MFP in IT-producing industries (they identify computers, communications equipment, software, and semiconductors) by the ratio of the respective IT prices to the prices of non-IT sectors (i.e., $MFP_i / MFP_j = (P_i / P_j) - C$), where C is an index of other input prices and the symbols should be interpreted as rates of change. They then calculate MFP contribution from, e.g., computers by applying Domar weights to this MFP number. Gordon (2002) uses the Oliner-Sichel results and buttresses them by backing out of the BLS nonfarm business MFP change the BLS estimate of MFP change in durable manufacturing, using the share of durables in nonfarm business, i.e., he finds: $MFP(\text{nonfarm}) - \gamma MFP(\text{durables}) = 0$, where γ is the share of durables, and the other symbols should be interpreted as rates of change, as above.²⁰

¹⁹ As we note above, our greater estimate of aggregate MFP growth seems consistent with our use of a smaller and somewhat faster growing output aggregate and a smaller and somewhat less faster growing IT component of capital services, compared with JHS. These differences rest on the production boundary (national accounts, or JHS' wider concept that includes household production) incorporated into the studies, not on the data or the estimating methods.

²⁰ In addition, his nonfarm MFP growth incorporated a cyclical correction that made it smaller than the growth rate that others had estimated, and because he did not remove any cyclical component from manufacturing durables, it made up more of the total than it otherwise would. Gordon's cyclical correction has been controversial, but his cyclically-corrected estimate of post-1995 labor productivity growth agrees exactly with our estimated trend (compare the growth rates in table 7). We estimated the trend from data that included the recession year 2001, which Gordon of course did not have when he made his original trend estimate.

The major alternative is, accordingly, the IT MFP growth estimate of Oliner and Sichel (2002). We think their indirect estimate is imprecise, and is inferior to estimating MFP for high tech production directly at the industry level.

O&S rely on the “dual” productivity estimation procedure for “high tech” products in Triplett (1996). The innovation in Triplett is not the dual itself, for productivity measurement by the dual (that is, use of input and output price indexes to estimate productivity change) dates back at least to Copeland and Martin (1938). Rather, the innovation might be called “one price dual” estimation: Triplett estimated MFP change in chains of user-supplier industries, specifically the semiconductor industry as a supplier to the computer industry (the example that O&S give), using only the price index for semiconductors as an input to the computer industry and the price index for the output of computers. Other input prices to computers and to semiconductors (e.g., wages and energy costs) were assumed dominated by national forces outside the two industries. Put another way, whatever differences existed in price movements for non-technological inputs to these two industries, *they were minor in comparison to changes in semiconductor and computer prices*, which were falling at prodigious rates (on the order of 20-30 percent per year). Other input prices thus could be neglected, because the error from neglecting them would be small.²¹

O&S apply Triplett’s “one price dual” method to industries that relate, not exactly as links in a vertical supply chain, but rather horizontally. There is some appeal to that: The relative price change in computers must be related to overall price change as is the relative MFP change in computer production to aggregate MFP. But the assumption that other input prices move together and can be neglected is more tenuous the more remote are the industries for which the calculation is done, and the greater is the difference in their input mixes.

In table 10, we compare the MFP estimates, Domar weights and contribution to aggregate MFP for computers, semiconductors, and communication equipment from O&S and JHS, with our own 2-digit

²¹ Triplett shows that the procedure is very sensitive to input shares, but that is not the issue here.

industry MFP growth estimates for reference. For computers, both MFP and the Domar weight (and therefore contributions) are very similar in O&H and JHS.²² However, O&H's estimate for semiconductor MFP is very large, so their contribution from semiconductors is 3 ½ times that of JHS. For communications equipment and software, their contributions are positive and so swell IT MFP, where those of JHS are negative and shrink it.

In sum, the O&S estimate of the contribution of MFP in computer production is close to the industry estimate, despite their indirect method. However, they find far greater MFP in production of semiconductors, communications equipment and software than is evident in the industry data, which is we think consistent with our concerns expressed above about the accuracy of the indirect method. In all, this suggests that O&S's estimate that IT MFP accounted for 0.77/0.99 share of the total is too high, as it is also in Gordon (2002), who depends on the work of O&S.

Conclusion. There is more acceleration in our measure of the private, non-farm business economy than is present in other studies (thus we have more “room” in our income side measure for contributions from both IT-producing and services industries). Additionally, our omission of labor quality from the input side swells our aggregate MFP, again producing more room for MFP in the services industries. Within that aggregate MFP measure, our estimates of industry MFP are consistent with the rapid growth in IT MFP (and therefore in durable goods manufacturing) that has emerged in other industry studies.

However, despite the large contribution from IT production to aggregate MFP, it is also true that net MFP in the goods-producing industries has not grown. Net MFP growth in the services industries, on the other hand, has been a strong contributor to recent economic growth.

²² The greater output in the numerator of JHS' MFP is balanced by the rapid growth of household IT.

VI. Measurement Issues

The BEA industry data set has been substantially improved in recent years. The situation has changed dramatically 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.²³ 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.

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 three aspects: inconsistent data sources, negative productivity growth industries, and shortcomings in the labor input data.

Inconsistent Data Sources. At present, 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 – i.e. IRS for profits and BLS for wages and salaries – and those 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 accounts, primarily the Census Bureau business census and surveys. 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.

²³ 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 large number of service industries.

As shown in table 11, the industry estimates of value added (GDP originating) can differ substantially from those of the I-O accounts. Columns 1 and 2 show the estimates of value added from the industry accounts and the 1992 I-O table. The differences and percent differences are shown in columns 3-4. A time dimension is provided by including the percent differences from the 1996 annual I-O table. 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 4-digit SIC level largely using price indexes from the BLS price programs and aggregated as chained indexes to the 2-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.

The concerns about measurement error are most evident in our measures of labor productivity. While we expect measures of labor productivity growth to vary between gross output and value added, the magnitudes are often vary large and volatile over time. For our group of 54 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, since the computation of MFP using either gross output or value added yields 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 particular 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 BEA is planning to achieve a partial integration of its GDP by industry and the annual I-O accounts over the next several years.

The Negative Productivity Growth Industries. Negative productivity growth always attracts skepticism, and well it should. Negative labor productivity growth, especially, seems implausible on its face. In our estimates, the following industries have negative labor productivity growth over the 1995-2001 interval:

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

Earlier 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 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.

1. Education. Educational output was the subject of a Brookings workshop in which two conclusions emerged. (1) No agreed on measure of the output of the educational function itself exists, and (2) universities, and to an extent perhaps secondary education as well, are classic multi-output 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 productivity (see our Table A1) 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 (2003) 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 mis-measurement of educational output.

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

3. Hotels. For hotels, 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.

4. Insurance. We suspect that negative productivity for insurance carriers is the result of an inadequate and unworkable definition of insurance output in the NIPA and the 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 policyholders, 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 minus 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.

5. 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% per year), and goes in the opposite direction from its labor productivity. It is also possible that the industry is a good example of the inconsistency of the source data for gross output and value added.

6. Construction. Construction is an industry whose productivity performance has puzzled many economists (see Baily and Gordon, 1989, and 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 a hedonic price index 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. BEA will be introducing hedonic indexes for commercial construction in this year's benchmark revision, but these indexes rise more rapidly than the deflators they replace, which would make the negative productivity in construction even more negative.²⁴

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 (2002); and, in addition, we do not apply a labor quality adjustment. Neither of these aspects is included in the 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 worked 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, or 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.

²⁴ Based on conversations with Bruce Grimm of BEA.

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 program²⁵ 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/non-supervisory worker” definition for its establishment surveys rests on preserving time series comparability. Although we, too, value time series continuity, it should not be at the cost of a failure to collect the information that is most relevant for analysis.

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.

²⁵ In both budgetary and sample size (so in respondent 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.

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Table 1

Labor Productivity and MFP Growth
Goods-Producing and Service-Producing Industries
(Trend rates growth, value added per worker, BEA industry accounts)

	1987-95	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
Multi-factor 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 A1. As explained I section II of this paper, the aggregate productivity numbers differ from those published by BLS.

Table 2. Alternative Measures of Nonfarm Business Output and Productivity, 1987-2001

Period	Output		Labor	Capital	Value Added per Worker	Multi-factor Productivity
	Gross Output	Value Added				
Bureau of Labor Statistics						
1987-2001	n.a.	3.3	1.5	4.0	1.8	1.0
1987-1995	n.a.	2.9	1.5	3.0	1.4	0.9
1995-2001	n.a.	3.8	1.5	5.3	2.3	1.1
Change	n.a.	0.9	0.0	2.3	0.9	0.2
Industry Aggregate (BEA/BLS Data)						
1987-2001	3.4	3.5	1.8	3.9	1.6	1.0
1987-1995	3.1	2.9	1.7	2.9	1.1	0.7
1995-2001	3.9	4.3	1.9	5.2	2.3	1.3
Change	0.8	1.4	0.2	2.2	1.2	0.5

Note; The BLS published measures of the labor input and MFP have been adjusted to exclude changes in labor composition. In addition, the industry aggregate is an income-side measure that excludes the statistical discrepancy of the national accounts. The industry data set measures labor as persons, BLS uses hours.

Table 3. Alternative Measures of Manufacturing Output and Labor Productivity, 1987-2001

annual rates of change

Period	Durables		Nondurables	
	BLS	BEA	BLS	BEA
Output Index				
1987-2001	3.6	3.7	1.5	1.1
1987-1995	3.1	3.5	2.1	1.6
1995-2001	4.1	3.9	0.7	0.4
Change	1.0	0.4	-1.4	-1.2
Labor Productivity				
1987-2001	3.9	4.0	2.3	1.8
1987-1995	3.2	4.0	1.9	1.5
1995-2001	4.8	4.2	2.7	2.2
Change	1.6	0.2	0.8	0.7

Note: Output measures are based on gross output. Labor productivity is an hours-based measure for BLS and full-time equivalent employees plus the self employed for BEA,

Table 4. Growth in Labor Productivity and Multi-factor Productivity by Major Industry Group, 1987-2001
annual trend rates of change based on gross output

INDUSTRY	Value Added Weight		Trend Growth in Output per worker		Domar weight	Trend Growth in Multi-factor Productivity		
	1987-95	1995-2001	1987-95	1995-2001		1987-95	1995-2001	Change
Private non-farm business	100.0	2.1	1.3	0.8	186.9	0.3	0.8	
Goods-producing Industries	29.6	2.1	2.1	0.0	73.1	0.5	0.5	
Mining.....	1.9	1.6	3.5	-1.9	3.1	1.1	-1.0	
Construction.....	5.3	-1.1	-0.4	-0.7	9.3	0.2	-0.5	
Manufacturing.....	21.7	3.6	2.8	0.9	59.7	0.6	1.0	
Durable goods.....	12.3	4.8	3.9	0.9	31.7	1.1	1.9	
Non-durable goods.....	9.4	2.4	1.4	1.0	28.1	0.0	-0.4	
Service-producing Industries	70.4	2.4	1.3	1.1	113.8	0.2	0.9	
Transportation.....	4.0	0.8	1.9	-1.2	7.8	1.2	0.0	
Communications.....	3.4	4.1	4.1	2.6	5.6	1.7	0.0	
Telephone and telegraph.....	2.6	5.0	5.0	3.0	4.3	1.2	1.2	
Radio and television.....	0.7	1.8	2.3	-0.6	1.2	4.0	-4.5	
Electric, gas, and sanitary services.....	3.4	2.0	2.1	-0.1	5.6	0.5	-0.6	
Wholesale trade.....	8.5	4.2	3.4	0.7	12.4	1.5	3.1	
Retail trade.....	11.3	3.4	1.3	2.2	17.4	0.2	2.9	
Finance and insurance.....	8.7	3.6	1.8	1.8	14.8	-0.1	1.6	
Depository institutions.....	4.0	3.1	2.9	0.2	5.6	0.2	1.5	
Nondepository institutions.....	0.6	1.9	2.4	-0.6	1.4	-0.2	2.1	
Security and commodity brokers.....	1.4	10.3	7.2	3.2	2.4	3.1	6.6	
Insurance carriers.....	1.9	-1.7	-0.6	-1.0	4.1	-0.1	0.0	
Insurance agents, brokers, and service.....	0.8	2.8	-3.3	6.1	1.3	-3.6	-0.1	
Real estate (excluding owner-occupied housing).....	6.6	1.7	2.7	-1.0	11.2	0.4	1.4	
Other Service Industries.....	24.6	1.5	0.4	1.1	39.1	-0.6	0.2	
Hotels and other lodging places.....	1.0	-0.6	1.0	-1.6	1.7	0.0	-1.3	
Personal services.....	0.8	1.5	0.7	0.8	1.4	-1.2	0.4	
Business Services	5.2	3.6	2.9	0.7	7.8	0.9	-0.6	
Auto repair, services, and parking.....	1.1	1.5	0.9	0.6	1.9	-1.4	1.4	
Miscellaneous repair services.....	0.4	1.8	1.9	-0.1	0.7	-1.1	-1.6	
Motion pictures.....	0.4	0.3	0.8	-0.5	0.9	-0.5	0.2	
Amusement and recreation services.....	0.9	-0.4	1.9	-2.3	1.6	0.4	-1.1	
Health services.....	7.1	0.9	-0.7	1.6	10.7	-1.7	-0.5	
Legal services.....	1.7	1.5	0.0	1.5	2.2	-0.8	0.9	
Educational services.....	0.9	-1.0	0.2	-1.1	1.6	-0.2	-0.8	
Other Services	4.9	2.0	-0.4	2.4	8.5	-0.3	-0.1	

Table 5. Contributions to Nonfarm Labor and Multifactor Productivity Growth by Industry, 1987 - 2001

Trend growth rates, except where noted

	Growth Rate		
	1987-95	1995-01	Change
	Labor Productivity		
BLS Measure (Table 2)/a/	1.45	2.32	0.88
Direct Aggregate Level	1.01	2.46	1.45
Intermediate inputs reallocation(-)	-0.47	0.14	0.60
Labor reallocation	-0.44	-0.31	0.13
Weighted Industry Aggregate	1.93	2.63	0.70
	Multi-factor Productivity		
BLS Measure (Table 2)/a/	0.92	1.17	0.25
Direct Aggregate Level	0.56	1.44	0.88
Input reallocation	-0.10	-0.14	-0.03
Weighted Industry Aggregate	0.67	1.58	0.91

Source: Equations (3) and (4) of text.

a/ average annual rates of change

Table 6. Contributions to Nonfarm Labor and Multifactor Productivity Growth by Industry, 1987 - 2001
Trend growth rates

SIC CODE	INDUSTRY NAME	Labor Productivity			Multi-factor Productivity		
		Value-added Weight	1987-95	Contribution 1995-01 Change	Domar Weight	1987-95	Contribution 1995-01 Change
GD	Private non-farm business	100.0	1.93	2.63	186.9	0.67	1.58
	Goods-producing industries	29.6	0.77	0.71	73.1	0.39	0.38
	Agricultural services, forestry, and fishing...	0.6	0.00	0.01	0.9	-0.01	0.00
	Mining.....	1.9	0.07	0.01	3.1	0.04	-0.03
15-17	Construction.....	5.3	-0.01	-0.06	9.3	0.02	-0.05
	Manufacturing.....	21.7	0.72	0.76	59.7	0.34	0.45
	Durable goods.....	12.3	0.58	0.60	31.7	0.35	0.59
35	Industrial machinery and equipment.....	2.32	0.15	0.15	5.54	0.10	0.22
36,38	Electronic equipment and instruments	3.25	0.28	0.31	7.19	0.20	0.29
	Non-durable goods.....	9.4	0.14	0.16	28.1	0.00	-0.13
SER	Service-producing industries	70.4	0.00	0.00	113.8	0.28	1.20
	Transportation.....	4.0	0.00	0.00	7.8	0.10	-0.09
48	Communications.....	3.4	0.03	0.01	5.6	0.09	-0.09
483-484	Telephone and telegraph.....	2.6	0.00	0.00	4.3	0.05	0.06
49	Radio and television.....	0.7	0.04	0.01	1.2	0.05	-0.10
49	Electric, gas, and sanitary services.....	3.4	0.00	0.00	5.6	0.03	-0.07
50-51	Wholesale trade.....	8.5	0.00	0.01	12.4	0.18	0.20
52-59	Retail trade.....	11.3	0.00	0.00	17.4	0.03	0.50
	Finance and insurance.....	8.7	0.01	0.01	14.8	0.01	0.34
60	Depository institutions.....	4.0	0.15	0.22	5.6	0.01	0.09
61	Nondepository institutions.....	0.6	0.15	0.21	1.4	-0.01	0.04
62	Security and commodity brokers.....	1.4	0.00	0.02	2.4	0.06	0.15
63	Insurance carriers.....	1.9	0.07	0.06	4.1	0.00	0.00
64	Insurance agents, brokers, and service.....	0.8	0.31	0.36	1.3	-0.04	0.04
65	Real estate (excluding owner-occupied housing).....	6.6	0.15	0.38	11.2	0.05	0.16
	Other Service Industries.....	24.6	0.18	0.31	39.1	-0.23	-0.15
70	Hotels and other lodging places.....	1.0	0.12	0.13	1.7	0.00	-0.02
72	Personal services.....	0.8	0.01	0.01	1.4	-0.02	0.01
73	Business Services	5.2	0.09	0.18	7.8	0.06	-0.07
75	Auto repair, services, and parking.....	1.1	-0.01	-0.04	1.9	-0.03	0.03
76	Miscellaneous repair services.....	0.4	-0.02	0.02	0.7	-0.01	0.00
78	Motion pictures.....	0.4	0.16	0.11	0.9	-0.01	0.01
79	Amusement and recreation services.....	0.9	0.05	0.43	1.6	0.00	-0.02
80	Health services.....	7.1	0.02	-0.01	10.7	-0.18	0.13
81	Legal services.....	1.7	0.00	0.01	2.2	-0.02	0.04
82	Educational services.....	0.9	0.11	0.22	1.6	0.00	-0.01
83-87	Other Services	4.9	0.01	0.02	8.5	-0.03	-0.01

Source: Appendix table 5

Table 7. Alternative Estimates, Contributions to Labor Productivity Growth, Selected Components Post-1995 (to end period indicated)

(average annual or trend rates of change)

source end period	Macro Studies			Industry Studies	
	O&S 2001	Gordon 2002	J&S 1998	JHS 2000	B&T ^d 2001
LP growth	2.43	2.46 ^a	2.37	2.21	2.46
IT K-deepening	1.02	1.02 ^b	{1.13} ^c	1.00	0.85
Non IT K-deeping	0.17	0.17 ^b	{ }	0.41	0.17
MFP	0.99	0.99 ^b	0.99	0.63	1.44
IT	0.77	0.77 ^b	0.44	0.41	0.51 ^e
(semiconductor)	0.42	0.42 ^b	{0.32}	0.27 ^f	
(computer)	0.19	0.19 ^b	{ }	0.22 ^f	
non IT	0.23	0.23 ^b		0.22	0.93 ^h
Labor quality	0.25		0.25	0.17	0.00 ^h
Other factors ^g	0.00	0.28 ^g	0.00	0.00	

Notes:

a/ trend, estimated by removing cyclical effect (0.40) from end-period average annual growth.

b/ According to Gordon (notes to table 3.2, which records accelerations), the data for these factors are taken from O&S, so we record O&S data for post-1995 growth in this column.

c/ total capital deepening = 1.13, not divided into IT and nonIT.

d/ trend rates of growth

e/ sum of industrial machinery (contains computers) and electrical machinery and instruments (contains semiconductors and communications equipment); from table A5.

f/ estimated from the chart in figure 26; does not add to IT total, because (from the same chart) communications equipment and software made negative contributions to MFP, of approximately

g/ includes labor quality, where no explicit estimate appears in the table.

h/ from table zz.

i/ did not include a labor quality correction.

Sources:

O&S = Oliner and Sichel (2002), tables 1 and 2

J&S = Jorgenson and Stiroh (2000), tables 3 and 5.

JHS = Jorgenson, Ho, and Stiroh (2002), table 2, and figure 26.

Gordon (2002), table 3.2

B&T = Bosworth and Triplett, this paper, tables A1 and A5.

Table 8

Alternative “Backing Out” Exercises for Comparisons of IT-producing and Other Industries’ MFP
(trend rates of change, 1995-2001)

	BLS MFP	BEA Direct	Sum, industry MFP's	Sum, positive industry MFP's
1. Economy-wide MFP Estimates (table 5)	1.17	1.44	1.58	2.09a/
2. Machinery industries MFP (table 6)	0.51	0.51	0.51	0.51
3. Oliner and Sichel (2002) IT MFP	0.77	0.77	0.77	0.77
4a. Remainder (row 1 – row 2 = “MFP outside IT”)	0.66	0.93	1.07	1.58
4b. Remainder (row 1 – row 3 = “MFP outside IT”)	0.40	0.67	0.87	1.32

Note:

a/ Sum of positive (only) industry MFP growth, from table 6.

**Table 9. Estimates of MFP for Computers, Semiconductors, and Other Machinery, 1995-2000
As derived from Jorgenson, Ho, and Stiroh (2002)**

(average annual rates of change)

Industry	MFP	Domar Weights
1. Industrial machinery, except computers	0.23	0.034
2. Computers	16.75	0.012
3. Total, industrial machinery	4.396	
4. Other electrical machinery	0.93	0.017
5. Communications equipment	-0.38	0.007
6. Electrical components (including semiconductors)	18.00	0.011
7. Total, electrical machinery	5.66	
Addendum:		
8. Industrial machinery, 1995-00 (Bosworth & Triplett)	4.19	
	(3.92)	
9. Electrical machinery, 1995-00 (Bosworth & Triplett)	4.68	
	(4.04)	

Sources: Lines 1, 2, 4, 5 and 6: Jorgenson, Ho, and Stiroh (2002), table 18.

Lines 3 and 7: Computed by the authors, using sum of the Domar weights to define the 2-digit industry total.

Lines 8 and 9: computed by the authors as the change over the period 1995-2000. The values in parenthesis are the least square trends for 1995-2001 from table A1.

Table 10. Post-1995 MFP Estimates, IT-producing Industries
(average annual rates of change)

	Computers	Communication Equipment	Semi- conductors	Software
Jorgenson, Ho and Stiroh (2002)				
MFP	16.75	-0.38	18.00 ^a	-2.79 ^b
Contribution	0.16	0.01	0.12 ^a	-0.01 ^b
Domar weight	0.012	0.007	0.011 ^a	0.013 ^b
Oliner and Sichel (2002)				
MFP	14.0	2.5	45.2	4.3
Contribution	0.19	0.05	0.42	0.11
Domar weight	0.0132	0.0183	0.0091	0.027
Bosworth and Triplett				
MFP	3.92 ^c	4.04 ^d		
Contribution	0.22 ^c	0.29 ^d		
Domar weight	0.55 ^c	0.72 ^d		

Notes:

a/ Electronic components

b/ Computer services

c/ Industrial machinery

d/ Electronic and electrical machinery

Table 11. Comparison of Gross Domestic Product by Industry and I-O Value Added, 1992 and 1996

	Industry Value Added					
	1992				1996	
	Gross Product	I-O Table	Difference IO-GP	Percent Difference	Percent Difference	Change 1992-96
Private industries	5369.8	5354.7	-15.1	-0.3	1.9	2.2
Goods-Producing Industries	1504.2	1572.2	68.0	4.5	7.2	2.6
Agriculture, forestry, and fishing	111.6	99.2	-12.4	-11.1	7.7	18.8
Farms	80.5	74.1	-6.4	-8.0	8.6	16.6
Agricultural servs, forestry, &	31.2	25.1	-6.1	-19.6	4.1	23.7
Mining	87.4	91.9	4.5	5.1	4.8	-0.3
Metal mining	5.6	4.5	-1.1	-19.6	2.4	22.0
Coal mining	12.0	15.9	3.9	32.5	-15.1	-47.6
Oil and gas extraction	62.0	63.2	1.2	1.9	10.2	8.3
Nonmetallic minerals, except fuels	7.7	8.3	0.6	7.8	-1.8	-9.6
Construction	234.4	220.9	-13.5	-5.8	52.5	58.2
Manufacturing	1070.8	1160.2	89.4	8.3	0.4	-8.0
Durable goods	587.1	618.5	31.4	5.3	0.4	-5.0
Lumber and wood products	32.2	32.3	0.1	0.3	6.2	5.8
Furniture and fixtures	16.5	19.9	3.4	20.6	0.9	-19.7
Stone, clay, and glass	25.9	29.8	3.9	15.1	0.2	-14.8
Primary metal industries	39.3	42.9	3.6	9.2	-1.0	-10.2
Fabricated metal products	69.2	71.5	2.3	3.3	0.2	-3.1
Industrial machinery and equipment	111.5	108.9	-2.6	-2.3	0.2	2.5
Electronic and other electric	106.3	99.0	-7.3	-6.9	-0.8	6.1
Motor vehicles and equipment	58.5	51.6	-6.9	-11.8	0.4	12.2
Other transportation equipment	57.2	68.3	11.1	19.4	1.2	-18.2
Instruments and related products	51.0	76.7	25.7	50.4	-0.6	-51.0
Miscellaneous manufacturing industries	19.5	17.8	-1.7	-8.7	2.6	11.4
Nondurable goods	483.8	541.7	57.9	12.0	0.4	-11.6
Food and kindred products	105.2	122.9	17.7	16.8	0.6	-16.3
Tobacco manufactures	13.8	25.7	11.9	86.2	-0.3	-86.5
Textile mill products	25.6	23.8	-1.8	-7.0	-0.4	6.7
Apparel and other	27.3	25.4	-1.9	-7.0	0.3	7.2
Paper and allied products	45.3	51.3	6.0	13.2	-0.6	-13.9
Printing and publishing	77.8	93.4	15.6	20.1	0.7	-19.4
Chemicals and allied products	118.0	125.1	7.1	6.0	1.1	-5.0
Petroleum and coal products	27.8	20.3	-7.5	-27.0	-0.1	26.9
Rubber and miscellaneous plastics	38.2	50.0	11.8	30.9	0.2	-30.7
Leather and leather products	4.9	3.7	-1.2	-24.5	0.0	24.5
Service-Producing Industries	3821.9	3790.4	-31.5	-0.8	-1.2	-0.4
Transportation	192.9	193.3	0.4	0.2	-0.6	-0.8
Railroad transportation	21.6	22.1	0.5	2.3	-5.2	-7.5
Local and interurban passenger	10.9	12.4	1.5	13.8	15.7	1.9
Trucking and warehousing	74.5	82.4	7.9	10.6	-1.2	-11.8
Water transportation	10.6	13.3	2.7	25.5	-2.7	-28.2
Transportation by air	50.0	42.1	-7.9	-15.8	0.7	16.5
Pipelines, except natural gas	5.5	5.3	-0.2	-3.6	1.3	4.9
Transportation services	19.8	15.7	-4.1	-20.7	-4.8	15.9
Communications	162.8	142.1	-20.7	-12.7	-2.8	9.9
Telephone and telegraph	127.8	116.5	-11.3	-8.8	-3.7	5.1
Radio and television	34.9	25.5	-9.4	-26.9	0.4	27.3
Electric, gas, and sanitary	179.5	160.6	-18.9	-10.5	-2.0	8.5
Wholesale trade	406.4	405.6	-0.8	-0.2	1.4	1.6
Retail trade	547.1	510.1	-37.0	-6.8	-1.4	5.3
Finance, insurance, & real estate	1126.3	1175.1	48.8	4.3	-4.3	-8.6
Depository institutions	198.9	165.7	-33.2	-16.7	-3.9	12.8
Nondepository institutions	24.8	24.9	0.1	0.4	-33.6	-34.0
Security and commodity brokers	54.2	52.6	-1.6	-3.0	-1.7	1.3
Insurance carriers	77.8	63.4	-14.4	-18.5	-15.2	3.3
Insurance agents, brokers, etc.	39.2	40.5	1.3	3.3	10.1	6.8
Real estate	724.7	820.9	96.2	13.3	-1.9	-15.2
Holding and other investment	6.7	7.1	0.4	6.0	58.4	52.5
Services	1206.9	1203.6	-3.3	-0.3	0.9	1.2
Hotels and other lodging	50.3	52.2	1.9	3.8	-1.6	-5.4
Personal services	40.6	37.8	-2.8	-6.9	0.6	7.5
Business services	222.0	229.0	7.0	3.2	8.2	5.0
Auto repair, services, and	51.3	48.0	-3.3	-6.4	-0.1	6.4
Miscellaneous repair services 76	17.5	24.4	6.9	39.4	-1.9	-41.4
Motion pictures	18.0	18.8	0.8	4.4	0.7	-3.7
Amusement and recreation services	45.1	43.9	-1.2	-2.7	1.8	4.5
Health services	376.7	371.8	-4.9	-1.3	-1.2	0.1
Legal services	92.1	84.2	-7.9	-8.6	-0.4	8.2
Educational services	46.4	44.0	-2.4	-5.2	-1.7	3.4
Social services	37.3	40.1	2.8	7.5	-6.8	-14.3
Membership organizations	39.9	40.8	0.9	2.3	-1.5	-3.7
Other services	159.5	158.6	-0.9	-0.6	0.1	0.6
Private households	10.1	10.1	0.0	0.0	2.5	2.5
Statistical discrepancy +iva	43.7	-8.0	-51.7			

Source: Yuskavage, 2000.

Table A1. Growth in Gross Output per Worker, 1987-2001
Least squares trend growth

SIC CODE	INDUSTRY NAME	Growth in Output per worker		Capital		Contribution of:				Contribution of:			
		1987-95	1995-2001	1987-95	1995-2001	Intermediate Inputs		TFP		IT Capital		non-IT Capital	
						1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001
	Private non-farm business	1.31	2.14	0.23	0.53	0.81	0.85	0.28	0.76	0.18	0.44	0.04	0.09
GD	Goods-producing industries	2.14	2.09	0.23	0.38	1.43	1.19	0.48	0.53	0.12	0.19	0.11	0.19
	Agricultural services, forestry, and fishing...	0.10	1.18	0.29	0.60	0.68	0.19	-0.86	0.40	0.10	0.13	0.19	0.46
10-14	Mining.....	3.54	1.61	0.68	0.72	1.75	1.89	1.11	-1.00	0.09	0.24	0.58	0.47
10	Metal mining.....	5.82	5.64	-0.50	1.13	2.40	-2.68	3.92	7.19	0.31	0.26	-0.80	0.88
12	Coal mining.....	7.37	5.54	0.21	0.96	3.37	1.97	3.79	2.60	0.12	0.19	0.10	0.77
13	Oil and gas extraction.....	2.72	0.16	0.84	0.20	1.53	2.72	0.35	-2.76	0.07	0.25	0.77	-0.04
14	Nonmetallic minerals, except fuels.....	1.48	1.35	0.52	0.92	0.82	-1.30	0.14	1.73	0.12	0.28	0.40	0.64
15-17	Construction.....	-0.37	-1.12	-0.08	0.49	-0.50	-1.06	0.21	-0.55	0.06	0.09	-0.14	0.40
	Manufacturing.....	2.77	3.64	0.26	0.37	1.91	2.29	0.60	0.98	0.11	0.18	0.14	0.19
	Durable goods.....	3.87	4.79	0.29	0.49	2.52	2.42	1.06	1.89	0.12	0.24	0.17	0.25
24	Lumber and wood products.....	-0.63	0.80	-0.10	0.13	0.98	1.09	-1.51	-0.42	0.06	0.08	-0.16	0.06
25	Furniture and fixtures.....	1.77	1.84	0.12	0.23	1.26	1.39	0.39	0.22	0.07	0.12	0.05	0.11
32	Stone, clay, and glass products.....	0.77	0.88	-0.01	0.54	-0.24	0.71	1.01	-0.37	0.03	0.20	-0.03	0.34
33	Primary metal industries.....	2.82	0.52	0.04	0.12	1.87	-0.30	0.92	0.70	0.02	0.06	0.02	0.06
34	Fabricated metal products.....	1.45	1.44	0.12	0.32	0.88	1.29	0.45	-0.17	0.10	0.17	0.02	0.15
35	Industrial machinery and equipment.....	6.18	6.92	0.40	0.64	3.97	2.36	1.81	3.92	0.23	0.49	0.17	0.15
37	Motor vehicles and other transportation equipment.....	3.15	3.23	0.13	0.28	2.81	2.31	0.21	0.64	0.05	0.12	0.08	0.16
36,38	Electronic equipment and instruments	7.61	10.04	0.81	0.91	3.99	5.09	2.82	4.04	0.25	0.37	0.56	0.54
39	Miscellaneous manufacturing industries.....	0.87	2.44	0.14	0.44	0.68	-0.06	0.05	2.06	0.12	0.16	0.03	0.28
	Non-durable goods.....	1.42	2.39	0.32	0.55	1.10	2.27	0.01	-0.43	0.15	0.23	0.16	0.32
20	Food and kindred products.....	1.25	1.21	0.15	0.28	0.92	2.03	0.18	-1.09	0.05	0.09	0.10	0.19
21	Tobacco products.....	2.81	0.16	0.60	0.18	4.72	7.93	-2.51	-7.95	0.09	0.11	0.51	0.07
22	Textile mill products.....	2.83	2.91	0.15	0.47	1.47	2.34	1.20	0.11	0.10	0.15	0.05	0.33
23	Apparel and other textile products.....	2.31	7.35	0.26	0.82	1.51	5.80	0.54	0.74	0.09	0.15	0.18	0.67
26	Paper and allied products.....	1.43	1.04	0.30	0.39	1.02	0.91	0.11	-0.26	0.10	0.12	0.20	0.28
27	Printing and publishing.....	-0.61	0.58	0.37	0.55	0.61	0.72	-1.59	-0.69	0.33	0.57	0.04	-0.02
28	Chemicals and allied products.....	1.69	1.68	0.58	0.68	0.47	1.18	0.64	-0.18	0.30	0.31	0.29	0.37
29	Petroleum and coal products.....	1.04	3.09	0.30	0.14	1.85	2.54	-1.12	0.41	0.15	0.05	0.15	0.08
30	Rubber and miscellaneous plastics products...	3.20	3.09	0.16	0.53	1.61	1.82	1.43	0.74	0.07	0.15	0.09	0.38
31	Leather and leather products.....	1.63	4.72	0.99	0.66	-0.35	4.75	0.99	-0.69	0.09	0.30	0.89	0.35

continued

SIC CODE	INDUSTRY NAME	Growth in		Contribution of:						Contribution of:			
		Output per worker		Capital		Intermediate Inputs		TFP		IT Capital		non-IT Capital	
		1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001
SER	Service-producing industries	1.27	2.41	0.25	0.64	0.85	0.89	0.17	0.88	0.23	0.59	0.02	0.04
	Transportation.....	1.91	0.75	-0.12	0.39	0.83	0.33	1.21	0.03	0.13	0.31	-0.26	0.09
40	Railroad transportation.....	6.22	2.14	0.31	0.27	2.50	0.33	3.42	1.54	0.03	0.04	0.28	0.22
41	Local and interurban passenger transit.....	-1.71	-0.61	-0.43	0.04	-0.31	-1.94	-0.97	1.29	0.01	0.04	-0.44	0.00
42	Trucking and warehousing.....	4.22	0.78	0.05	0.19	2.94	0.68	1.23	-0.10	0.10	0.08	-0.05	0.11
44	Water transportation.....	1.74	1.01	-0.20	-0.15	0.38	0.99	1.56	0.17	0.03	0.05	-0.23	-0.21
45	Transportation by air.....	-1.87	0.42	-0.32	0.79	-3.38	0.08	1.83	-0.45	0.08	0.52	-0.39	0.27
46	Pipelines, except natural gas.....	-0.67	1.15	0.75	1.84	1.35	-2.33	-2.78	1.64	0.61	0.91	0.14	0.93
47	Transportation services.....	1.99	3.53	0.05	1.80	2.23	1.56	-0.29	0.17	0.70	1.56	-0.65	0.24
48	Communications.....	4.12	6.68	1.59	1.60	0.86	5.11	1.68	-0.04	0.86	1.29	0.73	0.32
	Telephone and telegraph.....	4.99	7.95	1.58	1.11	2.22	5.63	1.19	1.21	0.89	0.97	0.69	0.14
483-484	Radio and television.....	2.33	1.77	1.93	3.23	-3.56	3.07	3.95	-4.53	1.03	2.31	0.90	0.92
49	Electric, gas, and sanitary services.....	2.15	2.05	0.75	0.81	0.85	1.84	0.54	-0.60	0.25	0.25	0.51	0.56
50-51	Wholesale trade.....	3.44	4.19	0.63	1.78	1.31	-0.66	1.50	3.07	0.49	1.42	0.14	0.35
52-59	Retail trade.....	1.26	3.44	0.35	0.30	0.72	0.23	0.19	2.92	0.11	0.26	0.24	0.04
	Finance and insurance.....	1.82	3.60	0.88	1.40	0.99	0.58	-0.06	1.61	0.62	1.09	0.26	0.31
60	Depository Institutions.....	2.91	3.12	1.46	1.36	1.27	0.30	0.19	1.47	0.85	1.24	0.60	0.12
61	Nondepository Institutions.....	2.44	1.86	0.38	1.78	2.31	-2.04	-0.25	2.12	1.10	1.61	-0.72	0.17
62	Security and commodity brokers.....	7.17	10.35	0.50	0.35	3.55	3.37	3.12	6.63	0.06	0.20	0.44	0.15
63	Insurance carriers.....	-0.63	-1.66	0.57	0.87	-1.08	-2.56	-0.13	0.03	0.31	0.63	0.26	0.24
64	Insurance agents, brokers, and service.....	-3.35	2.79	0.10	0.54	0.13	2.35	-3.58	-0.10	0.07	0.25	0.02	0.29
65	Real estate (excluding owner-occupied housing).....	2.74	1.71	0.29	0.06	2.01	0.24	0.44	1.41	-0.01	0.02	0.30	0.03
	Other Service Industries.....	0.43	1.54	0.16	0.53	0.87	1.45	-0.59	-0.43	0.14	0.47	0.02	0.06
70	Hotels and other lodging places.....	1.02	-0.57	0.38	0.29	0.63	0.47	0.01	-1.33	0.06	0.13	0.32	0.16
72	Personal services.....	0.70	1.54	0.27	0.28	1.64	0.88	-1.21	0.38	0.12	0.11	0.14	0.17
73	Business Services	2.86	3.56	0.03	1.00	1.93	3.17	0.90	-0.60	0.15	1.08	-0.12	-0.09
75	Auto repair, services, and parking.....	0.85	1.46	1.03	0.25	1.24	-0.18	-1.41	1.39	0.04	0.11	0.99	0.14
76	Miscellaneous repair services.....	1.90	1.81	0.20	0.57	2.81	2.84	-1.11	-1.60	0.16	0.34	0.04	0.23
78	Motion pictures.....	0.81	0.26	0.36	0.32	0.96	-0.26	-0.52	0.20	0.20	0.14	0.16	0.19
79	Amusement and recreation services.....	1.87	-0.41	-0.31	0.31	1.74	0.40	0.44	-1.11	-0.04	0.07	-0.27	0.24
80	Health services.....	-0.69	0.92	0.19	0.48	0.78	0.95	-1.66	-0.51	0.19	0.34	0.01	0.14
81	Legal services.....	0.00	1.49	0.07	0.28	0.76	0.29	-0.82	0.91	0.14	0.28	-0.07	0.00
82	Educational services.....	0.19	-0.95	0.01	0.05	0.42	-0.22	-0.24	-0.79	0.02	0.07	-0.01	-0.01
83-87	Other Services	-0.44	1.95	0.05	0.22	-0.19	1.87	-0.30	-0.13	0.10	0.25	-0.05	-0.03

Source: Least squares applied to log changes. Reported values are log changes.

Table A2. Growth in Value Added per Worker, 1987-2001
Least squares trend growth

SIC CODE	INDUSTRY NAME	Growth in		Contribution of:				Contribution of:			
		Value Added per worker		Capital		TFP		IT Capital		Non-IT Capital	
		1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001
	Private non-farm business	1.01	2.46	0.44	1.02	0.56	1.44	0.36	0.85	0.08	0.17
GD	Goods-producing industries	1.81	2.28	0.58	0.96	1.23	1.31	0.30	0.48	0.27	0.49
	Agricultural services, forestry, and fishing...	-0.72	1.39	0.40	0.84	-1.12	0.56	0.14	0.19	0.27	0.65
	Mining.....	3.39	-0.36	1.27	1.21	2.12	-1.57	0.18	0.42	1.09	0.78
10	Metal mining.....	7.62	16.25	-1.02	2.44	8.64	13.81	0.68	0.57	-1.70	1.87
12	Coal mining.....	10.30	9.30	0.60	2.81	9.70	6.48	0.33	0.57	0.27	2.24
13	Oil and gas extraction.....	2.28	-4.00	1.46	0.16	0.82	-4.15	0.13	0.38	1.33	-0.23
14	Nonmetallic minerals, except fuels.....	1.28	4.35	0.96	1.54	0.32	2.81	0.22	0.47	0.74	1.07
15-17	Construction.....	0.22	-0.09	-0.15	0.85	0.37	-0.95	0.11	0.16	-0.26	0.69
	Manufacturing.....	2.42	3.84	0.72	1.06	1.70	2.77	0.32	0.53	0.40	0.54
	Durable goods.....	3.50	6.34	0.74	1.30	2.76	5.04	0.31	0.65	0.43	0.66
24	Lumber and wood products.....	-3.88	-0.71	-0.29	0.37	-3.59	-1.07	0.14	0.21	-0.42	0.16
25	Furniture and fixtures.....	1.33	1.21	0.31	0.61	1.02	0.60	0.18	0.32	0.13	0.29
32	Stone, clay, and glass products.....	3.04	0.42	-0.01	1.29	3.05	-0.87	0.07	0.47	-0.08	0.82
33	Primary metal industries.....	3.34	2.88	0.14	0.43	3.20	2.45	0.06	0.22	0.08	0.21
34	Fabricated metal products.....	1.33	0.34	0.28	0.74	1.05	-0.40	0.23	0.38	0.05	0.36
35	Industrial machinery and equipment.....	5.23	11.91	0.90	1.68	4.34	10.23	0.51	1.29	0.38	0.39
37	Motor vehicles and other transportation equipment.....	1.07	3.02	0.45	0.90	0.62	2.13	0.18	0.40	0.27	0.49
36,38	Electronic equipment and instruments	7.74	11.75	1.71	2.15	6.03	9.61	0.52	0.87	1.19	1.28
39	Miscellaneous manufacturing industries.....	0.41	4.79	0.28	0.85	0.14	3.94	0.24	0.33	0.04	0.52
	Non-durable goods.....	0.96	0.44	0.99	1.69	-0.03	-1.25	0.48	0.70	0.52	0.99
20	Food and kindred products.....	1.30	-2.99	0.61	1.12	0.69	-4.11	0.20	0.36	0.41	0.75
21	Tobacco products.....	-3.63	-17.22	2.37	0.78	-5.99	-18.00	0.35	0.42	2.02	0.35
22	Textile mill products.....	4.00	1.85	0.47	1.50	3.53	0.35	0.31	0.46	0.16	1.03
23	Apparel and other textile products.....	2.14	4.77	0.70	2.48	1.45	2.29	0.23	0.45	0.47	2.02
26	Paper and allied products.....	1.22	0.40	0.89	1.16	0.33	-0.77	0.30	0.34	0.59	0.82
27	Printing and publishing.....	-2.68	-0.33	0.81	1.22	-3.49	-1.55	0.73	1.29	0.08	-0.07
28	Chemicals and allied products.....	2.38	1.21	1.50	1.65	0.88	-0.44	0.77	0.74	0.73	0.90
29	Petroleum and coal products.....	-2.00	2.41	1.60	0.80	-3.60	1.61	0.80	0.31	0.80	0.49
30	Rubber and miscellaneous plastics products...	4.14	3.81	0.50	1.58	3.64	2.23	0.22	0.45	0.28	1.13
31	Leather and leather products.....	3.68	0.36	1.86	1.62	1.82	-1.26	0.18	0.68	1.68	0.94

continued

SIC CODE	INDUSTRY NAME	Growth in		Contribution of:				Contribution of:			
		Output per worker		Capital		TFP		IT Capital		Non-IT Capital	
		1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001	1987-95	1995-2001
SER	Service-producing industries	0.75	2.56	0.41	1.08	0.33	1.48	0.38	1.01	0.04	0.07
	Transportation.....	2.19	0.84	-0.24	0.78	2.43	0.06	0.27	0.61	-0.52	0.17
40	Railroad transportation.....	6.25	3.21	0.51	0.48	5.74	2.73	0.04	0.08	0.47	0.40
41	Local and interurban passenger transit.....	-2.69	2.09	-0.83	0.04	-1.86	2.05	0.02	0.07	-0.84	-0.03
42	Trucking and warehousing.....	2.80	0.20	0.08	0.45	2.72	-0.25	0.22	0.18	-0.15	0.26
44	Water transportation.....	3.85	0.23	-0.61	-0.49	4.46	0.72	0.08	0.16	-0.69	-0.66
45	Transportation by air.....	2.36	0.54	-0.68	1.34	3.05	-0.80	0.14	0.89	-0.83	0.45
46	Pipelines, except natural gas.....	-2.52	4.51	1.10	2.50	-3.61	2.01	0.89	1.24	0.20	1.26
47	Transportation services.....	-0.20	3.18	0.08	2.86	-0.28	0.33	0.99	2.47	-0.91	0.39
48	Communications.....	5.09	3.41	2.52	3.01	2.56	0.40	1.36	2.42	1.16	0.59
	Telephone and telegraph.....	5.08	5.00	2.43	2.22	2.65	2.78	1.37	1.93	1.06	0.29
483-484	Radio and television.....	6.24	-1.75	3.47	5.28	2.76	-7.03	1.85	3.78	1.63	1.50
49	Electric, gas, and sanitary services.....	2.26	0.51	1.32	1.45	0.93	-0.94	0.44	0.45	0.89	1.00
50-51	Wholesale trade.....	3.39	6.81	1.00	2.72	2.38	4.09	0.79	2.19	0.22	0.54
52-59	Retail trade.....	0.98	4.95	0.58	0.49	0.40	4.46	0.19	0.43	0.39	0.06
	Finance and insurance.....	1.47	5.14	1.54	2.42	-0.07	2.71	1.07	1.89	0.46	0.53
60	Depository Institutions.....	2.38	3.85	2.02	1.87	0.36	1.98	1.19	1.70	0.83	0.16
61	Nondepository Institutions.....	0.49	9.68	1.09	4.75	-0.60	4.93	2.43	4.33	-1.34	0.41
62	Security and commodity brokers.....	6.08	12.39	0.74	0.66	5.35	11.74	0.06	0.37	0.67	0.28
63	Insurance carriers.....	1.03	1.38	1.51	1.74	-0.48	-0.36	0.81	1.28	0.70	0.46
64	Insurance agents, brokers, and service.....	-5.31	0.71	0.15	0.86	-5.46	-0.15	0.11	0.40	0.04	0.47
65	Real estate (excluding owner-occupied housing).....	1.50	2.67	0.50	0.11	1.00	2.56	-0.02	0.04	0.52	0.06
	Other Service Industries.....	-0.68	0.20	0.25	0.86	-0.93	-0.67	0.22	0.76	0.03	0.10
70	Hotels and other lodging places.....	0.72	-1.64	0.66	0.49	0.06	-2.13	0.11	0.23	0.55	0.26
72	Personal services.....	-0.99	1.14	0.45	0.48	-1.45	0.66	0.20	0.20	0.25	0.29
73	Business Services	1.39	0.66	0.04	1.54	1.35	-0.88	0.22	1.67	-0.18	-0.13
75	Auto repair, services, and parking.....	-0.51	2.79	1.85	0.45	-2.36	2.34	0.08	0.20	1.77	0.24
76	Miscellaneous repair services.....	-1.69	-2.03	0.42	1.26	-2.11	-3.29	0.34	0.75	0.08	0.51
78	Motion pictures.....	-1.86	1.15	0.84	0.75	-2.70	0.40	0.47	0.32	0.36	0.43
79	Amusement and recreation services.....	-0.20	-1.47	-0.56	0.61	0.35	-2.08	-0.08	0.14	-0.48	0.47
80	Health services.....	-2.19	-0.02	0.29	0.74	-2.48	-0.77	0.28	0.52	0.01	0.23
81	Legal services.....	-0.97	1.59	0.08	0.37	-1.06	1.22	0.17	0.37	-0.09	0.00
82	Educational services.....	-0.40	-1.29	0.02	0.09	-0.42	-1.38	0.03	0.12	-0.01	-0.02
83-87	Other Services	-0.43	0.18	0.09	0.39	-0.52	-0.22	0.18	0.45	-0.09	-0.06

Source: Least squares applied to log changes. Reported values are log changes.

Appendix B

Comparing the BEA Industry Database with the Output and Input Data Used in The BLS Productivity Measurement Program and with the Accounts of Jorgenson, Ho and Stiroh (2002)

The BLS computes labor productivity for a modified measure of the private nonfarm business sector (table 1.7 of the national accounts) that excludes the output of nonfarm owner-occupied housing (table 8.12) and the rental value of non-residential real estate owned by nonprofit institutions (table 8.21). The BLS measure of the nonfarm business sector represents a little more than three-fourths of GDP, and explicitly excludes general government, households and nonprofit institutions, and the farm sector. In its calculation of multi-factor productivity, the BLS also excludes government enterprises because of the lack of information on capital services (BLS, 1997, pp. 89-102).

While a seemingly comparable measure of the nonfarm business sector can be constructed from the BEA industry accounts, crucial differences exist. First, the output of nonprofit institutions is implicitly included in our analysis, since it is not identified at the level of individual 2-digit industries.¹ Second, we have excluded a small industry, holding and other investment companies (SIC 67), because it has no natural measure of output within national accounts conventions (those conventions preclude interpreting earnings from interest and profits from ownership of other units as income from production or the activities as productive economic activities). We are able to follow the BLS in excluding government enterprises.

More importantly, our measure of nonfarm gross product is a bottom-up construct compared to the top-down concept used by the BLS, which leads to the difference between the *expenditure side* of the national accounts, used for the BLS output measure and the *income side* of the national accounts, which is incorporated into the BEA industry accounts. The implications of this are explained in the text.

¹ Ownership status is deemed irrelevant to industry classification, which depends only on the economic activity of the establishment.

Additionally, the difference between the estimates of aggregate price change obtained from the expenditure-side measure of GDP and the double-deflation of industry value added is another frequently overlooked source of difference. The expenditure-based estimate of the GDP price index is based on a chain index in which the weights are the shares of individual components of final demand. In contrast, the industry measure of price change for value added is the difference between two chain indexes, gross output and purchased inputs. Each of those two indexes is constructed, in turn, on the basis of the composition of the industry's sales (final and intermediate) and purchases. The nonfarm sector is then an aggregation of these industry value added estimates. Not surprisingly, the two measures of aggregate real output and price change are not identical, given the gaps in information on both prices and shipments. The residual is assigned by BEA to a line labeled "not allocated by industry," and we exclude both it and the real value of the statistical discrepancy from our measure of the nonfarm sector.² This difference in price deflation between the industry and expenditure-side measures of the nonfarm sector adds 0.1 percent per year to the 1995-01 growth rate and 0.3 percentage points to the acceleration over 1987-95.

The manufacturing output series of BLS and BEA are both gross output and they both rely on Census Bureau shipments data. BLS constructs its own measures of output and exclude an estimate of intra-manufacturing shipments. The the growth rates of the two measures of durables output are virtually the same over the full 1987-2001 period, but differ in subperiods. Part of this arises presumably from changes in the amount of intra-manufacturing shipments, but we do not know the sources.

Jorgenson, Ho, and Stiroh (2002) use a broader measure of output than is in the national accounts, with a large component originating in the household sector, whose output grows somewhat slower than the rest of the economy (JHS, 2002, table 5). The wider output concept dampens labor productivity growth over the 1995-2000 period, compared with the national accounts total we use—judging from table 7, presumably by about 0.2 points (we cannot estimate it precisely). For the same reason, the JHS study contains a larger quantity of capital services, both IT and non-IT (IT input growth in the household "industry" is somewhat faster than the rest of the economy—

² The residual is separate from the deflated value of the statistical discrepancy; however, it is positively correlated with the real value of the statistical discrepancy. It is zero in the base year of 1996, and represented -2.2 percent of GDP in both 1987 and 2001.

Jorgenson, Ho, and Stiroh, 2002, table 10). This increases their capital deepening effects, compared with studies that follow the national accounts production boundary; again, we do not estimate it precisely, and instead we take the difference in the table (combined, 1.41 compared with 1.02) as an estimate, that is, about 0.4 points. Finally, Jorgenson, Ho, and Stiroh (2002) are better than we in accounting for labor input, in that they incorporate a labor quality adjustment, which we lack. Each of these three factors affects MFP; they sum to approximately 0.81, which is the difference between the MFP estimates in our two studies. Though the reconciliation is to an extent forced, rather than an independent estimate, an independent check on the most important factor—the estimates for MFP growth in IT—shows that our two studies have very similar results. The IT estimate is discussed more fully in the text.