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Productivity Growth and the New Economy

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Abstract

The present study is the third in a series of three papers devoted to issues in the measurement of productivity and productivity growth. The major findings are as follows. First, this study shows that the new data set used here, which develops data on total output, business sector output, and "well-measured" output, and relying on income-side data, provides a useful supplement to existing data sets. Second, there has clearly been a rebound in labor-productivity growth in recent years. All three sectoral definitions show a major acceleration in labor productivity in the last three years of the period (1996–98) relative to the 1978–95 period. The rebound was 1.2 percentage points for GDP, 1.8 percentage points for business sector, and 2.1 percentage points for well-measured output. Third, productivity growth in the new economy sectors has made a significant contribution to economy-wide productivity growth. For the business sector, of the 1.82 percentage point increase in labor-productivity growth in the last three years, 0.65 percentage point was due to the new-economy sectors. Finally, for all three output measures, there has been a substantial upturn in labor-productivity growth outside the new economy. After removing the direct effect of new economy sectors, the productivity acceleration was 0.54 percentage points for total GDP, 0.65 percentage points for business output, and 1.18 percentage points for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new-economy sectors.

I. Introduction and Summary [1]

Variations in productivity growth have proven one of the most durable puzzles in macroeconomics. After growing rapidly for a quarter century, productivity came to a virtual halt in the early 1970s. There was no shortage of explanations for the productivity-growth slowdown. The explanations included rising energy prices, high and unpredictable inflation, rising tax rates, growing government, burdensome environmental and health regulation, declining research and development, deteriorating labor skills, depleted inventive possibilities, and societal laziness.

These explanations seemed increasingly inadequate as inflation fell, tax rates were cut, regulatory burdens stabilized, government's share output fell, research and development and patents granted grew sharply, energy prices fell back to pre-1973 levels, and a burst of invention in the new economy and other sectors fueled an investment boom in the 1990s. One of the major puzzles in the mid-1990s revolved around the inability of increasingly sophisticated and powerful computers and software to give an upward boost to productivity growth. This puzzle was expressed in the famous Solow paradox, "Computers are everywhere except in the productivity statistics." Notwithstanding

[1]The author is grateful for comments from Ray Fair. Version is [d1284.wpd]

the ubiquitous computer, through thin and thick labor-productivity growth seemed to be on a stable track of slightly over 1 percent per year.

However, in the late 1990s, productivity growth rebounded sharply. Over the period from 1995 to mid-2000, productivity growth in the business sector grew at a rate close to that in the pre-1973 period. The causes of the rebound were widely debated, but at least part was clearly due to astonishing productivity growth in the "new economy" sectors of information and communications.

The present study is the last of three papers devoted to developing new data and methods for measuring productivity growth and examining the extent and sources of the current productivity rebound. In addition to examining recent productivity behavior, the current study adds a few new features to the analysis. First, it examines the welfare-theoretic basis of productivity measures and proposes an "ideal" index of productivity growth. Second, it lays out a different way of decomposing productivity growth which divides aggregate productivity trends into factors that increase average productivity growth from the changing shares of the sizes of different sectors. Third, we develop an alternative way of measuring aggregate and industrial productivity based on industrial data built up from the income side rather than the product side of the accounts. By relying on the industrial data, we can focus on different definitions of output and get sharper estimates of the sources of productivity growth. Fourth, by working with the new industrial data, we can make more accurate adjustments for the contribution of the "new economy" than has been the case in earlier studies. Finally, this new data set allows us to create a new economic aggregate, which we call "well-measured output," that allows us to remove those sectors where output is poorly measured or measured by inputs.

Because the study is heavily methodological and data-intensive, we summarize the approach and major results in this introductory section.

1. The present study introduces a new approach to measuring industrial productivity. It develops an income-side data base, currently available to 1997–98, on labor productivity relying on data that are published by the Bureau of Economic Analysis (BEA). The data are internally consistent in that both inputs and outputs are income-side measures of value added, whereas the usual productivity measures combine expenditure-side output measures with income-side input measures. The advantage of the unified income-side measures is that they present a consistent set of industrial accounts. The disadvantages are that they are only available for the period 1977–98 and that they do not contain a set of capital accounts, so we can only examine labor productivity.

2. We have constructed a set of labor productivity measures for four different definitions of output:

- GDP from the income side
- BLS's business sector output from the income side
- A new measure called "well-measured output," which includes only those sectors for which output is relatively well measured
- The "new economy" as defined below

3. The constructed measures of labor productivity are reasonably consistent with the most widely studied measure, the BLS's measure of labor productivity in the business sector. Over the period of investigation, the difference between the labor-productivity growth rate estimates of the income-side and product-side constructs is 0.05 percentage points per year. However, in the last three years, productivity from the income-side series grew more than 1 percentage point more rapidly, primarily because of the movement in the statistical discrepancy between output and income side measures.

4. There has clearly been a rebound in productivity growth since 1995. The rebound is found

in all three sectoral definitions developed for this study. The labor productivity acceleration in the last three years of the period (1996–98) relative to the 1978–95 period was 1.2 percentage points for GDP, 1.8 percentage points for business sector, and 2.1 percentage points for well-measured output.

5. We have developed a new technique for decomposing changes in labor-productivity growth between different sources. This decomposition identifies a pure productivity effect (which is a fixed weighted average of the productivity growth rates of different industries); the Denison effect (which captures the effect of changing shares of employment on aggregate productivity); and the Baumol effect (which captures the interaction between the differences in productivity growth and the changing hours shares of different industries over time). Total productivity growth is the sum of these three effects.

6. Our estimates show that the pure productivity effect in recent years has been substantially above total productivity growth. For example, in the business sector for the period 1996–98, total labor-productivity growth has been 3.19 percent per year while the pure productivity effect was 3.61 percent per year. The difference was primarily due to the Baumol effect, with a rising share of hours in services accompanying slow labor-productivity growth in services. The Baumol and Denison effects are relatively small for well-measured output.

7. The first companion paper to this study provides a rigorous definition of the appropriate measure of productivity growth from a welfare-theoretic point of view. The present paper applies the ideal measure to the new data set. We find that the ideal measure is higher than other commonly used measures of labor-productivity growth in every period. The differences are relatively small in the most recent period, but they are substantial in earlier periods. On average, the ideal or welfare-theoretic measure over the 1978–98 period is about 0.2 percentage points per year higher than the other measures.

8. One key question is the contribution of the new economy to the productivity rebound. For the purpose of this study, we define the new economy as machinery, electric equipment, telephone and telegraph, and software. These sectors grew from 3 percent of real GDP in 1977 to 9 percent of real GDP in 1998.

9. Productivity growth in the new economy sectors has made a significant contribution to economy-wide productivity growth. In the business sector over the last three years, labor-productivity growth excluding the new economy sectors was 2.24 percent per year as compared to 3.19 percent per year including the new economy. Of the 1.82 percentage point increase in labor-productivity growth in the last three years relative to the earlier period, 0.65 percentage point was due to the new economy sectors. The contribution of the new economy was slightly larger for well-measured output because that sector is smaller than the business economy.

10. Which sectors within the new economy have contributed most to the productivity rebound? The major contributors have been manufacturing electric and nonelectric machinery, the major subsectors of which are computers and semiconductors. These two sectors, which constituted under 4 percent of nominal GDP, contributed to 0.60 percentage points of the 2.39 percent per year GDP productivity growth in the 1996–98 period.

11. Finally, to what extent has there been an acceleration of productivity growth outside the new economy? For all three output measures, there has been a substantial upturn in non-new-economy productivity growth. After stripping out the new economy sectors, the productivity acceleration was 0.54 percentage points for total GDP, 0.65 percentage points for business output, and 1.18 percentage points for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new-economy sectors.

II. Review of Concepts and Data

This section reviews the methods and data used in productivity studies.

Productivity Accounting

The first issue reviewed is the appropriate approach to measuring labor productivity. This section summarizes the results presented in the first companion paper to this one.[2] Consider aggregates of output (X_t), composite inputs (S_t), and total factor or labor productivity ($A_t = X_t/S_t$). These aggregates are the sum (or chained indexes) of industry output, inputs, and productivity (X_{it}, S_{it}, and A_{it}). Aggregate productivity is calculated as:

$$(1) \qquad A_t = \sum_i A_{it} w_{it}$$

where w_{it} = share of total inputs devoted to industry i, that is, $w_{it} = S_{it}/(\Sigma_j S_{jt})$. With some manipulation, this becomes:

$$(2) \qquad g(A_t) = \sum_i s_{ik} g(A_{it}) + \sum_i (s_{it} - s_{ik}) g(A_{it}) + \sum_i R_{it-1} \Delta w_{it}$$

where R_{it} are productivity relatives equal to A_{it}/A_t; $\sigma_{1t} = X_{it}/X_t$, which is the share of industry i in nominal output; and $s_{it} = (S_{it}/S_t)(X_{it\bullet 1}/X_{t\bullet 1})/(S_{it\bullet 1}/S_{t\bullet 1})$, which is approximately equal to σ_{1t} for small times steps and smooth series. For small time steps, equation (2) becomes:

$$(2') \qquad g(A_t) = \sum_i \sigma_{ik} g(A_{it}) + \sum_i (\sigma_{it} - \sigma_{ik}) g(A_{it}) = \sum_i R_{it-1} \Delta w_{it}.$$

Equations (2) and (2′) show that aggregate productivity growth can be broken into three components: a pure, fixed-weight productivity term which uses fixed base-year expenditure or output weights ("pure productivity effect"), a term that reflects the difference between current weights and base-year weights (the "Baumol effect"), and a third term which reflects the interaction between changing weights and relative productivity levels in different sectors (the "Denison effect").

Welfare-theoretic measures of productivity growth

Another important and neglected issue in productivity studies is the appropriate measure of productivity growth. Measurements of prices and output have increasingly turned to welfare or utility theory as a basis for the concepts. Using this approach, we have examined the question of the ideal welfare-theoretic measure of productivity in an economy with many sectors experiencing varying rates of productivity growth. The major result is that the ideal measure of productivity growth is a weighted average of the productivity growth rates of different sectors, as shown by the following equation:

$$(3) \qquad g(R_t) = \sigma_{1t} g(A_{1t}) + \sigma_{2t} g(A_{2t}) + \cdots + \sigma_{nt} g(A_{nt}).$$

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[2] William D. Nordhaus, "Alternative Methods for Measuring Productivity Growth ," November 14, 2000, available at *www.econ.yale.edu/~nordhaus/homepage/ writings_and_presentations_on_th.htm.*

The important point is that the indexes used in the appropriate measure are chain indexes of productivity growth rather than differences in the growth rates or indexes of output and inputs.

We can relate this result to the equations in the last section. It turns out that a welfare-theoretic based measure of productivity growth should include only the first two terms of equations (2) or (2'). That is, the pure productivity and Baumol effects should be included in appropriate measures of productivity growth, but the Denison effect should normally be excluded. Additionally, the ideal equation has slightly different weights from the first two terms in (2). Surprisingly, none of the current measures of productivity growth follow the appropriate procedure for measuring productivity growth.

The productivity data

The present study relies upon a data set for measuring labor productivity that differs from standard measures. The second companion paper to this one develops an income-side data base on productivity which relies on industrial data that are published by the BEA.[3] These data are internally consistent in that both inputs and outputs are income-side measures of value added, whereas the usual productivity measures combine product-side output measures with income-side input measures. The advantage of the income-side measures is that they present a consistent set of industrial accounts. The disadvantages are that they are only available for the period 1977–98 and that they do not contain a set of capital accounts, so we can only examine labor productivity.

Because of interest in the "new economy," we have also constructed a set of new-economy accounts. For the purpose of this study, we define the new economy as machinery, electric equipment, telephone and telegraph, and software. These sectors grew from 3 percent of real GDP in 1977 to 9 percent of real GDP in 1998. These sectors are somewhat more inclusive than a narrow definition of the new economy but are the narrowest definition for which a complete set of accounts is available.

The second companion paper develops a data base for three different output concepts which can be used in productivity studies. One set is standard GDP (measured from the income side of the accounts). A second output concept is what the Bureau of Labor Statistics (BLS) defines as "business sector output." A third concept responds to concerns in productivity studies about the poor quality of the price deflation in several sectors. For this purpose, we have constructed a set of accounts called "well-measured output," which includes only those sectors for which output is relatively well measured.

III. Review of Alternative Productivity Measures

In this section, we begin with a review of standard labor productivity measures and then turn to a comparison of standard measures with the measures constructed for this study.

The BLS productivity data

The most widely followed measure of labor productivity examines productivity in the business sector and is constructed and published by the Bureau of Labor Statistics (BLS). Figure 1 shows the behavior of that series for the business sector; for this purpose, we have used a three-year

[3] William D. Nordhaus, "Constructing Alternation Estimates of Output for Productivity Analysis," November 4, 2000, available at www.econ.yale.edu/~nordhaus/homepage/writings_and_presentations_on_th.htm .

moving average of labor-productivity growth. Table 1 shows a simple regression with two breaks in trend, one in 1973 and the second in 1995.

Four points are worth noting. First, the labor-productivity growth data do not show dramatic and obvious breaks in trend. Labor productivity began deteriorating in the late 1960s, and the really terrible period was in the early 1980s. An untutored analyst would probably not recognize any sharp break in trend labor productivity after 1973. Second, the productivity upsurge in the late 1990s was not a particularly rare event. Productivity accelerations of greater magnitude were seen in the early 1960s, the early 1970s, and the early 1980s — indeed, there were breaks in trend in virtually every decade. The volatile nature of productivity growth is a warning that we should not read too much into a period even as long as four years. Third, even with the rapid productivity growth of the last four years, labor-productivity growth is still below three other postwar highs. The early 1950s, the mid-1960s and, briefly, the mid-1980s were periods with more rapid labor-productivity growth than have been attained in the last three years. Finally, data revisions have led to substantial changes in the patterns of productivity growth. Figure 2 shows the ratio of productivity in the latest data to productivity estimated with data as of 1995. The data revisions tended to reduce the estimated growth rate of labor productivity by about 0.2 percent per year from 1947 to 1977 (6 percent/30 years). Then in the decade after 1982, labor-productivity growth was revised upwards by about 0.8 percent per year (8 percent/10 years). These data revisions actually removed a substantial part of the labor productivity slowdown about which so much was written in the last quarter century.

Notwithstanding these cautions, it is important to examine the current upturn in productivity with an eye to understanding its sources. In particular, we will want to determine the role of the "new economy" in the recent productivity rebound.

Comparison of labor-productivity growth rates between BLS (output-side) and BEA (income-side)

We have prepared a data set on business sector output using an alternative source from the standard measure. Figures 3 through 5 and Table 2 show a comparison of estimates of labor-productivity growth using the BEA (income-side) and BLS (product-side) data sources. There are substantial discrepancies between the estimates of productivity growth for the two sources. The BLS product-side series yields higher productivity growth rate numbers in the early period, but in the most recent period the BEA income-side estimates are 0.65 percentage points per year more rapid.

The difference between the two estimates comes both from the output and the hours data. Table 3 compares the trends in workers, hours per worker, and total hours for the BLS and BEA concepts based on the data described above along with unpublished data on hours from both sources. BEA (income-side) output is estimated to have grown 1.09 percentage points per year faster in the last 3 years, while BEA hours are estimated to have grown about 0.24 percent more slowly in the last three years. Labor productivity using the BEA income-side concepts has grown 0.65 percentage points per year faster. However, the differences are not entirely consistent, and we have not succeeded in identifying the reason for the differences between the two sources.

Well-measured output

We have developed an alternative measure of output that develops input and output data for a concept that we designate as "well-measured output." The sectors included in well-measured output are:

1. Agriculture, forestry, and fishing
2. Mining

3. Manufacturing
4. Transportation and public utilities
5. Wholesale trade
6. Retail trade

There are four major sectors that are excluded from well-measured output.

7. Construction.
8. Finance, insurance, and real estate.
9. Services.
10. Government.

A full discussion of the reasons for the separation is contained in the companion paper on the data.[4]

Figure 6 shows a comparison of productivity growth for the three different concepts of total GDP from the income side, business sector, and well-measured output. Three conclusions are readily apparent. First, productivity growth for the well-measured sectors is about twice that in the poorly-measured sectors. Second, for the last three years of the period, productivity growth in the well-measured sectors has been impressive, averaging almost 4½ percent per year in 1996–98. Third, there was a sharp productivity acceleration in the late 1990s, with productivity growth in the well-measured sectors rising more than 2 percentage points above the earlier period.

III. Productivity Resurgence and the New Economy

We now turn to the central questions about productivity performance in the late 1990s: What was the magnitude of the productivity upturn? How much of the growth was due to each of the three factors derived above — pure productivity acceleration, the Denison effect, and the Baumol effect? Do measures of productivity growth using ideal measures differ from conventional measures? What was the contribution of the new economy to the productivity acceleration? And is there a different view in the well-measured as opposed to the entire economy?

What was the Size of the Productivity Acceleration?

Figure 6 and Table 4 show the basic numbers on labor-productivity growth using different output concepts and time periods. GDP is the standard concept in the national accounts measured from the income side. Business output is the measure as defined by the BLS and constructed here. Well-measured output and the new economy are sectoral concepts that were defined in the last section.

The basic story is straightforward: Labor-productivity growth in the three major sectors showed little change over the 1978–1995 period. It averaged around 1.1 percent per year for private GDP and around 1.3 percent per year for business output. Well-measured output showed more robust productivity growth, averaging around 2.3 percent per year, but was relatively stable over this period. The new economy showed substantial productivity growth, but there was little acceleration over the period.

The last three years of the sample period showed a dramatic upturn in labor-productivity growth in all of the measures. Private GDP grew 1.18 percentage points per year more rapidly, while business sector output grew about 1.82 percentage points more rapidly. Well-measured output showed a dramatic upturn in productivity growth, almost doubling with a 2.08 percentage point increase. The new economy logged a breathtaking increase in productivity of 13.3 percent per year

[4] See footnote 3.

in the last three years, which was approximately double that of the earlier period.

In short, while the period is relatively short, the last three years witnessed a major upturn in productivity growth for all the major aggregates we examined, particularly for the well-measured sectors.

Decomposition of the Productivity Acceleration

How much of the growth was due to each of the three factors derived above. Recall from equation (2) that we can decompose productivity growth into pure productivity growth, the Denison effect, and the Baumol effect. What were the sources of the acceleration in the last three years?

Table 5 shows the basic results for the overall economy. The results are quite surprising. The major finding is that the pure productivity effect is markedly higher than conventionally measured average productivity growth. For overall (GDP) productivity over the last three years, productivity as measured from the output side averaged 1.66 percent per year, while that from the income side grew more rapidly at an average rate of 2.32 percent per year. However, the pure productivity effect in the last three years was 0.14 percent per year higher than the total. The difference was due primarily to the Baumol effect — that is, to the fact that productivity growth was higher in industries whose output shares were declining.

The other interesting point is seen in the last column of Table 5. This shows the acceleration of productivity in the last three years relative to the first period (1978-89). Whereas overall GDP productivity showed a meager acceleration of 0.41 percentage points, the acceleration as measured by the pure productivity effect was 1.37 percentage points.

Table 6 and Figure 7 shows the results for the business sector. For this sector, we cannot compare output and income side measures directly because the statistical discrepancy is not allocated by sector. Two important results can be seen. First, there was a major acceleration in productivity in the business sector in the last three years, with total productivity averaging 3.16 percent per year. Second, the pure productivity effect was even more substantial, and accelerated even more, but was dragged down by large negative Baumol and Denison effects. Unlike the overall economy, in the business sector the Baumol and Denison effects were both quite large and in the last three years reduced productivity growth by 0.46 percentage points.

Table 7 and Figure 8 shows the results for the well-measured sector. The results here parallel those in the other sectors. Productivity growth in the last three years was very rapid: 4.65 percent per year as compared to 2.39 percent per year in the first part of the period studied. For the well-measured sectors, the Denison and Baumol effects were small relative to the overall impact, pulling down the pure productivity effect by only 0.13 percentage points in the last three years.

The basic conclusions regarding the decomposition of productivity growth is that pure productivity growth in the most recent period has been even more rapid than the total. This is most clearly seen for overall output, where the conventional product-side estimates of productivity growth are well below the pure productivity growth because of the statistical discrepancy as well as modest Denison and Baumol effects. The understatement is even larger for the business sector.

Comparison of Alternative Measures from Welfare-Theoretic Point of View

The next question is how the different measures compare with the ideal welfare-theoretic measure of productivity growth. Recall from section II above that the ideal measure of productivity growth is a chain index of productivity growth where the weights are current nominal output. In practice, we measure the weights as Tornqvist weights, which are averages of the weights of the two periods.

Figures 9 and 10 and Table 8 show a comparison of four measures for the overall economy. The series called "welfare measure" is the ideal measure shown in equation (3) of section II. This captures the estimate of productivity growth that best measures the growth in average living standards. The measure labeled "variable" is very similar to the ideal except that it uses a more complex set of weights rather than nominal output weights; this series includes the fixed productivity effect plus the Baumol effect. The third series, labeled "total GDI," is total income-side productivity growth measured simply as output per unit input; this is therefore the variable productivity effect plus the Denison effect. The final series, called "total GDP," is identical to total GDI except that the numerator is product-side output rather than income-side output.

The results show two important differences between the different concepts. First, the ideal or welfare-theoretic measure is higher than any of the other measures in every period. The differences are relatively small in the most recent period, but they are substantial in earlier periods. On average, the ideal or welfare-theoretic measure over the entire period was 0.21 percentage points per year higher than total income-side productivity. The second point, which was clear in the earlier results, is substantial difference between the GDI and GDP concepts in the most recent period.

Contribution of the New Economy to the Productivity Rebound

The next issue involves using the new data set to answer an important question: What is the contribution of the new economy to the remarkable resurgence in productivity over the last few years. In this exercise, we limit our answer to the direct contribution of more rapid productivity growth in new-economy industries; this analysis omits the question of the contribution of capital deepening and of spillover effects of the information economy to productivity.

The technique for calculating the impact of the new economy is as follows. We calculate old-economy output and hours of the relevant sector (e.g., durable manufacturing) by removing the new-economy output and hours from the sectoral total. For example, in the durable manufacturing sector, we subtract output and hours of Machinery, except electrical and Electric and electronic equipment. We then calculate total labor productivity with these sectors omitted.

The results are shown in Tables 9 through 11. We focus first on the business sector, which is the most widely followed of the productivity constructs. In the last three years, as shown in Table 10, the new economy contributed almost a percentage point (0.97 percentage points) to labor-productivity growth (see the third number on the last line of Table 10). Another important finding is the contribution of the new economy to the labor productivity rebound in the last three years. Of the 1.89 percentage point acceleration in labor productivity (see the last column of line 1 in Table 10), one third was due to the acceleration in the contribution of the new economy (see the last column of line 4 in Table 10).

Similar results are found for the overall economy. For that sector as well, slightly less than one-half of the acceleration of income-side productivity growth was due to the new economy (see the last columns of lines 1 and 4 in Table 9). The role of the new economy in well-measured sectors is marginally more important that in the two larger sectors. In this sector, as shown in Table 11, the new economy was responsible for 1.09 percentage points of the 2.26 percentage point increase in productivity growth.

Figure 11 shows the contribution of the different new economy sectors to overall GDP productivity. These weight the productivity growth rates of each of the four sectors by its weight in nominal GDP (following the approach of the ideal welfare-theoretic formula). The total impact, shown in the last set of bars, was slightly below 0.5 percentage points of productivity in the first two subperiods, and then grew to 0.86 percentage points for the 1996-98 period. The largest single

contributor was Electric and electronic equipment (primarily semiconductors), followed by Machinery, except electrical.[5]

Evaluation of the Gordon Hypothesis

Based on Tables 9 through 11, we can evaluate the Gordon hypothesis. This view holds that most if not all of the productivity acceleration in the late 1990s was due to productivity in the computer industry. As summarized in *The Economist:*

> Robert Gordon of Northwestern University, one of the country's top authorities on the subject, has found that more than 100% of the acceleration in productivity since 1995 happened not across the economy as a whole, nor even across IT at large, but in computer manufacturing, barely 1% of the economy. Elsewhere, growth in productivity has stalled or fallen.[6]

The most recent presentation of the Gordon hypothesis (see the reference in footnote 7 below) argues that nonfarm private business experienced a *slowdown* in labor-productivity growth of 0.28 percentage points for the period 1995:4 to 1999:4 relative to the period 1972:2 to 1995:4.

The results developed here definitely reject the Gordon hypothesis. For all three output concepts (total GDP, the business sector, and well-measured output), labor-productivity growth without the new economy has shown a marked upturn in the last three years relative to the 1977–1995 period. The acceleration in non-new-economy productivity growth was 0.64 percentage point for overall GDP, 0.91 percentage point for business output, and 1.16 percentage point for well-measured output. A rough approximation is that new economy contributed directly to about one-half of the total acceleration in labor-productivity growth.

It should be emphasized that the results presented here are likely to underestimate the impact of the new economy because they omit the impact of capital deepening on labor-productivity growth. Recent estimates of the impact of capital deepening on labor productivity are approximately 0.3 percentage point for the period under consideration.[7] Although we do not develop independent estimates of the contribution of capital deepening, we can incorporate the results from other analysts in Figure 12. This figure shows the breakdown of the acceleration in productivity in the three sectors between capital deepening (assumed to be 0.33 percentage points), new-economy output productivity, and other. It is clear that the new economy is a major contributor to the productivity acceleration, but even after correcting for capital deepening productivity has accelerated in all three sectors considered here.

A final decomposition of productivity growth examines how much each industry contributes to the total. Figure 13 shows how productivity growth for the overall economy (measured as income-side GDP) derives from the different industries. For this calculation, we have used the "variable" productivity growth rate, which incorporates the pure productivity effect plus the Baumol effect (see the discussion above). This measure is the closest to the welfare-theoretical ideal of the

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[5] The estimates here varies from those in other tables because the weighting procedure is slightly different.

[6] *The Economist*, July 22, 1999 available at www.economist.com .

[7] See Dale W. Jorgenson and Kevin J. Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, 2000: 1, pp. 125–211 along with the discussion by Robert J. Gordon and Daniel E. Sichel, pp. 212–227.

different indexes. The individual-sector figures sum to the total, so the length of each bar in Figure 13 shows the relative importance of each sector.

There is no surprise that durable manufacturing is the most important contributor to overall productivity. Some of the other sectors are more surprising. For example, retail and wholesale trade have each made major contributions to overall productivity growth in the latest period. Indeed, the *acceleration* of productivity for 1996–98 in each of these two sectors has been larger than in durable manufacturing. The data in these sectors are somewhat of a mystery, however, which emphasizes the importance of closer attention to measuring output of the trade sectors. The other anomalies are the poor performance in services and construction. These sectors, which have the most questionable price indexes and are excluded from our index of well-measured output, showed negative productivity growth in each of the three subperiods.[8]

Another important question is the behavior of the industries within manufacturing, shown in Figure 14 and summarized in Figure 15. The importance of industrial machinery (notably computers) and electronic machinery (notably semiconductors) is striking.[9] As Figure 15 shows, the totality of other industries showed a marked productivity deceleration in the latest period. Of the 1.15 percentage point slowdown in non-new-economy manufacturing showed in the first set of bars in Figure 15, food is responsible for 0.78 percentage points, which raises questions about either the data or the performance of that industry. If the two major new-economy sectors and food are removed from Figure 14, the latest data look pretty routine. It seems reasonable to conclude, therefore, that up through 1998, the acceleration in manufacturing productivity was limited to the two major new-economy sectors led by computers and semiconductors.

To conclude, the present study is the last in a series of three papers devoted to issues in the measurement of productivity and productivity growth. We can summarize the major points here, although a more detailed summary is contained in the first section. First, the present study explores a new income-side data set for analysis of productivity, and constructs data for total output, the business sector, "well-measured" output, and the new economy. Second, there has clearly been a rebound in labor-productivity growth in recent years. All three sectoral definitions show a major acceleration in labor productivity in the last three years of the period (1996–98) relative to the 1978–95 period. The rebound was 1.2 percentage points for GDP, 1.8 percentage points for business sector, and 2.1 percentage points for well-measured output. Third, labor-productivity growth in the new economy sectors has made a significant contribution to economy-wide productivity growth. For the business sector, of the 1.82 percentage point increase in productivity growth in the last three years, 0.65 percentage point was due to the new-economy sectors. Finally, for all three output measures, there has been a substantial upturn in productivity growth outside the new economy. After removing the direct effect of new economy sectors, the labor productivity acceleration was 0.54 percentage points for total GDP, 0.65 percentage points for business output, and 1.18 percentage points for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new-economy sectors.

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[8] These results are on the whole similar to the results of Jorgenson and Stiroh, which use an accounting framework that includes all inputs and explains the movement of gross output.

[9] Within SIC 35 and 36, Appendix Table 1 shows the major data on shipments and the price of shipments. The industries with sharply falling price indexes have hedonic treatment.

Figure 1

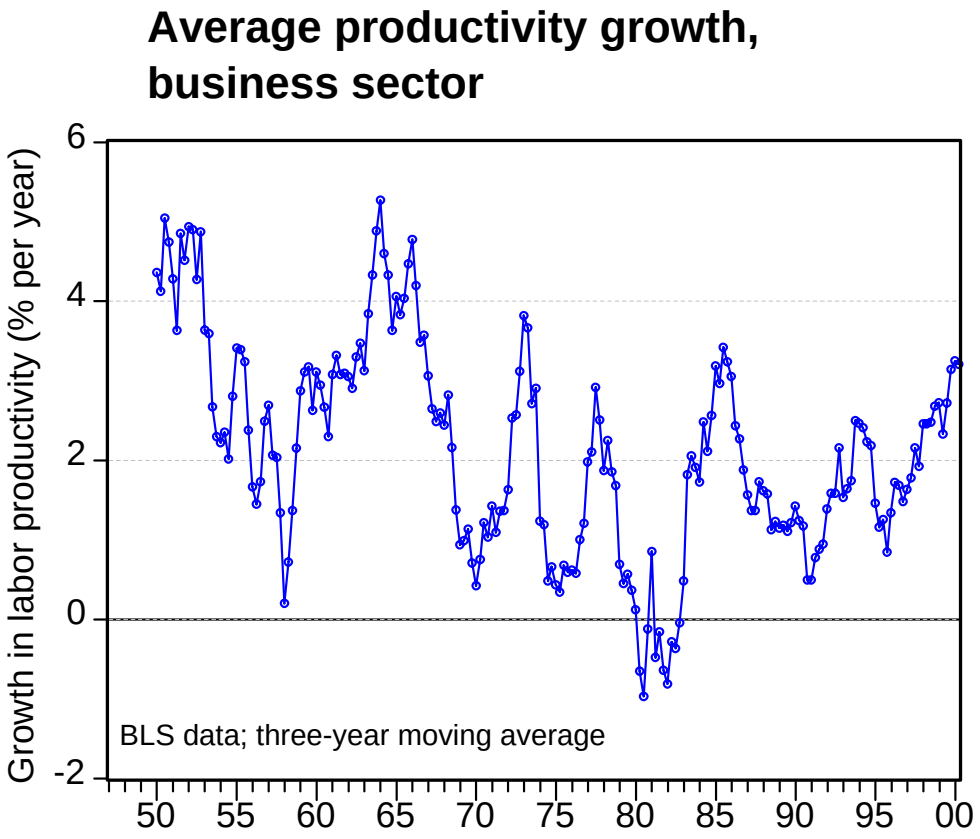

Average productivity growth, business sector
Growth in labor productivity (% per year)
6
4
2
0
-2
BLS data; three-year moving average
50
55
60
65
70
75
80
85
90
95
00

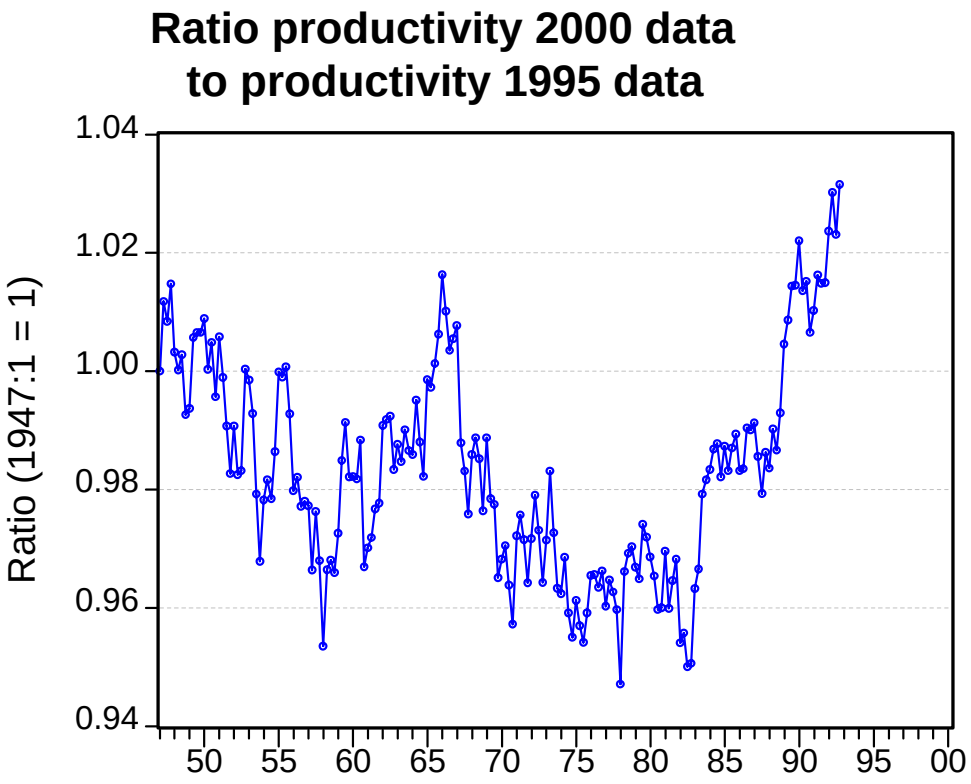
Table 1
Trends in Labor Productivity, BLS Measure, 1947:1 – 2000:2

Dependent Variable: One-quarter change in log of labor productivity
Sample(adjusted): 1947:2 2000:2
Included observations: 213 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic
C	2.97	0.386	7.69
DUM73	–1.78	0.570	–3.13
DUM95	1.61	0.956	1.69
R-squared	0.047		
S.E. of regression	3.93		

Note: DUM73 is a dummy variable which takes the value of 1 after 1973:2.
Note: DUM95 is a dummy variable which takes the value of 1 after 1995:2.

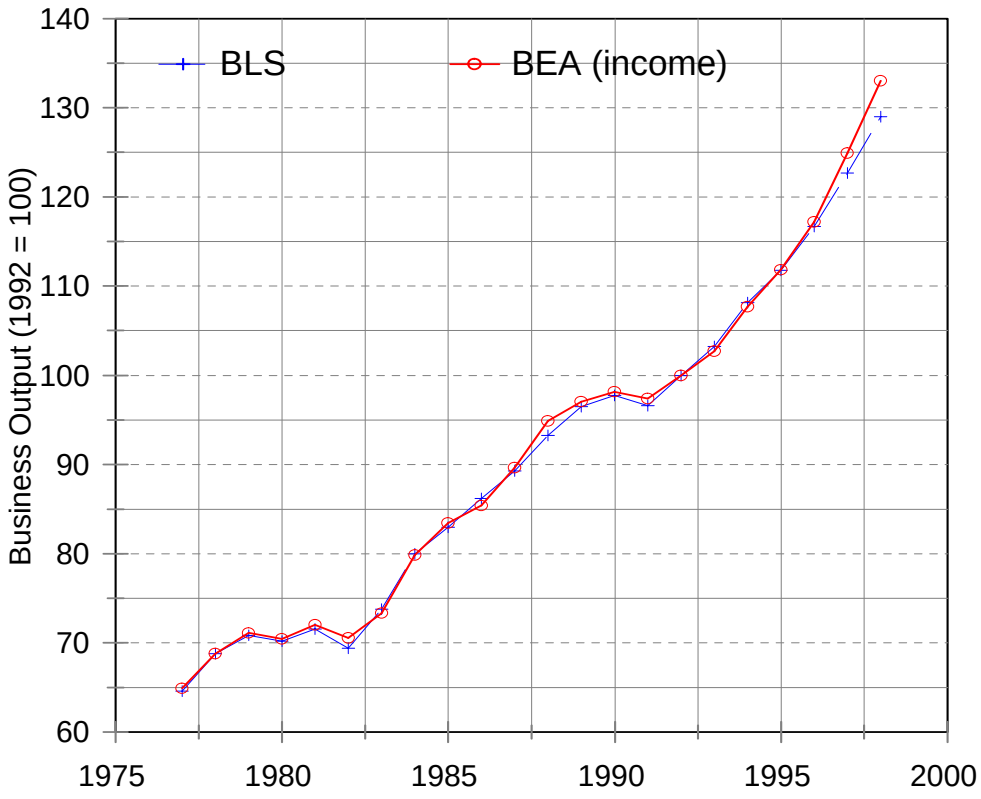
Figure 2
Effect of Data Revisions on Labor Productivity



Note: This graph shows the ratio of labor productivity levels using data published in September 2000 to labor productivity using data published in 1995.

Figure 3

Comparison of Business Sector Output: BLS and BEA Constructed



Note: "BLS" is the output-side product of the business sector used by BLS in its business sector productivity measures. "BEA" is the income-side output measure as derived in this paper.
Source: Tables: revised industry 110300.wb3

Table 2

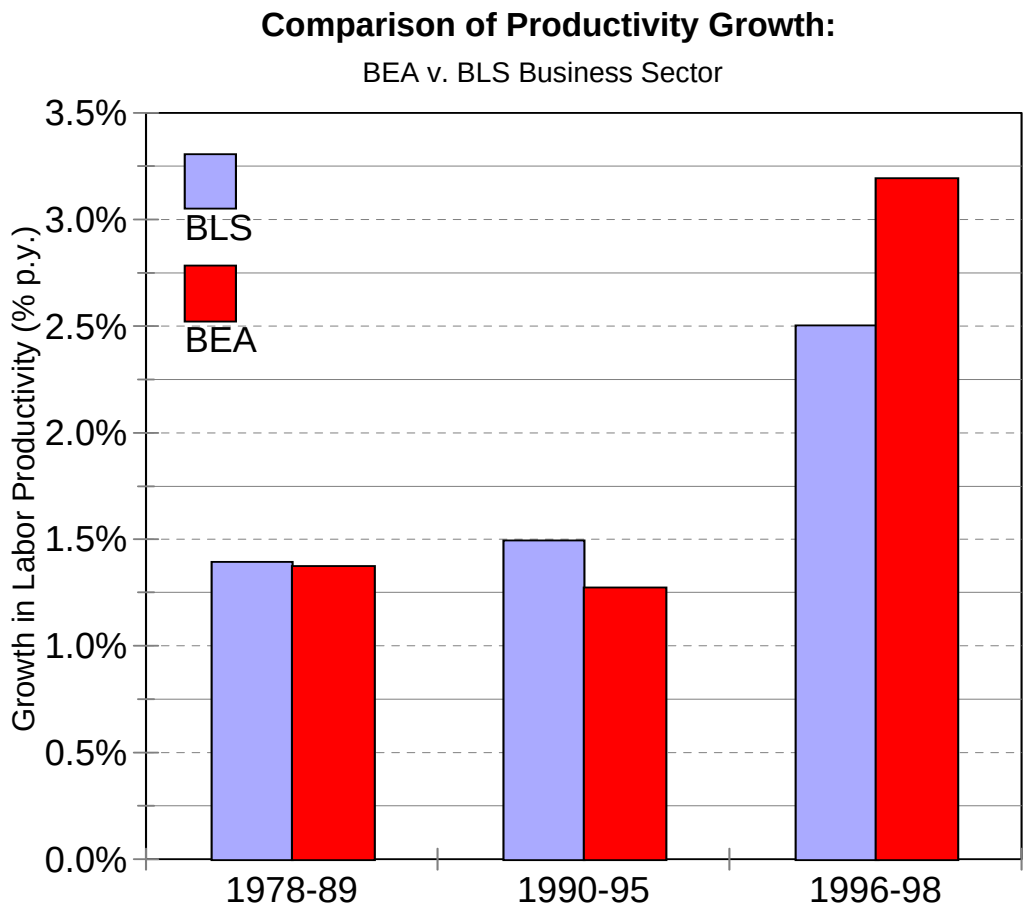
Comparison of BEA and BLS Measures of Labor-Productivity growth in the Business Sector Output

	1978-89	1990-95	1996-98
BLS (product side)	1.37%	1.49%	2.50%
BEA (income side)	1.27%	1.26%	3.16%
Difference	0.10%	0.23%	-0.65%

Source: Tables: revised industry 111300.wb3: BusSec.

Note: "BLS (product side)" is the output-side product of the business sector used by BLS in its business sector productivity measures. "BEA (income side)" is the income-side output measure as derived in this paper.

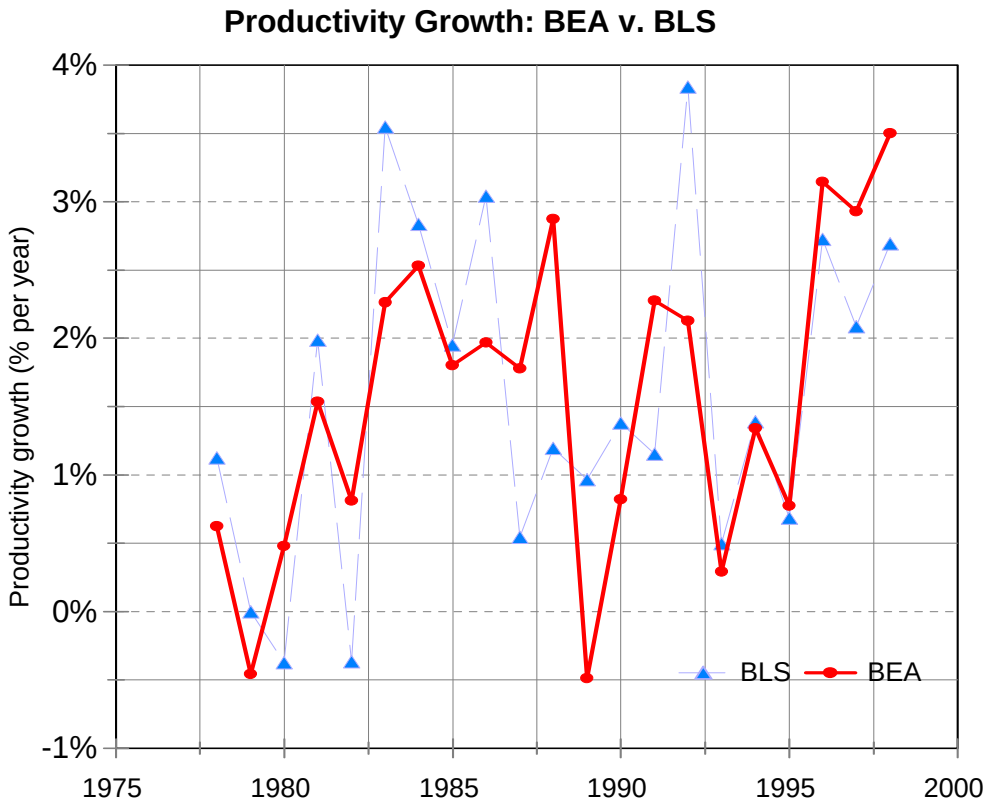
Figure 4



See Note to Figure 3.

Source: Tables: revised industry 111300.wb3: Tables: Chart 9.

Figure 5



See Note to Figure 3.

Source: Tables: revised industry 111300.wb3: Tables: Chart 23.

Table 3

Comparison of BEA and BLS Measures
for Different Components of Labor Productivity

Output

Period	*BLS*	*BEA*	*Difference* (BLS-BEA)
1978-89	3.41%	3.41%	0.00%
1990-95	2.49%	2.39%	0.10%
1996-98	4.87%	5.96%	-1.09%

Total Hours

Period	*BLS*	*BEA*	*Difference* (BLS-BEA)
1978-89	2.16%	2.12%	0.04%
1990-95	1.02%	1.11%	-0.09%
1996-98	2.47%	2.72%	-0.24%

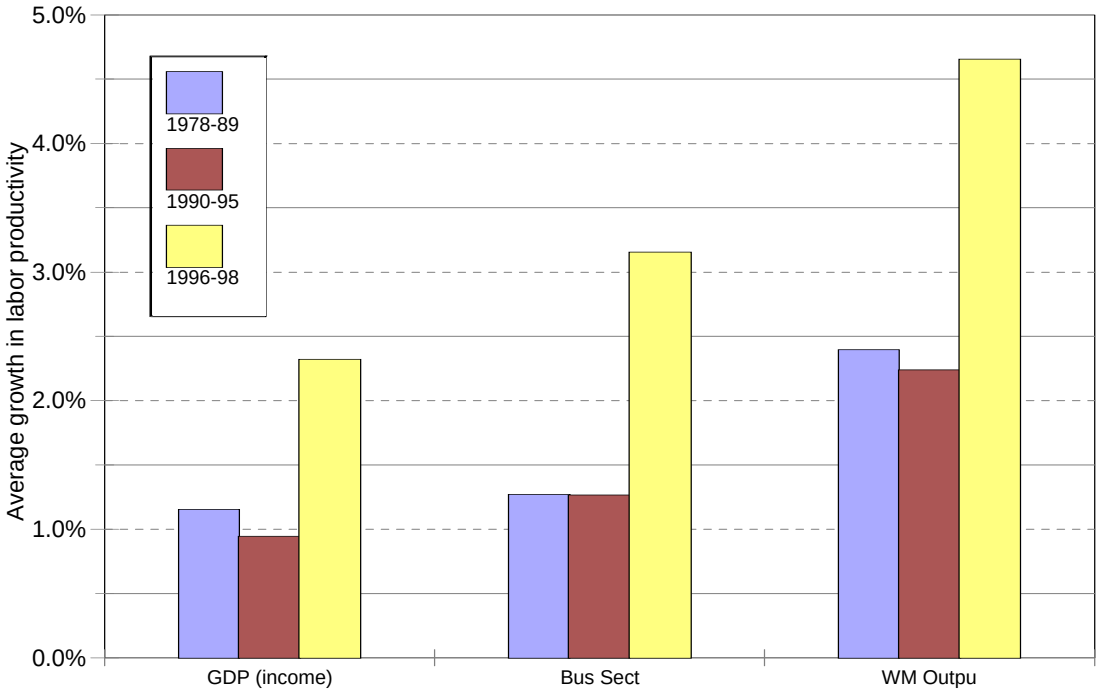
Productivity

Period	*BLS*	*BEA*	*Difference* (BLS-BEA)
1978-89	1.37%	1.27%	0.10%
1990-95	1.49%	1.26%	0.23%
1996-98	2.50%	3.16%	-0.65%

Source: bls data on hours 111300: summary.

Figure 6

Growth in Labor Productivity in Different Sectoral Definition



Note: "GDP (income)" is total GDP measured from the product side.
"Bus Sect" is the income-side measure of business output.
"WM output" is well-measured output as defined in text.

Source: Tables: revised industry 111300.wb3: Tables: Chart 24.

Table 4

Labor-Productivity Growth Alternative Concepts and Periods

Secto	*1978-89* *[1]*	*1990-95* *[2]*	*1996-98* *[3]*	*Change from earlier perio* *[2] - [1]*	*[3] - [1]*
Total GDP (income side)	1.15%	0.95%	2.32%	-0.21%	1.17%
Business output	1.27%	1.26%	3.16%	-0.01%	1.89%
Well-measured business outpu	2.39%	2.24%	4.65%	-0.16%	2.26%
New economy	6.79%	7.31%	13.30%	0.52%	6.51%

Note: See Figure 6 for definitions of first three rows. The new economy is four sectors described in text.

Source: Tables: revised industry 111300.wb3: HourProdGrowSyn.

Table 5

Decomposition of Productivity Growth for Total Economy
Alternative Concepts and Periods

TOTAL GDP

	[1] 1978-89	[2] 1990-95	[3] 1996-98	Change from earlier perio [2] - [1]	[3] - [1]
Total					
GDP	1.25%	1.12%	1.66%	-0.13%	0.41%
GDI	1.15%	0.95%	2.32%	-0.21%	1.17%
Pure productivity effect	0.95%	1.29%	2.58%	0.34%	1.37%
Baumol	0.04%	-0.15%	-0.22%	-0.19%	-0.26%
Denison	0.16%	-0.20%	-0.05%	-0.36%	-0.21%

Note: The exact definitions of the terms are given in the text in equation (3). An approximate definition is as follows:

Pure productivity effect is the weighted average of sectoral productivity growth using fixed employment weights for 1987.

The Baumol effect is the difference between the variable productivity effect and the pure productivity effect, where the variable productivity effect uses actual year weights.

The Denison effect is the impact of reallocation among industries which have different levels of productivity per worker.

Source: Tables: revised industry 111300.wb3: GDPTab.

Table 6

Decomposition of Labor-Productivity Growth for Business Sector: Alternative Concepts and Periods

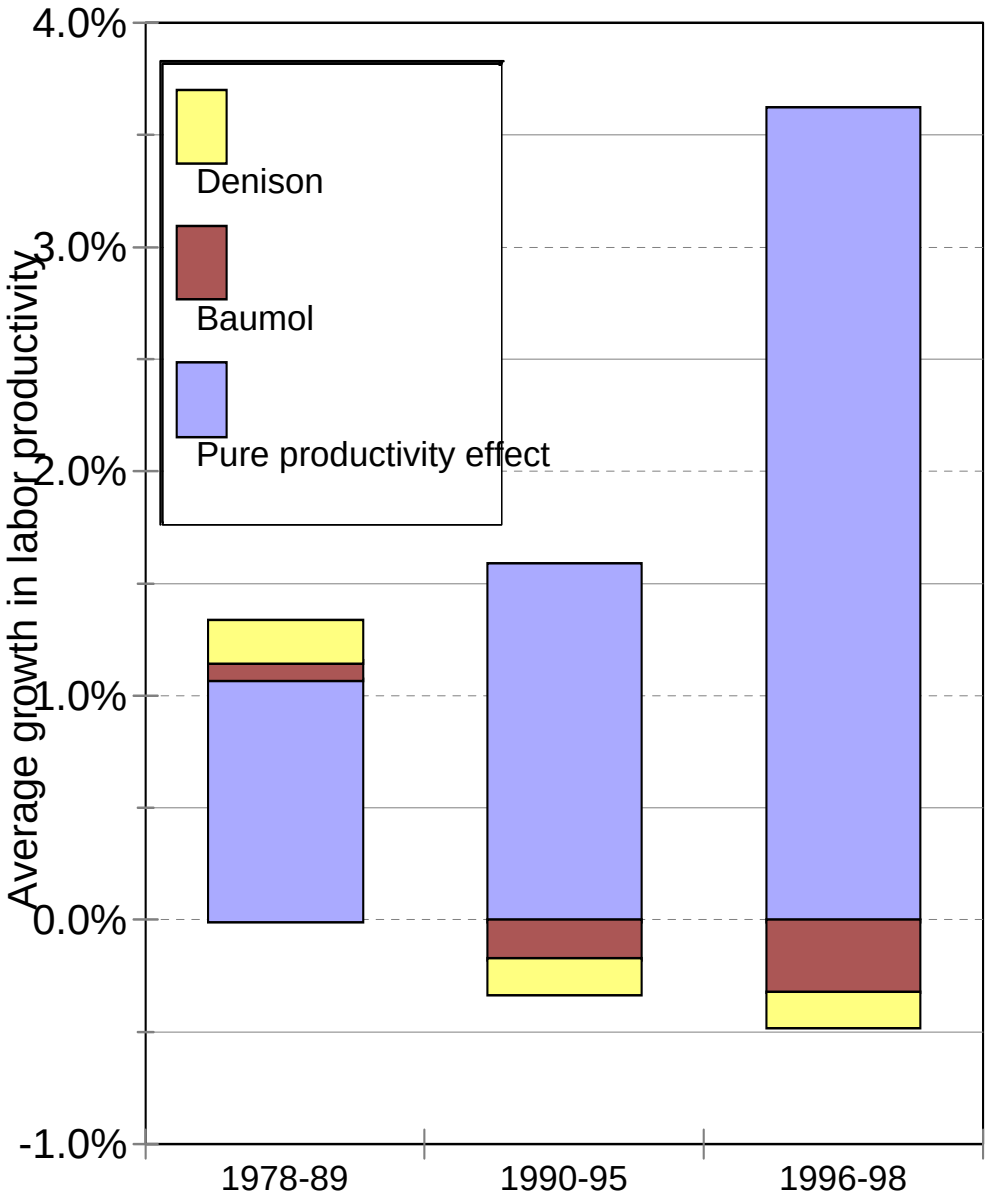
Business Sector

	[1]	*[2]*	*[3]*	*Change from earlier perio*	
	1978-89	*1990-95*	*1996-98*	*[2] - [1]*	*[3] - [1]*
GDI in Business Sector	1.27%	1.26%	3.16%	-0.01%	1.89%
Pure productivity effect	1.07%	1.59%	3.62%	0.52%	2.15%
Baumol	0.08%	-0.17%	-0.32%	-0.25%	-0.40%
Denison	0.18%	-0.15%	-0.15%	-0.34%	-0.33%

Source: Tables: revised industry 111300.wb3: BusSec.

Figure 7

Decomposition of Labor-Productivity Growth for Business Sector



Source: Tables: revised industry 111300.wb3: Tables: Chart 28.

Table 7

Decomposition of Labor-Productivity Growth for Well-Measured Economy: Alternative Concepts and Periods

Well-Measured Output

	[1]	*[2]*	*[3]*	*Change from earlier period*	
	1978-89	*1990-95*	*1996-98*	*[2] - [1]*	*[3] - [1]*
GDI in Well-Measured Sectors	2.39%	2.24%	4.65%	-0.16%	2.26%
Pure productivity effect	2.45%	2.48%	4.78%	0.03%	2.31%
Baumol	-0.00%	-0.11%	-0.03%	-0.10%	-0.02%
Denison	-0.05%	-0.13%	-0.10%	-0.08%	-0.05%

Source: Tables: revised industry 111300.wb3: WMOut.

Figure 8

Decomposition of Labor-Productivity Growth for Well-Measured Output

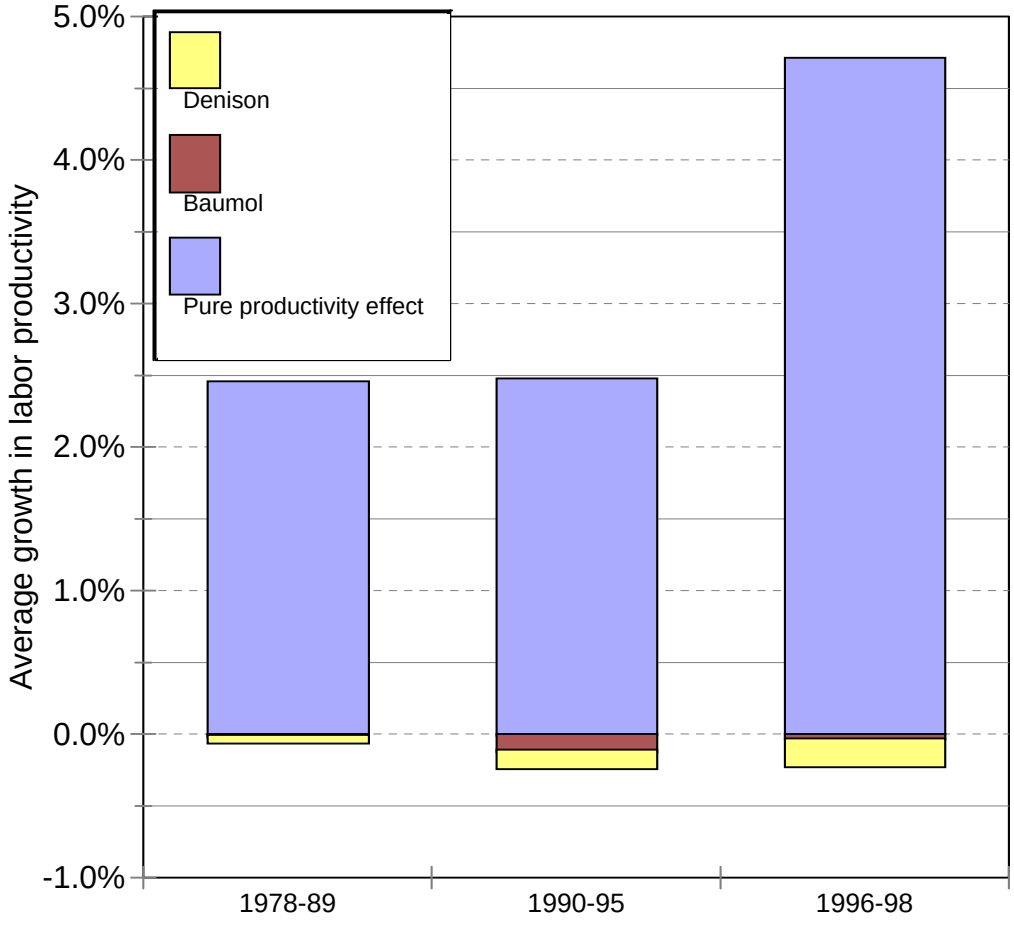
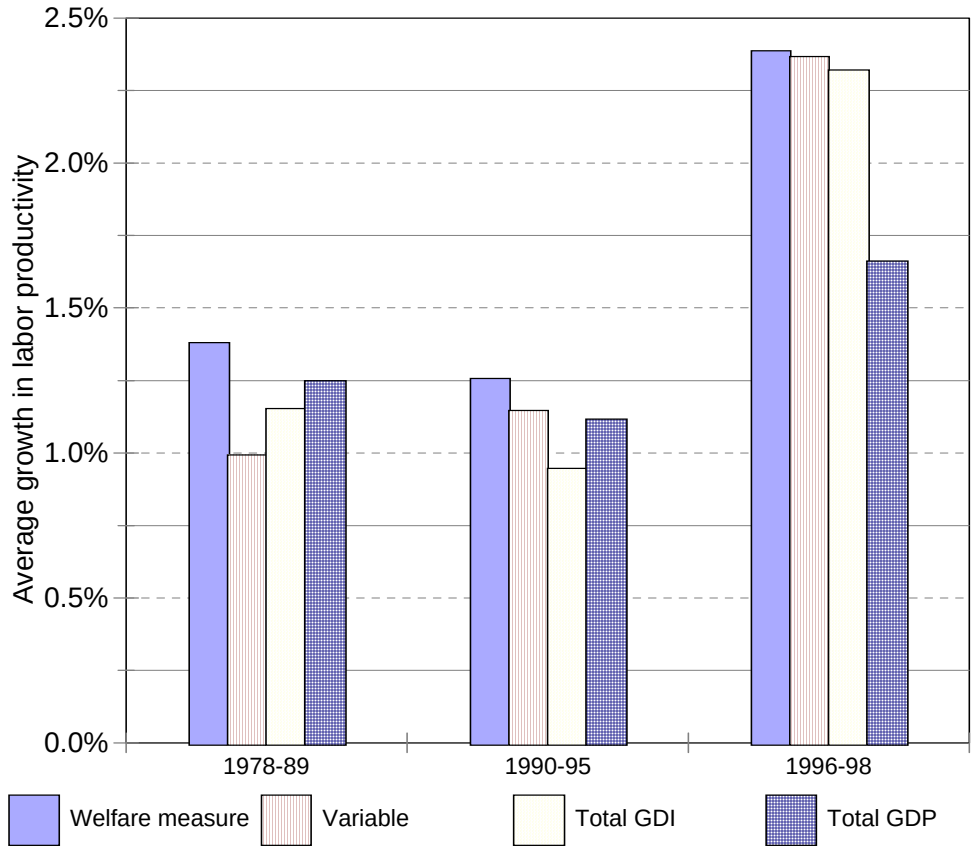


Figure 9

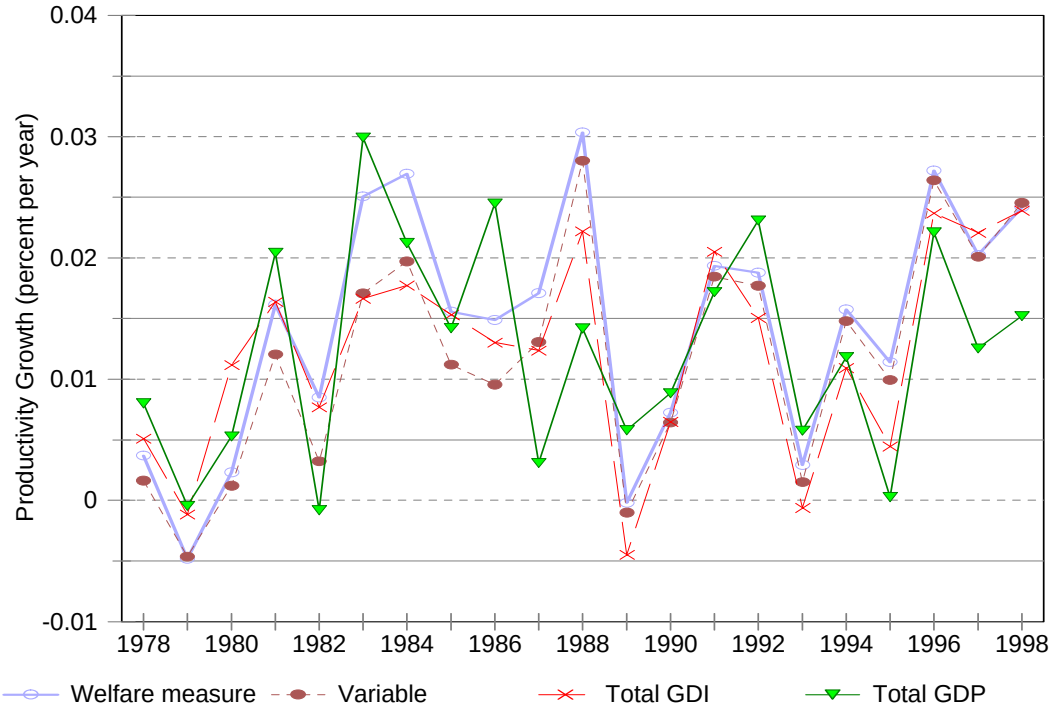
Averages of Different Measures of Labor Productivity for Overall Economy



Source: Revised industry 111000: Tables: Chart 76.

Figure 10

Annual Series for Different Measures of Labor Productivity for Overall Economy, 1978–98



Source: Revised industry 111000: Tables: Chart 75.

Table 8

Different Measures of Labor-Productivity Growth for Overall Economy, 1978–98 and Subperiods

	[1] 1978-89	*[2] 1990-95*	*[3] 1996-98*	*[4] 1978-98*	*[2] - [1]*	*[3] - [1]*
Ideal Measure	1.38%	1.26%	2.39%	1.44%	-0.12%	1.01%
Variable productivity growth	0.99%	1.15%	2.37%	1.19%	0.15%	1.37%
Total GDI	1.15%	0.95%	2.32%	1.23%	-0.21%	1.17%
Total GDP	1.25%	1.12%	1.66%	1.25%	-0.13%	0.41%

Source: Revised industry 111000: BasicData.

Table 9

Impact of New Economy on Total Labor-Productivity Growth for Total GDP

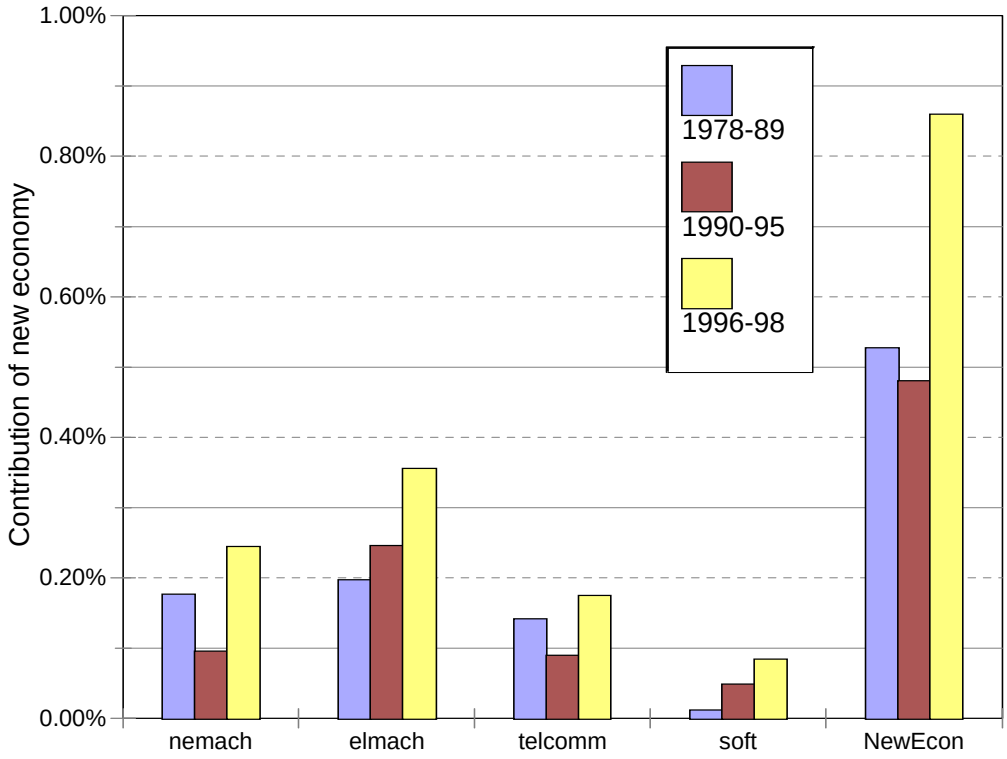
TOTAL GDP (removing new economy)

	[1]	*[2]*	*[3]*	*Change from earlier period*	
	1978-89	*1990-95*	*1996-98*	*[2] - [1]*	*[3] - [1]*
1. Total (income side output)	1.15%	0.95%	2.32%	-0.21%	1.17%
2. Total without N.E.	0.89%	0.62%	1.55%	-0.26%	0.66%
3. Pure productivity effect	0.75%	0.94%	1.70%	0.19%	0.95%
4. Impact of new economy [(1) - (2)]	0.27%	0.32%	0.77%	0.06%	0.51%

Source: Revised industry 113000: GDPTab.

Figure 11

Impact of New Economy on Total Labor-Productivity Growth for Total GDP



Note: These estimates show the impact of the new-economy sectors on productivity of income-side GDP using nominal output Tornqvist weights. The last set of estimates is the sum of the first four.

Key to abbreviations:

nemach	Industrial machinery and equipment
elmach	Electronic and other electric equipment
telcomm	Telephone and telegraph
soft	Software
NewEcon	Total, four new-economy sectors

Source: Revised industry 111900: Tables: Chart 79.

Table 10

Impact of New Economy on Total Labor-Productivity growth for Business Sector

Business Sector (removing new economy)

		[1] 1978-89	[2] 1990-95	[3] 1996-98	Change from earlier period [2] - [1]	[3] - [1]
1.	*Total (income side output)*	1.27%	1.26%	3.16%	-0.01%	1.89%
2.	*Total without new economy*	0.97%	0.83%	2.19%	-0.14%	1.21%
3.	*Pure productivity effect*	0.81%	1.10%	2.43%	0.29%	1.61%
4.	*Impact of new economy [(1) - (2)]*	0.30%	0.43%	0.97%	0.13%	0.67%

Source: Revised industry 113000: BusSec.

Table 11

Impact of New Economy on Total Labor-Productivity Growth for Well-Measured Output

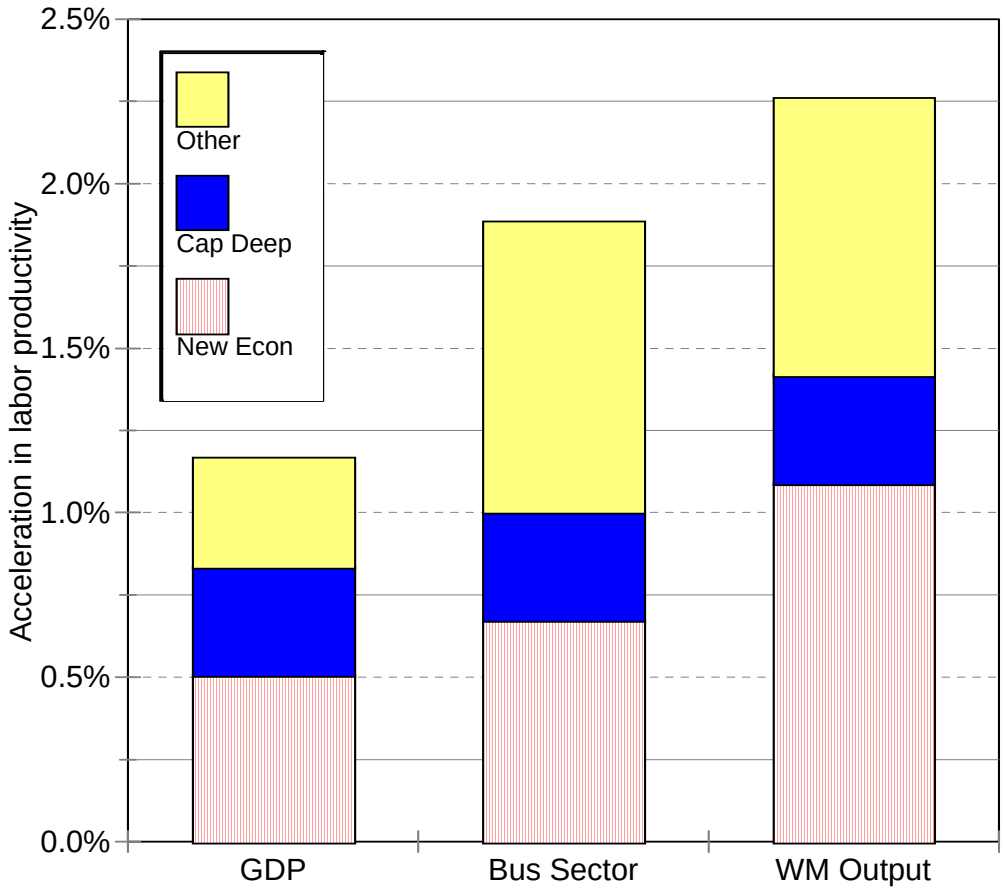
Well-Measured Output (removing new economy)

		[1] 1978-89	[2] 1990-95	[3] 1996-98	Change from earlier period [2] - [1]	[3] - [1]
1.	*Total (income side output)*	2.39%	2.24%	4.65%	-0.16%	2.26%
2.	*Total without new economy*	1.92%	1.60%	3.09%	-0.32%	1.17%
3.	*Pure productivity effect*	2.04%	1.82%	3.29%	-0.22%	1.25%
4.	*Impact of new economy [(1) - (2)]*	0.48%	0.64%	1.57%	0.16%	1.09%

Source: Revised industry 113000: WMOut.

Figure 12

Sources of Productivity Acceleration:
New Economy and Other Contributions

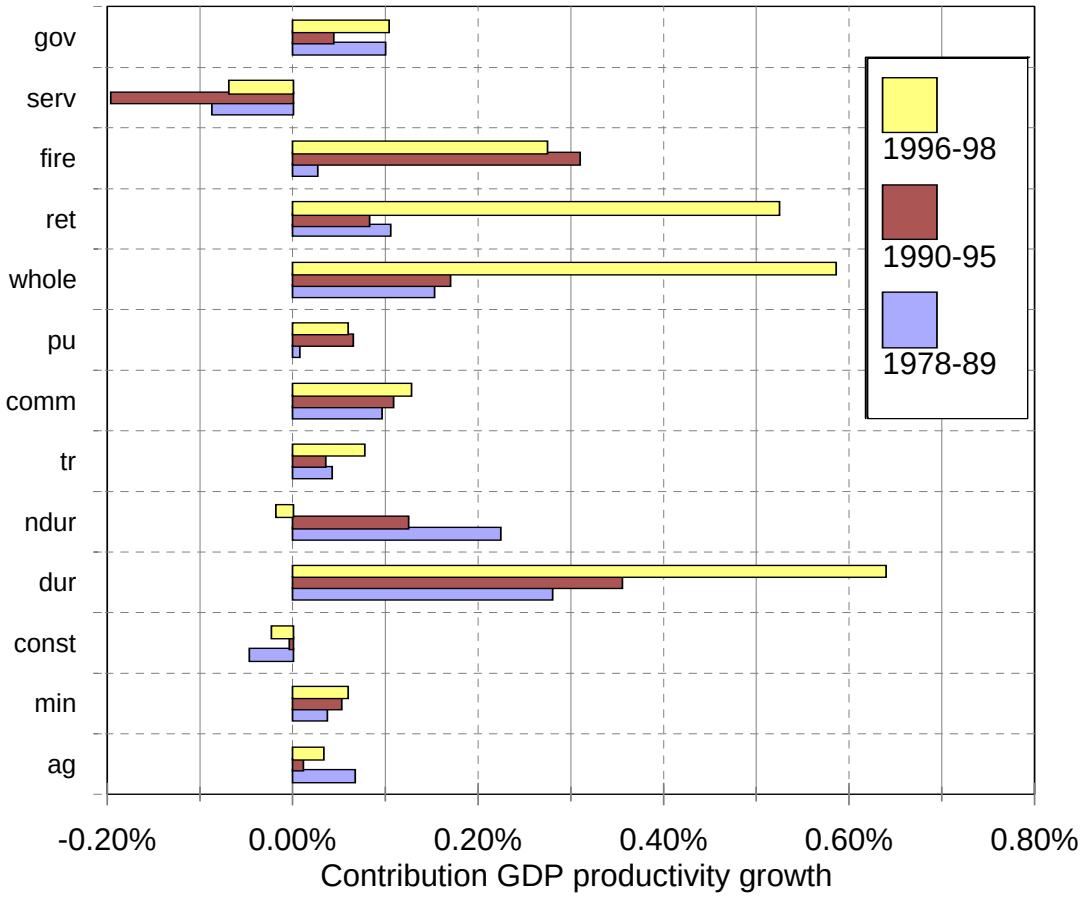


Note: "New Econ" is contribution of the four new economy sectors to labor productivity acceleration from 1977–95 to 1996–98. "Cap Deep" is capital deepening, primarily from computers and information technology. "Other contributions" is the difference between total productivity acceleration and that due to the new economy and capital deepening.

Source: Revised industry 111000: Tables: Chart 30.

Figure 13

Contribution of Different Sectors to Total Productivity Growth



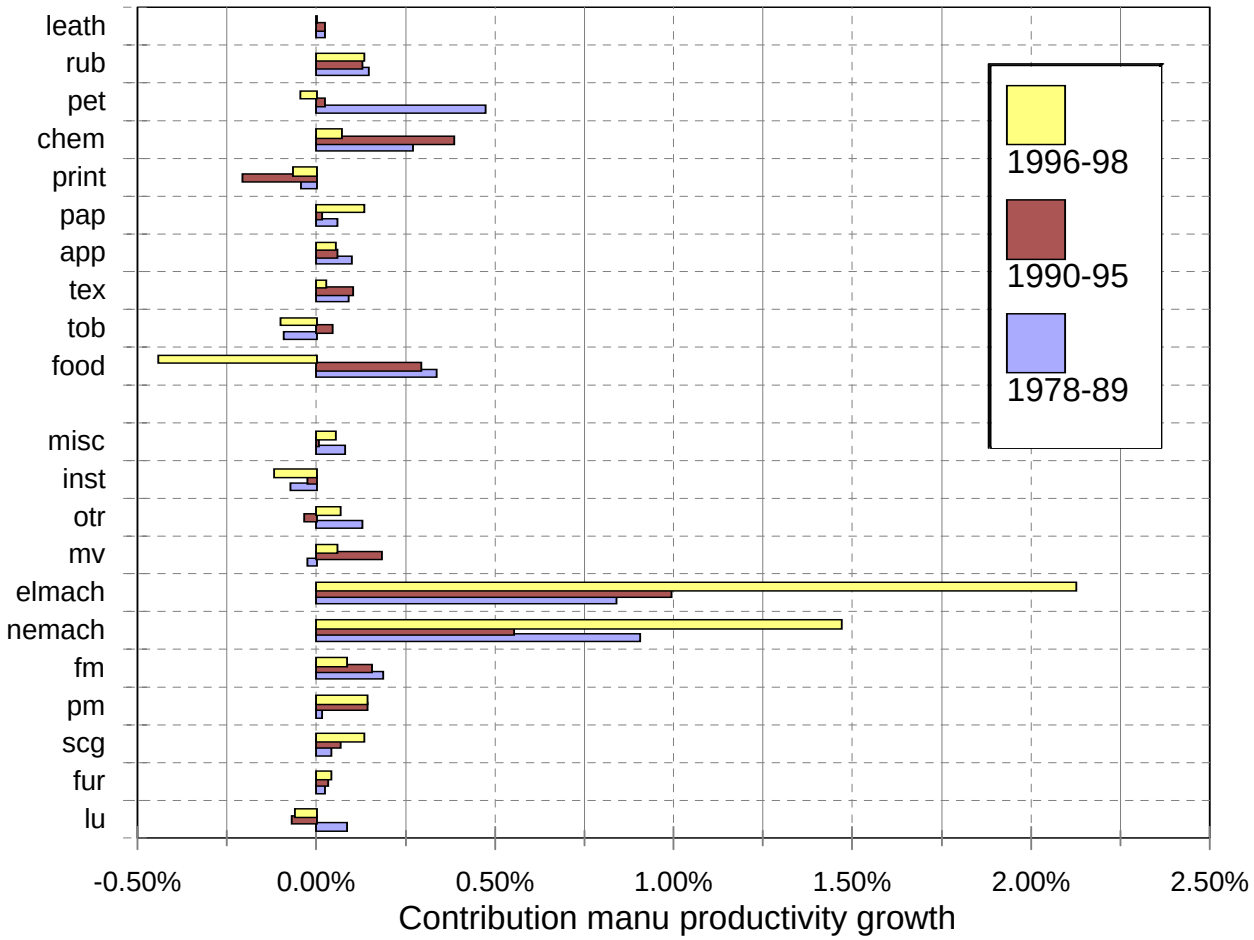
Key to abbreviations:

ag	Agriculture, forestry, and fishing
min	Mining
const	Construction
dur	Durable goods manufacturing
ndur	Nondurable goods manufacturing
tr	Transportation
comm	Communications
pu	E lectric, gas, and sanitary services
whole	Wholesale trade
ret	Retail trade
fire	Finance, insurance, and real estate
serv	Services
gov	Government

Source: Revised industry 111900: Tables: Chart 73.

Figure 14

Contribution of Different Sectors to Manufacturing Productivity Growth



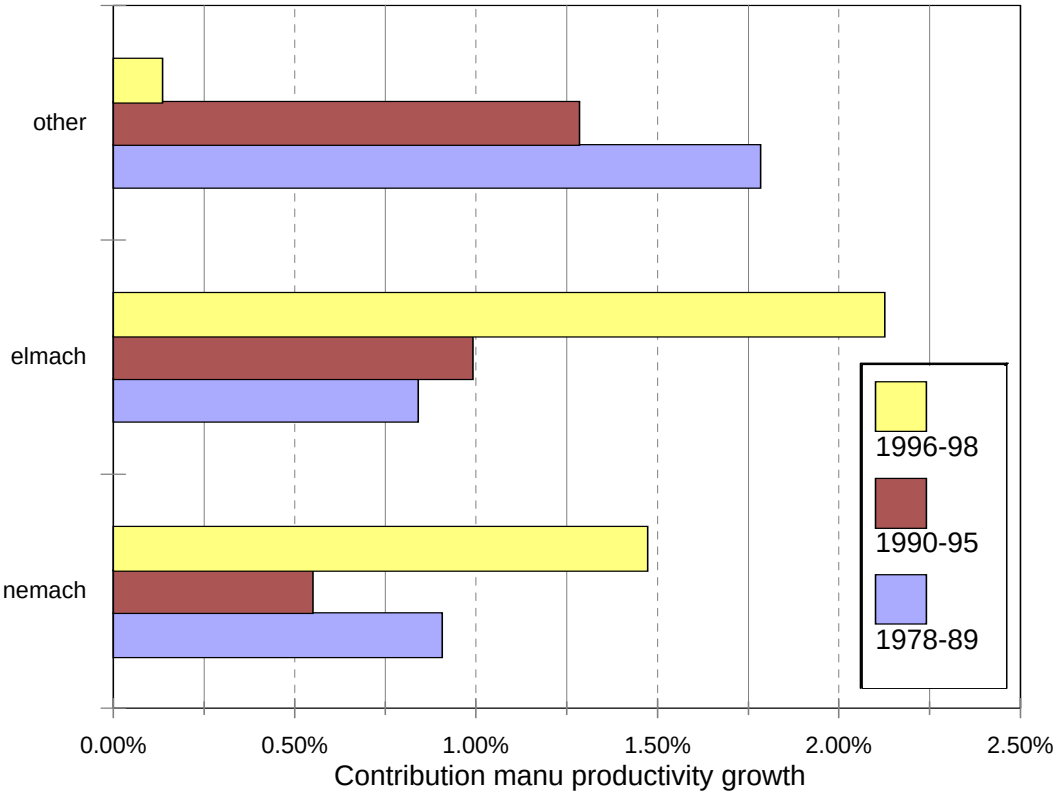
Key to abbreviations:

lu	Lumber and wood products
fur	Furniture and fixtures
scg	Stone clay and glass products
pm	Primary metal industries
fm	Fabricated metal products
nemach	Industrial machinery and equipment
elmach	Electronic and other electric equipment
mv	Motor vehicles and equipment
otr	Other transportation equipment
inst	Instruments and related products
misc	Miscellaneous manufacturing industries
food	Food and kindred products
tob	Tobacco products
tex	Textile mill products
app	Apparel and other textile products
pap	Paper and allied products
print	Printing and publishing
chem	Chemicals and allied products
pet	Petroleum and coal products
rub	Rubber and miscellaneous plastics products
leath	Leather and leather products

Source: Revised industry 111900: Tables: Chart 5

Figure 15

Contribution of Different Sectors to Manufacturing Productivity Growth



Source: Revised industry 111900: Tables: Chart 78.

Appendix Table 1

Major Indexes in New Economy Sectors of Manufacturing Machinery

SIC		Industry Shipments 1998 [millions $]	Change in price index 1987-98 [percent per year]
3571	Electronic computers	74,720	-17.9%
3572	Computer storage devices	15,734	-7.2%
3575	Computer terminals	1,180	-10.7%
3577	Computer peripheral equip nec	31,100	-12.0%
3578	Calculating/accounting machines	2,308	-1.5%
	Total, included industries	125,042	-14.5%
	Total, SIC 35	442,315	-2.3%
3651	Household audio and video equip	9,882	-1.0%
3652	Phonograph records and audio	2,504	-0.1%
3661	Telephone and telegraph apparatus	40,080	-3.4%
3672	Printed circuit boards	12,916	-2.0%
3674	Semiconductors	86,189	-20.1%
3679	Electronic components nec	39,790	-1.5%
3695	Magnetic/optical recording media	5,143	-1.0%
	Total, included industries	196,504	-7.4%
	Total, SIC 36	375,968	-4.2%

Source: BEA web page at http://www.bea.doc.gov/bea/dn2/gpo.htm . The price indexes for the totals are “mongrel deflators” rather than chain indexes because they are not chain indexes and they double count because they use gross output rather than value added weights.

See Hedonic industries. wks.