

Productivity Growth and the New Economy

William D. Nordhaus

September 26, 2002

Abstract

The present study addresses issues in the measurement of productivity growth. The major findings are as follows. First, this study analyzes a new data set by detailed industry. The new data set develops data on total output, business sector output, and “well-measured” output. 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 five years of the period (1996-2000) relative to the 1978-95 period. The rebound was 1.04 percentage points for income-side GDP, 1.61 percentage points for business sector, and 1.29 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 total economy, of the 1.04 percentage point increase in labor-productivity growth in the last three years, 0.27 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 0.76 percentage points for total GDP, 1.32 percentage points for business output, and 0.74 percentage points for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new-economy sectors.

To appear in *Brookings Papers on Economic Activity*, 2002:2.

I. Introduction and Summary ¹

What, another paper on the new economy? When financial markets are raking through the debris of \$7 trillion of lost equity values and “.com” is a reviled four-symbol word, a paper on the impact of the new economy of productivity would seem as welcome as an analysis of the role of whales in the lighting revolution.

In fact, the new economy (or more precisely information technologies) continues to raise important puzzles about productivity growth. Variations in productivity growth have proven one of the most durable puzzles in macroeconomics. After growing rapidly for the quarter century after World War II, productivity growth came to a virtual halt in the early 1970s. There was no shortage of explanations, including 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.²

These explanations seemed increasingly inadequate as inflation fell, tax rates were cut, regulatory burdens stabilized, government’s share of

¹ The author is grateful for comments from Ray Fair, Robert Yuskavage, and members of the Panel.

² See Nordhaus [1972], Baily [1982], and Denison [1979].

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.

The productivity-slowdown puzzle of the 1980s evolved into the Solow paradox of the early 1990s: Computers were everywhere except in the productivity statistics. The penetration of increasingly sophisticated and powerful computers and software apparently failed to give an upward boost to productivity growth, for through thin and thick labor-productivity growth seemed to be on a stable track of slightly over 1 percent per year.

Then, in the mid-1990s, productivity growth rebounded sharply. Beginning in 1995, 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 technology and communications. This period led to yet another paradox – due to Robert J. Gordon – who argued that after correcting for computers, the business cycle, and changes in measurement techniques, there was no productivity rebound outside the computer industry.

The present study attempts to sort out the productivity disputes by using a new technique for decomposing sectoral productivity growth rates and using a new data set that relies primarily on value added by industry. In addition to examining recent productivity behavior, the current study adds a few new features to the analysis.

First, 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. Second, it develops 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, I can focus on different definitions of output and get sharper estimates of the sources of productivity growth. Third, by working with the new industrial data, I 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 I call “well-measured output,” that allows us to remove those sectors where output is poorly measured or measured by inputs.

II. Productivity Accounting³

Measuring productivity would appear to be a straightforward issue of dividing output by inputs. In fact, particularly with the introduction of chain-weighted output measures, disentangling the different components of productivity growth has become quite complex. In this section, I explore how to decompose productivity growth into three components: a fixed-weight aggregate productivity index, a Baumol effect that reflects the effect of changing shares of output, and a Denison effect that reflects the effect of differences between output and inputs weights.

³ The formulas in this section are derived and discussed more extensively in Nordhaus [2002a]

Consider major aggregates in productivity indexes. Define aggregate output as X_t , composite inputs (here, hours of work) as S_t , and aggregate productivity as $A_t = X_t/S_t$. The share of output of sector i in nominal GDP is $F_{i,t}$, and the growth of output or other variables is designated by $g(X)$. Output is a chained index, while labor inputs and productivity are sums and ratios, respectively. In this paper, all growth rates will be calculated in logarithmic terms, so $g(X_t) = \ln(X_t) - \ln(X_{t-1})$.

The growth of labor productivity in logarithmic terms is:

$$g(A_t) = g(X_t) - g(S_t)$$

Considering only the first term, after some manipulation I get:

$$g(X_t) = \ln \left[1 + \sum_i g(X_{it}) F_{i,t-1} \right] \approx \sum_i g(X_{it}) F_{i,t-1}$$

Using the same methodology, we can derive the growth of productivity as $g(A_t) = g(X_t) - g(S_t)$, which after some manipulation is:

$$(1) \quad g(A_t) = g(X_t) - g(S_t) = \sum_i g(A_{it}) F_{i,t-1} + \sum_i g(S_{it}) [F_{i,t-1} - w_{i,t-1}]$$

where $w_{i,t-1}$ is the share of inputs in sector i in total inputs. The interpretation of (1) is that the rate of aggregate productivity growth is equal to the weighted average productivity growth of the individual sectors plus the difference-weighted average of the growth of inputs. The weights on productivity growth are the lagged shares of nominal outputs

while the difference-weights on input growth are the differences between output and input shares. (A symmetrical formula could be derived where the roles of input and output shares are reversed.)

It will be convenient to add a term to capture the role of changing shares of output. Add and subtract

3

$\sum_i g(A_{i,base}) F_{i,base}$ from equation (7) and rearrange terms, where “base”

indicates a base year. This yields:

$$(2) \quad g(A_t) = \sum_i g(A_{i,t}) F_{i,base} + \sum_i g(A_{it}) [F_{i,t-1} - F_{i,base}] + \sum_i g(S_{it}) [F_{i,t-1} - w_{i,t-1}]$$

Interpretation

Equation (2) shows that aggregate productivity growth can be broken into three components: a pure (fixed-weight) productivity term which uses fixed base-year nominal output weights, a term that reflects the difference between current nominal output weights and base-year nominal output weights, and a third term which reflects the interaction between the growth of inputs and the difference between output and input weights. For convenience, we will designate these three terms as follows.

Pure Productivity Effect. The first term on the right hand side of equation (2) is a fixed-weighted average of the productivity growth rates of different sectors. More precisely, this measures the sum of the growth rates of different industries weighted by base-year nominal output shares of each industry. Another way of interpreting the pure productivity effect is as the productivity effect if there were no change in the share of nominal output among industries.

The Baumol effect. The second term captures the interaction between the differences in productivity growth and the changing shares of nominal output among different industries over time. This effect has been emphasized by William Baumol in his work on unbalanced growth.⁴ According to Baumol, those industries which have relatively slow output growth generally are accompanied by relatively slow productivity growth (services being a generic example and live performances of Mozart string quartette being a much-cited specific example). This conjunction of factors leads to Baumol's "cost disease," which is a syndrome in which the drag of low productivity growth industries slows down the growth of aggregate productivity. In terms of equation (2), if the share of nominal output ($F_{i,t}$) devoted to slow productivity growth industries rises over time, the second term will be rising and overall growth will thereby be driven downward.

⁴ See Baumol [1967]. This study was updated and revised in Baumol, Blackman, and Wolff [1985]. A recent discussion focusing on the service sector is contained in Triplett and Bosworth [2002].

Denison Effect. The third term in (2) captures level effects due to differences in shares. I label this the Denison effect, after Edward Denison who pointed out that the movement from low-productivity-level agriculture to high-productivity-level industry would raise productivity even if the productivity growth rates in the two industries were zero. Denison showed that this effect was an important component of overall productivity growth when fixed-weight indexes are used to measure output.⁵

Earlier work on productivity decomposition implicitly or explicitly included a fourth effect, which is the *fixed-weight drift term*.⁶ That effect arises when real output is measured using Laspeyres indexes of output. Real output with a Laspeyres fixed-base quantity index tends to grow more slowly than a chain index in periods before the base year and more rapidly in periods after the base year. The divergence of relative real outputs from

⁵ A number of studies found this syndrome. See particularly Denison's studies of postwar Europe in Denison [1967].

⁶ More precisely, when output is measured using fixed weights, the fixed-weight drift term is

$$\sum$$

$\sum_i g(X_{it})[z_{it} - \sigma_{it}]$, where z_{it} is the share of industry i in total output when

output is measured by a Laspeyres index. This term is zero when output is measured using chain weights.

relative nominal outputs with “old-style” fixed-weight quantity indexes motivates the name “fixed-weight drift term.” This term (almost) vanishes with the introduction of chain indexes (or more precisely, well-constructed superlative index numbers) because real output shares used in calculating the growth rates are (almost) equal to nominal output shares. A careful examination of the measure of productivity growth that most closely corresponds to the welfare-theoretic measure of the growth of real income shows as well that the fixed-weight drift term should be omitted.⁷ All in all, moving to chain weights and removal of the fixed-weight drift term was a major advance in productivity measures.

III. Review of Alternative Productivity Measures

The underlying productivity data

The productivity data used in the present paper differ from standard measures used to track productivity. The output data are based on income-side value-added data developed by the BEA.⁸ BEA provides data on nominal output by industry (value added), Fisher indexes of real output and prices by industry, along with hours of work. The industries included

⁷ See Nordhaus [2002a].

⁸ The BEA data are available on the BEA web site. Details on the construction of the data sets is provided in Nordhaus [2002a].

in the BEA sectoral output and input data are shown in Table A-1. For this study, we have created Fisher indexes of output for different aggregates as well as estimates of labor productivity by industry and for different aggregates.⁹

The major advantage of the income-side measures is that they present a consistent set of detailed industrial accounts in which the nominal values sum up to total nominal GDP; by contrast, very little industrial detail is available on the product side of the accounts. The disadvantage is that the real output data using chain weights are available only for the period 1977-2000.

Because of interest in the “new economy,” I have also constructed a set of new-economy accounts. For the purpose of this study, I define the new economy as machinery, electric equipment, telephone and telegraph, and software. These sectors grew from 2.9 percent of real GDP in 1977 to 10.6 percent of real GDP in 2000. 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. I discuss details of the new economy below.

In addition, I develop productivity measures for three different output concepts which can be used in productivity studies. One set is

⁹ A discussion of the use of Fisher indexes in the national income and product accounts is found at Survey of Current Business [1992] and Landefeld and Parker [1997].

standard GDP (measured from the income side of the accounts). A second output concept is what the Bureau of Labor Statistics (BLS) defines as “non-farm 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, I have constructed a set of accounts called “well-measured output,” which includes only those sectors for which output is relatively well measured.

In this section, I 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 productivity measures are constructed and published by the Bureau of Labor Statistics (BLS). Figure 1 shows the behavior of the BLS series for the business sector; for this purpose, we have used a three-year 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.

Three points are worth noting. First, the labor-productivity growth data shown in Figure 1 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 changes 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 five years. Third, even with the rapid productivity growth since 1996, labor-productivity growth is still below four other postwar highs. The early 1950s, the mid-1960s, and, briefly, the early 1970s and mid-1980s were periods with more rapid labor-productivity growth than have been seen in the last three years.

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)

The BLS business output series is a product-side index provided by BEA. It is useful to compare the standard BLS series with the income-side productivity measures developed here. This is not straightforward because (in addition to the problem of dealing with the statistical discrepancy) the BLS business output (“Bus-Prod”) series does not correspond to a straightforward combination of the income-side industries. I have prepared a income-side business output measure (“Bus-Inc”) by combining the major industries as best I can. The nominal values of the two

aggregates are reasonably close, with a root mean squared error of 0.16 percent over the 1977-2000 period.¹⁰

Looking at productivity per hour worked, the two series agree reasonably well. For the entire 1978-2000 period, the income-side productivity growth of non-farm business output was about 0.07 percent per year faster. On the whole, the income-side and product-side data are reasonably consistent. Table 2 shows a comparison of the two estimates of productivity growth for three subperiods of the sample period. The basic story is the same except in the last period, where the income-side measure grew substantially faster; this difference is due primarily to the mysterious statistical discrepancy, which rose sharply from 1977 to 2000.

Well-measured output

The final output measure is one that include only those sectors where output is relatively well-measured. It is widely accepted today that in many sectors, real output is poorly measured in the national income accounts. In some cases, such as general government and education, there is no serious attempt to measure output and the indexes of activity are inputs such as employment. In other cases, the BEA (or the BLS, which prepares the underlying price data) uses deflation techniques that are potentially defective.

¹⁰ The Bus-Inc variable excludes general government and private households along with most of housing and non-profit sectors of the service industries. For the comparison in the text, I subtracted the statistical discrepancy from the income-side measure.

The idea of well- v. poorly-measured sectors was introduced by Zvi Griliches in his 1994 Presidential address:

Imagine a “degrees of measurability” scale, with wheat production at one end and lawyer services at the other. One can draw a rough dividing line on this scale between what I shall call “reasonably measurable” sectors and the rest, where the situation is not much better today than it was at the beginning of the national income accounts.¹¹

Defective deflation occurs for two quite different reasons. In one case, for which construction, insurance, or banking are examples, BEA does use price indexes for deflation of nominal magnitudes, but the prices indexes are for goods or services which are not representative of the range of outputs in that sector. A second reason, which has received much more attention, is that the underlying price index does not adequately capture quality change or new goods and services. An excellent historical example of this syndrome is computers. Before hedonic techniques were introduced, the government assumed that the price of computers was constant in nominal terms. When hedonic price indexes for computers were introduced, the prior assumption was found to overstate the “true” price increase by around 20 percent per year for the last three decades.

It is difficult for an outsider to assess the quality of the deflation of each sector included in the industrial accounts. There are many studies of

¹¹ Griliches [1994], p. 10.

this issue.¹² Nonetheless, after discussion with experts inside and outside of BEA, I have constructed a new measure of output for sectors that have relatively well-measured outputs. 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
7. A few services (software, other business services, hotels, repair)

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

8. Construction*
9. Finance,* insurance,* and real estate
10. Most services*
11. General government
12. Government enterprises*

¹² Griliches's definition of "measurable" sectors is identical to that of "well-measured" output except that he puts trade in the unmeasurable sector. (See the reference in the last footnote.)

Note that the sectors with asterisks are included in BLS's business output but are excluded from well-measured output. Non-farm business output has remained about 75 percent of nominal GDP over the 1977-2000 period, while well-measured output has declined from 68 percent in 1948, to 57 percent of nominal GDP in 1977, and to 50 percent in 2000. Note therefore that well-measured output is currently only about half of GDP and that the share of output that is well-measured has been declining steadily since World War II. This trend confirms, using a different approach and data set, Griliches observation that the degree of "measurability" of real output has been declining over time. At the same time, BEA has made considerable progress in introducing improved deflation techniques. Whether the progress of improved deflation has outstripped the decline in measurability is an interesting but open question.

Table 3 shows the growth of output per hour in the three major sectors for different subperiods of the 1977-2000 period. Productivity in the business sector has grown faster than for total GDP, primarily because of the low growth of productivity in the government sector. Productivity in the well-measured sectors has grown about 0.65 percent per year faster than in the nonfarm business economy because of poor performance in the construction and service industries.

The New Economy

This study also develops input and output data for the "new economy." For purpose of this study, I use the following formal definition of the new economy:

The new economy involves acquisition, processing and transformation, and distribution of information. The three major components are the hardware (primarily computers) that processes the information, the communications systems that acquire and distribute the information, and the software which, with human help, manages the entire system.

Which sectors are included in practice under this definition? Table A-2 shows the new-economy sectors as defined by the Commerce Department for its study *The Emerging Digital Economy*.¹³ The definition used by the Commerce Department overlaps with the formal definition, although the Commerce Department's definition includes some old-economy sectors as well as some sectors with questionable price indexes.

For purposes of this study, we are hamstrung because comprehensive data are limited to major industries as shown in Appendix Table A-1. We therefore include in the new economy those major industries which contain the new-economy sectors, which is limited to four industries: Industrial machinery and equipment (SIC 35), Electronic and other electric equipment (SIC 36), Telephone and telegraph (SIC 48), and software (SIC 873). BEA has developed detailed industrial data for the first three of these industries, but there is incomplete detail for software.

This definition of the new economy is somewhat broader than would be ideal for the present purposes. For example, SIC 35 contains computers and office equipment, but the computer sector comprises less than 25 percent of the total 1996 value added in that sector. Other parts of SIC 35

¹³ Department of Commerce [2000].

include ball bearings and heating and garden equipment, which are dubious candidates for the new economy. SIC 36 contains prominently semiconductors, which is central to the new economy, but semiconductors constitute only 8 percent of the 1996 value added. This sector includes communications equipment, one part of which has hedonic deflation. This sector also contains many old-economy industries, including incandescent bulbs, and a wide array of consumer electronics, whose prices are probably poorly measured.

Similarly, while telephone and telegraph is central to the communications components of the new economy, that sector includes some paleoindustries like telegraph, whose commercial applications date from 1844, and telephone, which premiered in 1876.

Software is genuinely a new economy industry. However, only the prepackaged component (slightly larger than one-third of the total) has hedonic deflation at present. The data on software are incomplete and some crude assumptions are necessary to fit software into the present data base.

Because of the importance of the new economy in the present analysis, it is worth emphasizing that relatively few industries use hedonic price indexes that systematically attempt to capture new goods and components or quality change. The BEA reports that only four major industries (all in new economy sectors) use systematic hedonic prices: computers and peripheral equipment, semiconductors, prepackaged software, and digital switching equipment. In 1998, these sectors comprised about 2.2 percent of GDP, while the four industries included in

the broad definition of the new economy in this study comprised 9.6 percent of GDP. This suggests that only a quarter of what we have labeled as the new economy has careful hedonic measurement of prices and output.

IV. Productivity Resurgence and the New Economy

I 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 Baumol effect, and the Denison effect? 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?

In the tables that follow, we divide the data into three periods: 1977-89, 1989-95, and 1995-2000. Labor-productivity growth in the three major sectors showed little change in the two subperiods between 1977 and 1995. It averaged around 1.1 percent per year for income-side GDP and around 1.3 percent per year for income-side non-farm business output. Well-measured output showed more robust productivity growth, averaging around 2.0 percent per year, but was relatively stable over this period. The new economy showed substantial productivity growth, averaging over 6 percent per year in the early two periods, but there was little acceleration over the period.

The last five years of the period showed a dramatic upturn in labor-productivity growth in all of the measures. Table 4 shows productivity growth using different measures in the first three data columns and the size of the upturn in the 1996-2000 period in the last column. Focusing on the total economy, the acceleration was 0.53 percentage points using GDP and almost twice as much, 1.04 percentage points, using GDI. The difference is the huge growth of the statistical discrepancy from 1997 to 2000.

Looking at major sectors, the nonfarm business sector showed an upturn of 1.61 percentage points using the income side measure and a slightly smaller increase of 1.24 percentage points according to the BLS measure. The difference between the two estimates is partially due to more rapid growth in the income-side estimate of nonfarm business output and

partially due to somewhat slower growth in BLS's estimate of hours for that sector.

Well-measured output was estimated to have higher productivity growth over the entire period than the other sectoral definitions. Over the entire period, productivity in the well-measured sectors was 0.65 percentage points faster than in the income-side measure of non-farm business and 0.89 percentage points faster than income-side GDP. The acceleration in productivity in the last five years in the well-measured sectors was slightly smaller than nonfarm business output but higher than either of the definitions for the entire economy.

The new economy logged a breathtaking acceleration in productivity of 3.7 percentage points per year in the last five years, to a growth rate of 10 percent per year.

In short, the last five years (1996-2000) witnessed a major upturn in productivity growth for all the major aggregates.

Decomposition of the Productivity Acceleration

Productivity growth is determined both by the rates of productivity growth within industries and by changes in the composition of industries. 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 effects of each of the three components of productivity growth?

Table 5 shows the basic results for the overall economy. The pure productivity effect was virtually identical to overall productivity growth over the entire period. However, the pure productivity effect was slightly higher than conventionally measured average productivity growth in the most recent period. For overall (GDI) productivity over the last five years, the pure productivity effect was 0.15 percentage points per year higher than the total. The difference was due a combination of Baumol and Denison effects and of the interaction terms. Even larger differences are seen for the nonfarm business sector and for well-measured sectors.

How much of the productivity acceleration in the last five years was due to the different effects? Figure 2 shows the results for the well-measured sectors, while the underlying data are seen in the last column of Table 5. These data show that all of the recent productivity acceleration was due to the pure productivity effect rather than the sectoral reallocations. In fact the pure productivity effect was almost exactly equal to the overall productivity acceleration for total GDI. For the other two concepts of output, the productivity acceleration from the pure

productivity effect was about 0.2 percentage points higher than the total. The implication of this finding is that the productivity improvement arose largely because the weighted-average productivity growth in the underlying industries increased, not because of sectoral shifts or other factors.

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 total productivity growth. 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 non-farm business sector and for the well-measured sector.

We can also use these results to determine the gravity of the Baumol effect. In a series of pioneering works, William Baumol analyzed the impact of differential productivity growth on different sectors and institutions such as services, health care, the cities, and the performing arts.¹⁴ His basic story is that those sectors whose productivity growth rates are below the economy's average will tend to experience above average cost increases and a growing share of total spending. The resulting "cost disease" may, according to Baumol, lead to above average price increases, financial pressures on the suppliers, and a reduction in the economy's overall rate of productivity growth.

¹⁴ See the references in footnote 4.

Table 5 shows the Baumol effect over the 1977-2000 period. In fact, the Baumol effect was slightly positive over the entire period for all three output concepts, indicating that changing shares added slightly to aggregate productivity. Examining equation (2) above, recall that the Baumol effect captures the interaction of changing shares of nominal output and productivity growth. As it turns out, those sectors with rising nominal output shares have experienced higher than average productivity growth rates (of which the new economy sectors are a good example). Baumol's cost disease has been cured, or at least is in remission.

Contribution of the New Economy to the Productivity Rebound

The next question involves using the new data set to ask, What is the contribution of the new economy to the remarkable resurgence in productivity over the last few years? In this exercise, the answer is limited to the direct contribution of more rapid productivity growth in new-economy industries, or to the production of new economy goods and services. This analysis omits the important question of the use of new economy goods and services through the contribution of capital deepening and of spillover effects of the information economy to productivity, which is addressed in a later section.

The technique for calculating the impact of the new economy is as follows. For each output concept, output and hours indexes are calculated with and without including the four new-economy sectors. In other words, in calculating the chain indexes, the index with the new economy sectors takes the Fisher index including the four industries, while the index

without the new economy omits those and rescales the weights and recalculates Fisher indexes so that the output and labor indexes sum to 100 percent of the total. This entire procedure is conceptually straightforward primarily because we have constructed a consistent set of value-added accounts.

Figure 3 shows the pattern of productivity growth in the four new economy sectors. The most impressive acceleration in the late 1990s was in the electronics sector (SIC 36), which contains microprocessors. In addition, industrial machinery (SIC 35), which contains computers, showed impressive gains in the late 1990s. The other two new economy sectors had healthy but not spectacular measured productivity gains. The software sector contains one part (prepackaged software) with rapid price declines, but the other two components (custom and own-account software) do not have hedonic estimates of prices and show modest price declines.

The results for the non-farm business economy are shown in Figure 4, while the results for all three major sectors are shown in Table 6. Focusing first on the nonfarm business sector, we see that relatively little of the productivity acceleration in the late 1990s was due to the new economy. Of the 1.61 percentage point acceleration in labor productivity from the 1990-95 period to the 1996-2000 period, only 0.25 percentage point, or one-sixth, was due to acceleration in the new economy sectors. The balance of 1.35 percentage points came in old economy sectors.

The results are roughly the same for the overall economy, as is shown in Table 6. For the well-measured sectors, the productivity acceleration

from the first half of the 1990s to the second half of the 1990s was one-third due to the new economy.

While the new economy contributed relatively little to the acceleration in productivity growth, it nonetheless was a substantial part of the total productivity growth. In the last five years, as shown in Table 6, the new economy contributed 0.64, 0.78, and 1.16 percentage points to the total for GDP, nonfarm business, and well-measured output, respectively.

Figure 5 shows the contribution of the four new economy sectors to overall GDP productivity. These weight the productivity growth rates of each of the four sectors by its share in nominal GDP (following the approach of the ideal welfare-theoretic formula). The impact on GDP productivity, shown in the last set of bars, was 0.5 percentage points of productivity in the first two subperiods, and then grew to 0.77 percentage points for the 1996-2000 period. The largest single contributor was Electric and electronic equipment, followed by Machinery, except electrical.¹⁵

¹⁵ The estimates here varies from those in other tables because the weighting procedure is slightly different.

Evaluation of the Gordon Hypothesis

Based on this new data set, 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.¹⁶

Since the first statement of the Gordon Hypothesis, there has been some backtracking. The most recent estimates associated with the Gordon hypothesis (see the last reference in footnote 16) find that outside durable manufacturing, private business experienced an acceleration of labor-productivity growth of only 0.22 percentage points for the period 1995:4 to 2000:4 relative to the period 1972:2 to 1995:4; this estimate has drifted upwards since his early calculations in 1999.

The results developed here definitely reject the Gordon hypothesis over the period studied. For all three output concepts (total GDP, the non-

¹⁶ The Economist [1999]. Also see Gordon [2000]. Further discussions can be found in Oliner and Sichel [2000]. The latest published version is Gordon [2002]. The latest unpublished version as of the time of writing is contained in the comments by Gordon in this volume.

farm business sector, and well-measured output), labor-productivity growth excluding the new economy has shown a marked upturn in the last five years relative to the 1977-1995 period. The acceleration in non-new-economy productivity growth was 0.85 percentage point for overall GDI, 1.33 percentage point for business output, and 0.80 percentage point for well-measured output (these can be calculated from the data in Table 6). The new economy contributed directly to about one-quarter of the total acceleration in labor-productivity growth for total output, one-sixth for non-farm business, and two-fifths for well-measured output.

A final decomposition of productivity growth examines how much each industry contributes to the total. Table 7 shows how productivity growth for the nonfarm business economy derives from the different industries. For this calculation, I measured productivity growth as the chain weighted average of sectoral productivity growth rates; this is equal to the pure productivity effect plus the Baumol effect (see the discussion above). This measure is the closest to the welfare-theoretical ideal of the different indexes. The advantage of using this measure is that the sum of the individual-sector figures equals the total.

Not surprisingly, three of the four new economy sectors are in the top ten contributors to the productivity upturn. 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- 2000 period in each of these two sectors has been larger than in any of the new economy sectors. 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. At the bottom of the league are food manufacturing, petroleum and coal, and nonfarm housing services. These sectors generally show a negative contribution because of very good productivity performance in the first subperiod followed by a poor performance in recent years.¹⁷ This is a reminder that the underlying industrial data are noisy and should be viewed as at best an approximation to the true performance.

Productivity growth in manufacturing has been an important contributor to growth in aggregate labor productivity. Manufacturing productivity growth clocked 4.1 percent per year in the 1978-1995 period according to the income-side data, and that rate moved up to 5.5 percent per year in the 1996-2000 period. Figure 6 shows the major contributors by industry in manufacturing. The importance of industrial machinery (notably computers) and electronic machinery (notably semiconductors) is striking as they contributed 4.5 of the 5.4 percentage point growth.¹⁸ Manufacturing productivity growth outside of the new economy was positive if modest.

¹⁷ 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.

¹⁸ Within SIC 35 and 36, Appendix Table A-3 shows the major data on shipments and the price of shipments. The industries with sharply falling price indexes have hedonic treatment.

On the other hand, the totality of non-new-economy manufacturing industries showed a marked productivity deceleration in the latest period, slowing from 2.00 to 0.97 percent per year between 1978-89 and 1996-2000. (This result was shown by Gordon using a different data set.) Of the 1.03 percentage point slowdown in non-new-economy manufacturing showed in the first set of bars in Figure 15, food is responsible for 0.81 percentage points, which raises questions about either the data or the performance of that industry. If the two major new-economy sectors and the oldest-economy industry (food) are removed from Figure 14, the latest data for manufacturing do not appear to show a major change. It seems reasonable to conclude, as has been argued by Gordon, that up through 2000, the acceleration in manufacturing productivity was limited to the two major new-economy sectors led by computers and semiconductors.

V. Qualifications

The present study is but one of many that analyze recent productivity trends and the role of the new economy. Before concluding, it will be useful to highlight some of the qualifications that attach to the results.

To begin with some technical details, it should be noted that the data for this study pertain exclusively to gross product (i.e., value added), which are derived from the industry accounts and are primarily based upon income rather than product data. Moreover, in these data, the nominal output data are directly estimated from income data, while the real output are derived from gross output and intermediate inputs by

double deflation.¹⁹ In the aggregate, the income side industry data differ from the conventional product side data by the statistical discrepancy; this discrepancy has moved in such a way that the nominal GDI grew 0.37 percentage points per year more rapidly than nominal GDP over the 1996-2000 period. Additionally, because of technical issues involving aggregation and differences in deflators, estimates of chained real GDP based on industry real gross product numbers differ somewhat from product-side real GDP even after correcting for the statistical discrepancy. Finally, it should be noted that the industry accounts are on a different revision cycle from the product accounts, and it seems likely that some of the downward product account revisions in mid-2002 will also occur in the industry-accounts revision.

From an operational point of view, the major implication arising from the use of income-side industry data is that real GDI calculated from income-side data is estimated to have grown faster than the usual product side estimates. Over the 1996-2000 period, real income-side GDI had an average annual growth rate of 4.46 percent while the rate for real GDP was 3.95 percent, for an average difference of 0.55 percentage points. Since this difference is a substantial part of the 1.04 percentage point acceleration in GDI productivity, these numbers are subject to substantial uncertainty and potential revision.

A second qualification is that the productivity estimates presented here refer to gross product (value added) rather than total output - the

¹⁹ Yuskavage [2002] and [2000].

difference being purchased goods and services. In principle, there should be no difference between the two approaches if the aggregation technique and source data are perfect since it makes no difference whether the weighted sum of inputs is subtracted from the left side or the right side of the multifactor input productivity equation. Subtle differences can creep in, however, if purchased goods and services are not measured accurately or if the index numbers suffer from aggregation non-neutrality²⁰ – both of which apply to the data and to the Fisher indexes. I am unaware of any studies indicating which approach is less prone to aggregation non-neutrality or which approach is more accurate given the inaccuracies of the source data on purchased goods and services.

A third and more important qualification concerns omitting the contribution of capital services to the productivity upturn. This omission is particularly important given the substantial increase in measured capital services in recent years. Studies by Oliner and Sichel, Jorgenson, Jorgenson and Stiroh, and Stiroh, among others, suggest that most if not all of the acceleration in labor productivity in the late 1990s was due to capital deepening.²¹

²⁰ An index is aggregation neutral if $F(x_1, x_2, x_3, x_4) = F[F(x_1, x_2), F(x_3, x_4)]$ for all elemental series x_1, x_2, \dots , where F is an aggregator such as the Fisher or Tornqvist index.

²¹ Stiroh [2001], Jorgenson and Stiroh[2000], Oliner and Sichel [2000], Jorgenson and Stiroh [2000], and Jorgenson [2001].

While multi-factor productivity is a central technique for understanding trends in productivity, labor productivity has a useful independent role to play. To begin with, the growth in labor productivity is a central policy concern given its strong linkage to the growth of real wages.

Moreover, from a technical point of view, it should be recalled that multifactor productivity depends upon *estimating* rather than *measuring* the inputs of capital services. Estimates of capital services depend upon several important and oft-criticized assumptions. The major assumptions implicit in this model include such things as the existence of perfect rental markets for capital, no difference between ex ante and ex post substitutability, no break-in or adjustment costs or learning costs, perfect competition, factor rewards proportional to marginal products, and so forth.

These assumptions are likely to be stretched particularly then in periods, such as the late 1990s, when new technologies with very high rates of depreciation dominate the data on the growth of capital services. Furthermore, measures of capital services generally use a cost of capital formula based on interest rates and therefore do not reflect the extraordinary equity valuations in the late 1990s; the effect of this is to overestimate the user cost and implicit marginal cost of capital, particularly in high-tech industries. The data for this period are particularly problematical given that the high-tech stock market bubble probably led to overinvestment in several sectors, particularly telecommunications, and that some of the investments (such as the ominous sounding “dark fiber”) turned out useless and have zero productivity.

A final shortcoming is that the production function includes only the return to fixed capital as a non-labor market inputs and excludes the return to other assets such as land, inventories, intangible assets such as patents and trademarks, brand value and marketing, and subsoil assets such as oil and gas reserves.

Given the list of unrealistic assumptions that underlie the multifactor productivity model, it is useful to examine techniques, such as labor productivity, that do not depend on the multitude of assumptions than underpin the full multifactor productivity model.

We can illustrate the issues involved in moving from labor productivity to multifactor productivity by estimating the extent to which capital deepening was associated with the changes in labor productivity. For this question, I took those 29 industries included in well-measured output and for which the BEA prepares net capital stock data. I then looked the relationship between output growth and the growth of labor and capital inputs over the 1978-2000 period. Pooling the data with industry and time effects along with cross-section equation weighting, the estimated equation was the following:

$$g(X_{i,t}) = 0.605 g(L_{i,t}) - 0.0308 g(K_{i,t}) + \text{industry effects} + \text{year effects}$$

(0.049) (0.085)

R2 = .515; n = 667.

where $g(X_{i,t})$, $g(L_{i,t})$, and $g(K_{i,t})$ are the growth of gross output, hours, and the net capital stock for industry i in year t , respectively.

If the assumptions underlying the calculation of total factor productivity were correct, the coefficients on $g(L_{i,t})$ and $g(K_{i,t})$ should correspond to the factor shares in the different industries. While the coefficient on labor is close to the average share of compensation for all industries, the coefficient on capital is negative. This equation indicates that the acceleration in the net capital stock made a small but insignificant *negative* contribution to the growth of gross output in these industries in the sample period. Since the average share of property type income is around 40 percent of total output, the estimated coefficient is around 4 standard errors from the null hypothesis that the coefficient equals the income share of capital; this indicates that, while the coefficient is not well determined, it is significantly different from the theoretical assumptions that underpin the calculation of multifactor productivity.

An alternative specification defines capital inputs as proportional to the depreciation of fixed capital plus an opportunity cost of fixed capital; this specification did not improve the estimates on capital growth. The coefficient on capital in this specification was very close to zero with a standard error of the coefficient of 0.048, again significantly different from the theoretical coefficient of around 0.4. Other specifications did not come to the rescue of the standard model.

These results should not be taken too seriously as they involve a highly oversimplified specification of the link between capital and

productivity. Moreover, they do not affect the *accounting* relationship involved in multifactor productivity indexes that depend basically on some identities and a host of underlying assumptions. But they should caution practitioners that the empirical relationship between the capital stock or capital services and productivity is at best a weak link and at worst unrelated to the model underlying typical multifactor productivity calculations.

A final qualification concerns the role of business cycles in productivity growth. This issue is particularly relevant given the strong economic expansion during the 1995-2000 period. The growth of real GDP was 4.0 percent in the 1995-2000 period as compared to 2.9 percent in the 1978-1995 period. The reason for concern is that productivity has typically been pro-cyclical.

I have not undertaken a systematic assessment of the cyclical effects for the industry data. Doing this requires confronting the potentially serious estimation bias that is present due to measurement errors in output at the industry level. For example, because of data peculiarities involving indirect taxes, the gross output of the tobacco industry fell by 63 percent (in logarithmic terms) in 1999. Productivity in that year also fell sharply, by 53 percent, primarily due to the strange output numbers. It is not surprising, therefore, that there is in fact a strong positive association of output and productivity in tobacco manufacturing.

A full investigation of the cyclical properties of productivity on an industry level is beyond the scope of this study. It is possible, however, to perform two simple tests to determine whether introducing an aggregate

cyclical term in the industry productivity equations changes the pattern of productivity growth shown in the tables and figures. For the first test, I ran a productivity equation adding the growth of real GDP, which is a proxy for aggregate cyclical conditions, into industry equations. The idea here is that shocks to aggregate demand will raise change real GDP in the short run, and these changes in real GDP will in turn affect the demand for output in different industries. This test led to the following result:

$$g(A_{i,t}) = \text{industry effects} + 0.093 g(\text{GDP}_t) \\ (0.060)$$

R2 = .256; n = 667.

This test is not entirely satisfactory because the estimates from the pooled regressions are inverse variance-weighted averages of industry productivity growth rates rather than averages weighted by nominal output shares. The coefficient estimates will therefore not correspond exactly to the aggregate productivity estimates in the tables and figures. Moreover, there will be some residual spurious correlation between aggregate output and industry output. Nonetheless, the test is illuminating. It is clear that introducing the growth of real GDP as a cyclical variable makes very little difference to average productivity growth. Looking at the coefficient on aggregate output, we see that a 1 percent increase in aggregate output would increase productivity in the average industry by only 0.09 percent. Real GDP grew at a rate of 0.80 percentage points per annum faster in 1996-2000 than the average for the sample period. This indicates that the rapid growth in the 1996-2000 period

raised average productivity growth rate by 0.0072 percentage points; this compares with an acceleration of 0.53 percentage points in GDP productivity and 1.04 percentage points in GDI productivity.

An alternative approach is to use the overall unemployment rate as the cyclical variable; this approach has the advantage of completely removing any spurious measurement error that infects both aggregate and industry output. Additionally, it is particularly illuminating to the extent that movements in the unemployment rate are a good index of movements in aggregate demand. This equation yields:

$$g(A_{i,t}) = \text{industry effects} + 0.218 U_t \\ (0.084)$$

R2 = .253; n = 667.

Using the unemployment rate as a cyclical variable indicates that industrial productivity is *anticyclical*. Using an Okun's Law coefficient of 2, this equation indicates that a 1 percent growth in aggregate output would *decrease* productivity in the average industry by 0.1 percent.

In summary, while these tests of the cyclical impact are hardly definitive, they do suggest that on average cyclical forces played but a small role in the productivity upsurge in the 1995-2000 period. However, more work needs to be done at the industry level to test the role of cyclical conditions.

VI. Conclusion

The present study considers issues in the recent behavior of productivity and productivity growth. I will summarize the major points in this concluding section.

First, the present study introduces a new approach to measuring industrial productivity. It develops an income-side data base, currently available for 1997-2000, on output, hours worked, and labor productivity relying on data that are published by the Bureau of Economic Analysis (BEA). The data are internally consistent and add up to total income-side GDP. 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 1977-2000.

Second, this paper presents a set of labor productivity measures for four different definitions of output:

- GDP from the income side (or Gross Domestic Income, GDI)
- BLS's non-farm 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"

Third, there has definitely been a rebound in productivity growth since 1995. The rebound is found in all three aggregates developed for this study. The labor productivity acceleration in the last five years of the

period (1996-2000) relative to the 1978-95 period was 1.12 percentage points for GDI, 1.61 percentage points for the nonfarm business sector, and 1.31 percentage points for well-measured output.

Fourth, the paper explores 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 Baumol effect (which captures the effect of changing shares of nominal output on aggregate productivity); and the Denison 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.

Fifth, the estimates show that the pure productivity effect in recent years has been above total productivity growth. For example, in the non-farm business sector for the period 1996-2000, total labor-productivity growth has been 2.87 percent per year while the pure productivity effect was 3.09 percent per year. The difference was due to a mixture of the Baumol and Denison effects. Moreover, using the data for all industries, the Baumol effect has been very close to zero over this period, indicating that composition shifts in output have had little effect on aggregate productivity over the last quarter century.

Sixth, a key question is the contribution of the new economy to the productivity rebound. For the purpose of this study, I 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 11

percent of real GDP in 2000. Productivity growth in the new economy sectors has made a significant contribution to economy-wide productivity growth. In the non-farm business sector over the last five years, labor-productivity growth excluding the new economy sectors was 2.08 percent per year as compared to 2.87 percent per year including the new economy.

Eighth, which sectors within the new economy have contributed most to the productivity rebound? The major contributors have been nonelectric and electric machinery, the major subsectors of which are computers and semiconductors. These two sectors, which constituted under 4 percent of nominal GDP, contributed 0.56 percentage points of the 2.34 percent per year GDI productivity growth in the 1996-1000 period.

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 from 1977-89 to was 0.85 percentage points for total GDI, 1.33 percentage points for business output, and 0.80 percentage points for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new-economy sectors.

References

- Baily, Martin N. [1982]. "The Productivity Growth Slowdown by Industry, Brookings Papers on Economic Activity, no. 2, pp. 423-54.
- Baumol, William J. [1967]. "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *The American Economic Review*, vol. 57, no. 3, June, pp. 415-426.
- Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff [1985]. "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence," *The American Economic Review*, vol. 75, no. 4, September, pp. 806-817.
- Denison, Edward F. [1967]. *Why Growth Rates Differ*, Brookings, Washington, D.C.
- Denison, Edward F. [1979]. *Accounting for Slower Growth: the United States in the 1970s*, Washington, Brookings.
- Department of Commerce [2000]. *Digital Economy 2000*, June, available at <http://www.esa.doc.gov/508/esa/DigitalEconomy.htm> .
- Gordon, Robert J. [2002]. "Technology and Economic Performance: the United States," in Benn Steil, David G. Victor, and Richard R. Nelson, *Technology and Economic Performance*, Council on Foreign Relations, Princeton University Press, pp. 49-73.
- Gordon, Robert J. "Does the 'New Economy' Measure up to the Great Inventions of the Past?," [2000]. *Journal of Economic Perspectives*, Vol. 14, No. 4, Fall, p. 49-74.
- Griliches, Zvi [1994]. "Productivity, R&D, and the Data Constraint," *American Economic Review*, vol. 84, no. 1, March, p. 10.
- Jorgenson, Dale W. [2001]. "Information Technology and the U.S. Economy," *American Economic Review*, Vol. 90, No. 1, March, pp. 1-32.
- Jorgenson, Dale W. and Kevin J. Stiroh [2000]. "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, 2000:1, pp. 125-211.
- Jorgenson, Dale W. and Kevin J. Stiroh [2000]. "U.S. Economic Growth at the Industry Level," *American Economic Review*, 161-167, , Vol. 90 (2) pp. 161-167.
- Landefeld, J. Steven and Robert P. Parker [1997]. "BEA's Chain Indexes, Time Series, and Measures of Long-Term Economic Growth," *Survey of Current Business*, vol. 77, May, p. 58-68.

Nordhaus, William D. [2002]. "New Data and Output Concepts for Understanding Productivity Trends," November 6, 2000, available at www.econ.yale.edu/~nordhaus/homepage/writings_and_presentations_on_th.htm .

Nordhaus, William D. [2002]. "Alternative Methods for Measuring Productivity Growth (Revised)," June 20, 2002, available at [available at www.econ.yale.edu/~nordhaus/homepage/writings_and_presentations_on_th.htm](http://www.econ.yale.edu/~nordhaus/homepage/writings_and_presentations_on_th.htm) .

Nordhaus, William D. [1972]. "The Recent Productivity Slowdown," Brookings Papers on Economic Activity, no. 3, pp. 493-536.

Oliner, Stephen and Daniel E. Sichel [2000]. "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?," Journal of Economic Perspectives, Vol. 14, No. 4, Fall, pp. 3-22.

Stiroh, Kevin J. [2001]. "Information technology and the U.S. productivity revival: what do the industry data say?," Federal Reserve Bank of New York, Staff Reports 115.

Survey of Current Business [1992]. vol. 72, April, pp. 49-52

The Economist, July 22, 1999 available at www.economist.com .

Triplett, Jack E. and Barry P. Bosworth [2002]. "'Baumol's Disease' Has Been Cured: It And Multifactor Productivity In U.S. Services Industries," Paper Prepared for the Texas A&M Conference, The New Economy: How New? How Resilient?, April 19.

Yuskavage, Robert E. [2000]. "Priorities for Industry Accounts at BEA," November, Paper for presentation at the November 17, 2000 meeting of the Bureau of Economic Analysis Advisory Committee, available at <http://www.bea.gov/bea/about/advisory.htm> .

Yuskavage, Robert E. [2002]. "Gross Domestic Product by Industry: A Progress Report on Accelerated Estimates," Survey of Current Business, June, pp. 19- 27

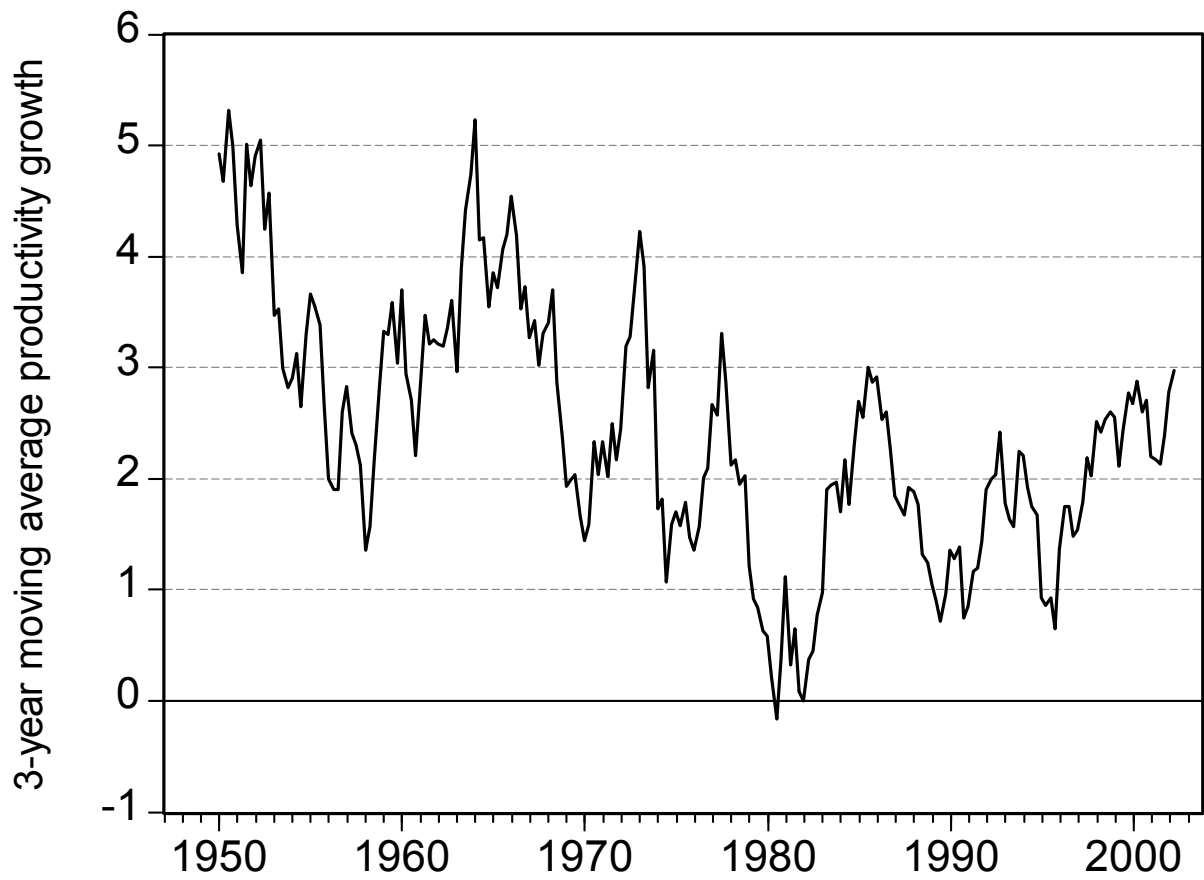


Figure 1. Growth of Labor Productivity in the Business Sector

Source: Bureau of Labor Statistics. The figure shows the 3-year moving average of the logarithmic growth rates. Data are from the Bureau of Labor Statistics and refer to the total business sector.

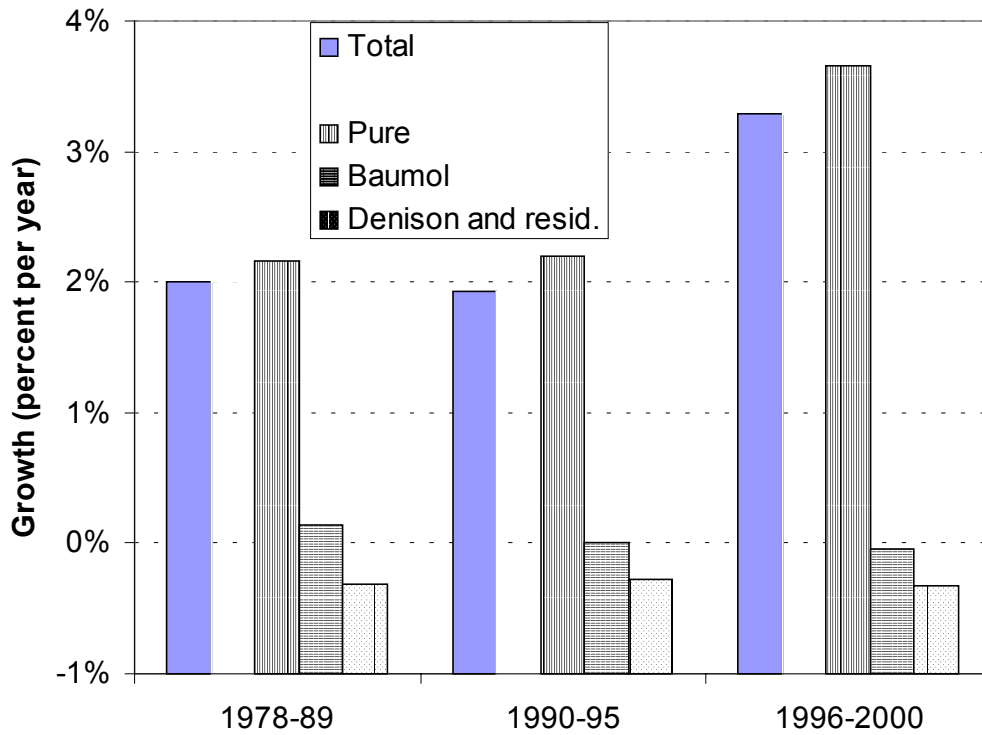


Figure 2. Components of Productivity Growth for Well-Measured Sectors

Figure shows how the total productivity growth is distributed among the different components. For all periods, pure productivity effect is largely than the total.

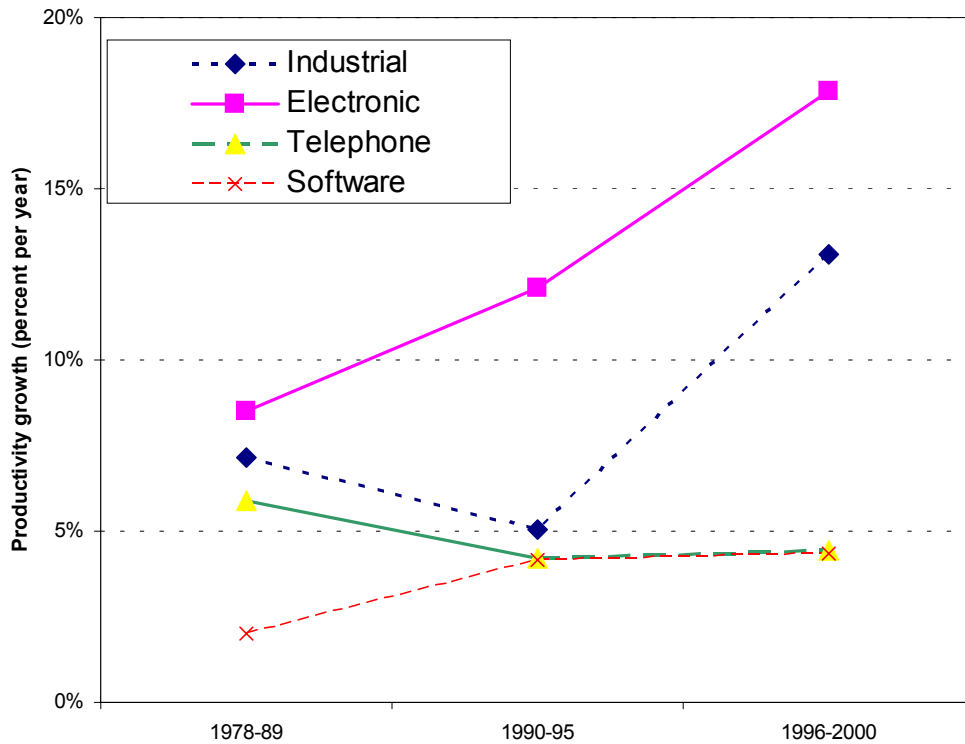


Figure 3. Trends in Productivity Growth of Four New Economy Sectors

Figure shows productivity growth in the four new-economy sectors in three subperiods. The key to the legend is as follows:

Industrial

Industrial machinery and equipment

Electronic

Electronic and other electric equipment

Telephone

Telephone and telegraph

Software

Software

Total

Total, four new-economy sectors

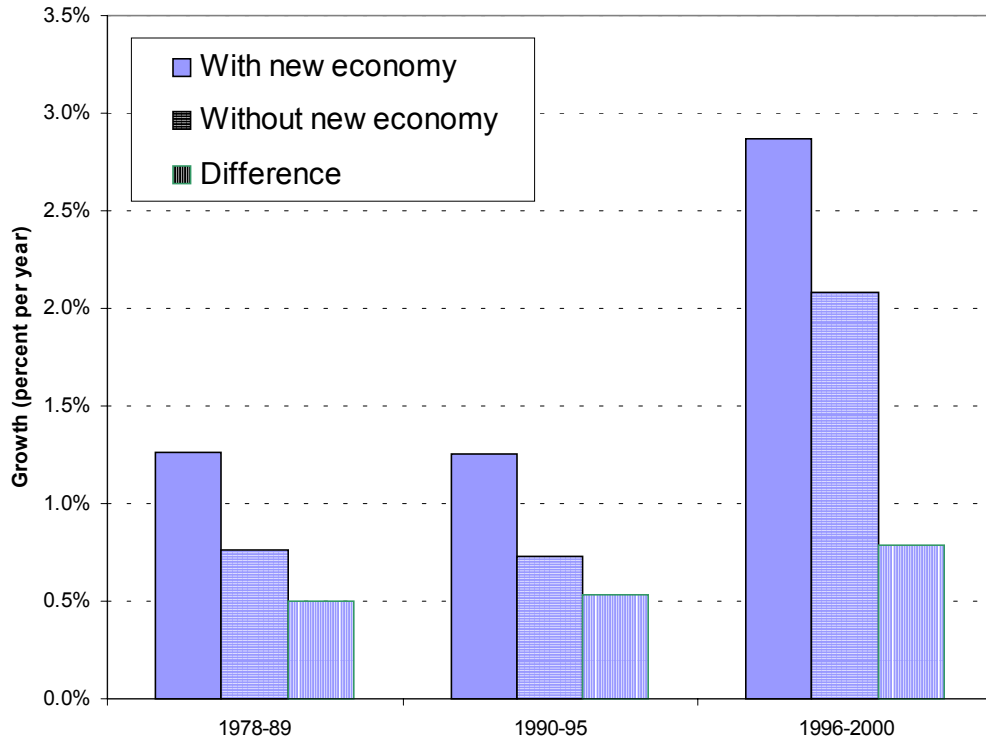


Figure 4. Contribution of New Economy to Productivity Growth in Non-farm Business Economy

Figure shows the contribution of the new economy to the productivity growth in three different periods.

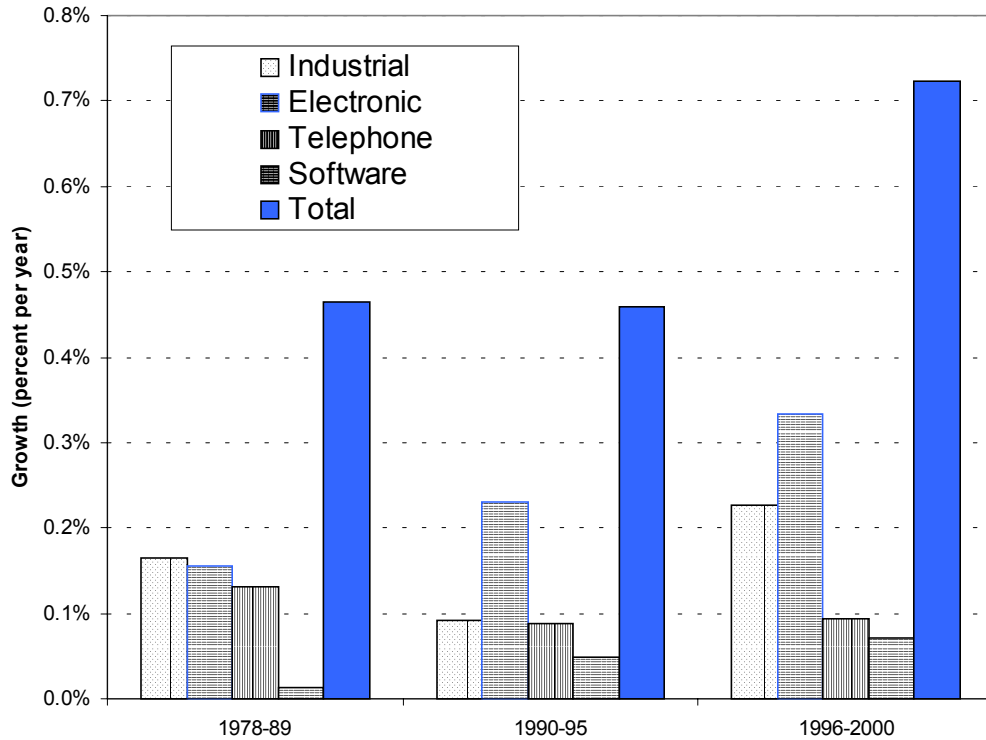


Figure 5. Impact of New Economy on Labor-Productivity Growth for Total Economy

Note: These estimates show the impact of the new-economy sectors on productivity of income-side GDP using nominal output weights. The estimates for the total is the sum of the four components. The industry key is provided in Figure 3.

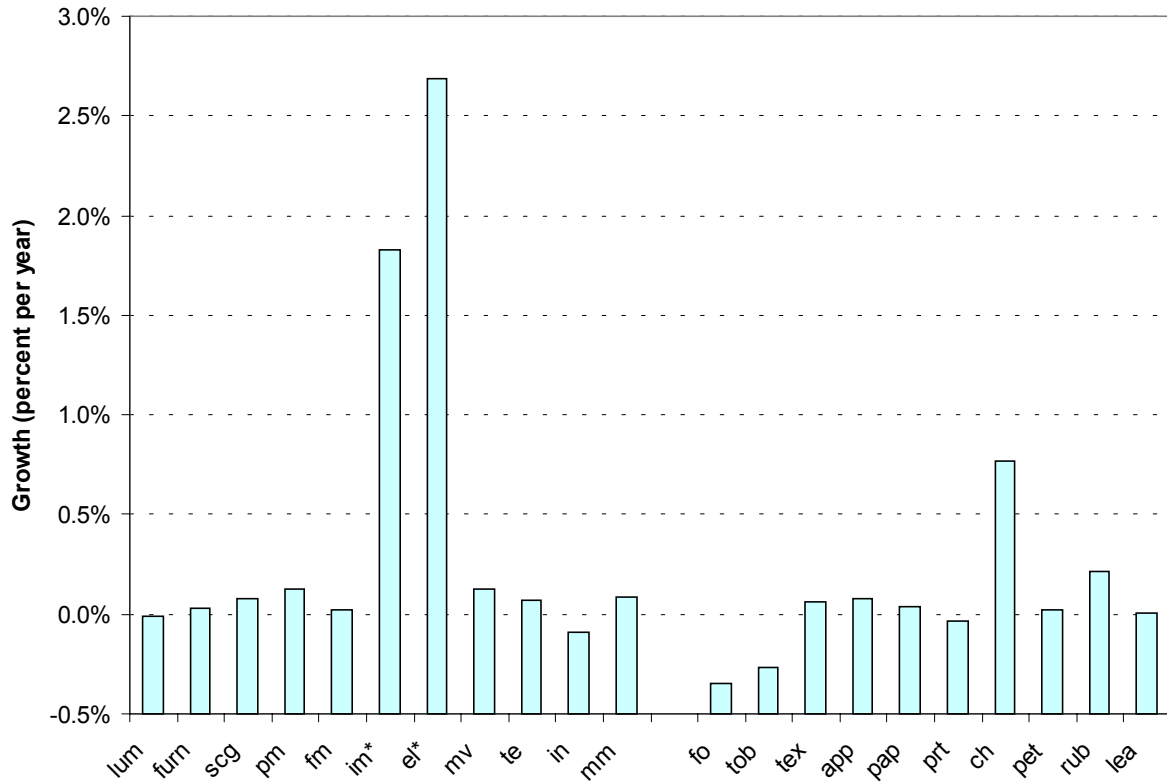


Figure 6. Contribution of Different Sectors to Manufacturing Productivity Growth

Each bar shows the contribution of the sector to the growth in productivity in manufacturing in the 1996-2000 period. The height of the bar is the productivity growth in the sector times the share of total output of manufacturing in that sector.

Key to abbreviations in Figure 6.

lum	Lumber and wood products
furn	Furniture and fixtures
scg	Stone, clay, and glass products
pm	Primary metal industries
fm	Fabricated metal products
im*	Industrial machinery and equipment
el*	Electronic and other electric equipment
mv	Motor vehicles and equipment
te	Other transportation equipment
in	Instruments and related products
mm	Miscellaneous manufacturing industries
fo	Food and kindred products
tob	Tobacco products
tex	Textile mill products
app	Apparel and other textile products
pap	Paper and allied products
prt	Printing and publishing
ch	Chemicals and allied products
pet	Petroleum and coal products
rub	Rubber and miscellaneous plastics products
lea	Leather and leather products

* Represent new economy industries.

<u>Variable</u>	<u>Coefficient</u>	<u>Std. Error</u>	<u>t-Statistic</u>
C	3.34	0.36	9.4
DUM73	-1.93	0.52	-3.7
DUM95	1.17	0.77	1.5

R-squared 0.060

S.E. of regression 3.58

Sample(adjusted): 1948:1 2002:2

Included observations: 218

Dependent Variable: One-quarter change in log of labor
productivity at annual rate

**Table 1. Trends in Labor Productivity in Total Business Sector,
1947:1 - 2000:2**

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.

Source: Bureau of Labor Statistics.

	(1)	(2)	(3)	(2) - (1)	(3) - (1)
	1978-89	1990-95	1996-2000		
Growth in output per hour worked in non-farm business sector					
BLS (product side)	1.21%	1.46%	2.45%	0.25%	1.24%
BEA (income side)	1.26%	1.26%	2.87%	0.00%	1.61%
Difference	-0.05%	0.20%	-0.41%	0.25%	-0.36%

Table 2. Comparison of BEA and BLS Measures of Labor-Productivity Growth in the Non-farm Business Sector Output

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

	1978-89	1990-95	1996-2000	Total period
Growth in output per hour worked				
GDP				
Output-based	1.20%	1.11%	1.73%	1.29%
Income-based	1.21%	0.96%	2.24%	1.37%
Nonfarm Business	1.26%	1.26%	2.87%	1.61%
Well-measured output	2.00%	1.93%	3.29%	2.26%

Table 3. Growth in Labor Productivity in Different Sectoral Definition

Sources: BEA, BLS, and the author as described in the text.

Table 4

	(1)	(2)	(3)	(2) - (1)	(3) - (1)
Growth, output per hour	1978-89	1990-95	1996-2000		
Total economy					
GDP	1.20%	1.11%	1.73%	-0.09%	0.53%
GDI	1.21%	0.96%	2.24%	-0.25%	1.04%
Nonfarm Business					
Income-side	1.26%	1.26%	2.87%	0.00%	1.61%
BLS measure	1.21%	1.46%	2.45%	0.25%	1.24%
Well-measured output	2.00%	1.93%	3.29%	-0.07%	1.29%
New economy	6.25%	6.37%	9.98%	0.12%	3.73%

Table 4. Growth in Labor Productivity in Different Sectoral Definition

Growth, output per hour	(1) 1978-89	(2) 1990-95	(3) 1996-2000	(2) - (1)	(3) - (1)
Total Gross Domestic Income	1.21%	0.96%	2.24%	-0.25%	1.04%
Pure productivity effect	1.27%	0.73%	2.39%	-0.54%	1.13%
Baumol effect	0.18%	-0.01%	0.04%	-0.18%	-0.14%
Denison effect	-0.18%	0.32%	-0.12%	0.50%	0.06%
Residual	-0.05%	-0.08%	-0.07%	-0.03%	-0.02%
Nonfarm Business Output	1.26%	1.26%	2.87%	0.00%	1.61%
Pure productivity effect	1.29%	1.45%	3.09%	0.16%	1.80%
Baumol effect	0.15%	-0.01%	0.03%	-0.16%	-0.12%
Denison effect and residual	-0.18%	-0.19%	-0.25%	-0.01%	-0.07%
Well-measured Output	2.00%	1.93%	3.29%	-0.07%	1.29%
Pure productivity effect	2.17%	2.20%	3.66%	0.03%	1.49%
Baumol effect	0.15%	0.00%	-0.04%	-0.14%	-0.19%
Denison effect and residual	-0.31%	-0.27%	-0.33%	0.04%	-0.01%

Table 5. Decomposition of Productivity Growth for Alternative Concepts and Periods

Note: The exact definitions of the terms are given in the text in equation (2). An approximate definition is as follows:

The pure-productivity effect is the weighted average of sectoral productivity growth using fixed nominal output weights for 1996.

The variable-productivity effect (not shown) is the weighted average of sectoral productivity growth using nominal output weights for the current year.

The Baumol effect is the difference between the variable productivity effect and the pure productivity effect.

The Denison effect is the impact of reallocation among industries which have different shares of labor incomes.

The residual is the interaction terms and second-order effects.

	(1) 1978-89	(2) 1990-95	(3) 1996-2000	(2) - (1)	(3) - (1)
Total Economy					
With new economy	1.21%	0.96%	2.24%	-0.25%	1.04%
Without new economy	0.84%	0.56%	1.60%	-0.28%	0.76%
Difference	0.37%	0.39%	0.64%	0.03%	0.27%
 Non-farm Business					
With new economy	1.26%	1.26%	2.87%	0.00%	1.61%
Without new economy	0.76%	0.73%	2.08%	-0.03%	1.32%
Difference	0.50%	0.53%	0.78%	0.03%	0.29%
 Well-measured output					
With new economy	2.00%	1.93%	3.29%	-0.07%	1.29%
Without new economy	1.38%	1.21%	2.13%	-0.17%	0.74%
Difference	0.61%	0.72%	1.16%	0.10%	0.55%

Table 6. Contribution of the New Economy to Productivity Growth in Three Sectors, 1978 - 2000

Sector	Productivity Growth		Contribution to Productivity Upturn [In percentage points]
	1978-89	1996-2000	
Retail trade	1.30%	5.25%	0.46%
Security and commodity brokers	2.80%	18.15%	0.32%
Wholesale trade	2.80%	5.86%	0.27%
Electronic and other electric equipment	8.49%	17.87%	0.23%
Other real estate	1.01%	5.64%	0.18%
Other services	-1.12%	1.40%	0.08%
Electric, gas, and sanitary services	-0.08%	2.59%	0.08%
Industrial machinery and equipment	7.17%	13.07%	0.08%
Software	2.01%	4.36%	0.08%
Chemicals and allied products	2.56%	4.87%	0.06%
Printing and publishing	2.52%	-0.62%	-0.06%
Chemicals and allied products	8.43%	1.32%	-0.07%
Petroleum and coal products	0.86%	-1.59%	-0.09%
Rubber and miscellaneous plastics products	3.85%	-2.94%	-0.15%
All other	na	na	0.22%
TOTAL	1.26%	2.87%	1.61%

Table 7. Contribution of Different Industries to Productivity Upturn in Nonfarm Business Economy

The table shows how the 1.61 percentage point increase in productivity growth in the nonfarm business economy are distributed among the major leaders and laggards. The new economy sectors are shown as bold.

Table A-1. Major Industries for BEA Industrial Output and Input Data

- Gross domestic product
- Private industries
 - Agriculture, forestry, and fishing
 - Farms
 - Agricultural services, forestry, and fishing
 - Mining
 - Metal mining
 - Coal mining
 - Oil and gas extraction
 - Nonmetallic minerals, except fuels
 - Construction
 - Manufacturing
 - Durable goods
 - Lumber and wood products
 - Furniture and fixtures
 - Stone, clay, and glass products
 - Primary metal industries
 - Fabricated metal products
 - Industrial machinery and equipment
 - Electronic and other electric equipment
 - Motor vehicles and equipment
 - Other transportation equipment
 - Instruments and related products
 - Miscellaneous manufacturing industries
 - Nondurable goods
 - Food and kindred products
 - Tobacco products
 - Textile mill products
 - Apparel and other textile products
 - Paper and allied products
 - Printing and publishing
 - Chemicals and allied products
 - Petroleum and coal products
 - Rubber and miscellaneous plastics products
 - Leather and leather products
 - Transportation and public utilities
 - Transportation
 - Railroad transportation
 - Local and interurban passenger transit
 - Trucking and warehousing
 - Water transportation

- Transportation by air
- Pipelines, except natural gas
- Transportation services
- Communications
 - Telephone and telegraph
 - Radio and television
- Electric, gas, and sanitary services
- Wholesale trade
- Retail trade
- Finance, insurance, and real estate
 - Depository institutions
 - Nondepository institutions
 - Security and commodity brokers
 - Insurance carriers
 - Insurance agents, brokers, and service
 - Real estate
 - Nonfarm housing services
 - Other real estate
 - Holding and other investment offices
- Services
 - Hotels and other lodging places
 - Personal services
 - Business services
 - Software (created for this study)
 - Other (residual)
 - Auto repair, services, and parking
 - Miscellaneous repair services
 - Motion pictures
 - Amusement and recreation services
 - Health services
 - Legal services
 - Educational services
 - Social services
 - Membership organizations
 - Other services
 - Private households
- Government
 - Federal
 - General government
 - Government enterprises
 - State and local
 - General government
 - Government enterprises

Table A-2. Information Technology Industries: Subsectors and Share of the Economy

Industry	SIC	1995 [Value added; \$millions except as noted]	1998
Total Gross Domestic Product (GDP)*		7,293,600	8,461,644
Hardware			
Computers & equipment	3571,2,5,7	32,931.2	45,081.8
Computers & equipment wholesale sales	5045 [part]	50,756.0	74,173.3
Computers & equipment retail sales	5734 [part]	2,513.8	3,441.3
Calculating & office machines, nec.	3578.9	3,036.2	3,478.1
Electron Tubes	3671	1,472.9	1,716.8
Printed circuit boards	3672	5,718.5	7,602.8
Semiconductors	3674	51,272.0	70,092.2
Passive electronic components	3675-9	19,097.6	29,801.9
Industrial instruments for measurement	3823	4,998.5	5,546.9
Instruments for measuring electricity	3825	7,512.3	8,399.0
Laboratory analytical instruments	3826	4,270.6	4,780.9
Total Hardware		183,579.6	254,115.0
Software/Services			
Computer programming services	7371	26,178.3	n.a.
Prepackaged software	7372	19,971.7	n.a.
Prepackaged software wholesale sales	5045 [part]	2,564.0	n.a.
Prepackaged software retail sales	5734 [part]	126.1	n.a.
Computer integrated systems design	7373	15,025.1	n.a.
Computer processing & data preparation	7374	17,924.5	n.a.
Information retrieval services	7375	3,768.5	n.a.
Computer services management	7376	2,135.2	n.a.
Computer rental and leasing	7377	1,329.0	n.a.
Computer maintenance and repair	7378	5,023.7	n.a.
Computer related services, nec	7379	8,549.1	n.a.
Total software and services	7371-9	102,595.2	151,999.3
Communications			
Household audio & video equipment	3651	2,343.0	2,767.6
Telephone & telegraph equipment	3661	14,925.2	17,373.7
Radio & TV & communications equipment	3663	19,862.0	27,854.3
Magnetic & optical recording media	3695	2,787.8	3,293.0
Total Communications Hardware		39,918.0	51,288.6
Telephone and telegraph communications	481,22, 99	144,100.0	163,674.4
Radio broadcasting	4832	6,149.6	8,695.8
Television broadcasting	4833	17,102.7	20,975.6
Cable and other pay TV services	4841	24,247.7	31,838.3
Total Communications Services		191,600.0	225,184.0
Total All Information Technology Industries		517,692.8	682,586.9
Share of the Economy (%)		7.1%	8.1%

Source: U.S. Commerce Department, *The Emerging Digital Economy*

Table A-3.
Major Industries in New Economy Sectors of Manufacturing

SIC	Industry Shipments	Change in price index	
	1998 [millions \$]	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.