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Productivity Growth and the New Economy

WHAT, ANOTHER PAPER ON the new economy? When financial markets are raking through the debris of $8 trillion in lost equity value, and ".com" is a reviled four-symbol word, a paper on the impact of the new economy on 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 proved to be one of the most durable puzzles in macroeconomics. After a period of rapid growth following World War II, productivity stagnated in the early 1970s. There was no shortage of explanations offered, 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 possibilities for invention, and societal laziness.[1] Yet these explanations seemed increasingly inadequate as inflation fell, tax rates were cut, regulatory burdens stabilized, government's share of output fell, research and development and patents granted grew sharply, real 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

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1. See Nordhaus (1972), Baily (1982), and Denison (1980).

productivity statistics. The penetration of the American workplace by 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 a year.

Then, in the mid-1990s, productivity growth rebounded sharply. Beginning in 1995, productivity 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, identified by Robert 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.

This paper 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 the recent behavior of productivity, the paper adds a few new features to the analysis.

First, it lays out a different way of decomposing productivity growth, one that divides aggregate productivity trends into factors that increase average productivity growth through changes in the shares 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 national 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 possible in earlier studies. Finally, this new data set allows creation of a new economic aggregate, which I call "well-measured output," that excludes those sectors where output is poorly measured or measured by inputs.

Productivity Accounting

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 input weights.[2]

Consider indexes for the major aggregates. 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 $\sigma_{i,t}$, and the growth of output or other variables is designated by $g(X)$. Output is measured as a chained index, whereas labor inputs and productivity are sums and ratios, respectively. In this paper all growth rates will be calculated in logarithmic terms, so that $g(X_t) = \Delta\ln(X_t) = \ln(X_t) - \ln(X_{t-1})$.

The growth of labor productivity in logarithmic terms is

$$\Delta\ln(A_t) = \Delta\ln(X_t) - \Delta\ln(S_t).$$

Considering only the first term, after some manipulation I get

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

Using the same methodology, I derive the growth of productivity as $g(A_t) = \Delta\ln(A_t)$, which after some manipulation gives

$$(1) \qquad g(A_t) = \Delta\ln(A_t) = \sum_i g(A_{it})\sigma_{i,t-1} + \sum_i g(S_{it})(\sigma_{i,t-1} - w_{i,t-1}),$$

where $w_{i,t-1}$ is the share of inputs in sector i in total inputs. The interpretation of equation 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 input growth. The weights on productivity growth are the lagged shares of nominal outputs, whereas 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.)

2. The formulas in this section are derived and discussed more extensively in Nordhaus (2002).

It will be convenient to add a term to capture the role of changing shares of output. Add and subtract $\sum_i g(A_{i,\text{base}})\sigma_{i,\text{base}}$ from equation 1 and rearrange terms, where "base" indicates a base year. This yields

$$(2) \qquad g(A_t) = \sum_i g(A_{i,t})\sigma_{i,\text{base}} + \sum_i g(A_{it})(\sigma_{i,t-1} - \sigma_{i,\text{base}}) + \sum_i g(S_{it})(\sigma_{i,t-1} - w_{i,t-1}).$$

Interpretation

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

THE 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 term 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 that would occur if there were no change in the shares 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.[3] According to Baumol, those industries that have relatively slow output growth are generally accompanied by relatively slow productivity growth (services being a generic example, and live performances of a Mozart string quartet a much-cited specific example). This conjunction of factors leads to Baumol's "cost disease," a syndrome in which the drag of slow-

3. See Baumol (1967). This study was updated and revised in Baumol, Blackman, and Wolff (1985). A recent discussion focusing on the services sector is contained in Triplett and Bosworth (2002).

productivity-growth industries retards the growth of aggregate productivity. In terms of equation 2, if the share of nominal output $\sigma_{i,t}$ devoted to slow-productivity-growth industries rises over time, the second term will also be rising, and overall growth will thereby be driven downward.

THE DENISON EFFECT. The third term in equation 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 sectors were zero. Denison showed that this effect was an important component of overall productivity growth when fixed-weight indexes are used to measure output.[4]

Earlier work on productivity decomposition implicitly or explicitly included a fourth effect, called the fixed-weight drift term.[5] That effect arises when real output is measured using Laspeyres indexes of output. Real output measured with a Laspeyres fixed-base quantity index tends to grow more slowly than output measured by 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 relative nominal outputs with "old-style" fixed-weight quantity indexes motivates the name. This term vanishes (or 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 equal (or 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.[6] All in all, moving to chain weights and removing the fixed-weight drift term marked a major advance in productivity measures.

4. A number of studies found this syndrome. See in particular Denison's studies of postwar Europe (Denison, 1967).

5. More precisely, when output is measured using fixed weights, the fixed-weight drift term is $\sum_i g(X_{it})[z_{it} - \sigma_{it}]$, 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.

6. See Nordhaus (2002).

Review of Alternative Productivity Measures

The Underlying Productivity Data

The productivity data used in this paper differ from standard measures used to track productivity. The output data are based on income-side value-added data (gross domestic income, or GDI) developed by the Bureau of Economic Analysis (BEA).[7] The BEA provides data on nominal output by industry (value added), Fisher indexes of real output and prices by industry, and hours of work. For this paper I have created Fisher indexes of output for different aggregates as well as estimates of labor productivity by industry and for different aggregates.[8]

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 to 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 paper, I define the new economy as machinery, electric equipment, telephone and telegraph, and software. The combined share of these sectors in real GDP grew from 2.9 percent in 1977 to 10.6 percent 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 broad output concepts that can be used in productivity studies. One of these is standard GDP (measured from the income side of the accounts). A second is what the Bureau of Labor Statistics (BLS) defines as nonfarm 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 that I call "well-measured output," which includes only those sectors for which output is relatively well measured. I begin with a review of standard labor productivity mea-

7. The BEA data are available on the BEA website. Details on the construction of the data sets are provided in Nordhaus (2002).

8. A discussion of the use of Fisher indexes in the national income and product accounts is found in Triplett (1992) and Landefeld and Parker (1997).

sures 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 BLS. Figure 1 shows the behavior of the BLS series for the business sector; for this purpose I 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 another in 1995.

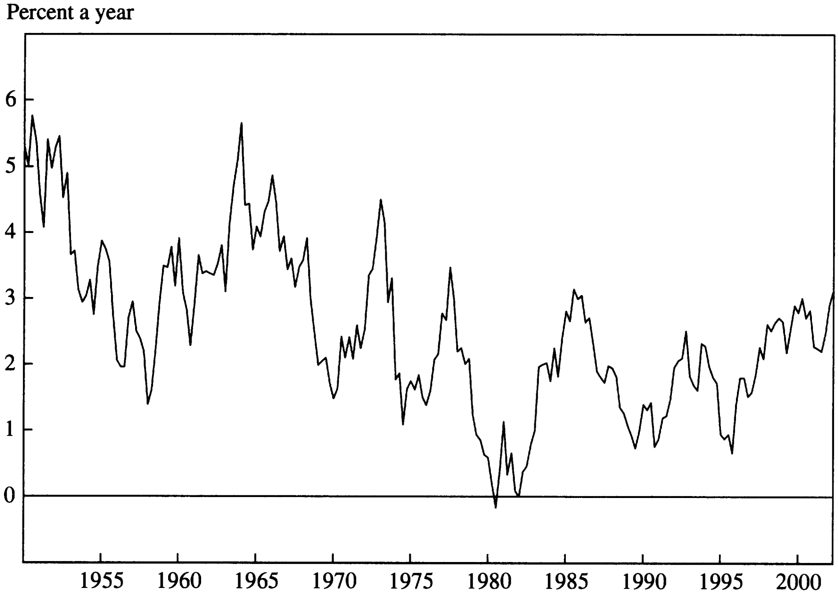
Three points are worth noting. First, the labor productivity growth data in figure 1 do not show dramatic and obvious breaks in trend. Labor productivity began deteriorating in the late 1960s, and the really terrible period was in the early 1980s. An untutored analyst would probably not recognize any 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 one should not read too much into a period even as long as five years. Third, even with the rapid productivity growth observed since 1995, labor productivity growth is still below four other postwar highs. The early 1950s, the mid-1960s, the early 1970s (briefly), and the mid-1980s were periods when labor productivity grew more rapidly than it has 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 Product Side and Income Side

The BLS business output series is a product-side index provided by the 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

Figure 1. Labor Productivity Growth in the Business Sector[a]



Source: Bureau of Labor Statistics.
a. Three-year moving average of logarithmic growth rates.

prepared an 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 square error of 0.16 percent over the 1977–2000 period.[9]

As far as productivity per hour worked is concerned, the two series agree reasonably well. For the entire 1977–2000 period the income-side productivity growth of nonfarm business output was about 0.07 percent a year faster. On the whole, the income-side and the product-side data are reasonably consistent. Table 2 shows a comparison of estimates of productivity growth from the two series for three subperiods of the 1977–2000 period. The basic story is the same except in the last period, when the income-side measure grew substantially faster; this difference is

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

Table 1. Trends in Labor Productivity in the Business Sector, 1948–2002

Variable[a]	*Regression coefficient*	*Standard error*	*t Statistic*
Constant	3.34	0.36	9.4
DUM73[b]	−1.93	0.52	−3.7
DUM95[c]	1.17	0.77	1.5
Summary statistic			
R^2	0.060		
Standard error of regression	3.58		
No. of observations	218		

Source: Author's regressions using data from the Bureau of Labor Statistics.

a. The dependent variable is the annualized one-quarter change in the logarithm of labor productivity. The sample period is 1948:1 to 2002:2.

b. Dummy variable that takes the value of 1 after 1973:2.

c. Dummy variable that takes the value of 1 after 1995:2.

due primarily to the mysterious statistical discrepancy, which rose sharply from 1977 to 2000.

Well-Measured Output

The final output measure is one that includes 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 instead 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.

The idea of well versus poorly measured sectors was introduced by Zvi Griliches in his 1994 presidential address to the American Economic Association:

> 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.[10]

Defective deflation occurs for two quite different reasons. First, in some sectors, of which construction, insurance, and banking are examples, the

10. Griliches (1994, p. 10).

Table 2. Alternative Measures of Productivity Growth in the Nonfarm Business Sector, 1977–2000[a]

Percent a year

Measure	*1977–89*	*1989–95*	*1995–2000*	*Change, 1977–89 to 1989–95*	*Change, 1977–89 to 1995–2000*
BLS (product side)[b]	1.21	1.46	2.45	0.25	1.24
BEA (income side)[c]	1.26	1.26	2.87	0.00	1.61
Difference	–0.05	0.20	–0.41	0.25	–0.36

Source: Bureau of Economic Analysis data.

a. Growth in output per hour worked; annual averages.

b. Product-side output of the nonfarm business sector, based on BLS hours-worked measures, and used by the BLS in its business sector productivity measures.

c. Uses income-side output and hours measures derived in this paper and using BEA hours data.

BEA does use price indexes for deflation of nominal magnitudes, but the price indexes are for goods or services that are not representative of the range of outputs in that sector. Second, and this has received much more attention, in some sectors the underlying price index does not adequately capture quality change or the introduction of 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 earlier assumption was found to overstate the "true" price increase by around 20 percent a 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 have been many studies of this issue.[11] Nonetheless, after discussion with experts inside and outside the BEA, I have constructed a new measure of output for sectors that have relatively well measured outputs. The sectors included are

Agriculture, forestry, and fishing
Mining
Manufacturing
Transportation and public utilities
Wholesale trade

11. Griliches's (1994) definition of "measurable" sectors is identical to that of well-measured output except that he puts trade in the unmeasurable sector.

Retail trade
Certain services (software, other business services, hotels, repair).

Five major sectors are excluded:

Construction*
Finance,* insurance,* and real estate
Most services*
General government
Government enterprises*.

The sectors marked by asterisks are included in the BLS's measure of business output. Nonfarm business output remained about 75 percent of nominal GDP over the 1977–2000 period, whereas well-measured output declined from 68 percent of nominal GDP in 1948 to 57 percent in 1977 and 50 percent in 2000. Thus, well-measured output is currently only about half of GDP, and 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's observation that the degree of "measurability" of real output has been declining over time. At the same time, the 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 for the three major aggregates—GDP, nonfarm business output, and well-measured output—for different subperiods of the 1977–2000 period. Productivity in the business sector has grown faster than productivity for total GDP, primarily because of the slow growth of productivity in the government sector. Productivity in the well-measured sectors has grown about 0.65 percentage point a year faster than in the nonfarm business economy because of poor performance in the construction and services industries.

The New Economy

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

Table 3. Productivity Growth for Alternative Measures of Aggregate Output and the New Economy, 1977–2000[a]

Percent a year

Measure	*1977–89*	*1989–95*	*1995–2000*	*1977–2000*	*Change, 1977–89 to 1989–95*	*Change, 1977–89 to 1995–2000*	*Change, 1989–95 to 1995–2000*
Total economy							
GDP	1.20	1.11	1.73	1.29	–0.09	0.53	0.62
GDI	1.21	0.96	2.24	1.37	–0.25	1.04	1.28
Nonfarm business sector							
Income-side	1.26	1.26	2.87	1.61	0.00	1.61	1.61
BLS measure	1.21	1.46	2.45	1.54	0.25	1.24	0.99
Well-measured output	2.00	1.93	3.29	2.26	–0.07	1.29	1.36
New economy	6.25	6.37	9.98	7.09	0.12	3.73	3.61

Source: Author's calculations using BEA and BLS data.

a. Growth in output per hour worked; data are annual averages. Details may not sum to totals because of rounding.

systems that acquire and distribute the information, and the software that, with human help, manages the entire system.

Which sectors are included in practice under this definition? Table A1 in the appendix shows the new economy sectors as defined by the Commerce Department for its study *The Emerging Digital Economy.*[12] That definition overlaps with the formal definition, and it 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. I therefore include in the new economy the four major industries that contain the new economy industries: industrial machinery and equipment (Standard Industrial Classification 35), electronic and other electric equipment (SIC 36), telephone and telegraph (SIC 48), and software (SIC 873). The BEA has developed detailed industrial data for the first three of these, 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 industry accounts for less than 25 percent of the total 1996 value added in that sector. Other parts of SIC 35 include ball bearings and heating and garden equipment, which are dubious candidates for inclusion in the new economy. A prominent component of SIC 36 is semiconductors, an industry central to the new economy, but semiconductors constitute only 8 percent of the 1996 value added in SIC 36. 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, although the telephone and telegraph sector is central to the communications components of the new economy, it also 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 data for the prepackaged component (slightly larger than one-fourth of the total) are hedonically deflated at present. The data on software are incomplete, and some crude assumptions are necessary to fit software into the present database.

12. U.S. Department of Commerce (2000).

Because of the importance of the new economy in the present analysis, it is worth emphasizing that relatively few industries are measured using hedonic price indexes that systematically attempt to capture new goods and components or quality change. The BEA reports that systematic hedonic prices are used for only four major industries (all in new economy sectors): computers and peripheral equipment, semiconductors, prepackaged software, and digital switching equipment. In 1998 these sectors accounted for about 2.2 percent of GDP, while the four industries included in the broad definition of the new economy in this study accounted for 9.6 percent of GDP. This suggests that only a quarter of what I have labeled as the new economy has careful hedonic measurement of prices and output.

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 it 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 for the well-measured part of the economy than for the entire economy?

How Large a Productivity Acceleration?

Returning to table 3, we see that labor productivity growth in the three major aggregates showed little change in the two subperiods between 1977 and 1995, averaging around 1.1 percent a year for the income-side measure of the total economy and around 1.3 percent a year for income-side nonfarm business output. Well-measured output showed more robust productivity growth, averaging around 2.0 percent a year, but was relatively stable over this period. The new economy showed substantial productivity growth, averaging over 6 percent a year in the first two subperiods, but with little acceleration.

The last five years of the period showed a dramatic upturn in labor productivity growth in all of the measures (last column of table 3). For the total economy the acceleration from the first to the last subperiod was

0.53 percentage point using the output-side measure and almost twice as much, 1.04 percentage points, using the income-side measure. Accounting for the difference is the huge growth in the statistical discrepancy from 1997 to 2000.

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 partly due to more rapid growth in the income-side estimate of nonfarm business output and partly due to somewhat faster growth in the BLS's estimate of hours for that sector.

Well-measured output is estimated to have seen faster productivity growth over the entire period than the other major aggregates. Over the entire period, productivity growth was 0.65 percentage point faster in the well-measured sectors than in the income-side measure of nonfarm business, and 0.89 percentage point faster than in income-side total output. The acceleration in productivity in the last five years of the period in the well-measured sectors was slightly smaller than that in income-side nonfarm business output, but larger than for either of the definitions of the entire economy. The new economy logged a breathtaking acceleration in productivity of 3.7 percentage points a year over the last five years of the period, to a growth rate of 10 percent a year. In short, the last five years of the period 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 recent growth in productivity was due to each of the three factors—pure productivity growth, the Baumol effect, and the Denison effect—derived above?

The first panel of table 4 shows the basic results for the overall economy, as measured from the income side. The pure productivity effect was virtually identical to overall productivity growth over the entire period. However, the pure productivity effect was slightly (0.15 percentage point) higher than conventionally measured average productivity growth in the most recent period. Even larger differences are seen for the nonfarm business sector and for well-measured output (bottom two panels of table 4).

Table 4. Decomposition of Labor Productivity Growth for Alternative Measures of Aggregate Output, 1978–2000[a]

Percent a year

Measure	*1977–89*	*1989–95*	*1995–2000*	*Change, 1977–89 to 1989–95*	*Change, 1977–89 to 1995–2000*
GDI	1.21	0.96	2.24	–0.25	1.04
Pure productivity effect[b]	1.27	0.73	2.39	–0.54	1.13
Baumol effect[c]	0.18	–0.01	0.04	–0.18	–0.14
Denison effect[d]	–0.18	0.32	–0.12	0.50	0.06
Residual[e]	–0.05	–0.08	–0.07	–0.03	–0.02
Nonfarm business sector	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

Source: Author's calculations.

a. Growth in output per hour worked; data are annual averages. Details may not sum to totals because of rounding.

b. Weighted average of sectoral productivity growth using fixed nominal output weights for 1996; corresponds to first right-hand term in equation 2.

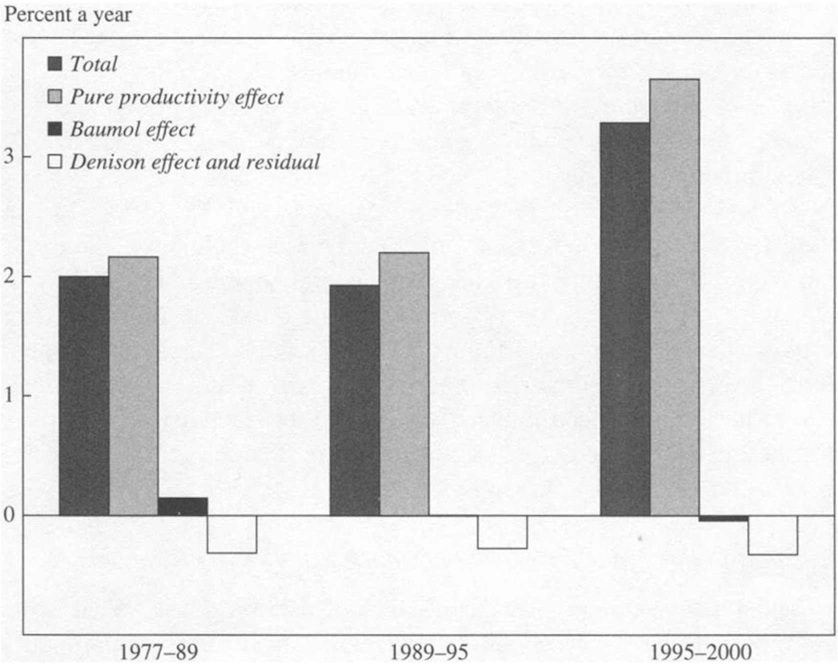
c. Difference between the variable productivity effect and the pure productivity effect; corresponds to second right-hand term in equation 2.

d. Impact of reallocation among industries that have different shares of labor incomes; corresponds to third right-hand term in equation 2.

e. Interaction terms and second-order effects.

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; the underlying data are presented in the bottom panel of table 4. 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 the income-side measure. For the other two concepts of output, the productivity acceleration from the pure productivity effect was about 0.2 percentage point larger than the total. This implies that the productivity improvement arose largely because

Figure 2. Components of Productivity Growth in Well-Measured Output, 1977–2000



Sources: Author's calculations using data from Bureau of Economic Analysis.

weighted-average productivity growth in the underlying industries increased, not because of sectoral shifts or other factors.

The basic conclusion 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 (table 3) are well below pure productivity growth (table 4) because of the statistical discrepancy as well as modest Baumol and Denison effects. The understatement is even larger for the nonfarm 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.[13] 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 suppliers, and a reduction in the economy's overall rate of productivity growth.

Table 4 shows the Baumol effect over the 1977–2000 period. In fact the effect was slightly positive over the period as a whole for all three output concepts, indicating that changing sectoral shares added slightly to aggregate productivity. Recall from equation 2 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 (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, addressed later in this paper, of the use of new economy goods and services elsewhere in the economy, through the contribution of capital deepening and of spillover effects from the information economy to productivity.

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 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, whereas 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 I have constructed a consistent set of value-added accounts.

13. See the references in note 3.

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 component (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.

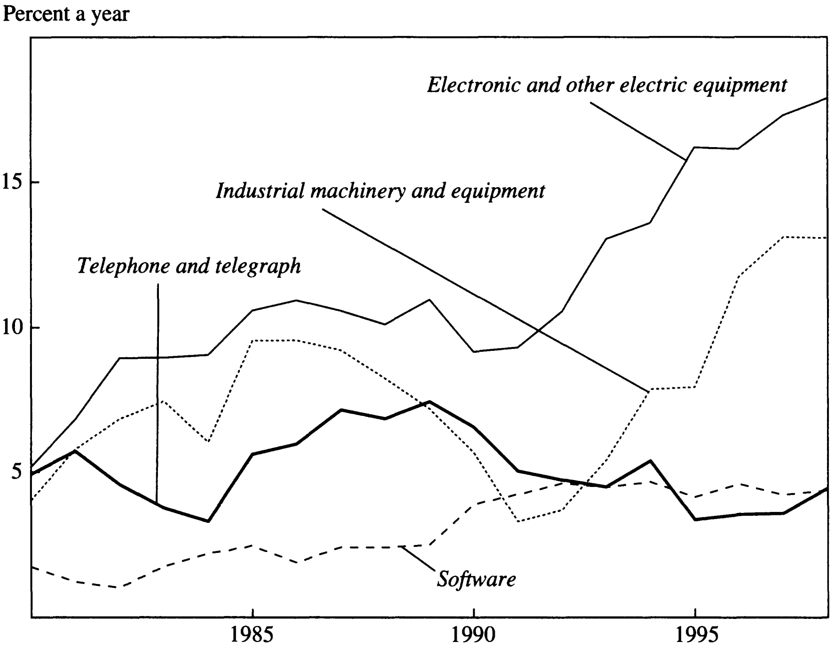
Table 5 shows the results for all three major sectors. Focusing first on the nonfarm business sector, we see that relatively little of the productivity acceleration in that sector in the late 1990s was due to the new economy. Productivity in the nonfarm business output measure that includes the new economy accelerated by 1.61 percentage points from the 1977–89 period to the 1995–2000 period. But only 0.29 percentage point, or one-sixth, was due to acceleration in the new economy sectors. The balance of 1.32 percentage points came in old economy sectors. The results are roughly the same for the overall economy. For the well-measured sectors, one-third of the productivity acceleration from the first half to the second half of the 1990s was due to the new economy.

Although the new economy contributed relatively little to the acceleration in productivity growth, it nonetheless provided a substantial part of total productivity growth. In the last five years of the period, as shown in table 5, 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 4 shows the contribution of the four new economy sectors to overall GDP productivity. These calculations 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 total impact on GDP productivity, shown in the far-right-hand bar in each group, was 0.46 percentage point in the first two subperiods and then rose to 0.72 percentage point for the 1995–2000 period. The largest single contributor for the period as a whole was electric and electronic equipment, followed by machinery, except electrical.[14]

14. The estimates here vary from those in the tables because the weighting procedure is slightly different.

Figure 3. Productivity Growth in Four New Economy Industries, 1980–98



Source: Author's calculations using Bureau of Economic Analysis data.

Evaluation of the Gordon Hypothesis

Equipped with this new data set, I can now evaluate the Gordon hypothesis. This view holds that most if not all of the productivity acceleration in the late 1990s was due to higher 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 [information technology] at large, but in computer manufacturing, barely 1% of the economy. Elsewhere, growth in productivity has stalled or fallen.[15]

Since the first statement of the Gordon hypothesis in 1999, there has been some backtracking. The most recent estimates associated with the

15. "How Real Is the New Economy?" *The Economist,* July 24, 1999. Also see Gordon (2000). Further discussions can be found in Oliner and Sichel (2000). The latest published version is Gordon (2002).

Table 5. Productivity Growth with and without the New Economy for Alternative Measures of Aggregate Output, 1978–2000[a]
Percent a year

Measure	*1977–89*	*1989–95*	*1995–2000*	*Change, 1977–89 to 1989–95*	*Change, 1977–89 to 1995–2000*
GDI					
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
Nonfarm business sector					
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

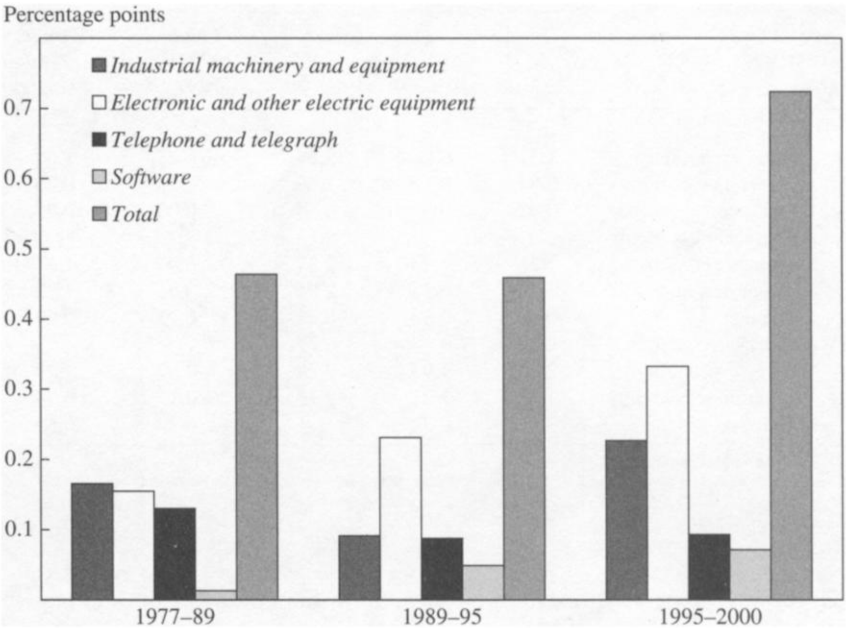
Source: Author's calculations.
a. Growth in output per hour worked; data are annual averages. Details may not sum to totals because of rounding.

Gordon hypothesis (presented by Gordon in his comment on this paper) find that, outside of durable manufacturing, private business experienced an acceleration of labor productivity growth of only 0.22 percentage point for the period 1995:4 to 2000:4 relative to the period 1972:2 to 1995:4; this estimate has drifted upward since Gordon's early calculations.

The results developed here definitely reject the Gordon hypothesis over the period studied. For all three broad output concepts (GDP, the nonfarm business sector, and well-measured output), labor productivity growth in the economy excluding the new economy showed a marked upturn over 1995–2000 relative to the 1977–95 period (table 5). The acceleration in non–new economy productivity growth was 0.85 percentage point for the overall economy (measured from the income side), 1.33 percentage points for nonfarm business output, and 0.80 percentage point for well-measured output (these can be calculated from the data in table 5). The new economy contributed directly about one-quarter of the total acceleration in labor productivity growth for total output, one-sixth for nonfarm business, and two-fifths for well-measured output.

A final decomposition of productivity growth examines how much each industry contributes to the total. Table 6 does this for the nonfarm

Figure 4. Contribution of New Economy Industries to Productivity Growth for the Total Economy, 1977–2000[a]



Source: Bureau of Economic Analysis.
a. Total economy is measured by income-side GDP. Estimates use nominal output weights.

business sector. 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 among 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 a major contribution to overall productivity growth in the latest period. Indeed, the contribution of each of these two sectors to the *acceleration* of productivity for the 1995–2000 period was larger than that of any of the new economy sectors. The data in these sectors are somewhat of a mystery, however, which emphasizes the importance of closer atten-

Table 6. Contribution of Selected Industries to Productivity Acceleration in the Nonfarm Business Economy[a]

Percent a year except where stated otherwise

	Productivity growth		*Contribution to productivity acceleration*
Industry	*1975–89*	*1995–2000*	*(percentage points)*
Leaders			
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
Laggards			
Nonfarm housing services	2.52	−0.62	−0.06
Petroleum and coal products	8.43	1.32	−0.07
Other services	0.86	−1.59	−0.09
Food and kindred products	3.85	−2.94	−0.15
All other	n.a.	n.a.	0.22
All industries	1.26	2.87	1.61

Source: Bureau of Economic Analysis data.

a. New economy sectors are shown in boldface.

tion to measuring their output. At the bottom of the league, meanwhile, 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.[16] 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

16. These results are on the whole similar to the results of Jorgenson and Stiroh (2000a), who use an accounting framework that includes all inputs and explains the movement of gross output.

growth clocked 4.1 percent a year in the 1977–95 period according to the income-side data, and that rate moved up to 5.5 percent a year in the 1995–2000 period. Figure 5 shows the major contributors by industry in manufacturing. The importance of industrial machinery (notably computers) and electronic machinery (notably semiconductors) is striking: these two industries contributed 4.5 percentage points of the 5.5-percentage-point total growth.[17] Manufacturing productivity growth outside of the new economy was positive if modest.

On the other hand, the totality of non–new economy manufacturing industries showed a marked productivity deceleration in the latest period, from 2.00 to 0.97 percent a year between 1977–89 and 1995–2000. (This result was shown by Gordon using a different data set.) Of this 1.03-percentage-point slowdown, food processing is responsible for 0.81 percentage point, which raises questions about either the data or the performance of that industry. If the two major new economy industries and the oldest old economy industry (food) are removed from the total, the latest data for manufacturing do not appear to show a major change in productivity growth. 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.

Qualifications

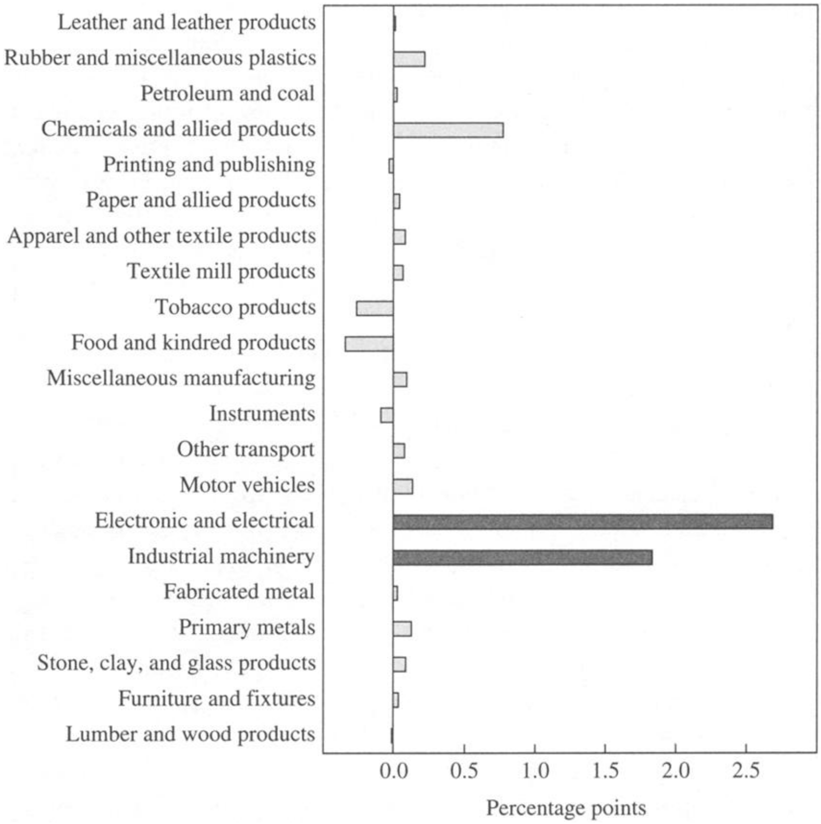
The present study is but one of many that have analyzed recent productivity trends and the role of the new economy. Before concluding, it will be useful to highlight some of the qualifications that attach to the results.

To begin with some technical details, the data for this study pertain exclusively to gross product (that is, value added), which is derived from the industry accounts and primarily based on income rather than product data. Moreover, in these data the nominal output data are directly estimated from income data, whereas the real output data are derived from gross output and intermediate inputs by double deflation.[18] In the aggre-

17. Within SIC 35 and 36, appendix table A2 shows the major data on shipments and the price of shipments. The industries with sharply falling price indexes have hedonic treatment.

18. Yuskavage (2000, 2002).

Figure 5. Contribution to Manufacturing Productivity Growth by Industry, 1995–2000[a]



Source: Bureau of Economic Analysis.
a. Each bar measures productivity growth in one industry times the share of that industry in total manufacturing output. Shaded bars indicate new economy industries.

gate, 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 nominal GDI grew 0.33 percentage point a year more rapidly than nominal GDP over the 1995–2000 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, 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 of using income-side industry data is that real GDI calculated from these data is estimated to have grown faster than the usual product-side estimates. Over the 1995–2000 period, real income-side GDI had an average annual growth rate of 4.46 percent, versus 3.95 percent for real GDP, for an average difference of 0.51 percentage point. 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 difference being purchased goods and services. In principle, there should be no difference between the two approaches if the aggregation technique and the 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 total factor 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 nonneutrality,[19] 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 nonneutrality 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 Stephen Oliner and Daniel Sichel, Dale Jorgenson, and Kevin Stiroh, among others, suggest that most if not all of the acceleration in labor productivity in the late 1990s was due to capital deepening.[20]

Although estimating total factor productivity is a central technique for understanding trends in productivity, labor productivity also has a useful,

19. 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 $x_1, x_2, \ldots$, where F is an aggregator such as the Fisher or Tornqvist index.

20. Oliner and Sichel (2000); Jorgenson and Stiroh (2000a, 2000b); Jorgenson (2001); Stiroh (forthcoming).

independent role to play. To begin with, 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 total factor productivity depends upon *estimating* rather than *measuring* the inputs of capital services. Estimates of capital services depend upon several important and often-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 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 of the late 1990s; the effect of this is to overestimate the user cost and implicit marginal cost of capital, particularly in high-technology industries. The data for this period are especially problematical given that the high-technology stock market bubble probably led to overinvestment in several sectors, telecommunications in particular, and that some of the investments (such as the ominous sounding "dark fiber") turned out to be useless and have zero productivity.

A final shortcoming is that the production function includes only the return to fixed capital as a nonlabor market input. It 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 total factor productivity model, it is useful to examine techniques, such as estimation of labor productivity, that do not depend on the multitude of assumptions that underpin that model.

One can illustrate the issues involved in moving from labor productivity to total factor productivity by estimating the extent to which capital deepening was associated with the recent changes in labor productivity. For this question I looked at the relationship between output growth and the growth of labor and capital inputs over the 1977–2000 period in those twenty-nine industries included in well-measured output for which the BEA prepares net capital stock data. Pooling the data with industry and time effects along with cross-sectional equation weighting yields the following estimated equation:

$$g(X_{i,t}) = \underset{(0.049)}{0.605}\, g(L_{i,t}) - \underset{(0.085)}{0.0308}\, g(K_{i,t}) + \text{industry effects} + \text{year effects}$$

$$R^2 = 0.515;\ n = 667,$$

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

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. Although 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 four standard errors from accepting the null hypothesis that the coefficient equals the income share of capital; this indicates that, although the coefficient is not well determined, it is significantly different from the theoretical assumptions that underpin the calculation of total factor productivity.

An alternative specification defines capital inputs as proportional to the depreciation of fixed capital plus an opportunity cost of fixed capital; this specification, however, 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 total factor 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 weak and at worst unrelated to the model underlying typical total factor 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. Annual growth of real GDP averaged 4.0 percent in that period, compared with 2.9 percent in the 1977–95 period. The reason for concern is that productivity growth has typically been procyclical.

I have not undertaken a systematic assessment of the cyclical effects for the industry data. Doing this would require confronting the potentially serious estimation bias 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 because of the strange output numbers. Not surprisingly, therefore, there is 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 estimated a productivity equation adding the growth of real GDP, as a proxy for aggregate cyclical conditions, into industry equations. The idea here is that shocks to aggregate demand will 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:

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

$$R^2 = 0.256;\ n = 667.$$

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 growth of real GDP as a cyclical variable makes very little difference to average productivity growth. The coefficient on aggregate output indicates 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 point a year faster in 1995–2000 than the average for the sample period. This indicates that the rapid growth in the 1995–2000 period raised average productivity growth by 0.072 percentage point; this compares with an acceleration of 0.44 percentage point in GDP productivity and 0.92 percentage point 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

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

$$R^2 = 0.253; n = 667.$$

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 growth in aggregate output by 1 percent would *decrease* productivity in the average industry by 0.1 percent.

In summary, although 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.

Conclusion

This paper has considered issues in the recent behavior of productivity and productivity growth. The major points can be summarized as follows.

First, the paper introduces a new approach to measuring industrial productivity. It develops an income-side database on output, hours worked, and labor productivity, relying on data published by the BEA. The data are internally consistent and add up to income-side GDP. The advantage of the unified income-side measures is that they present a consistent set of industrial accounts. The disadvantage is that they are available only for the period 1977–2000.

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

—GDP from the income side (GDI)

—The BLS's nonfarm 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 observed in all three broad aggregates developed for this study. The labor productivity acceleration in the last five years of the period (1995–2000) relative to the 1977–95 period was 1.12 percentage points for income-side GDP, 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 by source. This decomposition identifies a pure productivity effect (which is a fixed-weighted average of the productivity growth rates of different industries), a Baumol effect (which captures the effect of changing shares of nominal output on aggregate productivity), and a 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 exceeded total productivity growth. For example, in the nonfarm business sector for the period 1995–2000, total labor productivity growth was 2.87 percent a year, and the pure productivity effect was 3.09 percent a year. The difference was due to a mixture of the Baumol and Denison effects. Moreover, in analyses 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 growth 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 have defined 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 in 2000. Productivity growth in the new economy sectors has made a significant contribution to economy-wide productivity growth. In the nonfarm business sector over the last five years, labor productivity growth excluding the new economy sectors was 2.08 percent a year compared with 2.87 percent a year including the new economy.

Seventh, the major new economy contributors to the productivity rebound have been nonelectric and electric machinery, the major subsectors of which are computers and semiconductors. These two sectors, which accounted for less than 4 percent of nominal GDP, contributed 0.56 percentage point to income-side GDP productivity growth of 2.24 percent a year in the 1995–2000 period.

Finally, to what extent has there been an acceleration of productivity growth outside the new economy? According to all three output measures, there has been a substantial upturn in non–new economy productivity growth. After the new economy sectors are stripped out, the productivity acceleration from 1977 to 1989 was 0.76 percentage point for income-side GDP, 1.32 percentage points for business output, and 0.74 percentage point for well-measured output. It is clear that the productivity rebound is not narrowly focused in a few new economy sectors.

APPENDIX A

Supplemental Tables

Table A1. Value Added by Information Technology Industries, 1995 and 1998
Millions of current dollars except where stated otherwise

Industry	*SIC code*	*1995*	*1998*
Hardware			
Computers and equipment	3571,2,5,7	32,931.2	45,081.8
Computers and equipment, wholesale sales	5045 (part)	50,756.0	74,173.3
Computers and equipment, retail sales	5734 (part)	2,513.6	3,441.3
Calculating and office machines, n.e.c.[a]	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	70,092.0
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		183,579.6	254,115.0
Software and services			
Computer programming services	7371	26,178.3	n.a.[b]
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 and 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, n.e.c.	7379	8,549.1	n.a.
Total	7371–9	102,595.2	151,999.3
Communications hardware			
Household audio and video equipment	3651	2,343.0	2,767.6
Telephone and telegraph equipment	3661	14,925.2	17,373.7
Radio and television and communications equipment	3663	19,862.0	27,854.3
Magnetic and optical recording media	3695	2,787.8	3,293.0
Total		39,918.0	51,288.0

(*continued*)

Table A1. Value Added by Information Technology Industries, 1995 and 1998 (*continued*)

Millions of current dollars except where stated otherwise

Industry	*SIC code*	*1995*	*1998*
Communications services			
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 television services	4841	24,247.7	31,838.3
Total		191,600.0	225,184.0
All information technologies		517,692.8	225,184.0
As a share of the economy (percent)		7.1	8.1

Source: U.S. Department of Commerce (2000).
a. Not elsewhere classified.
b. Not available.

Table A2. Shipments by Selected New Economy Industries and Changes in Output Prices, 1987–98

Units as indicated

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

Source: Bureau of Economic Analysis at www.bea.doc.gov/bea/dn2/gpo.htm.
a. Price indexes for totals are "mongrels" rather than true chain indexes, and they double-count because they are based on gross output rather than value-added weights.