Productivity Measurement and Monetary Policymaking During the 1990s

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Abstract

The acceleration of productivity growth during the latter half of the 1990s was both the defining economic event of the decade and a major topic of debate among Federal Reserve policymakers. A key aspect of the debate was the conflict between incoming aggregate data, which initially suggested little productivity gain, and anecdotal firm-level evidence which hinted at an acceleration. Some FOMC members feared an overheating economy and higher inflation; others, including the Chairman, argued that revolutionary increases in productivity were occurring and the Committee should not prematurely forgo significant future gains in real income by tightening policy. We review the difficulty of measuring productivity during periods of rapid quality change, the large magnitude of subsequent data revisions during the 1990s, and, from FOMC transcripts, the contemporary monetary policy debate within the FOMC as the decade's data evolved.

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1. The Productivity Acceleration

During the last decade, a consensus has arisen among economists that trend growth rates for potential real output and labor productivity increased approximately a decade ago, and that the cause was an increase in the rate of decrease of semi-conductor prices.[1] In this study, we discuss measurement issues and examine revisions to the last decade's labor productivity data. We find that the revisions have been large, in some cases large enough to fully reverse initial preliminary conclusions regarding productivity growth slowdowns and accelerations. We examine the cautious response of policymakers to these incoming, uncertain, preliminary productivity data.

Because the 1990s acceleration of labor productivity was unforeseen and challenged extant views, its recognition was delayed. Typical is the 1996 *Economic Report of the President*, prepared during 1995. In the report, the Council of Economic Advisers projected that labor productivity in the private nonfarm business sector would increase at an average annual rate of 1.2 percent from the third quarter of 1995 to the end of 2002. This estimate extrapolated recent experience: from 1973 to 1995 productivity had grown at an average annual rate of 1.4 percent. Initial productivity measurements published during 1995 and 1996 were consistent with the Council's forecast, and did not signal an increase in productivity growth. Today's revised data shows that productivity growth had started to increase even before 1995. The incoming data during 1995 and 1996 clashed with widespread anecdotal firm-level evidence that spending on information and communication technology equipment was increasing productivity. A lively debate ensued, among private analysts and policymakers. To some analysts, the

[1] Some analysts have labeled this increase as the beginning of the "New Economy" era.

productivity acceleration was no more than a cyclical response to more robust economic activity. But, at the same time, large investments in information and communication technology (ICT) equipment could not be ignored.[2] Analysts quickly identified decreases in semi-conductor prices, and the prices of business equipment built with them, as the primary cause of the productivity acceleration. But, prices also had fallen in the past—would rapid price decreases be sustained? Further, some analysts asked if the increased investment in ICT was largely a change in the type of producers' durable equipment being purchased, rather than a genuine capital deepening. A typical after-the-fact assessment is Jorgenson, Ho and Stiroh (2002): "… the story begins with an increase in total factor productivity growth in the IT-producing sectors (computer hardware, software, and telecommunications), which led to falling relative prices and induced capital deepening in IT equipment."

The 2001 recession dispelled doubt regarding the staying power of the productivity acceleration. During the recession, productivity growth defied historical experience by increasing rather than decreasing, which was contrary to predictions from the historical record.[3] By 2001, the Council of Economic Advisors had increased its projection of the annual growth of structural labor productivity to 2.3 percent per year. Other forecasters, including many included in *Blue Chip Economic Indicators* and the

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[2] Such changes are not confined to the United States. Pilat (2001), Colecchia (2002), Colecchia and Schreyer (2002), and Baudchon (2002) survey the OECD countries. Armstrong et al. (2002) examine the Canadian experience.

[3] As the discussion in Edge, Laubach and Williams (2004) indicates, in 1997 Princeton University Professor Alan Blinder estimated that trend labor productivity growth was effectively its average since 1974, 1.1 percent. Further, in 1999 Northwestern University Professor Robert Gordon estimated a trend rate of growth of 1.85 percent; he then subsequently revised this up to 2.25 percent in 2000, and then to 2.5 percent in 2003. Interested readers also should compare Gordon (2000) and Gordon (2003). In his earlier writings, Gordon argued that productivity had not accelerated in nearly 90 percent of the economy and that trend growth of total factor productivity had actually decelerated. The passage of time, and revisions to the

Federal Reserve Bank of Philadelphia's *Survey of Professional Forecasters*, were even more optimistic.[4] Yet, for a second time, the forecasters underestimated the acceleration of productivity. Since the March 2001 NBER business cycle peak, labor productivity has been stronger than both these upward-revised forecasts and its average following past cyclical peaks; the latter is illustrated in Figure 1.

Productivity's acceleration has played a major role in monetary policymaking during the last decade, and a significant part of the policy debate concerned the quality of incoming data. Accurate, timely data are essential for activist monetary policymaking. The FOMC transcripts from 1996 and 1997 suggest that Chairman Greenspan placed little confidence in aggregate real GDP as an indicator of the direction of the economy. Rather, his focus was on a broad array of individual-industry data. In particular, he focused on productivity growth in manufacturing and the broader nonfinancial corporate sector. One danger in such a disaggregate approach is that many industries primarily produce intermediate products that do not appear directly in GDP.[5] Policymakers risk significant errors if they respond too rapidly to incoming data that later revise significantly.[6] Increases in labor productivity growth similar to that which occurred in the United States during the 1990s has occurred in other eras and other countries, usually associated with technological innovations.[7] In most instances, analysts (and

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data, have confirmed the shift in trend. The evidence for potential GDP remains mixed, however; see for example Kouparitsas (2005).

[4] See the Sept. 10, 2000, *Blue Chip Economic Indicators* or the First Quarter 2001 *Survey of Professional Forecasters*.

[5] This point is made clearly by Triplett (2002).

[6] In the models of Svensson and Woodford (2003, 2004), optimal response to imperfect observation of output (and productivity) depends on the noise in the system. The optimal response to the optimal *estimate* of output displays certainty equivalence—but what is to be done when different policymakers have different estimates of potential output?

[7] Basu et. al. (2003) compare and contrast the differing US and UK experiences after 1995.

policymakers) found it difficult to recognize the occurrence of a "structural break" due to lags in the timeliness of incoming data and to subsequent data revisions.[8]

2. Productivity in a Simple Model

A simple neoclassical model illustrates the relationships among the economy's level of real output, *Y,* number of workers, *L,* real (price-deflated) capital stock, *K,* and the aggregate number of hours worked, *H*. We omit current-period time subscripts to simplify notation. Similar to most productivity analyses, we also omit three sectors of the economy where output largely is measured by the quantity of inputs and, hence, measured labor productivity growth is zero: all government, including state and local educational institutions; households, including housekeeping, home maintenance, child rearing, and household consumption of the service flow from owner-occupied housing; and nonprofit organizations. After removing these sectors, what remains is the *private business sector*.[9]

Average labor productivity (ALP) is measured as the ratio of the economy's aggregate output to the aggregate number of hours of labor input,

$$y = \frac{Y}{H}. \tag{3}$$

Similarly, the aggregate capital-labor ratio is defined as

$$k = \frac{K}{H}. \tag{4}$$

Capital deepening is defined as increases in *k,* that is, increases in the amount of physical capital (buildings, machines and other equipment) available relative to the number of

[8] Orphanides (2001), Orphanides and Van Norden (2002, 2003).
[9] Our exposition here follows Jorgenson and Stiroh (2000) and Jorgenson, Ho and Strioh (2002, 2003).

hours worked. Capital deepening increases ALP by providing each worker with more capital; in the model, the increased growth of $\Delta \ln y$ is proportional to the share of capital. Note that *K* is an aggregate of many types of capital, in many industries, and of many vintages. Hence, *K* is measured by dividing the current-dollar values of a wide variety of capital goods (after allowing for depreciation) by their matching price indexes.

Increases in labor productivity are completely determined by gains in *total factor productivity* (TFP) and *capital deepening*. Let the aggregate output of the private business sector, Y, consist of consumption goods, C, and investment goods, I. Assume these outputs are produced from two inputs, capital, K, and labor, L, according to a relationship

$$Y(C,I) = A * F(K,L), \tag{1}$$

where $F(K,L)$ is an aggregate production function and A is a time-varying index of the amount of output that cannot be accounted for by measured inputs of labor and capital, that is, of TFP.[10] Assuming competitive markets and constant returns to scale, the growth rates of outputs and inputs are related via the growth accounting equation

$$\overline{w}_I \Delta \ln I + \overline{w}_C \Delta \ln C = \overline{v}_K \Delta \ln K + \overline{v}_L \Delta \ln L + \Delta \ln A \tag{2}$$

where Δ is the first-difference operator defined as $\Delta X_t \equiv X_t - X_{t-1}$.[11] The weights $\overline{w}_I$ and $\overline{w}_C$ are the average (over periods *t* and *t*-1) value shares of investment and consumption goods output in aggregate output ($\overline{w}_I + \overline{w}_C = 1$); $\overline{v}_K$ and $\overline{v}_L$ are the average

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[10] For the aggregate economy, economists tend to interpret the index *A* as a strictly increasing sequence (as a function of time). But, for an individual industry, many events may cause decreases in *A*, including changes in its regulatory regime and changes in its competitive environment.

[11] Stiroh (2002b) finds that the model's implications are little changed by relaxing the assumptions of perfect competition and that the aggregate production function displays constant returns to scale.

value shares, over periods *t* and *t*-1, of capital and labor in aggregate national income, ($\bar{v}_K + \bar{v}_L = 1$); and $\Delta \ln A$ is the growth of TFP.

Re-arranging equation (2) shows the relationship between the growth rate of average labor productivity, $\Delta \ln y$, and its determinants,

$$\Delta \ln y = \bar{v}_K \Delta \ln k + \bar{v}_L (\Delta \ln L - \Delta \ln H) + \Delta \ln A . \tag{3}$$

To focus on the role of ICT capital,, equation (1) may be re-written as

$$Y(Y_n, I_c, I_s, I_m) = A * X(K_n, K_c, K_s, K_m, L) \tag{4}$$

where Y_n is non-ICT output; I_c, I_s, and I_m are outputs of computer hardware, software and communications equipment, respectively; and K_c, K_s, and K_m are service flows from stocks of computer hardware, software and communications equipment. In this notation, equation (2) may be written as

$$\begin{aligned} &\bar{w}_{Y_n} \Delta \ln Y_n + \bar{w}_{I_c} \Delta \ln I_c + \bar{w}_{I_s} \Delta \ln I_s + \bar{w}_{\mathrm{I_m}} \Delta \ln I_m \\ &\quad = \bar{v}_{K_n} \Delta \ln K_n + \bar{v}_{K_c} \Delta \ln K_c + \bar{v}_{K_s} \Delta \ln K_s + \bar{v}_{K_m} \Delta \ln K_m + \bar{v}_L \Delta \ln L + \Delta \ln A \end{aligned} \tag{5}$$

where $\bar{w}_{Y_n} + \bar{w}_{I_c} + \bar{w}_{I_s} + \bar{w}_{\mathrm{I_m}} = \bar{v}_{K_n} + \bar{v}_{K_c} + \bar{v}_{K_s} + \bar{v}_{K_m} + \bar{v}_L = 1$. Then, equation (3) illustrates the relationship of labor productivity growth to ICT capital:

$$\Delta \ln y = \bar{v}_{K_n} \Delta \ln k_n + \bar{v}_{K_{IT}} \Delta \ln k_{IT} + \bar{v}_L (\Delta \ln L - \Delta \ln H) + \Delta \ln A \tag{6}$$

where $\bar{v}_{K_{IT}} = \bar{v}_{K_c} + \bar{v}_{K_s} + \bar{v}_{K_m}$.

Measurement is a difficult problem when seeking to take this aggregate production model to the data. The three right hand-side terms of equation (3), for example, are *not* independently measured. Some variables—Y, L, H, K—can be measured, at least approximately. The growth rate of total factor productivity, however, is measured as a residual:

(4) $$\Delta \ln A = \bar{v}_K \Delta \ln k + \bar{v}_L (\Delta \ln L - \Delta \ln H) - \Delta \ln y .$$

Measurement issues arise for real output, Y, and the real constant-quality capital stock, K. Real output may be mis-measured if the price deflators used to convert nominal output into "real" are not accurate. This may be a particularly difficult problem for the services sector, what Griliches (1994) described as a difficult-to-measure sector. The Bureau of Economic Analysis uses component price indexes from the CPI to measure, via the deflation method, approximately 57 percent of the output of the business sector. Hence, any bias in the CPI's component price indexes will appear as bias in the measured output quantities; see Eldridge (1999). Similarly, the real quantity of capital, *K*, is difficult to measure accurately because it is a sum of quality-adjusted (constant-quality) across many types of capital goods (discussed further below), each of which requires an adjustment for quality prior to being deflated for price change. Biases in measuring the quantity of capital inputs, *K*, will not bias the measured growth rate of average labor productivity, $\Delta \ln y$, but will bias the measured growth rate of total factor productivity.

In general, data availability makes timely measurement of TFP more difficult and less certain than measurement of ALP. Studies that have sought to separate increases in ALP into its components—capital deepening, changes in labor quality, and increases in TFP—have often relied on a "price dual" measurement method.[12] Intuitively, price decreases for ICT goods, relative to other goods, reflect relatively larger increases in TFP for ICT goods. Therefore, the rate of TFP growth is *measured* by the negative of the rate of ICT-goods price decrease, relative to the price change for labor and capital. While not fully satisfactory, alternative procedures are difficult to design for products whose quality

and price are changing rapidly, such as semiconductors and computers. In equation (6), errors in measuring the prices of ICT capital affect the growth rate of ICT capital, $\Delta \ln k_{IT}$, and the growth rate of total factor productivity, $\Delta \ln A$. To the extent that prices of ICT capital are measured with significant uncertainty, then the attribution of labor productivity growth to capital deepening versus gains in total factor productivity must be highly uncertain. This distinction is crucially important for projecting forward changes in labor productivity because rapid capital deepening—that is, increases in *k*—tapers off as a new steady-state capital-labor ratio, k, is achieved. As a result, long-run projections of labor productivity growth depend critically on projections

In the balance of this study, we focus on growth rate of ALP, rather than TFP, for several reasons. In the long-run, increases in ALP are the driving force behind economic growth and higher living standards (the increased capital stock that contributes to TFP is, itself, produced by labor and capital). The sustainability of ALP is the key issue for future growth projections. Further, TFP is difficult to measure. Measures of TFP require measures of capital stocks, *K*, which often are subject to more uncertainty than measurements of labor inputs and output. Finally, monetary policy-related discussions during the 1990s concerning the growth of potential GDP—the economy's "speed limit—were conducted in terms of accelerating labor productivity growth.

To understand the channels through which ICT affects productivity, it is useful to distinguish between effects due to the *production* of ICT and due to the *use* of ICT. For the former, technical progress in semiconductor manufacturing allows more computing power to be produced from the same inputs of capital and labor, that is, causes increases

[12] Examples include Council of Economic Advisors (2001); Jorgenson and Stiroh (2000); Jorgenson,

in TFP (and ALP) for ICT-producing industries. Since ICT-producing industries also are large users of ICT (in both development and production), the lower cost of ICT goods induces capital deepening in these industries, again increasing ALP. For the latter, decreases in the cost of ICT induce capital deepening, $\Delta \ln k$. No increase in TFP occurs if the contributions to output are entirely captured by capital deepening. Increases in TFP, if any, arise when the firm reorganizes the *way* the firm operates. Examples include initiating/expanding e-commerce on the Internet; improving the timeliness of linkages between point-of-sale cash registers and inventory management systems; and improving network links among geographically separated sites. Studies suggest that such changes in business practice may take considerable time to implement, and hence the response of productivity to changes in ICT investment varies among firms and industries. Such variation may delay timely recognition that forces have arisen which, eventually, will increase productivity economy-wide.

We conclude that improvements in ICT goods, and resulting decreases in the price of computing power and communications, tend to increase both TFP and ALP. Further, both the strength and timing of such effects will tend to differ across industries, complicating recognition of increases in aggregate productivity.

A number of published studies have used models similar to the above to measure the contributions of information and communications technology (ICT) to productivity growth. Perhaps the best-known are Oliner and Sichel (2000, 2002) and Jorgenson, Ho, and Stiroh (2002, 2003). Although the details differ, both attribute approximately three-fifths of the acceleration in labor productivity growth during the second half of the 1990s

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2001; Jorgenson, Ho and Stiroh (2002); Oliner and Sichel (2000, 2002).

to capital deepening and, in turn, approximately 80 percent of the capital deepening to increases in ICT-related capital.[13] Of the residual TFP growth, both studies attribute approximately half to ICT-related developments—specifically, increases in the productivity of semiconductor manufacturing.

Overall, both studies conclude that the productivity acceleration of the 1990s can be traced, in large part, to rapid decreases in the prices of information-technology equipment and components, especially prices of semiconductors. As shown in Figure 6, semiconductor prices trended downward throughout the 1990s with the rate of decrease accelerating during the latter half of the decade. Caution must be used in interpreting these figures, however, because rapid technical change has introduced thorny quality-adjustment problems. In other cases, the survey sample for some products, such as semiconductors, has changed.[14] Typical is Holdway (2001), p. 15:

> "It would be disingenuous to imply that the PPI has been able to properly value and account for technological change in its cmpu [CPU] price measurements. The standard PPI methodologies for valuing quality change is [sic] rather limited when faced with quality improvements that are accompanied by reduced input costs due to shifts in the production function."

Holdway also notes that the apparent acceleration of semiconductor price decreases during early 1997, as shown in Figure 6, most likely is a result of the introduction of secondary source pricing data.[15] Similarly, Gullickson and Harper (2002) express

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[13] Jorgenson, Ho and Stiroh (2002, 2003)., following Evsey Domar, measure an industry or sector's "output" as gross value of shipments to households and firms outside its industry or sector. Oliner and Sichel measure output as GDP-originating (value added), which excludes from an industry's shipments the value of materials purchased from other sectors.

[14] For semiconductor prices, for example, the Bureau of Labor Statistics has a series in the PPI, the Bureau of Econonic Analysis has a series used in the national income accounts, and the Federal Reserve Board has a price measure used in its industrial production index. See, for example, Hulten (2001). The semiconductor price series plotted in figure 6 is the PPI measure relative to the GDP price index.

[15] Secondary source prices are price figures collected from catalogs and industry publications, rather than from the manufacturer's price list. Holdway doesn't speculate on whether secondary-source price data, if available, might change the pre-1997 trend, but the absence of such data introduces a risk into any study that attributes the productivity acceleration to more rapid price decreases: Would the studies reach the same conclusion if the rate of price decrease from 1993 to 1997 had been the same as that beginning in 1997?

caution:

> "These findings rest on estimated trends for high tech inputs and outputs that incorporate adjustments to account for changes in their quality. Many of the high tech input and output growth rates are well up in the double-digit percentage range. These extraordinary trends, in turn, rest on the use of quality adjusted price indexes in deflation. These indicate that prices for high tech goods of constant quality have fallen very rapidly. These price trend estimates have withstood much scrutiny, but we must emphasize their importance for our conclusions. While it is likely that real output trends have been underestimated in many or all of the service sector industries with negative MFP trends, it is also possible that the growth trends for high tech imputs have been overestimated. Underestimating service sector output trends would bias the aggregate productivity trend downward. Overestimating high tech input and output trends would bias the aggregate productivity trend upward. … We can express a concern that the "measurement playing field" imay not be level. We have very intrictate means of making quality adjustments to high tech goods, but we have few means to make quality adjustments to service outputs."

Interested readers also should see Grimm (1998), Landefeld and Grimm (2000), and the papers in Corrado et al (2005).

As an example of the interaction between measurement and economic modeling, consider the Oliner and Sichel (2000, 2002) model. In this model, the rate of increase in total factor productivity is measured by the inverse of the rate of decrease of semiconductor prices, creating a direct, mechanical link between *observed* decreases in semiconductor prices and *unobserved* increases in productivity growth. The intuition is that, because semiconductor prices are falling rapidly relative to the aggregate price level, total factor productivity at semiconductor manufacturers must be increasing; if not, the firms would exit the industry. The effect of this clever measurement technique is that the sharp decline in semiconductor prices in 1997—seen visually in Figure 2—appears immediately as an increase in labor productivity growth. But, any bias in measuring total factor productivity at firms producing semiconductors also appears immediately in their productivity growth estimates.

Or, did the decision to solicit secondary source price data reflect observations of increased pricing pressure?

Updated estimates provided by Dan Sichel suggest that the *direct* contribution from the semiconductor industry directly was responsible for 0.08 percentage points of the 0.37 percent growth of TFP from 1974 to 1990 and by 0.13 percentage points of the 0.58 percent growth of MFP from 1991 to 1995. However, from 1996 to 2003, Oliner's updated estimates show that the direct contribution from the semiconductor industry was responsible for 0.40 percentage points of the 1.34 percent growth of MFP.[16] But as semiconductor prices continue to drop sharply, estimates of structural labor productivity growth were revised downward after 2001 as the economy fell into recession.[17] This suggests that the role of cyclical factors in boosting ALP growth in the 1990s noted earlier were also significant. For their projections for the next decade, Oliner and Sichel (2002) forecast average annual labor productivity growth at between a 2.0 and 2.8 percent rate. They also include ten projections by other authors, also between 2 and 3 percent per year, with both the mean and mid-point of the forecasts near 2.25 percent

As seen in Figure 2, the relative change in semiconductor prices has ceased declining at the rates that prevailed in the latter part of the 1990s. Although relative prices of semiconductors fell by about 38 percent in 2004, this was much less than its average decline of about 65 percent from 1998 to 2000. Thus, unless this trend reverses, it appears that one can rule out the "optimistic" productivity scenario cited above, and that structural labor productivity growth of between 1.33 (pessimistic) and 2.45 percent (baseline) appears to be the most likely outcome.

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[16] Unpublished estimates received from Dan Sichel via e-mail correspondence on June 28, 2004.

[17] In the CEA's growth accounting table that appears annually in the *Economic Report of the President*, projected long-term labor productivity growth in the nonfarm business sector was lowered from 2.3 percent in the 2001 *Report* to 2.1 percent in the 2002 *Report*.

A complementary analysis is presented by Jorgenson, Ho, and Stiroh (2003). During 1995-2000, ALP growth was 0.8 percent faster, on average, than during 1973-1995. The authors estimate that 0.5 percentage points of this increase, roughly two-thirds, was due to capital deepening as firms responded to decreasing prices of ICT equipment by increasing their capital-labor ratios. As some analysts anticipated, purchases of non-ICT capital (whose prices were not falling) decreased slightly, subtracting approximately half of one percentage point. Increased ALP also reflected increased TFP in both the ICT-producing and non-ICT producing sectors, contributing approximately one-quarter and one-eighth of one percentage point, respectively. Overall, the picture is clearly one of decreasing capital goods prices inducing capital deepening.

3. Productivity and Data Revisions: How Much Has the Picture Change Through Time?

Published labor productivity growth rates have two characteristics that complicate recognizing changes in trend growth: volatility and revisions. Volatility is illustrated in Figure 3, which shows quarterly compound annual growth rates calculated from currently published data for 10-year, 1-year, and 1-quarter intervals. High volatility is obvious. The figure also illustrates that "trend" labor productivity growth since World War II displays three phases: more rapid growth from 1948 to 1973; slower growth from 1973 to 1994; and more rapid growth beginning circa 1995. Since 1995, the pace of productivity growth in the *nonfarm business sector* has modestly exceeded its rate during the earlier high-growth period of 1949 to 1972; for the larger *private business sector*, however, growth over the past 10 years still remains modestly below its earlier pace. Measured labor productivity growth in the nonfarm business sector averaged 3 percent per annum

during 1949 to 1972, but less than half this pace during 1973 to 1994, despite strong productivity growth in manufacturing.

Table 1 decomposes productivity growth into growth of its numerator (output) and of its denominator (hours). The increase in productivity growth from 1973-94 (column 2) to 1995-2004 (column 3) reflects both more rapid growth of the numerator (output) and slower growth of the denominator (hours). For broad sectors, the table shows that the post-1973 productivity growth slowdown (compare columns 1 and 2) largely was due to slowdowns in the services and nondurable manufacturing sectors—durable manufacturing's labor productivity growth increased modestly throughout the slowdown period. [18] During the most recent decade, durable manufacturing's productivity growth has jumped to an average annual pace of approximately 5.75 percent, double its 1949-72 pace.

We include separate figures for manufacturing because a number of researchers have emphasized that understanding the measurement of, and revisions to, economic data requires separating manufacturing from other sectors. Perhaps the best-known analysis is Zvi Griliches's 1994 presidential address to the American Economic Association (Griliches, 1994), in which he separates "well-measured" from less well-measured sectors. He notes, ironically, that the frequency and size of near-term revisions to published sectoral data often are inversely related to the data's quality. The reason is straightforward: Data for well-measured sectors, such as manufacturing, arrives more promptly and, hence, results in more near-term revisions. Data for less well-measured sectors, such as service sectors, typically contains a good deal of extrapolation and

[18] See for example Bosworth and Triplett (2003a,b), and Kozicki (1997).

interpolation; because useful additional data arrives in a less timely fashion, revisions are delayed. This was the case during the 1990s. Initial published data for the service sectors showed no acceleration of productivity growth in services during the 1990s; see, for example, Corrado and Slifman (1999). Currently published data suggest, however, that circa 1995 the trend rate of growth of labor productivity in the economy's services sector more than doubled. Part of the story, as Gullickson and Harper (2002) note, is that the Bureau of Economic Analysis, in its 1999 comprehensive revision to the national income and product accounts (NIPAs), re-classified computer software as a fixed investment, and hence as a part of business sector final output (see Table 2). Previously, software had been classified as an intermediate input, and did not explicitly appear in value-added calculations. They note that this methodological change raised measured trend productivity growth, particularly in the nonmanufacturing sector.[19] In many cases, these data revisions have fully reversed previously published conclusions about stagnant productivity in the services sectors—compare, for example, Triplett and Bosworth (2003) to Triplett and Bosworth (2001) and Stiroh (2002) to Jorgenson and Stiroh (2000). In these later revised data, for example, for years since 2000 the contribution of the services sectors to economy-wide labor productivity growth exceeds the contribution of manufacturing; for years prior to 2000, the contribution of manufacturing exceeds that of the services sectors.

Finally, consider the "high tech" industries.[20] As of early 2002, BLS estimated

[19] Gullickson and Harper (2002) found that the nonmanufacturing sector's contribution to the trend growth rate of total factor productivity in the private business sector was 0.5 percent per year between 1990 and 1995 and 0.6 percent per year from 1995 to 1999. In a 1999 article published before the 1999 NIPA revisions, the estimated contribution of the service sector was zero.

[20] There are no official boundaries for the high-tech sector. Kask and Sieber (2002) discuss the issue in terms of 2 and 3 digit SIC industries. The SIC classification system has significant shortcomings for

that labor productivity in high-tech manufacturing had increased annually at a 9.5 percent rate from 1987-99, and at a 13.1 percent pace during 1995 to 1999; labor productivity for all manufacturing, in comparison, increased during the same periods at average annual rates of 3.2 percent and 4.4 percent.[21] Within the high-tech sector, two industries account for nearly three-quarters of the sector's total: output per hour of labor in the production of computers and office equipment grew 27.5 percent per year during 1987-99, and in electronic components and accessories the rate was 21.8 percent. Communications equipment exceeded the manufacturing average at 10.4 percent, but four high-tech industries experienced labor productivity growth at *less* than the overall rate for total manufacturing.

Revisions

Published measures of the economy's output and labor input are subject to revision. Data revisions complicate the task facing policymakers—measuring the strength or weakness of near-term economic conditions—and, in some cases, dramatically alter historical measurements of economic activity.[22] Each year, for example, the Bureau of Economic Analysis revises the national income and product accounts, and the Bureau of Labor Statistics revises employment and aggregate hours worked in the establishment survey. Whenever there are significant revisions to

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analyzing high-tech industries. Triplett (2002) discusses these limitations, and compares the SIC system to the newer NAICS system.

[21] The growth rate of labor productivity equals the growth rate of constant-quality real output (nominal output, adjusted for quality change and deflated for price changes) minus the growth rate of labor input (measured in hours). During 1987-99, multifactor productivity in high-tech manufacturing average 5.0 percent annual growth, versus 1.3 percent for all manufacturing. Multifactor productivity growth equals the growth rate of real output minus an index of the combined growth of all inputs. During the same period, the index of combined inputs grew 2.8 percent per year; see Kask and Sieber (2002). Note that the relevant output concept is nominal output, adjusted for quality change and deflated to constant prices. When the performance characteristics of a product are changing rapidly, both quality and price adjustments likely are subject to considerable uncertainty. Hence, measured real output may be less reliable.

economic output (the NIPA) or to total labor input (total employment, or hours worked), there also are revisions to nonfarm labor productivity; these revisions typically affect 12 quarters of data and often are substantial in size. Selected revisions, and their effects, are shown in Table 2.[23] During this period, annual revisions changed the prevailing understanding of productivity growth several times.

Revisions to national income data change measured productivity, often significantly. Changes since 1994 are summarized in Table 3.[24] Overall, revisions to productivity growth primarily are due to revisions to measured output and not to revisions in measured employment or aggregate hours worked. Since 1994, for example, the mean absolute revision to the growth rate of output, 0.26 percentage points, is one-third greater than hours worked, 0.19 percentage points, and approximately equal to that of the growth rate of productivity growth, 0.32 percentage points.[25]

"Case studies" of periods during which breaks in trend productivity growth occurred provide further insight:

- A common feature of changes in trend labor productivity growth is that they are not promptly recognized. A startling demonstration of this phenomenon is shown in Figure 4, for 1973. The figure shows, for each year 1974 to 2004, the then-current published growth rate of labor productivity for 1973. The first-published estimate of

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[22] See Himmelberg, et. al. (2004), Kozicki (2004), Orphanides and Van Norden (2003), or Runkle (1998).
[23] These revisions incorporate both the annual multi-year revisions to the NIPAs and the annual benchmark revisions to employment and hours from the Bureau of Labor Statistics. The revision period is nine quarters. See the footnotes to the table.
[24] These revisions incorporate both the annual three-year revisions to the national income and product accounts as well as the periodic comprehensive revisions, which occur about every five years. See the footnote to the table.
[25] The Bureau of Labor Statistics' annual benchmark revisions to establishment data have become smaller over time. From 1984 to 2004, the absolute percentage change in nonfarm payrolls averaged 0.2 percent, a third as much as the 1964-83 period. See Haltom, Mitchell, and Tallman (2005).

labor productivity growth was approximately 3 percent. This value was sharply lower in subsequent revisions until, during the late 1980s, the value began to increase. In the most-recently published data, 1973's measured productivity growth is *greater* than its initially published value—removing entirely any "slowdown" during the year.[26]

- Vintage productivity data for 1995 and 1996, shown in Figures 5 and 6, also illustrate the magnitude of revisions. For 1995, the currently published value is much lower than the initially published value. Although values published during the first three quarters 1995 suggested a productivity *acceleration*, by mid-1996 the published figures for 1995 had been revised downward to less than 1 percent, a *deceleration*. For 1996, the currently published value is much higher than the initially published value; see Figure 6. Figures for 1996 published during 1996 and 1997 were between 0.5 and 1.5 percent, hardly supportive of acceleration. Published data for 1995 and 1996 did not suggest an acceleration of productivity until the third quarter of 1997—and not until mid-1998 were published data clearly supporting the assertion that productivity growth had increased.
- In both 1998 and 1999, the Bureau of Labor Statistics reported sharply higher growth rates of nonfarm labor productivity due to upward revisions in the economy's measured output. For 1999, the increase largely was due to the Bureau of Economic Analysis reporting that the economy had grown faster than originally measured—

[26] In this vein, it appears that the switch to chain weights from fixed weights in 1996 (see Table 2) was particularly significant. See Gullickson and Harper (2002). We focus on labor productivity in this analysis. Gullickson and Harper (2002) provide a thorough analysis of the BLS total factor (multi-factor) productivity measures.

helped, in part, by the Bureau's decision to classify purchased computer software as a final output (fixed investment), rather than as an intermediate expense.[27]

- In its 2001 and 2002 annual revisions, the Bureau of Economic Analysis reduced the measured growth of the economy in 2001. The 2001 revision reduced the measured three-year growth rate of labor productivity by more than three-quarters of a percentage point.
- The national income and product accounts revisions published during mid-2005, for example, trimmed measured real GDP growth over the previous three years by 0.3 percentage points per year, to approximately 3.25 percent.

A longer-horizon picture of historical revisions to measured labor productivity growth is shown in Figure 7. For each year, 1959 to 2003, the figure has one vertical line that summarizes all the values of that year's labor growth as published in various issues of the *Economic Report of the President*. The lower and upper ends of each line correspond to the lowest and highest published growth rates, respectively, for that year, while the "dot" indicates the most recent estimate. For many years, the minimum-to-maximum range equals or exceeds 2 percentage points.

Revisions may cause policymakers, through no fault of their own, to find that economic conditions at the time of past policy decisions were not as believed at the time. Accordingly, economists and policymakers should subjectively place large confidence intervals around initial estimates of labor productivity growth.[28] But, how large should

[27] See Gullickson and Harper (2002).

[28] Initial estimates are published by the BLS in its *Productivity and Cost Report*. Revisions to estimated output in the nonfarm business sector are primarily due to the Bureau of Economic Analysis's revisions to

they be? The differences between first-published and most recently published productivity figures provides some insight; figures for 1985 to 2005 are summarized in Table 4 and Figures 8 and 9.

Consider, first, Table 4. The principal conclusion to be drawn from the table is that, while mean revisions are small, mean absolute revisions are large, in some cases approximately equal to the estimated annual growth rate itself. For both total private business and nonfarm private business sector productivity, the cumulative revisions of one-quarter estimates are slightly biased, with a mean of 0.41 and 0.34 percentage points, respectively. The mean absolute revision is larger, roughly 1.8 percentage points. The largest near-term revisions are to manufacturing productivity, output, and hours. The absolute mean of one-quarter durable manufacturing productivity growth is nearly 2.2 percentage points. Revisions to four-quarter growth rates are smaller than revisions to one-quarter growth rates, although this is due, in part, to the arithmetic of expressing all changes—including those for one quarter—as annualized growth rates. Finally, note that revisions to output growth rates are smaller than those for productivity, and that revisions to hours worked are smaller than revisions to output—suggesting that hours worked may be measured, at least in the near-term, with less error than output. The appreciably larger magnitude of revisions to the manufacturing sector reflects the relatively better measurement of the sector, relative to others, not inferior data collection (e.g., Grilliches, 1994). Among the aggregate business sectors, durable goods manufacturing has the largest mean absolute revision—again, likely due to the better near-term precision with which this sector is measured, including more timely incoming revised data.

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the national income and product accounts, although BLS's definition of the nonfarm business sector are is

Consider next Figures 8 and 9, which suggest two conclusions. First, there are large differences between first-published and subsequent revised data. Second, more accurate measurement matters: comparing Figures 8 and 9 shows revisions for the narrower and somewhat better-measured *nonfinancial corporate business sector* are smaller than for the broader and less well-measured *nonfarm private business sector*. Below, we note that the FOMC transcripts show Chairman Greenspan pressing the same point well before revised data were available: measured productivity in the nonfinancial corporate sector was a superior indicator of the economy's trend productivity growth, when compared to other sectors.

Finally, as anticipated, we note that mean revisions to four-quarter measures of productivity, output and hours generally are less then two-thirds the size of revisions to one-quarter growth. An exception is mean revisions to growth of manufacturing productivity, output, and hours—a highly well-measured sector—that are *larger* at the four-quarter horizon then at the one-quarter horizon, although the absolute mean of the revisions is not.

4. Productivity and Policymaking: How Much Did Forecasts Change Through Time?

Productivity "surprises" can arise both when near-term productivity growth differs from that which was anticipated, and when measured past growth is revised. Both types of surprises are important for policymakers.

Figure 8 displays projections, from the FOMC's "Greenbook," of annual labor productivity growth for 1997-2000 as reported in various issues from September 1996 to

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subject to revision because it differs from the BEA definition.

December 1999.[29] Apparent are the marked changes through time in the forecast of each year's productivity growth. Further, the upward trend in each year's forecast suggests that the staff persistently under-estimated the strength of labor productivity over this period. Indeed, the pattern of upward revisions in Figure 8 is very similar to those seen in Figure 6. FOMC transcripts, discussed further below, show that Chairman Greenspan, and others, were frustrated by the slow pace at which the Board staff revised upward their productivity forecasts.

Following the more rapid labor productivity growth that began in 1995, many forecasters—public and private—increased their estimates of the structural (or long-term) growth of labor productivity and potential GDP. Typical are Congressional Budget Office (CBO) projections, shown in Table 5. In 1997, the CBO projected that labor productivity and potential real GDP would grow during the next decade at 1.1 percent and 2.1 percent rates, respectively. Later, in 2001, the CBO projected growth rates of 2.7 percent and 3.3 percent. More recently, the CBO has trimmed both projections by a bit more than one-fourth of a percentage point.

During the latter 1990s, private sector analysts tended to be as reluctant as the FOMC's staff to revise upward projected trend productivity growth; hence, their revisions are similar to the Greenbook. Later, as the data revised, their forecasts moved rapidly. In January 1997, a survey of forecasters by *Blue Chip Economic Indicators* pegged potential GDP growth at 2.5 percent, implying long-term annual productivity growth near 1.4 percent. By September 2000, this estimate had increased to 3.8 percent,

[29] Prior to each meeting, the Federal Reserve Board staff prepares a suite of briefing material for the FOMC. One of these documents is referred to as the "Greenbook" due to its grass-green cover. Greenbook contents are available to the public after five years and redaction of certain confidential material.

implying a structural labor productivity growth rate of approximately 2.7 percent. In retrospect, it is likely that the faster pace was overly optimistic, perhaps unduly influenced by the latter 1990's rapid growth. During 2001, as economic activity slowed and the economy slid into recession, estimates of "long-term" structural productivity growth also were reduced. But, productivity growth remains difficult to forecast. Labor productivity in the non-farm private business sector increased 5.4 percent between the first quarter of 2003 and the first quarter of 2004. This was both the largest increase since 1965 and substantially faster than projected.

5. Monetary Policymaking and the New Economy

At the January 2004 meeting of the American Economic Association, Federal Reserve Chairman Alan Greenspan characterized monetary policy as a matter of risk management, an application of Bayesian decisionmaking. With respect to the early 1990s resurgence of productivity growth, he said:

> "The rise in structural productivity growth was not obvious in the official data on gross product per hour worked until later in the decade, but precursors had emerged earlier. The pickup in new bookings and order backlogs for high-tech capital goods in 1993 seemed incongruous given the sluggish economic environment at the time. Plant managers apparently were reacting to what they perceived to be elevated prospective rates of return on the newer technologies, a judgment that was confirmed as orders and profits continued to increase through 1994 and 1995. Moreover, even though hourly labor compensation and profit margins were rising, prices were being contained, implying increasing growth in output per hour."

> "As a consequence of the improving trend in structural productivity growth that was apparent from 1995 forward, we at the Fed were able to be much more accommodative to the rise in economic growth than our past experiences would have deemed prudent. We were motivated, in part, by the view that the evident structural economic changes rendered suspect, at best, the prevailing notion in the early 1990s of an elevated and reasonably stable NAIRU. Those views were reinforced as inflation continued to fall in the context of a declining unemployment rate that by 2000 had dipped below 4 percent in the United States for the first time in three decades."

While many pundits had long recognized that digital computers were changing the economy, the effects had been gradual and heterogenous among firms and industries.

For monetary policymakers during the 1990s, as it had been since 1982, the question was setting an appropriate target level for the federal funds rate.[30] Discussion in the Committee's meetings often concerned both the "GDP gap" and the "sustainable" growth rate of real GDP (even before the term "potential" came into common use). Taylor (1993) later adroitly summarized the Committee's reaction function. The growth rate of labor productivity entered the discussion as one component of the growth rate of potential real GDP.

The issues confronting the FOMC during the 1990s were not new—the same issues had arisen during the 1980s "high-tech" boom. What *was* uncertain were the size and persistence of the effects. The potential for ICT capital to increase productivity in specific firms and industries was well-known; Wynne (2002) notes that a computer was *Time* magazine's "Man of the Year" in 1982. And, judged by growth rates, there had been previous "high-tech" capital booms: Gross private investment in information processing equipment and software soared during the mid-1960s, late 1970s and, more briefly, during the early 1980s. Surrounding each episode were both the optimists, arguing that computers would change the world, and the pessimist, skeptical that computers would increase productivity and real output.

It is useful to re-visit the 1980s FOMC meetings to place the 1990s debate in perspective.[31] Productivity growth was a major topic at the May 1983 FOMC meeting.

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[30] Wynne (2002) discusses in detail the time-line of federal funds rate targets during the 1990s in response to incoming productivity data. Thronton (2005) more generally discusses the FOMC's federal funds rate target beginning September 1982.

[31] This section is based on FOMC transcripts publicly available on the Board of Governors web site. To locate all references to "productivity," the transcripts were both visually scanned (that is, read) and searched in Adobe Acrobat. Transcripts for some earlier years on the Board's web site are PDF image-only files, not text searchable. We thank Dan Thornton for making available his OCR versions of these transcripts.

The Board staff was forecasting near-term annual labor productivity growth at a 3-1/2 percent rate, based largely on a cyclical rebound. The staff noted that they had revised upward their trend growth rate for labor productivity to a one percent pace, from a previous ¾ of 1 percent. For 1984, they predicted near-trend increases of 1-1/4 to 1-1/2 percent. Members, including Chairman Volcker, labeled the forecast "pessimistic." At the July meeting, the staff was "just a little over 1 percent," "in the 1-1/4 percent range." At the December meeting, an exchange between President Morris and Board staff economist Joyce Zickler highlighted the problem of discerning trend from cycle in incoming productivity data:

> MR. MORRIS. I have an intuitive feeling that your 1 percent productivity assumption is too pessimistic just because I see so many structural changes that were made in the last three years in terms of reducing staff overhead and in terms of changes in work rules. When we went through the 1970s with a lower rate of productivity growth than we could explain on the basis of the ordinary analytical factors, we got a big negative residual. It seems to me that maybe we will start to see some bounce back: maybe we'll start getting a positive residual. What was the basis for your 1 percent productivity assumption, which I think is 1 percentage point too low?
>
> MS. ZICKLER. At this point in the business cycle we're seeing increases that are largely cyclical in nature. We try as best we can to look through these increases and see what underlying trend that type of behavior would be consistent with. And that's basically how we came up with it. Now, you're right, that during the last recession we saw a lot of shedding of labor, a lot of changes that kept productivity growing—even last year during a period when normally it would decline. So, to some extent, these developments that you talk about could be once-and-for-all changes in the productivity level that wouldn't become embodied in a continued improvement in the growth rate. But to the extent that business is making an attempt to invest in new technology and really change on an ongoing basis some of those undefined things--things that we couldn't define during the '70s very well—then, yes, we could be too pessimistic. I think the coming year will be the critical year for evaluating where we are on this productivity path because generally what shows up in the second year of recovery is a sharp deceleration toward a trend rate of growth. If we keep getting information that tells us that the productivity is doing better than 1 percent, that will firm up the view that perhaps the trend is changing and could be closer to 2 percent or whatever.

Throughout the year, members remained skeptical that trend productivity was not increasing. This exchange between President Roberts and Ms. Zickler at the November 1983 meeting highlights the issues:

> MR. ROBERTS. … On the productivity [issue]. I guess you took into account this major change from manufacturing to services in the 1970s as one of the factors holding back productivity. With services now such a large part of the economy, would that from here on out tend to cause the same or an increased rate of productivity if it stabilized, let's say?

> MS. ZICKLER. The bulk of the research that was done, as we discussed earlier, was unable to pin that down for the 1970s. Most of the research showed that productivity slowed in service industries as well as in manufacturing industries. The pattern of the slowdown was at least the same across different types of industries, so we were unable to pin this productivity slowdown on the growing services sector. Looking ahead and having the services sector be one of the growing sectors, I'm not sure that that should detract from the things that seem to be important in the productivity slowdown. however undefined they may be. There are some technological changes that could affect the services sector as well as manufacturing.
>
> MR. ROBERTS. That really is the point that I was coming to. I think maybe some of the drag in productivity in the services sector is now being overcome. Productivity is coming to the services sector. And if you have lower [productivity in the] manufacturing sector also as [the staff] has here--I'm just saying that I think productivity estimates are too low for the short run anyway.

At this meeting, somewhat more than earlier meetings, FOMC members discussed the linkage between productivity growth and inflation. Indeed, most members seemed concerned with productivity growth via a markup pricing model in which markups were extremely sticky such that more rapid productivity growth both tempered inflation and boosted profits.

At the May 1984 meeting, President Morris and Chairman Volcker noted that the capital- goods boom underway was substantially "…all electronics," and hence augured well for productivity gains. At the July meeting, the staff continued to predict a trend productivity growth rate of 1-1/4 percent. President Morris, however, cited anecdotal evidence that firms were expecting "extraordinarily high productivity" from new capital—and had better be, given the high cost of capital funding. James Kichline, director of the Board's division of research and statistics, explained that the staff's projected 1-1/4 percent trend for the 1980s was a significant increase relative to the staff's estimated trend of 0.6 percent annual growth during the 1970s.

Throughout 1984, members continued to relate anecdotes regarding firms' productivity gains in their districts. Although most of the gains were in manufacturing, some members cited gains in services. Such anecdotes fueled the belief that mis-

measurement plagued the services sector. At the September 1986 meeting, Governor Angell pressed the issue:

> "Productivity in the service sector is low but I don't think we know how to measure it. Productivity in the goods producing sector remains right at the 3.2 percent level that it has been at for some time."

Members continued to press the issue at subsequent meetings, as illustrated by the following exchange at the November 1986 meeting. Chairman Volcker's impatience with official productivity statistics is apparent:

> MR. PRELL [Mike Prell, deputy director of the Board's division of research and statistics]. It seems like whenever I'm up here giving a briefing the same question arises about the productivity figures. I think many of these collective bargaining agreements involve the manufacturing sector where the data would indicate that we have been getting fairly substantial increases in productivity--maybe not as much as the anecdotal evidence for individual companies would suggestbut, on the whole, quite good gains. For this cycle the gains are much more favorable in comparison to past cyclical experience than for the rest of the economy.
>
> CHAIRMAN VOLCKER. More favorable than past cyclical experience?
>
> MR. PRELL. Well, I guess at least as favorable as—
>
> MR. ANGELL. Yes.
>
> MR. PRELL. --previous cycles in contrast to the overall picture. But, as you know, the total for the nonfarm business sector has been less favorable and the data, such as they are, show that in a number of the more service-oriented sectors we just aren't seeingproductivity improvement.
>
> MR. ANGELL. Of course, what this means--and I've had several conversations with our staff over this--is that, with productivity in manufacturing doing what it is and the way we go about measuring it, we have to have negative productivity in the service sector. And that raises the question as to how we measure productivity in the service sector; the fact of the matter is that we really don't. So there is some kind of strange averaging process going on there. I think there's really grave doubt as to what our productivity in the service sector is. But if productivity in the service sector is stronger than we're measuring then that means, of course, that our economy is doing a little better than we are measuring. So there are those two aspects that are very interesting.
>
> CHAIRMAN VOLCKER. You don't think more computers mean less productivity?
>
> MR. ANGELL. No.

At the December 1986 meeting, Governor Angell again raised the argument that aggregate productivity data are mis-measured:

> MR. ANGELL. Jim [James Kichline, director of the Board's division of research and statistics], how much different does productivity look if you differentiate between the service sector and the goods producing sector?

MR. KICHLINE. Well, we don't really have good data, as you know, for well over a year. The evidence that we have suggests that manufacturing productivity is probably rising 3-1/2 to 4 percent. Service sector productivity is just really quite poor. So, we are getting strong productivity gains: that is important in this forecast. In terms of potential growth, we are trying to look at trend productivity for the economy in total, but there is a great deal of variation among sectors.

MR. ANGELL. Then it is possible that we really don't measure productivity in the service sector and don't measure the value of output in the service sector. We just assume productivity is going to be zero in the service sector, and lo and behold it is.

MR. KICHLINE. No, I think there is a little more information than that. Let's say it is open to question but there is a little more information than an assumption of zero.

Resisting member anecdotes, at the November 1989 meeting Mike Prell re-affirmed that the staff's projected trend rate of labor productivity growth is 1-1/4 percent.

As economic activity slowed during 1989 and 1990, productivity tended to be less discussed at FOMC meetings—perhaps because disagreements over projections of the trend growth rate of potential output seemed less important during a recession. In August 1992, as the economy strengthened, a discussion trend productivity arose:

CHAIRMAN GREENSPAN. President Stern.

MR. STERN. Dave [Stockton, deputy director of the Board's division of research and statistics], while we're on this: What is your estimate of potential growth in the economy these days and how do you parcel that out?

MR. STOCKTON. At this point our estimate of potential would be 2 percent with roughly 1 percent in trend productivity and a 1 percent increase in labor input. That's a tad lower than where we were before we saw all the [unintelligible] revisions, which revised output growth down. So, we're just a little below.

CHAIRMAN GREENSPAN. Is there a tendency that that 1 percent might be higher?

MR. STOCKTON. On trend productivity? Yes, that's certainly a possibility, although currently when we're coming out of the business cycle trough—

CHAIRMAN GREENSPAN. We are? [Laughter]

MR. STOCKTON. --it's difficult to pin down what the trend in fact is. The good productivity performance that we've seen thus far in the recovery is not inconsistent with normal cyclical behavior if one were to assume a trend of 1 percent. That is in some sense how we infer what the trend is. But one could certainly say that at this stage we don't know how much of this restructuring is actually accomplishing some underlying improvement in trend productivity and how much of it is just simply using the existing work force more effectively as firms always don in a cyclical recovery. So, there's certainly a possibility that it could be better, but I wouldn't bet on it at this point. If one thinks back to where we were in the early '80s, coming out of that recession there was a tendency, I think, for many people to overestimate the improvement in productivity. There was talk then that the trend had improved to maybe 2 percent or in excess of 2

percent and it turned out to be a disappointment that as we progressed through the decade we didn't see that kind of improvement. So, I think it's always difficult when you see the good increases in productivity early on [in a recovery] to know exactly how much is trend and how much is cyclical.

Finally, at the December 22, 1992 meeting, Chairman Greenspan offered a lengthly discourse on a possible shift in trend productivity growth. It is included here in its entirety because of its value in setting the stage for policy discussions throughout the 1990s:

CHAIRMAN GREENSPAN: One of the more interesting aspects of what is going on at the moment--it's something that a number have alluded to--is that we basically have a productivity-driven recovery, or more exactly arithmetically the gross domestic product increase is largely attributable to the rise in productivity and to a marginal extent to the rise in average hours worked. The outlook for that particular variable is really quite critical to a number of the issues that have been raised around this table. There is an interesting question as to whether, in fact, we can have continued strong growth without employment growth. Obviously, theoretically we can. The question really gets to the issue of whether or not this productivity surge we've been looking at is abnormal or not. It is quite unprecedented in the context of how little economic growth we have had since March 1991.

There are essentially two hypotheses about what those increases are attributable to, both of which could turn out to be right. The first is that the level of output per work hour at the bottom of the recession was quite low relative to the inputs of both physical capital and human capital. In a sense that's saying that the economy was not operating at an efficient level relative to its inputs. In that case, by just tightening up one can very readily reduce labor input and create within a certain range a rise in output per work hour. One presumes that that can continue to increase until we run up to the upper edge of that range, meaning that the existing capital, both physical and human, is being employed at its most efficient levels.

The second possibility here is that the norm of long-term productivity growth … has tilted upward. In that case. we're not looking at 1 percent or slightly more than 1 percent [as the norm], but conceivably all of a sudden something has occurred which has changed the longer-term productivity growth [trend]. Some anecdotal evidence suggests that there is at least something to that. Jerry [Corriganl, I don't know if you remember that breakfast where we had a very interesting representation of manufacturing corporations who were raising the point that this restructuring that is going on had only really begun, which is the same issue that you were getting from the New York [business leaders]. It strikes me that what may be happening--and say "may"--is that we have looked for years and years for the significant impact of productivity growth coming off the major computer input in telecommunications and high-tech capital assets and, as you may recall, we got very little of it. I think the reascm is that we did not have the software. Essentially we could not really employ that degree of computational power without a major upswing in the analytic capabilities in using the equipment. In the last five or six years, or maybe a little longer, there has been a very dramatic increase in applicable software. One need only look at the stock market price of Microsoft to see the market valuation of this particular asset coming on stream. The people Jerry and I were talking to at the breakfast were talking about [unintelligible] systems manufacturing. I remember one of the people there was an old friend of mine from a company called which used to put DC motors into the rolling mills of a lot of the steel operations: that was their market. So, I raised the question: Is the big steel business now

basically heavily DC motors? And he said "We don't even think that way anymore. What we think of is complete computer operating systems of manufacturing." If you go around and speak to people. what you find is that in the last two or three years there has been a major change in the way manufactured goods are created. And if you look~at the data in the nonmanufacturing area, we are finally beginning to see some definite quickening in output per work hour in that area as well.

So, what we may well be looking at, and what the restructuring is essentially all about, is the stripping out of big segments of employment. Companies are literally taking divisions and just wiping them out. A lot of that is directly applicable to the information systems that are created by the telecommunications-computer matrix. That is. a very large part of overhead has been communications overhead, meaning in the extreme form [a situation] where everyone just writes memoranda to each other. But the communications managerial systems have improved very dramatically to the point where people have been washed out of the system at a very rapid rate.

If this is the beginning of something of quite important significance, the question is whether it is in fact saying that our potential GDP is being underestimated. Something may be going on here. The trouble is that we will not be able to know that for a while. It is quite conceivable that part of the problem that we're looking at is that the marginal cost of adding new people is so great at this stage that it may be creating somewhat of an illusion about the relationship between capital and labor: it may be creating an attitude on the part of a number of managers that they just will not hire new people except under duress because the obvious medical costs, employment training, and all the other costs are very large. And the big upswing in the temporary employment rolls is really quite impressive and clearly out of line with what the previous history of temporary employment has been.

So, we may have a technical problem here which is obscuring what is going on and may be making it appear to be a much bigger issue than it is. But what is certainly the case. if the Greenbook GDP figures are right or if those figures are any stronger than that, is that we are going to get one of two scenarios. One is that we will get a very marked increase in actual employment growth, because it's difficult to imagine the average workweek going very much higher than it is. And if we are at the upper ranges of productivity growth, then the arithmetic of the system basically says that it all falls out to increased employment. The alternate scenario is that we are badly missing a major secular change in the productivity trend, in which case this is going to work out somewhat differently. It's not clear to me how it will play out in the sense that we do know that without a significant increase in employment, we will run into problems with how to get consumption continuing to [increase]. especially when the saving rate is as low as it is. And this is a low saving rate despite the fact that we still have significant debt repayment going on. The debt pressures are clearly still there.

I suspect the outlook, therefore, is a bit uncertain because of secular changes that are occurring, and I'm a little hesitant at this point to argue that we have a clear view as to how it will come ol.lt. I'm not saying, incidentally, that there are negative elements in this. There is, however. as pointed out by a number of you and in the excellent memo that the International Division put out, a very clear indication that the rest of the world is in really sad shape. We don't need the published data from foreign statistical agencies to tell us what,.is going on. As a number of you have mentioned, in terms of the general view of the multinational corporations, sometime a couple of months ago the order series for the foreign affiliates of U.S. corporate manufacturers all of a sudden just went "bang." There was a hole and Germany apparently just fell off the cliff. That's true in a lot of discussions. I was a little surprised at the Canadian [situation]. but presumably that's not all that much different. But there is a potentially fairly significant drag coming from the international side, which affects this [outlook] as well.

The discussion continued at the February 2-3, 1993 meeting. Noting 1992's 3 percent increase in labor productivity, members questioned why the forecast expected a rapid decrease to a 1.3 percent pace. In response, Board staff noted that the 1.3 percent pace in fact was an increase from their previous projection of a 1 percent trend growth rate. Little was said regarding productivity at the March meeting except the Chairman's comment that "Productivity is picking up in a fairly substantial way, and I suspect it is basically real." Productivity was little discussed during subsequent meetings until Governor Angell's frustration at the August 1993 meeting:

> Productivity has been a real puzzle for me. Clearly, if your forecast gets really thrown awry you say it's a puzzle; and part of my real economic forecast for [1993] has certainly missed the mark. I Really just don't understand productivity. I don't understand how we can have a decline in productivity for the business sector of 1-1/2 and 2-1/2 percent two quarters in a row when productivity in manufacturing has been rising at 4-1/2 to 5 percent! Somebody is doing very, very poorly; and if anyone knows who it is—who really snuffing on the job--they haven't been spotted yet. So, that is indeed a real puzzle.

At the following meeting in September, Governor Angell noted that the recent revisions to the national income accounts had worsened the productivity-trend puzzle:

> "To make it even worse, the revisions seem to show productivity trends, higher than we thought they were. We've got productivity trends very, very high…"

Chairman Greespan also made clear his suspicion of the incoming data:

> I think the policy questions are less difficult, less a matter of concern. The more I look at the data the more I'm inclined to believe, as some of you have hinted, that there is something wrong with the numbers we are looking at. It's just not credible to me that we can have a significant rise in employment and in hours both from the payroll series and the household series--two measures that are about as independent as one can get of an economic phenomenon—and say that the GDP indicates productivity declined in the first half of this year. Now, I don't know what is going on in the statistical system, but I'm almost certain that out in the real world in an economy that is growing, the thought that we are having declining productivity just doesn't square with my understanding of the real world.
>
> Historically we have had alternate measures of output—for example, gross domestic income. Granted, the income side of the national income accounts is a little more flaky measure--with the proprietor incomes categories and even some of the profitability numbers--than the output side, which is the reason obviously that the output side is used. But if you look at it, you get something that frankly looks a lot more credible. You get a much lower rate of increase in gross real incomes in the second half of last year, or more exactly in the growth of gross domestic income in constant dollars; that grew a lot more slowly than the GDP and it was moderately faster in the first half of this year. I haven't looked to see what happened to the productivity numbers but my suspicion is they were still going

> down a little. I'm inclined to believe that when we look back at this period with the better annualized data, which may be a year or two years from now, it's going to look better because we can't have the unemployment rate declining, the initial claims falling and, as Governor Mullins said, a tight labor market with average hours of work moving up, and have declining productivity. It just doesn't make sense. Something is wrong with the data system, and I suspect—or I hope—that eventually that will get resolved. If you look at the industrial production index and its counterparts in other elements of GDP, it does look as though it was extraordinary even before the revisions; but with the revision we're still getting some evidence that the real part--the goods part--of the GDP may be running somewhat under what we're picking up in the industrial production index. It's a close issue and, frankly, I haven't had a chance to have somebody look at it in the detail that I would look at it. But the numbers just don't square. If that is in fact the case, we may be not all that far from potential here. I'd say the economy is moving [up at a rate] that has to be over 2 percent at this point, maybe 2-1/2 percent. I realize that this may seem to be making the figure look the way I think policy ought to run, but since I don't sense that anybody out there is talking in terms of any radical changes, I won't press this issue.

At the December 19, 1995 FOMC meeting, Chairman Greenspan offered "a broad hypothesis about where the economy is going over the longer term and what the underlying forces are." He argued that anecdotal evidence from industry-level sources suggested that purchases of equipment and software were changing businesses in fundamental ways. He noted the shortcomings of the productivity statistics

> "One would certainly assume that we would see this in the productivity data, but it is difficult to find it there. In my judgment there are several reasons, the most important of which is that the data are lousy."

and emphasized that major technological innovations usually take a long time to have their full impact on productivity as businesses reorganize to take full advantage of the opportunities afforded by the new technology. For monetary policy, he noted:

> "It is unclear exactly how [the restructuring of business to make better use of computer technology] fits into our policy process. But I think it is important to put this point on the table, and I present it as a hypothesis since it is something that we will not be sure is the appropriate assessment of our changing world for probably five to ten years."

For the Chairman, rapid increases in business profits were signaling gains in productivity beyond the gains evident in published data.[32] As Meyer (2004) notes, Chairman

[32] The indicator value of increasing profits as a signal of increased productivity has a long history; see, for example, comments by Edward Boehne during the February 1983 FOMC meeting. The Board staff's productivity trend rate, as of February 1983, was approximately 1 percent, vs. 2-1/2 percent earlier in the post-war period. The Board staff was forecasting actual productivity growth of 2-1/2 percent in 1983 and 1-1/2 percent in 1984, driven by manufacturing with "not as much going on" in the services sector. In the

Greenspan's view of the nascent acceleration in productivity growth was formed largely by both his numerous contacts in the business sector and his abiding belief that the published aggregate data were not correctly measuring the effects of information technological innovations that businesses were claiming to have garnered.

With few exceptions, Greenspan views were discounted by both the Board's staff and his colleagues on the Federal Open Market Committee (FOMC). But the Chairman was not dissuaded. He noted, for example, that available data suggested that the service sector had achieved no productivity gain in twenty years, an unlikely event. If this measurement was wrong, how many more were incorrect? As the discrepancies widened, in 1996 he requested that the Board's economic research staff conduct a project to assess the accuracy of the Bureau of Labor Statistics' published productivity figures.[33] Although that study confirmed the picture painted by the then-current data, subsequent data revisions changed the picture. Later published aggregate data converged to the more rapid growth suggested by the Chairman's anecdotal, firm-level data.

An interesting question is whether "anecdotal evidence" is an adequate basis for formulating national monetary policy. Yet, there was significant evidence supporting the Chairman's views; a number of published studies had explored the growing importance of IT in business. For example, Brynjolfsson and Hitt's (1996) paper had been written in 1993 and presented at a number of workshops, including the Federal Reserve. In their article, they argue that previous studies which had concluded that computers added nothing to total output were flawed because those authors sought to measure the impact

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FOMC transcripts, Board research director Kichline notes that ".. some interesting things happened in 1982. One is that productivity started rising very early. "

[33] See Woodward (2000) for a detailed discussion of this episode and the mechanics of the 1996 internal study, which was subsequently published by Corrado and Slifman (1999).

of computers by searching for excess stock returns in firms with high IT-related investment. In equilibrium, however, efficient markets theory argues that firms wich spend more on IT capital should *not* have higher rates of return on equity than other firms. Rather than compare stocks prices and earnings, they fit an economic production-theory, input-demand model to data collected during five annual surveys, 1987–1991, of several hundred large firms. They conclude that the "…gross marginal product for computer capital averaged 81% for the firms in our sample." Subtracting typical annual depreciation of approximately 30 percent, net annual yields to IT investment, averaged over the five years, were near 50 percent. Dewan and Min (1997) analyzed the same data for 1988-1992 using a more flexible input demand model. They noted that IT capital, for their sample firms, was 2% of total capital outlays in 1982 but nearly 16% by 1994, motivated by a 20% average annual rate of decline in the quality-adjusted price of IT capital from 1960–1992. Their estimated the gross marginal return for their median firm was similar to Brynjolfsson and Hitt (1996).

The above studies of IT capital in large firms were approximately contemporaneous with FOMC deliberations during the early 1990s (especially considering the lag between authorship and publication). While speculative, it seems reasonable that at least some FOMC members had heard similar messages.

Later studies of IT strategies at large firms during 1987–1996 reached similar conclusions. Ramirez and Melville (1998) examined a panel of 517 publicly traded firms.[34] The firms' IT capital stock as a share of tangible assets increased from

[34] Ramirez and Melville (1998) examine large U.S. firms drawn from the *Fortune* 1,000 list. While 1694 firms are observed for at least one year, only 517 firms are observed in all 10 years. Average revenue, profit and number of employees of these firms aligns well with figures for both the Fortune 500 and 1,000 firms. Seventy variables are available for each firm in each year.

approximately 2 percent in 1987 to 8 percent in 1996, and the annual growth rate of IT capital as a share of total tangible capital accelerated to a 46 percent pace during 1992–1994, from 13 percent during 1987–1992. Among these firms, the increase in the average per-firm IT capital stock differed little between manufacturing-sector and service-sector firms—both increased from approximately $20 million in 1987 to $120 million in 1994.

Disaggregating further, however, they found that the service-sector firms had larger IT capital stocks than the manufacturing-sector firms, approximately $160 million per firm in the "transportation, communications, utilities" sector, for example, versus $80 million in the manufacturing-sector firms. Measured relative to corporate revenues (gross output), service-sector firms other than retail and wholesale trade also were more IT-intensive than manufacturing. Finally, measured per employee, services-sector firms were almost *twice* as IT-capital intensive as manufacturing firms (see second Figure below). Gurbaxani, Melville and Kraemer (1998) find that a higher degree of networking within the firm, closely related to the use of PCs, has strong positive returns. Recently, Brynjolfsson and Hitt (2003) revisited the 1987–1994 data to measure the time-profile of returns to IT capital investment. They conclude that first-year returns are small rates, and that returns increase sharply with the length of the measured time interval. Their results reinforce other studies which have found that the greatest rewards from IT investment accrue to firms which re-organize their business practices, a time-consuming process. In a recent review, Melville, Kraemer and Gurbaxani (2004) find even today's business strategy "best practices" inadequate for maximizing organization performance from information technology.

Skepticism regarding a productivity acceleration due to IT investment was apparent in the Boards' February 1997 Humphrey-Hawkins Monetary Policy Report:

> "Growth of output per hour in the nonfarm business sector as a whole picked up in 1996, rising about 1¼ percent over the year according to preliminary data. However, coming after a three-year period in which output per hour changed little, this rise left the average rate of productivity growth in the 1990s a bit below that of the 1980s and well below the average gains achieved in the first three decades after World War II. The sustained sluggishness in measured productivity growth this decade is difficult to explain, as it has occurred during a period when high levels of investment in new capital and extensive restructuring of business operations should have been boosting the efficiency of workers. Of course, measurement problems could be distorting the data…A considerable amount of recent research suggests that growth of output and productivity is in fact understated, but whether the degree of understatement has been increasing over time is less clear."

The *Monetary Policy Report* is a public document, careful and moderate in tone. At the February 4, 1997, FOMC meeting, the Chairman had been somewhat more blunt in response to suggestions that productivity growth had not picked up as much as he asserted:

> "So, the productivity gains implicit in these data [anecdotal reports] are larger than the ones we are getting in the official data. The one thing we know about the official data on productivity is that they are wrong."

Wynne (2002) tracks the gradual acceptance of increased productivity growth through FOMC documents during the 1990s. Commenting on the outlook for inflation at the Minutes of the September 1996 FOMC meeting note that members

> "…observed that the recent behavior of price inflation was a welcome though highly unusual development, given current pressures on resources. The statistical and anecdotal information provided evidence of increasingly tight labor markets that under similar conditions historically had been associated with considerable upward pressure on nominal labor compensation and, in turn, on prices."

and that

> "Standard statistical measures that pointed to relatively limited increases in productivity seemed inconsistent with strong profits as well as with anecdotal reports of sizable gains associated with widespread business restructuring activities and large additions of high-technology equipment to an increasingly efficient capital stock."

In the July 1997 *Monetary Policy Report* testimony, Chairman Greenspan noted:

> "We do not now know, nor do I suspect can anyone know, whether current developments are part of a once or twice in a century phenomenon that will carry productivity trends nationally and globally to a new higher track, or whether we are merely observing some unusual variations within the context of an otherwise conventional business cycle expansion."

Wynne (2002) notes that not until 1998 did indications appear that the FOMC was becoming confident of an increase in trend productivity. In the February 1998 *Monetary Policy Report to the Congress,* the Board staff wrote:

> "Although the average rate of productivity increase since the 1980s still is only a little above 1 percent per year, the data for the past two years provide hopeful indications that sustained higher levels of investment in new technologies may finally be translating into a stronger trend."

In the July 1998 *Report*, the Board noted that productivity growth had picked up—to approximately 1½ percent per year on average over the previous three years, due in part to increases capital deepening and total factor productivity (the latter are obvious, of course, since capital deepening and TFP, by construction, account of most of increases in labor productivity!). The February 1999 *Monetary Policy Report* noted that while transitory factors had contributed to recent performance, technology-related increases in productivity were also important and suggested that some of the gains would be permanent:

> "…reasons for thinking that the trend might have picked up to some degree are becoming more compelling in view of the incoming data. The 1998 gain in output per hour was particularly impressive in this regard, in part because it came at a time when many businesses were diverting resources to correct the Y2K problem, a move that likely imposed a bit of drag on growth of output per hour. Higher rates of capital formation are raising the growth of capital per worker, and workers are likely becoming more skilled in employing the new technologies. Businesses not only are increasing their capital inputs but are also continuing to implement changes to their organizational structures and operating procedures that might enhance efficiency and bolster profit margins."

The minutes of the February 1999 FOMC meeting noted that

> "…the conjuncture over an extended period of strong economic growth, very low rates of unemployment, and the absence of any buildup of inflation could not be explained in terms of normal historical relationships. While temporary factors, such as declining oil prices, had played a role in depressing inflation, the persistence of very low inflation under these conditions most likely also resulted form more lasting changes in economic relationships. These were perhaps best evidenced by the widespread inability of business firms to raise prices because of strong competitive pressures in domestic and global markets and the related efforts to hold down costs, including labor costs. Contributing importantly to the success of those cost-saving efforts were the continued rapid growth of increasingly efficient business capital. The accumulation of such capital evidently had greatly enhanced productivity in a broad range of economic activities."

The July 1999 *Monetary Policy Report* noted that productivity had increased at a 2 percent annual rate since 1995 "…well above the trend of roughly 1 percent per year that had prevailed over the preceding two decades." Again the Board cautioned against interpreting all of the increase as a change in trend, but noted that it may be part of a "…more persistent payoff from a boom in business investment …over the past several years." At the October meeting, the FOMC noted that "A great deal of uncertainty surrounded the behavior of productivity growth going forward", at the December meeting they also noted that "…they saw no indications that the impressive gains in productivity might be moderating." The February 2000 *Monetary Policy Report* noted that the performance of the economy over the course of the year would depend crucially on the course of productivity. The Board noted that many firms were

> "…still in the process of implementing technologies that have proved effective in reorganizing internal operations …[and]…in gaining speedier access to outside resources and markets" while the technologies themselves continued to advance at a rapid pace. As a result, the Board argued that "…a further increase in productivity growth from the average pace of recent years also is possible."

In his comments, Chairman Greenspan noted the

> "… distinct possibility …that the development and diffusion of new technologies in the current wave of innovation may still be at a relatively early stage and that the scope forth further acceleration of productivity is thus greater than is embodied in [the projections of private and government forecasters]."

The July 2000 *Monetary Policy Report* cautioned that

> "…a portion of the very rapid rise in measured productivity in recent quarters may be a result of the cyclical characteristics of this expansion rather than an indication of structural rates of increase…" but also pointed out that "…the acceleration of productivity in the past several years has exceeded the pickup in output growth over the period and, thus, does not appear to be simply a cyclical response to more rapidly rising demand. Rather, businesses are likely realizing substantial and lasting payoffs from their investment in equipment and processes that embody the technological advances of the past several years."

By mid-2000, the US economy had begun the desired slowdown. In the July *Monetary Policy Report,* Chairman Greenspan said

> "…the more important question for the longer-term economic outlook is the extent of any productivity slowdown that might accompany a more subdued pace of production and consumer spending, should it persist. The behavior of productivity under such circumstances will be a revealing test of just how much of the rapid growth of productivity in recent years has represented structural change as distinct from cyclical aberrations and, hence, how truly different the developments of the past five years have been…. So far there is little evidence to undermine the notion that most of the productivity increase of recent years has been structural and that structural productivity may be accelerating."

Interestingly, this "waiting and watching" model for separating cycle from trend is the same test discussed by the Board staff during the 1980s.

6. Conclusions

Since 1995, estimates of the economy's long-run, or structural, rate of labor productivity growth have increased significantly. After having increased at about a 1.4 percent annual rate from 1973 to 1994, the current sustainable pace of labor productivity

growth in the nonfarm business sector is widely believed to be from one-half to 1 percentage point higher.

Recognition during the mid-1990s of the acceleration of productivity was delayed by weaknesses in measuring productivity. Initial aggregate data for 1995 and 1996, for example, showed little increase in measured productivity. Relying on anecdotal evidence, and conviction that the data was incomplete, Federal Reserve Chairman Alan Greenspan thought otherwise. Although both anecdotal observations at individual firms and available data on business investment spending (which suggested that rapidly falling semiconductor and computer prices were encouraging significant capital deepening), not until mid-1997 did revised data for 1995 and 1996 display gains in productivity growth. Our analysis suggests that such measurement delays and revisions are not uncommon.

Our analysis highlights the difficulties in formulating monetary policy using preliminary, incoming data. Policymakers should be—and are—wary about placing too much faith in initial estimates because data revisions often have significantly challenged the perceptions that policymakers previous held in "real time."

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Table 1

Decomposition of Average Labor Productivity Growth for the Business Sector

	Growth for Periods Indicated			
	1949-72	1973-94	1995-2004	1949-2004
	(1)	(2)	(3)	(4)
Output per Hour				
Business	3.23	1.58	3.14	2.55
Nonfarm Business	2.77	1.48	3.05	2.29
Manufacturing	2.58	2.59	5.01	2.98
Durable	2.64	3.02	6.33	3.39
Nondurable	2.83	1.90	3.49	2.56
Nonfinancial Corporate Business	2.61	1.41	3.76	2.25
Output				
Business	4.10	3.18	4.04	3.72
Nonfarm Business	4.22	3.17	4.05	3.77
Manufacturing	3.74	2.51	2.48	3.04
Durable	4.21	2.87	4.18	3.66
Nondurable	3.48	1.90	0.36	2.32
Nonfinancial Corporate Business	5.51	3.25	4.78	4.27
Hours				
Business	0.84	1.57	0.87	1.14
Nonfarm Business	1.41	1.67	0.98	1.44
Manufacturing	1.14	-0.09	-2.40	0.06
Durable	1.53	-0.15	-2.02	0.27
Nondurable	0.63	0.00	-3.02	-0.23
Nonfinancial Corporate Business	2.86	1.81	0.99	1.99

NOTE: Compounded annual growth rates using quarterly data; 1949:Q1 to 1972:Q4; 1972:Q4 to 1994:Q4; 1994:Q4 to 2004:Q4. Data for nonfinancial corporations begins in 1958:Q1

Data for total manufacturing and durable and nondurable manufacturing are on an SIC basis prior to 1987.

SOURCE: Bureau of Labor Statistics

Table 2

Table 2
Major Statistical Revisions Since 1996 and Real-Time Estimates of their Effects

Publication Date	Statistical Series	Major Aspects of Revision	Estimated Magnitude of Revision
Jan-1996	Comprehensive revision of the NIPAs	Switch to chain-weighted price indexes from fixed-weighted price indexes in the NIPAs. Government investment defined differently. New methodology for calculating depreciation of fixed capital.	Revised estimates show real GDP grew at a 3.2 percent annual rate from 1959 to 1984, 0.2 percentage points faster than old estimate. Real GDP growth from 1987 to 1994 was lowered 0.1 percentage point.[1]
Jul-1998	Annual revision of the NIPAs	Updated source data. Methodology changes to expenditures and prices for autos and trucks; improved estimates for several categories of consumer expenditures for services; new method of calculating change in business inventories; some purchases of software by businesses classified as expenses (removed from business fixed investment).	From 1994:Q4 to 1998:Q1 the growth of real GDP was revised 0.3 percentage points higher to 3.4 percent; growth of real fixed investment revised 0.6 percentage points higher to 12.7 percent; growth or GDP price index reduced 0.3 percentage points to 1.8 percent.
Feb-1999	Consumer Price Index	Switch to geometric means estimation to eliminate lower-level bias; affected 61 percent of consumer expenditures.	According to the BLS, this switch will reduced the annual rate of increase of the CPI by 0.2 percentage points per year. According to the CEA, methodological changes to the CPI from 1994 to 1999 reduced the annual rate of increase of the CPI by 0.6 percentage points in 1999 compared with the 1994 estimator.[2]
Oct-1999	Comprehensive revision of the NIPAs	Introduction of CPI geometric weights; classification of software as a fixed investment; incorporated data from the latest 5-year economic census and 1992 benchmark input-output accounts.	From 1987 to 1998, these revisions boosted the annual rate of growth of real GDP by an average of 0.4 percentage points per year.[3]
Jul-2001	Annual Revision to the NIPAs	Updated source data (for example, Census Bureau Annual Surveys); new price index for communications equipment from Federal Reserve Board; monthly data used to calculate GDP converted from SIC to NAICS.	Growth of real GDP during revision period (1998:Q1 to 2001:Q1) reduced from 4.1 percent to 3.8 percent (compared with pre-revision estimates).
Jul-2002	Annual Revision to the NIPAs	Updated source data (for example, Census Bureau Annual Surveys); new methodology for estimating quarterly wages and salaries; new price index within PCE services.	Growth of real GDP during revision period (1999:Q1 to 2002:Q1) reduced from 2.8 percent to 2.4 percent (compared with pre-revision estimates).

Table 2 (Continued)

Jul-2004	Annual Revsions to the NIPAs	Updated source data; only minor changes in methodology for treatment of health care plans for retired military and measurement of motor vehicle inventories.	Growth of real GDP over revision period (2000:Q4 to 2004:Q1) was unchanged at 2.5 percent; growth of real fixed investment in equipment and software revised 0.6 percentage points lower.
Jul-2005	Annual Revsions to the NIPAs	Updated source data; incorporation of Census' Quarterly Services Survey as source for investment in computer software and for consumer spending for services; improved method of calculating implicit services provided by commercial banks. BEA claims these changes will reduce the volatility of the price index for PCE.	Growth of real GDP from 2001:Q4 to 2005:Q1 reduced from 3.5 percent to 3.2 percent. Over the same period, growth of the GDP price index and the core PCE price index were revised 0.2 percentage points higher to 2.2 and 1.7 percent, respectively.

[1]Source: 1996 Economic Report of the President, page 48.

[2]Source: 2000 Economic Report of the President, page 61.

[3]Source: *Ibid* , page 81.

NOTE: Discussion and estimates of annual revisions to the NIPAs were taken from archived reports at their web site, www.bea.gov.

Table 3

Effect of Annual NIPA Revisions on Measured Growth of Labor Productivity, Output, and Hours in the Nonfarm Business Sector

[Pre-and Post-Benchmark figures as published in the BLS *Productivity and Cost Report*]

(Percent Change at a Compound Annual Rate)

	Output Per Hour			**Output**			**Hours**		
NIPA Revision Period*	Initial	Revised	Diff.	Initial	Revised	Diff.	Initial	Revised	Diff.
1994	2.55	2.36	-0.19	3.99	4.12	0.13	1.40	1.70	0.30
1995	1.72	1.68	-0.04	4.70	4.85	0.15	2.87	3.09	0.22
1996	0.83	0.57	-0.26	2.92	2.84	-0.08	2.03	2.28	0.25
1997	0.75	0.88	0.13	3.21	3.33	0.12	2.40	2.44	0.04
1998	1.55	2.06	0.51	4.15	4.76	0.61	2.60	2.64	0.04
1999	2.31	2.60	0.29	4.44	4.74	0.30	2.38	2.42	0.04
2000	3.30	3.30	0.00	5.41	5.51	0.10	2.06	2.13	0.07
2001	3.05	2.28	-0.77	4.28	3.60	-0.68	1.16	1.27	0.11
2002	3.08	2.71	-0.37	2.00	1.44	-0.56	-1.08	-1.27	-0.19
2003	2.87	3.60	0.73	1.56	1.50	-0.06	-1.27	-2.02	-0.75
2004	4.69	4.45	-0.24	4.33	4.23	-0.10	-0.38	-0.23	0.15
2005	3.97	3.68	-0.29	4.76	4.59	0.17	0.76	0.87	0.11
Average Revision:			-0.04			0.01			0.03
Average Absolute Revision:			0.32			0.26			0.19

*** NOTE:** The *NIPA Revision Period* is the nine quarters up to and including the first quarter of the year indicated. The year indicated is the year of publication of the NIPA revision, usually July or August. The 1999 NIPA revision, more extensive than most, incorporated the Oct. 28, 1999, introduction of computer software into business fixed investment. This resulted in revisions back to 1959. Nevertheless, for consistency, the revisions shown here are for the nine quarters ending in the first quarter of the year indicated. (The 1999 revisions to "hours" appeared in the August 5, 1999, *Productivity and Cost Report*.)

Table 4

Initially Published vs Most-Recently Published Growth Rates of Nonfarm Labor Productivity
(quarterly, percent annual rate, 1985:Q3 to 2005:Q1)

Each figure is equal to the initially published growth rate minus the most-recently published growth rate, for the span indicated.

Growth from Preceding Period (quarterly, percent annual rate)

	Output per Hour		Output		Hours	
	Mean Revision	Mean Absolute Revision	Mean Revision	Mean Absolute Revision	Mean Revision	Mean Absolute Revision
Business Sector	0.41	1.82	0.38	1.59	-0.02	1.10
Nonfarm	0.34	1.84	-0.08	1.58	0.12	1.06
Manufacturing	0.04	2.20	-0.07	1.72	-0.07	1.30
Durable	-0.16	2.79	-0.13	2.18	0.05	1.46
Nondurable	0.18	2.34	-0.11	1.85	-0.24	1.40
Nonfinancial Corporate	-0.09	2.05	-0.10	1.85	-0.02	1.06

Growth from Corresponding Period One-Year Earlier (quarterly, percent annual rate)

	Output per Hour		Output		Hours	
	Mean Revision	Mean Absolute Revision	Mean Revision	Mean Absolute Revision	Mean Revision	Mean Absolute Revision
Business Sector	0.26	1.05	0.24	0.83	-0.02	0.64
Nonfarm	0.02	1.02	-0.05	0.82	0.04	0.64
Manufacturing	-0.16	1.46	-0.19	0.94	-0.01	0.78
Durable	-0.36	1.91	-0.27	1.42	0.11	0.85
Nondurable	-0.13	1.15	-0.36	0.78	-0.21	0.85
Nonfinancial Corporate	-0.04	1.15	-0.05	1.08	-0.02	0.72

SOURCE: Bureau of Labor Statistics, *Productivity and Cost*.

Table 5

Change in CBO Projections of Structural Labor Productivity Growth and Potential Real GDP Growth Since 1997

Projection Publication Date [a]	Projection Period	Average Annual Growth Rate of Labor Productivity [b]	Average Annual Growth Rate of Potential Real GDP (Output)
		Estimate	Estimate
2005	2005-2015	2.4	2.9
2004	2004-2014	2.2	2.8
2003	2003-2013	2.2	2.9
2002	2002-2012	2.2	3.1
2001	2001-2011	2.7	3.3
2000	1999-2010	2.3	3.1
1999	1998-2009	1.8	2.5
1998	1997-2008	1.5	2.3
1997	1996-2007	1.1	2.1
Addenda:			
Actual Growth Rate	1973-1996	1.0	3.0

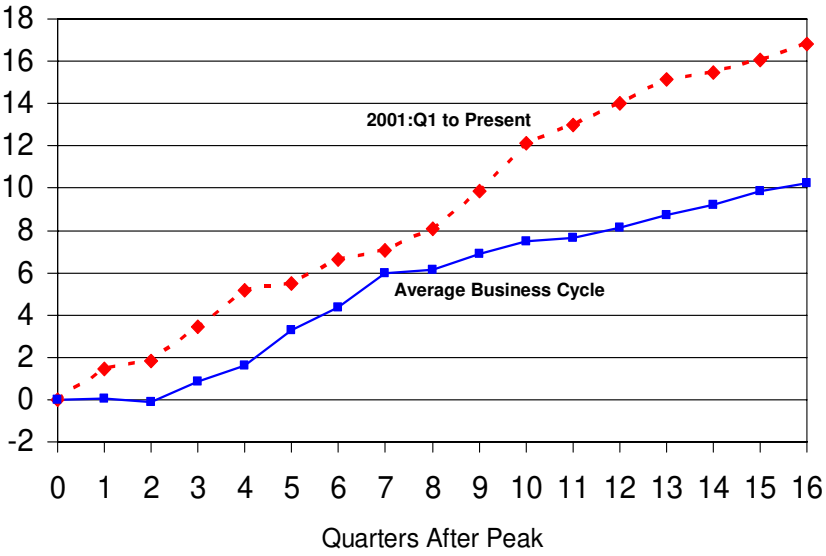
SOURCES: *The Budget and Economic Outlook*, Congressional Budget Office, various years. For example, 2005 estimates taken from Table 2-2, p. 45 (January 2005 *Outlook*).

a. CBO projections were published in January and completed in November or December of the previous year.
b. Nonfarm Business Sector

Figure 1

Nonfarm Labor Productivity

Percent Change from Peak Value

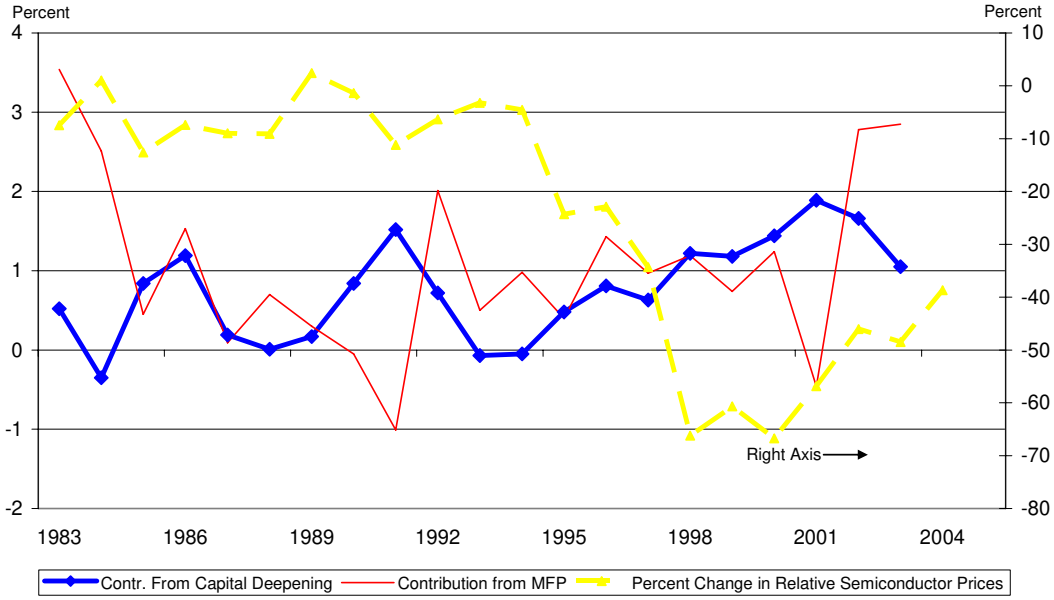


The NBER's business cycle dating committee on November 26, 2001, selected the first quarter of 2001 as the cyclical peak. The business-cycle average is calculated as the mean of the nine NBER post-World War II business cycles, excluding the 1980 recession and the 2001 recession.

Figure 2

Figure 2

Contributions to Labor Productivity Growth and Relative Changes in Semiconductor Prices



SOURCE: Productivity data, Dan Sichel (via e-mail); semiconductor prices, Bureau of Labor Statistics

Figure 3

Labor Productivity Growth, Nonfarm Business Sector
Compound annual rate, percent, quarterly data

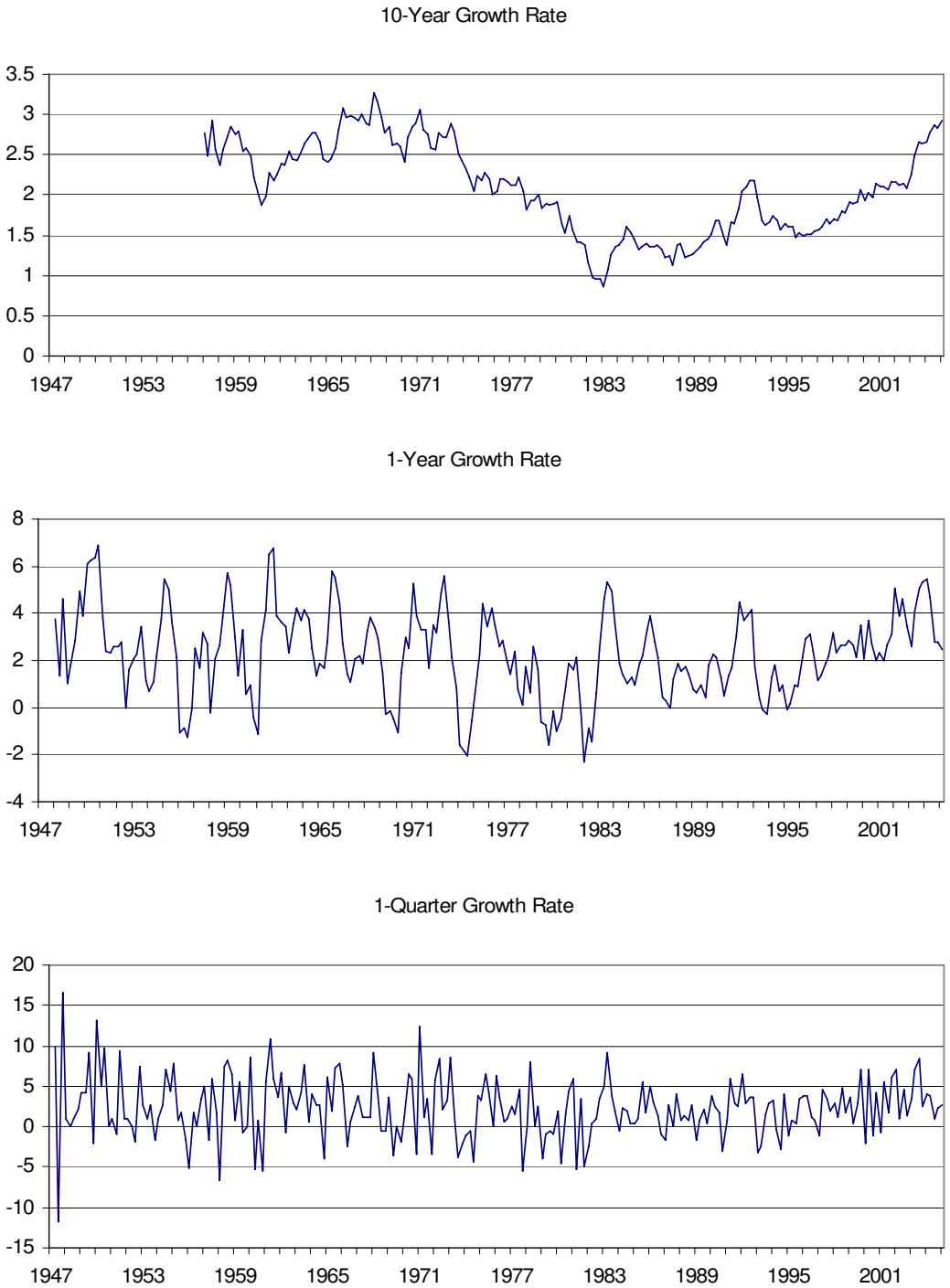


Figure 4

Figure 4

Real-Time Estimates of 1973 Labor Productivity Growth

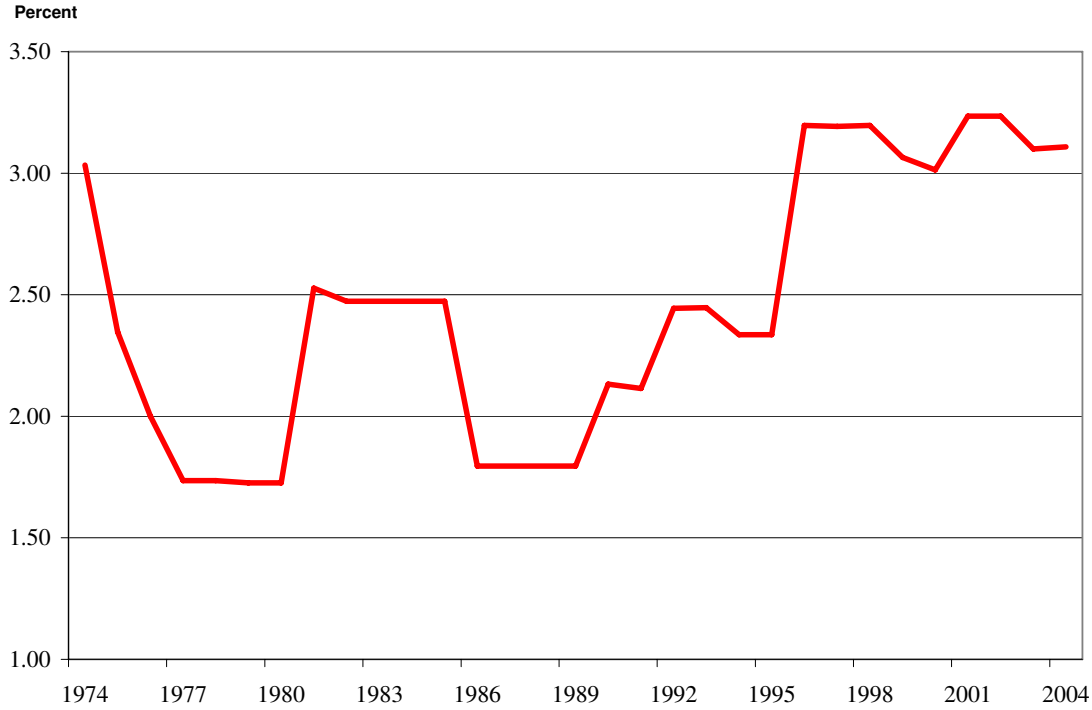


Figure 5

Labor Productivity Growth, 1995

(year over year percent change, quarterly; monthly figures, Jan 1995 - Dec 2000)

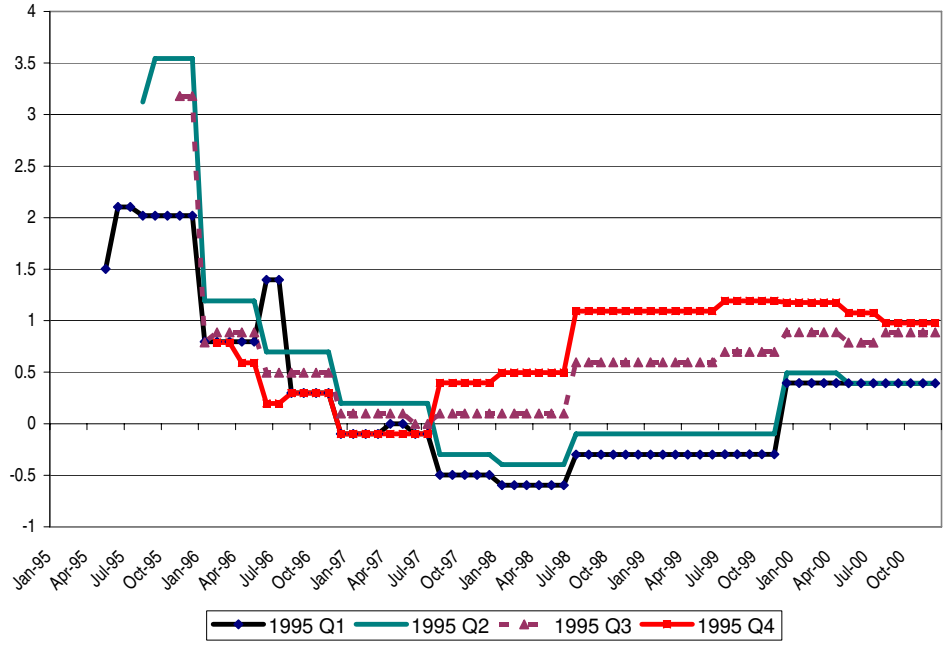


Figure 6

Labor Productivity Growth, 1996

(year over year percent change, quarterly; monthly figures, Jan 1996 - Dec 2000)

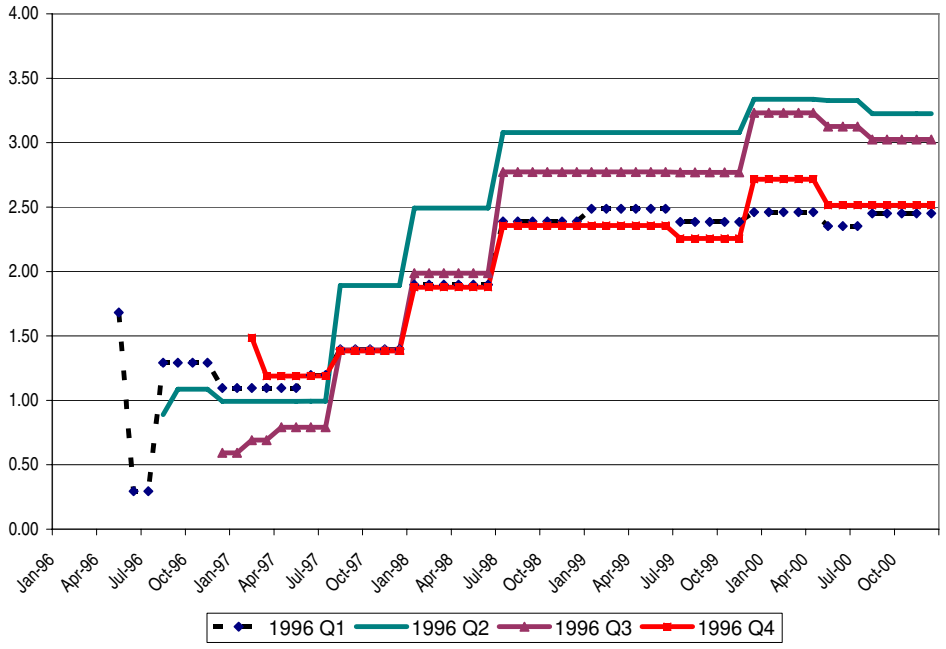
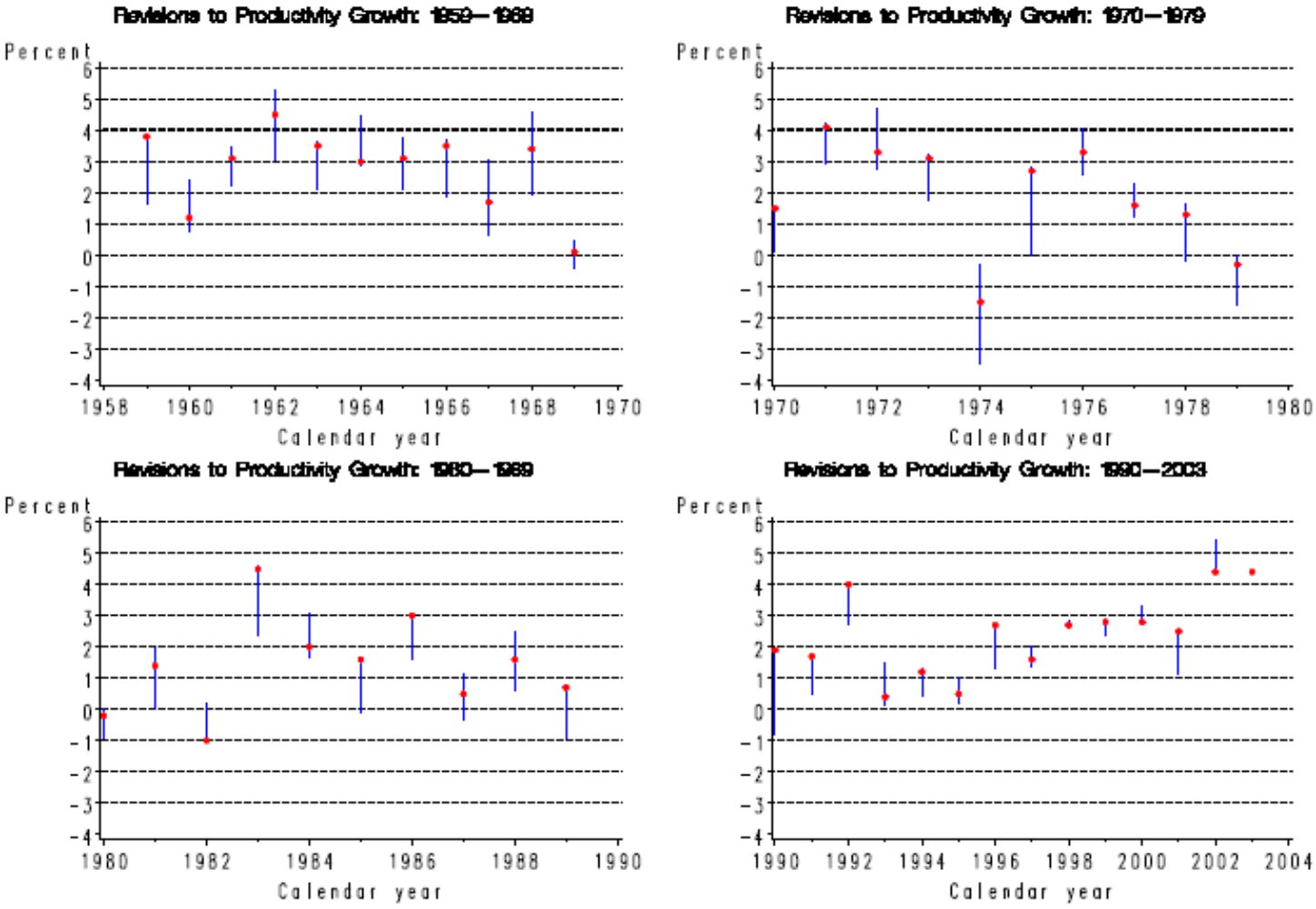


Figure 7

Revisions to Estimates of Labor Productivity Growth, 1959-2003



SOURCE: Council of Economic Advisers, various issues

Figure 8

Figure 7

Greenbook Labor Productivity Forecasts, 1997-2000

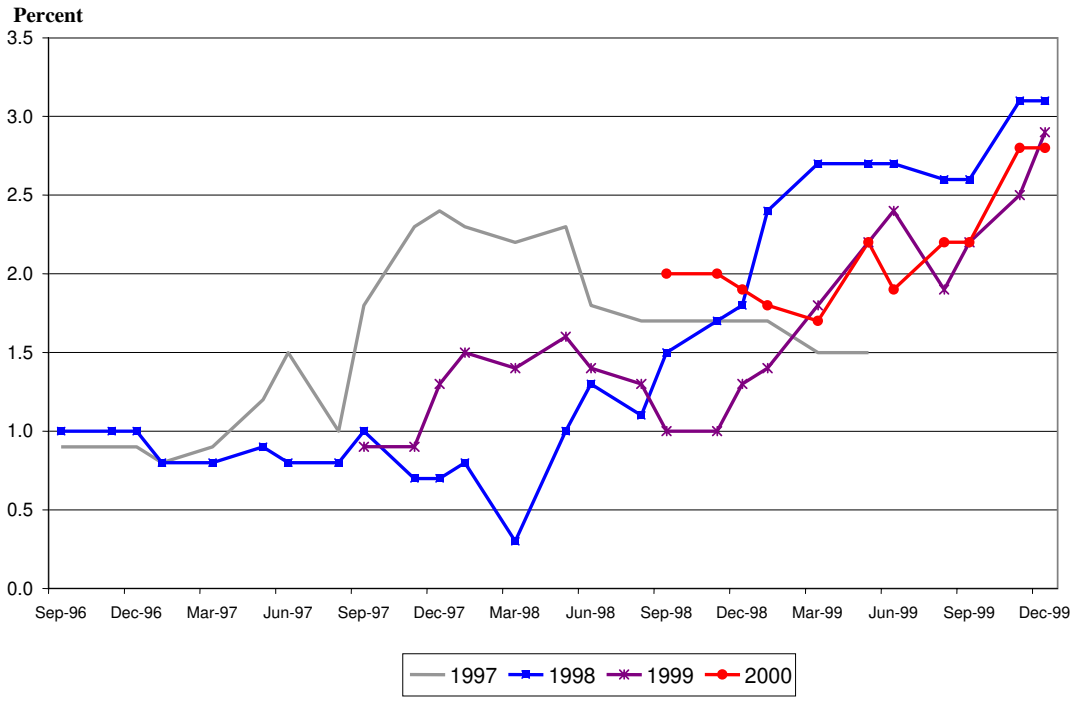


Figure 9
Nonfarm Business Sector Labor Productivity Growth Estimates
(Four-Quarter Growth Rate)

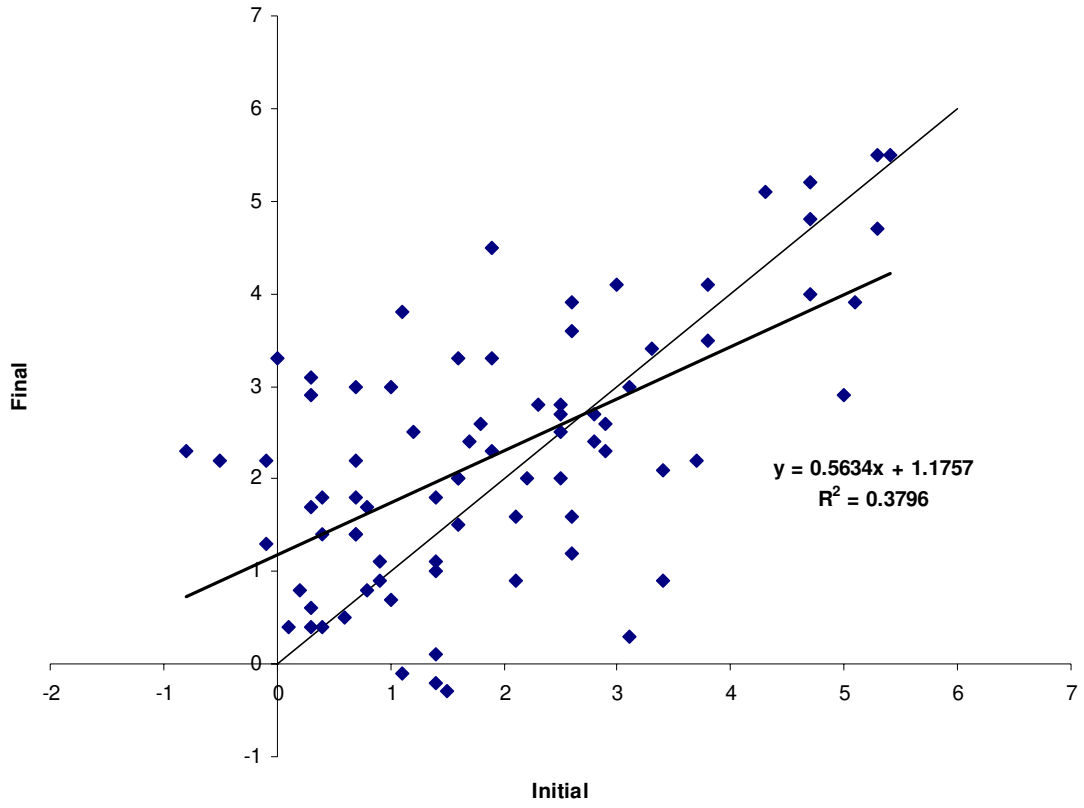


Figure 10
Nonfinancial Corporate Business Labor Productivity Growth Estimates
(Four-Quarter Growth Rate)