Preliminary – Comments Welcome

The Sources of the Second Surge of U.S. Productivity and Implications for the Future

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Abstract

This paper analyzes the sources of U.S. productivity growth through 2004 and compares the first surge in productivity growth after 1995 to the second surge after 2000. We find important differences with the production and use of information technology (IT) equipment and software dominating the first surge, while non-IT factors were more important during the second. Our base-case projection for private sector productivity growth for the next decade remains at 2.6 percent per year, which is close to the 1995-2000 average, but a substantial decline from the 2000-2004 pace. We emphasize the substantial range of uncertainty by presenting an optimistic productivity projection of 3.2 percent per year and a pessimistic projection of only 1.4 percent.

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I. Introduction

Few analysts predicted the acceleration of aggregate productivity growth during the recession and recovery in the U.S. after 2000. The first surge of productivity growth after 1995 was similarly unexpected, but is now well-documented with a consensus view that the production and use of information technology (IT) were driving forces.[1] The sources of the second surge of productivity growth since 2000, however, remain to be documented and explained, particularly given the bursting of the NASDAQ bubble, September 11 2001, the 2001 recession, corporate scandals, and a major slowdown in investment, all of which were expected to slow U.S. productivity growth.

Figure 1 illustrates these two surges of productivity by plotting labor productivity growth in the U.S. nonfarm business sector (on a four-quarter basis and averages for three longer periods) for 1973:Q4 to 2005:Q4. Annual productivity growth initially increased by 1.1 percentage points after 1995 and then increased a further 0.7 percentage points after 2000.[2] To provide another perspective, Figure 2 compares the U.S. experience to that of the European Union (EU), measured by GDP per hour, and shows very divergent paths as the EU continued to slow while the U.S. accelerated.

The main goal of this paper is to document and compare the proximate sources of the first productivity surge after 1995 to the second surge after 2000. There has been relatively little work on this and the underlying sources remain mysterious. Gordon (2003) estimates a dynamic productivity model that includes cyclical factors and finds that his model cannot explain the increase in productivity growth after the 2001 GDP trough. Van Norden (2005) uses structural break tests and concludes that the evidence is in fact stronger for a productivity break in 2001 than in the mid-1990s. van Ark and Inklaar (2005) attribute the divergence between the U.S. and the EU to the relatively strong performance of market services in the U.S., while Stiroh (2006b) shows that the second surge originated in a different set of industries from the first and that the link with IT-intensity has weakened.

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[1] See Jorgenson, Ho and Stiroh (2005) and the references given there. In this paper, productivity refers to output per hour worked unless otherwise indicated.
[2] It could be argued that the second surge began after 2001, but the 2001 recession makes it difficult to identify a precise starting point. Data are from BLS (2006).

Our primary conclusion is that the sources of productivity growth are quite different. As has been documented exhaustively, the first surge after 1995 was driven by IT-related forces. The contribution of IT total factor productivity (TFP) and IT capital deepening, for example, accounted for about 60% of productivity growth from 1995-2000 and most of the acceleration when 1995-2000 is compared to 1973-1995. In sharp contrast, these two IT forces accounted for only 30% of productivity growth from 2000-2004 and declined in relative importance after 2000. The acceleration in aggregate productivity after 2000 reflects other factors such as non-IT capital deepening and non-IT TFP growth, both of which increased markedly.

We use the new productivity estimates to update our medium-term projections of productivity growth for the U.S. private economy from Jorgenson, Ho, and Stiroh (2004).[3] Our base-case estimate is that productivity will grow about 2.6 percent per year over the next decade. This is similar to both our earlier projections and the experience for 1995-2000, but incorporates a modest shift in the sources of projected productivity away from IT factors. Our estimates are quite similar to those provided by the Congressional Budget Office (CBO, 2006) and the Council of Economic Advisors (CEA, 2006), both of which present medium-term projections of about 2.5 percent.

We conclude that the outlook for productivity growth remains strong by historical standards, although the torrid pace since 2000 is unlikely to continue. An obvious interpretation is that the second surge of productivity at least partially reflects normal cyclical dynamics, cautious hiring by firms, and competitive forces that increased pressure to improve productivity and efficiency (Gordon (2003), Stiroh (2006a)). As suggested by Sichel (2003), these changes are likely to have a level impact, but not to increase the underlying trend growth. The most recent data, in fact, suggest that productivity growth may already be approaching a more sustainable path as nonfarm business productivity averaged 2.5 percent per year since 2003:Q4. These data, of course, are for a relatively short span and are subject to revision, but our base-case estimates, as well as those of CBO and CEA, remain relatively optimistic and there is no indication of a return to the "productivity slowdown" of the 1970s and 1980s.

[3]Note that these estimates are for the private economy, while the lower estimates in Jorgenson, Ho, and Stiroh (2006) refer to the full economy, which includes the government sector.

II. Recent Productivity Trends

The Bureau of Labor Statistics (BLS) is the source of "headline" productivity estimates for the business, nonfarm business, and manufacturing sectors of the U.S. economy and the most recent estimates end in 2005:Q4 (BLS (2006)). These data, plotted in Figure 1, show that productivity growth accelerated after 1995 and then accelerated again after 2000. To be precise, productivity growth increased from 1.45 percent for 1973:Q4-1995:Q4 to 2.53 percent for 1995:Q4-2000:Q4 to 3.19 percent for 2000:Q4-2005:Q4.[4] These two surges of productivity motivate the paper.

Figure 1 also highlights the cyclical nature of productivity growth, which typically slows when the economy enters recession and accelerates afterward. The 2001 recession follows this pattern, but the decline is not as great and the recovery is stronger and has lasted longer. To show this, we compare productivity performance around the 2001 recession to other recessions in Figure 3.[5] This comparison highlights the strength of productivity growth in recent years. Nonfarm productivity was 11.6 percent higher three years after the beginning of the 2001 recession, compared to the 4.6 percent gains for the average recession from 1973 to 2000 and 7.2 percent for the average recession from 1947 to 2000.

An obvious and important question is whether the recent strength of productivity during the second surge of aggregate productivity is likely to be sustained. One interpretation is that the recent strength primarily reflects a set of temporary factors linked to a normal cyclical recovery as the economy exited the 2001 recession, cautious hiring by firms, and increased competitive pressures to improve productivity. Aggregate hours worked in the nonfarm business sector, for example, declined by 0.3 percent per year since 2000:Q4 after rising 2 percent per year during the first surge of productivity in the late 1990s. This is striking and suggests an important cyclical difference in the most recent period.

An alternative set of explanations is that these gains could reflect the delayed returns or spillover benefits to earlier investments like IT, continued technological progress, or other types of capital accumulation. These types of gains might be expected to be longer lasting. As a first

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[4]These nonfarm business sector estimates are average annual growth rates, calculated as log differences.

[5]The estimates for 1973-2000 normalize the productivity series at the beginning of each recession and average the productivity level across four recessions, while the estimates for 1947-2000 average across nine recessions. These estimates differ from those in Jorgenson, Ho, and Stiroh (2004), due to revisions in the BLS data.

step in sorting out these alternative explanations, we compare the sources of economic growth over these periods and for the two productivity surges.

III. Explaining U.S. Productivity Growth

We employ standard growth accounting techniques to quantify the proximate contributions to the growth in productivity from increased inputs of labor and capital services, as well as residual growth of total factor productivity (TFP), defined as output per unit of both capital and labor inputs. This section briefly outlines our methodology, data sources, and empirical estimates. Methodological details are given in Jorgenson, Ho, and Stiroh (2002).

a) Growth Accounting

Average labor productivity (ALP) is defined as the ratio of output to hours worked. Under assumptions of constant returns to scale and competitive factor markets, the growth of ALP can be decomposed into three sources. The first is capital deepening, defined as the increase in capital services per hour worked. The explanation is that workers become more productive if they have more and better capital with which to work. Examples include an accountant with a faster computer or a manufacturing worker with a more sophisticated, numerically-controlled, machine tool.

The second source of labor productivity growth is labor quality, defined as labor input per hour worked. This reflects changes in the composition of the workforce. As firms substitute workers with more experience and education for the less skilled, average labor productivity rises. The third source is total factor productivity (TFP) growth, which reflects the labor productivity growth not attributable to capital deepening or labor quality gains. This is often associated with improvements in technology, but also includes changes in utilization rates, reallocations of resources among sectors, increasing returns to scale, and changes in unmeasured inputs.

The standard framework is extended in two ways to highlight the important role that information technology (IT) plays in the U.S. economy. First, economy-wide TFP growth can be allocated between gains in the IT-producing industries and gains in the rest of the economy. This allows us to quantify technological progress in the production of IT equipment and software, i.e., the ability to produce faster and more powerful computers at lower prices. Second, capital deepening can be decomposed into the part that reflects more intensive use of IT capital, such as computer hardware, software, and telecommunications equipment, and the part resulting from investment in other types of capital.

This implies the following sources of productivity equation:

$$(1)\quad \Delta \ln y = \bar{v}_{K_n} \Delta \ln k_n + \bar{v}_{K_{IT}} \Delta \ln k_{IT} + \bar{v}_L \Delta \ln L_Q + \bar{w}_n \Delta \ln A_n + \bar{w}_{IT} \Delta \ln A_{IT}$$

where y is labor productivity or output per hour, k_n is non-IT capital per hour worked, k_{IT} is IT capital per hour worked, L_Q is labor quality (defined as the difference between labor input and hours), A_n is TFP growth outside of IT-production, and A_{IT} is TFP growth in IT-production. Each v represents the input share of the subscripted input and each w represents the share of the subscripted output in aggregate output. A bar over the shares indicates two-period average shares. Each element on the right-hand side of Equation (1) is a contribution to labor productivity growth.

As a practical matter, we employ the price dual of productivity to generate estimates of TFP growth in the production of IT assets. The intuition is that declines in relative prices for IT goods reflect fundamental technological change and productivity growth in the IT-producing industries. We weight these relative price declines by the shares in output of each of the IT investment goods in order to estimate the contribution of IT production to economy-wide TFP growth. We calculate the contribution of non-IT TFP as the residual TFP growth after removing the IT contribution.

b) Data

Our output estimates are based on data from the U.S. National Income and Product Accounts (NIPA), published by the Bureau of Economic Analysis (BEA). The BLS productivity estimates are focused on the private business sector; here we include the entire private economy by also including the services provided by residential housing and consumer durables. Jorgenson, Ho, and Stiroh (2006) provide estimates for the full economy including the government sector.

Our capital input estimates are based on the Fixed Asset accounts published by BEA. These accounts present business and government investments and consumer durable purchases for the U.S. economy, including detailed asset classes, such as computers, office buildings, and 1-to-4 family homes. We employ a broad measure of capital that includes fixed assets owned by businesses and households, as well as land and inventories. Our prices for capital services use asset-specific values for price changes, service lives, and depreciation rates for each type of asset.

Our labor data incorporate the decennial Censuses of Population for 1960-2000, the annual Current Population Surveys (CPS), beginning in 1964, as well as labor statistics compiled by BLS and presented in the NIPA. We take total hours worked for domestic employees directly from the NIPA, self-employed hours worked for the nonfarm business sector from the BLS, and self-employed hours worked in the farm sector from the Department of Agriculture. Labor input is a quantity index of hours worked that captures the heterogeneity of the workforce. We classify workers by sex, employment class, age, and education levels and weight the hours for each type of worker by labor compensation. Labor quality growth reflects the difference between the growth rates of the compensation-weighted index of labor input and an index of hours worked.

c) Empirical Results

Table 1 presents the growth of output and allocates this growth between hours worked and labor productivity. We examine the period 1959 to 2004, and four sub-periods 1959-1973, 1973-1995, 1995-2000, and 2000-2004.[6] We are particularly interested in comparing the two productivity surges and an important issue is the appropriate baseline for comparison. Table 2 uses the "productivity slowdown" era from 1973-1995 as the baseline and compares both the first surge for 1995-2000 and the second surge 2000-2004 to that period. We are also interested in how the sources of growth differ after 2000, so we also compare 2000-2004 directly to 1995-2000.

Private output grew 3.60 percent per year for 1959-2004 with considerable variation across periods from 2.90 percent for 2000-2004 to 4.77 percent for 1995-2000. Perhaps most striking is the sharp slowdown in hours growth since 2004 as hours growth fell from 2.09 percent per year for 1995-2000 to -0.47 percent per year for 2000-2004. The sluggish growth of hours has been widely discussed and had led to considerable debate about the nature of "jobless recoveries" and the dating of the 2001 business cycle.[7] In contrast, labor productivity continued

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[6]Computer and software investment data begin in 1959 and 2004 is the last year for which complete data are available.

[7]The NBER Business Cycle Dating Committee, for example, pointed to the gap between output and employment growth in 2002 and early 2003 as a major concern in dating the end of the 2001 recession See the memo from the NBER Business Cycle Dating Committee from October 2, 2003 at http://www.nber.org/cycles/recessions.html.

to accelerate, rising from 1.51 percent per year for 1973-1995 to 2.68 percent for 1995-2000 to 3.36 for 2000-2004.[8]

The remainder of Table 1 reports the growth accounting decomposition of average labor productivity growth described in Equation (1). For the full period 1959-2004, ALP grew at 2.21 percent per year. Capital deepening made the greatest contribution of 1.17 percent, followed by total factor productivity growth of 0.78 percent and labor quality growth of 0.27 percent. This ranking also holds for each sub-period and highlights the leading role of investment, as the composition of capital steadily shifted toward a greater role for information technology equipment and software.

We now turn to the changes in the sources of productivity reported in Table 2. We begin with the first surge after 1995 and show the now familiar result that IT played a critical role. IT TFP and IT capital deepening contributed 0.34 and 0.61 percentage points, respectively, which accounted for more than 80 percent of aggregate increase in productivity growth. Clearly, IT played a dominant role in the first productivity surge. Other forms of capital deepening and labor quality growth made insignificant contributions, while non-IT TFP contributed 0.24 percentage points. This reflects an increase from the 1970s and 1980s when non-IT TFP growth was essentially flat, but was small relative to the IT contribution.

It is useful to summarize the standard interpretation of the economic forces that drove these developments. The story begins in the IT-producing industries that make information technology equipment and software. Rapid technological progress epitomized by "Moore's Law," the doubling of computer chip density every 12-24 months, has allowed each generation of new equipment to readily outperform prior generations.[9] As a consequence, the performance of IT has improved even as prices have fallen. This is captured in the high rates of TFP growth in IT-production. In response to the spectacular price declines for IT investment, firms have quickly substituted IT assets for other productive inputs. Massive investment in IT, about one-third of nonresidential fixed investment in 2000, led to the large contribution of IT capital deepening to labor productivity growth.[10]

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[8]Note that these estimate differ from the official BLS data reported in Figure 1 because we use annual data, our analysis ends in 2004, and we include consumer durables and residential capital services flows.
[9]A more detailed discussion of Moore's Law is presented by Jorgenson, Ho, and Stiroh (2005).
[10]This share reflects investment by businesses in computers, software, and communications equipment.

The productivity surge after 2000, however, appears quite different. When we compare the most recent period 2000-2004 to the same 1973-1995 baseline, the data show an attenuated contribution from IT. Labor productivity growth was much stronger, so the smaller IT TFP and IT capital deepening contributions accounted for only 20 percent of the aggregate increase. The majority of the increase in productivity relative to the productivity slowdown era reflects other forms of capital deepening and TFP growth outside of IT-production.

The final column of Table 2 directly compares the first surge in productivity to the second by reporting the difference between 2000-2004 and 1995-2000. Over this period, average labor productivity growth increased by 0.68 percent per year, but the contribution of both IT TFP and IT capital deepening declined. Non-IT TFP and non-IT capital deepening made substantial positive contributions that account for all of the aggregate gains. Labor quality continued its slow decline as demographic trends slow the rate of growth of quality-adjusted hours.

While the impact of IT has declined, we emphasize that the IT forces remain relatively large sources of growth in the post-2000 period. IT investment, for example, is less than 5 percent of aggregate output, but the two IT channels accounted for about 30 percent of the productivity growth since 2000 (Table 1). It is only when looking at the second surge of productivity, i.e., the change in the growth rate after 2000, that the IT contribution turns negative, which can be interpreted as a return to more sustainable growth rates after the IT-boom of the late 1990s.[11]

We conclude that IT remains an important source of productivity growth, but that other factors drove the post-2000 surge of productivity growth. A closer look at the investment and capital numbers suggests the increase in capital deepening was largely due to slow hours growth, rather than particularly rapid accumulation of capital. Nonresidential investment, for example, decline by 0.9 percent per year for 2000-2004, which is considerably slower than the long-run average growth of 6.2 percent for 1959-2000. This combination suggests that this capital deepening contribution is likely to be temporary as employment growth returns to trend.

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[11]This slowdown is also apparent in the underlying data. The growth of quality adjusted prices of IT equipment, for example, fluctuated from -3.5 percent per year for 1973-1995 to –8.6 for 1995-2000 and then to -4.6 for 2000-2004. Our methods for estimating the IT TFP is based on the price dual, so those TFP estimates mirror the price declines. Similarly, real investment in IT equipment fluctuated from 16.6 percent to 22.2 to 2.1 for the same periods.

Non-IT TFP is measured as a residual (aggregate TFP, which is itself a residual, less the IT component), so it is hard to provide a clean interpretation as the changes likely reflect many factors. One plausible explanation is that the most recent gains reflects factors like increased competitive pressures and normal cyclical dynamics, which suggests that these gains are not likely to be sustained. Alternative possibilities are that this reflects the productive benefits of other forms of technological progress outside of IT-production, the general purpose technology (GPT) nature of IT as it facilitates subsequent innovation, or gains from other types of unmeasured capital input like investment in research and development, organizational change, and other internal innovations.[12]

IV. Projecting Productivity Growth

The future of productivity growth is a critical issue for the U.S. economy, but a key challenge is to distinguish permanent changes from temporary shocks. Projections require assumptions about technological progress and substitution among different types of investment and workers that are difficult to quantify. We now discusses our methodology, present our empirical results, and compare our estimates to estimates by the Congressional Budget Office (CBO), Council of Economic Advisors in the Economic Report of the President (CEA), and Board of Trustees of the Social Security Administration (SSA).

a) Methodology and Data

We make two key assumptions that are consistent with the experience of the U.S. over time periods longer than a typical business cycle. First, output and the reproducible capital stock are projected to grow at the same rate. This smoothes fluctuations like the investment boom of the late 1990s and the investment bust during the 2001 recession. Second, hours worked are projected to grow at the same rate as the labor force, which implies that the unemployment rate, labor force participation rates, and hours per worker remain constant. These assumptions are appropriate for projections of the potential growth of output, but would obviously be unsuitable for short-run forecasting of output and productivity growth.

[12] See Corrado, Hulten, and Sichel (2006) for a discussion of the prevalence and importance of intangible capital. Note that their estimates do not attribute the first surge of productivity after 1995 to intangible capital, but it remains to be determined if it played a role in the second surge.

We transform our basic growth accounting identity in Equation (1) to construct a framework for projecting output and productivity growth, conditional on the projected growth of the remaining sources of economic growth as:

$$(2)\quad \begin{aligned} \Delta \ln y &= \frac{\bar{v}_K \Delta \ln K_Q - \bar{v}_K (1-\bar{\mu}_R)\Delta \ln H + \bar{v}_L \Delta \ln L_Q + \bar{w}_{IT} \Delta \ln A_{IT} + \bar{w}_n \ln A_n}{1-\bar{v}_K \bar{\mu}_R} \\ \Delta \ln Y &= \Delta \ln y + \Delta \ln H \end{aligned}$$

where y is labor productivity, K_Q is capital quality (defined as the difference between capital input and capital stock, H is hours, and L_Q is labor quality. Each v represents the input share of the subscripted variable and each w represents the output share of the subscripted output. u_R is the share of reproducible capital in total capital and we assume that non-reproducible capital, land and inventories, do not grow.[13]

Calibration of Equation (2) require projections of the output shares of capital and labor, the share of IT output in total output, the share of reproducible capital stock in total capital, capital quality growth, labor quality growth, and TFP growth. Some of these variables can be projected with some confidence, while others involve much greater uncertainty. We present a single value for the variables we consider relatively easy to project - labor quality growth, growth in hours, and the shares of capital, reproducible capital stock, and IT output. For the variables considered more difficult to project - IT-related TFP growth, non-IT TFP growth, and capital quality growth - we present base-case, pessimistic, and optimistic scenarios in order to emphasize the uncertainty inherent in the projections.

We first discuss the variables held constant across all three scenarios. For growth in hours worked and labor quality, we construct our own projections of demographic trends, based on the demographic model of the Bureau of Census. This breaks the population down by individual year of age, as well as by race and sex. Our estimates suggest that hours growth will be about 0.66 percent per year and that growth in labor quality will be 0.07 percent per year for the next decade. Both are marked down relative to our earlier projections, due to a later time period and the introduction of more recent Census population estimates.

The capital share of output fluctuates, but does not show an obvious trend over the past 40 years, so we assume it remains constant at 42 percent, the average for 1959-2004. Similarly, the fixed reproducible capital share in total capital exhibits no trend and we assume it remains constant at 81 percent, the 1959-2004 average. We also assume the IT output share stays at 4.6 percent, the average for 1995-2004. This may be conservative, since IT has increased in relative importance.

For the variables that vary across scenarios – IT-related TFP growth, non-IT TFP growth, and capital quality growth – we rely on technology expertise as well as the historical record. Our base-case scenario incorporates data from the period 1990-2004, combining periods before and after the growth acceleration dating from 1995. The optimistic scenario assumes the patterns of 1995-2004, which include both surges of productivity growth, will persist, while the pessimistic case assumes that the economy reverts to 1973-1995 averages.

For IT-related TFP growth, 1995 marked an acceleration of the pace of technological progress that can be seen in the increased pace of IT price declines and faster TFP growth in the IT-producing industries. Jorgenson (2001) argues that this shift was triggered by a much sharper acceleration in the decline of semiconductor prices that can be traced to a shift in the product cycle for semiconductors in 1995 from three years to two years as competition intensified.[14] As noted above, however, IT-related prices have slowed since 2000 and a critical question is whether this reflects a permanent or transitory development is critical in gauging the likely speed of TFP gains in IT-production, but there is considerable uncertainty.

The 2004 edition of *The International Technology Roadmap for Semiconductors*, a detailed evaluation of semiconductor technology performed annually by a consortium of industry experts, projects a return to three-year product cycles.[15] Our base-case scenario averages the two-year and three-year cycles observed in the 1990s and projects TFP growth for each of the IT components from data for 1990-2004, which yields IT-related TFP growth of 9.45 percent.

Our optimistic projection assumes that the two-year product cycle for semiconductors continues, so that IT-related TFP growth reflects rates for 1995-2004 and continues at 10.70 percent per year. Our pessimistic projection assumes the semiconductor product cycle reverts to the slower pace of 1973-1995, so IT-related productivity growth equals 8.28 percent per year. In all three cases, the contribution of IT to aggregate TFP growth reflects the 1995-2004 average output share of each IT component.

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[13] Additional details about our methodology are presented in Jorgenson, Ho, and Stiroh (2002).
[14] The product cycle refers to the time between new model introductions.
[15] See International Technology Roadmap for Semiconductors, 2004 Edition, http://public.itrs.net.

The TFP contribution from non-IT sources is more difficult to project because the post-1995 performance has been so uneven. We present a range of assumptions consistent with the U.S. historical experience. Our base case uses the average contribution from the period 1990-2004 and assumes a contribution of 0.52 percentage points for the intermediate future. This assumes that the myriad factors that drove TFP growth through 2004 will continue – factors such as innovation, resource reallocations, and technological progress, coming either from increased competitive pressures or as manna from heaven. Our optimistic scenario assumes that the contribution for 1995-2004 of 0.70 percentage points per year will continue for the intermediate future, while our pessimistic case assumes that the U.S. economy will revert back to the slow-growth period from 1973-1995 when this contribution averaged only 0.15 percent per year. We emphasize the considerably uncertainty here by recalling the wide variation in non-IT TFP after 1973 shown in Table 1.

The final variable is the growth in capital quality, which reflects the shift towards assets with shorter service lives and high depreciation rates such as IT equipment and software. A key difficulty is that the boom of the late 1990s and the bust afterward are both unsustainable. Our base case uses the average rate of capital quality growth of 1.75 percent for 1990-2004. Our optimistic projection combines the unsustainably high capital quality growth of the late 1990s with the slowdown during the recession of 2001 and the recovery that followed. As a result, we assume capital quality growth continues at the rate of 2.13 percent for 1995-2004, as firms continue to substitute toward relatively inexpensive IT assets. Our pessimistic scenario assumes that the growth of capital quality reverts to the 0.85 growth rate for 1973-1995.

b) Productivity Projections

Table 3 combines the components of our projections and presents the three alternative scenarios. The top panel shows the projected growth of output and labor productivity. The second panel reports the five factors that are held constant across scenarios: growth of hours and labor quality and shares of capital reproducible capital stock, and IT output. The bottom panel reports the three factors that vary across scenarios: TFP growth in IT production and the implied contribution, the TFP contribution from other industries, and capital quality growth.

Our base-case scenario puts economy-wide labor productivity growth at 2.57 percent per year and output growth at 3.23 percent per year for the next decade. Projected productivity growth is in line with the 1995-2000 experience, but falls short of our estimates for 2000-2004 primarily due to a substantial decline in non-IT TFP and capital deepening. Output growth faces the additional drag of slower growth in hours. These projections reflect the slowdown in the pace of technological progress in semiconductors and put the contribution of IT-related TFP growth about equal to 1995-2004 as the semiconductor industry returns to a three-year product cycle. Slower growth is partly offset by a larger IT output share. Non-IT TFP growth also makes a smaller contribution than the full post-1995 period and substantially slower than the 2000-2004 experience.

Our optimistic scenario puts labor productivity growth at 3.18 percent per year and output growth at 3.83 percent per year, due to the assumption of continued rapid technological progress. In particular, the two-year product cycle in semiconductors is assumed to persist for the intermediate future, which drives rapid TFP growth in the production of IT equipment and software, as well as continued substitution toward IT assets and rapid growth in capital quality. In addition, non-IT TFP growth continues its rapid growth after 1995. Productivity growth is more rapid than during 1995-2004, but still falls short of the strong performance since 2000.

Finally, the pessimistic projection of 1.35 percent annual growth in labor productivity assumes that many trends revert to the sluggish growth rates of 1973-1995 and the three-year product cycle for semiconductors begins immediately. The substantial share of IT implies that labor productivity growth will be close to the rates of the 1970s and 1980s when labor productivity averaged 1.5 percent per year for 1973-1995 even with projected demographic trends.

Our base-case projection suggests that the U.S. productivity resurgence will continue, but at the more moderate pace seen for 1995-2000 and not the truly outstanding growth rates seen afterward. Moreover, it is unlikely to revert to the sluggish pace of the 1970s and 1980s. This optimism reflects the observation that the fundamental drivers of the productivity gains like technological progress in information technology, a growing share of IT-production, and a more competitive and deregulated economy remain firmly in place.[16] These positive effects, however, are likely to be moderated by demographic developments that will lead to a slower growth of labor input. Finally, our estimates imply that a substantial portion of the post-2000 gains were transitory in nature and are not expected to continue over the next decade.

[16]See Baily (2002) for a detailed discussion of the structural changes in the U.S. economy that contributed to stronger productivity growth.

c) Alternative Projections

The trend of future economic growth is obviously critical for a wide range of public policy and private sector issues and considerable effort has been expended in this area. Within the U.S. federal government alone, for example, medium-growth projections are presented on a regular basis by the Congressional Budget Office (CBO), the Council of Economic Advisors ((CEA) through the Economic Report of the President, and in the annual report by the Board of Trustees of the Social Security Administration (SSA).[17] Given the uncertainties we have emphasized, it is not be surprising that there is considerable divergence among estimates and that the estimates are frequently, and often substantially, revised. To provide some context for our results, we compare our estimates with other recent projections and then discuss the evolution of the detailed projections made by CBO.

Table 3 reports estimates of the ten-year growth rate of private output to be about 3.2 percent per year, reflecting 0.7 percent growth in hours and 2.6 percent growth in labor productivity. This is similar to the most recent projections by CBO (2006, Table 2-2), which estimates potential private output growth to be 3.2 percent per year for 2006-2016. This reflects 0.8 percent potential labor force growth and 2.4 percent potential growth in labor productivity. The CEA (2006, Table 1-2) estimates are also similar, with a projection of nonfarm business productivity growth of 2.6 percent per year of 2005:Q3-2011:Q4. Finally, SSA (2005, Table V.B1) is the most pessimistic with an estimate of 1.7 percent productivity growth for the full economy (GDP per hour worked) for 2006-2016. While nonfarm business productivity growth has generally outpaced that for the full economy, the implied SSA estimate for business productivity growth is still quite pessimistic.

We emphasize that we are not criticizing any of the government agencies or questioning their methodology. Rather, these comparisons are made in order to highlight the inherent uncertainty in any projection exercise, including our own. Nonetheless, our overall conclusion is one of cautious optimism. The point estimates reported in Table 3 suggest productivity growth over the next decade that is relatively rapid by historical standards, but we acknowledge the high degree of uncertainty and potential for abrupt reversals due to macroeconomic shocks.

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[17]See Stiroh (1998) for a review of these approaches. We do not consider the projections in the Analytical Perspectives of the Office of Management and Budget separately because they are virtually identical to those in the Economic Report of the President.

V. Conclusions

The strength and resiliency of U.S. productivity growth since 1995 continues to surprise economic analysts. Despite a series of negative shocks that began with the bursting of the NASDAQ bubble in 2000 and continued through the current spike in energy prices, productivity growth has remained strong and has even accelerated in a second surge after 2000. Indeed, the U.S. economy has not enjoyed such a lengthy period of sustained productivity growth in three decades.

Our estimates show the critical importance of IT in the first surge of U.S. productivity after 1995. These gains come from both technological progress in the industries that produce IT equipment and software and continued substitution towards relatively cheap and highly productive IT assets in the industries that use IT intensively. Since 2000, however, the further acceleration of productivity growth reflects broader gains in total factor productivity growth outside the IT-producing industries and other forms of capital deepening.

A critical question is whether the most recent gains are transitory in nature due to business cycle and competitive dynamics or are more indicative of deeper structural changes. This will likely be the subject of considerable research and our projections suggest that much of the recent gains are likely to be temporary. We estimate that U.S. productivity growth is likely to remain strong over the medium-term, but will slow relative to the extremely rapid pace enjoyed since 2000. This is a natural evolution as the economy moves toward a more sustainable path and widely anticipated demographic trends unfold. There is considerable uncertainty in these projections, however, as future productivity growth depends critically on factors like the evolution of semiconductor technology and business investment patterns that are difficult to predict. Nonetheless, there is little evidence to suggest that the technology-led productivity resurgence is over or that the U.S. economy will revert to the slower pace of productivity growth of the 1970s and 1980s.

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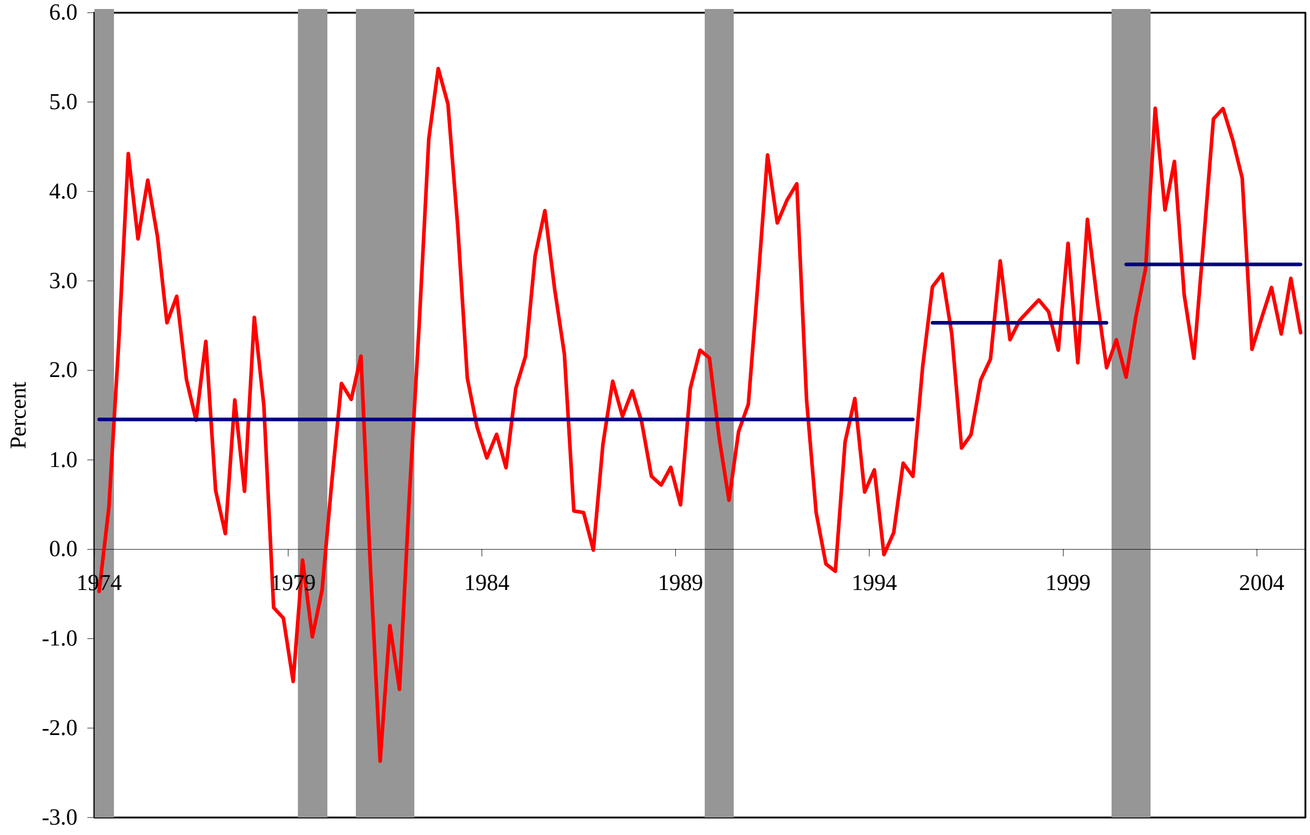
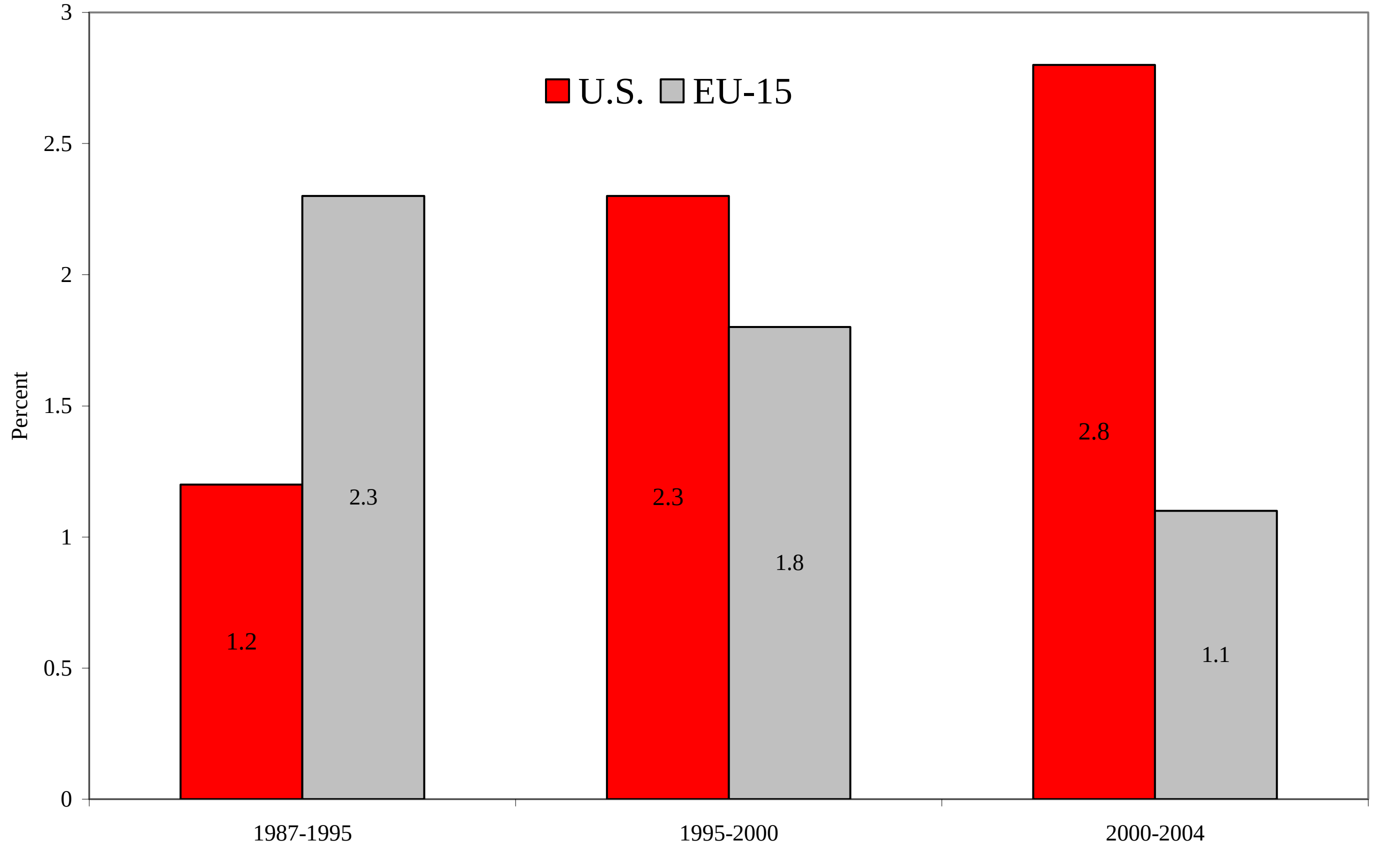
Figure 1: U.S. Productivity Growth

U.S. Nonfarm Business Sector, 1973:Q4-2005:Q4



Note: Data are four-quarter growth rates from BLS, March 7, 2006. NBER recession periods are shaded.

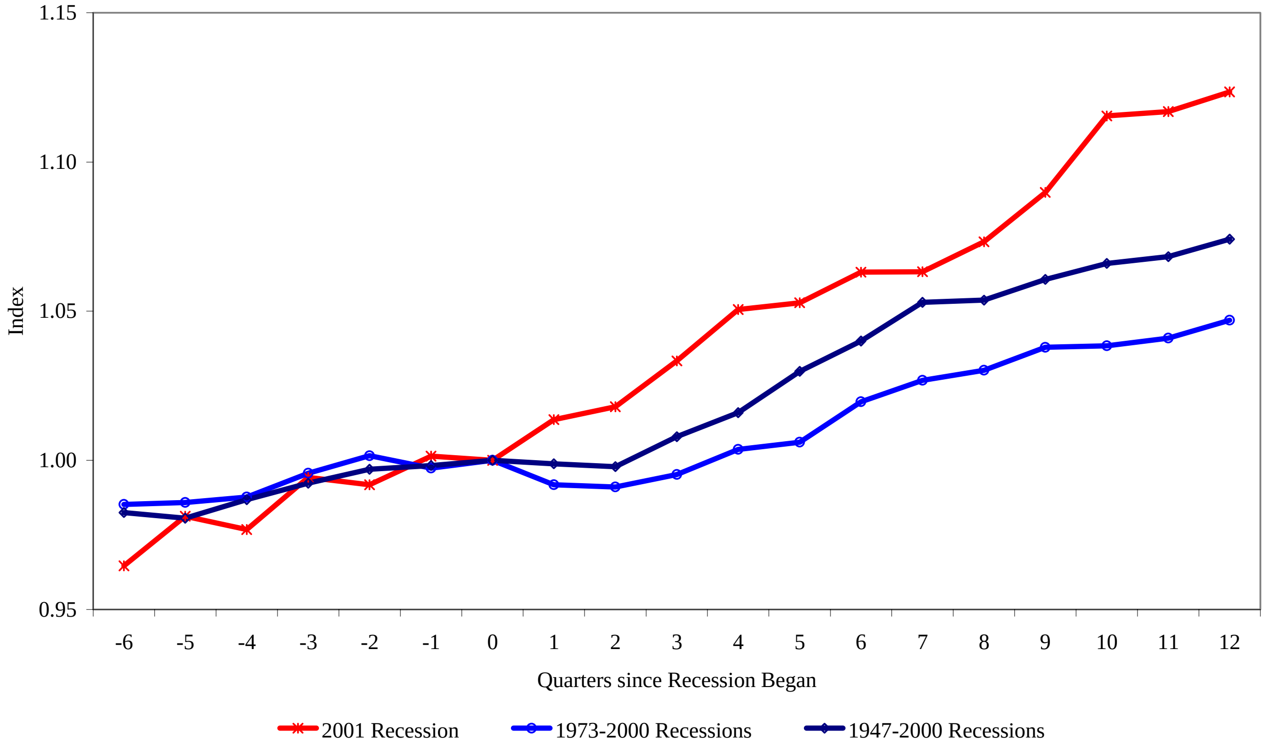
Figure 2: U.S. Productivity is Accelerating, while EU Slows



Note: van Ark and Inklaar (2005), Table 2. Productivity is defined as GDP per hour worked. All figures are average annual percent growth.

Figure 3: Productivity over the Business Cycle

2001 Recession vs. Average of Earlier Recessions



Note: Productivity series are normalized to equal 1.0 at the beginning of each recession. 1973-2000 Recessions averages over the four recessions during that period, while 1947-2000 Recessions averages over the nine recessions during that period. Data are for the nonfarm business sector from BLS, March 7, 2006.

Table 1: Sources of U.S. Output and Productivity Growth
1959-2004

	1959-2004	**1959-1973**	**1973-1995**	**1995-2000**	**2000-2004**
Private Output	3.60	4.18	3.08	4.77	2.90
Hours Worked	1.38	1.36	1.57	2.09	-0.47
Average Labor Productivity	2.21	2.82	1.51	2.68	3.36
Contribution of Capital Deepening	1.17	1.40	0.85	1.49	1.73
Information Technology	0.43	0.21	0.40	1.01	0.66
Non-Information Technology	0.74	1.19	0.45	0.48	1.07
Contribution of Labor Quality	0.27	0.33	0.26	0.21	0.16
Total Factor Productivity	0.78	1.10	0.40	0.98	1.47
Information Technology	0.25	0.09	0.25	0.58	0.39
Non-Information Technology	0.53	1.00	0.15	0.40	1.08
Share Attributed to Information Technology	0.31	0.11	0.43	0.60	0.31

Notes: Data are for the U.S. private economy. All figures are average annual growth rates. A contribution of an input reflects the share-weighted growth rate. Capital is broadly defined to include business capital and consumer durables. Information technology includes computer hardware, software, and communications equipment. Share Attributed to Information Technology is the average contribution of information technology capital deepening plus the average contribution of information technology total factor productivity divided by average labor productivity for each period.

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Table 2: Changes in the Sources of Productivity Growth

	1995-2000 less 1973-1995	2000-2004 less 1973-1995	2000-2004 less 1995-2000
Average Labor Productivity	1.17	1.85	0.68
Contribution of Capital Deepening	0.64	0.88	0.24
Information Technology	0.61	0.26	-0.35
Non-Information Technology	0.03	0.62	0.59
Contribution of Labor Quality	-0.05	-0.10	-0.04
Total Factor Productivity	0.58	1.07	0.49
Information Technology	0.34	0.15	-0.19
Non-Information Technology	0.24	0.92	0.68
Share Attributed to Information Technology	0.81	0.22	

Notes: All figures are average annual growth rates taken from Table 1. Share Attributed to Information Technology is the average contribution of information technology capital deepening plus the average contribution of information technology total factor productivity divided by average labor productivity for each comparison period.

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Table 3: Output and Labor Productivity Projections

	Projections		
	Pessimistic	**Base-case**	**Optimistic**
		Projections	
Private Output Growth	2.00	3.23	3.83
Average Labor Productivity Growth	1.35	2.57	3.18
		Common Assumptions	
Hours Growth	0.66	0.66	0.66
Labor Quality Growth	0.07	0.07	0.07
Capital Share	0.42	0.42	0.42
Reproducible Capital Stock Share	0.81	0.81	0.81
IT Output Share	0.05	0.05	0.05
		Alternative Assumptions	
TFP Growth in IT	8.28	9.45	10.70
Implied IT-related TFP Contribution	0.38	0.44	0.49
Other TFP Contribution	0.15	0.52	0.70
Capital Quality Growth	0.85	1.75	2.13

Notes: In all projections, hours growth and labor quality growth are from internal projections for 2005-2015, capital share and reproducible capital stock shares are for 1959-2004 averages, and the IT output shares is the 1995-2004 average. The pessimistic case uses 1973-1995 average growth of IT-related TFP growth, non-IT TFP contribution, and capital quality growth. The base-case uses 1990-2004 averages, and the optimistic case uses 1995-2004 averages.

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