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Will the U.S. Productivity Resurgence Continue?

Dale W. Jorgenson, Mun S. Ho, and Kevin J. Stiroh

U.S. productivity growth has accelerated in recent years, despite a series of negative economic shocks. An analysis of the sources of this growth over the 1995-2003 period suggests that the production and use of information technology account for a large share of the gains. The authors project that during the next decade, private sector productivity growth will continue at a rate of 2.6 percent per year, a significant increase from their 2002 projection of 2.2 percent growth.

The unexpected resurgence of U.S. productivity growth that began in 1995 is by now well documented and widely understood. A consensus has emerged that a large portion of the acceleration through 2000 can be traced to the sectors of the economy that produce information technology (IT) or use IT equipment and software most intensively.[1] What is surprising observers at present, however, is the strength of U.S. productivity since the end of the 2001 recession. This development is less well understood and has important implications for our understanding of U.S. productivity trends now and in the future.

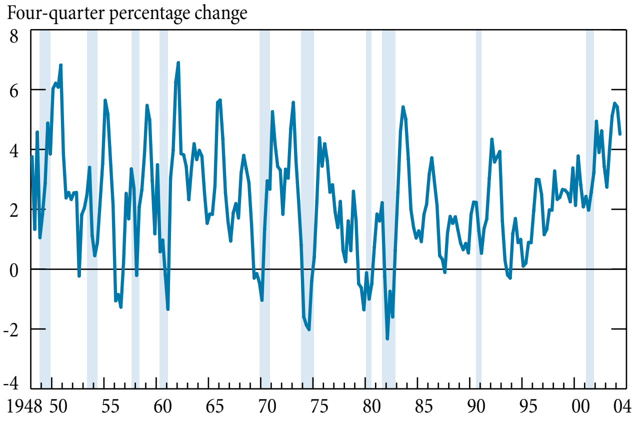
In this edition of *Current Issues*, we seek to shed light on the recent performance of U.S. productivity growth. We begin with a comparison of U.S. productivity growth during the 2001 business cycle and earlier cycles. We then extend through 2003 our earlier analysis of the sources of productivity growth and document the changing factors that explain the robust performance in recent years. Finally, we use our findings to update our medium-term projections for U.S. labor productivity growth for the U.S. private economy.

We project labor productivity growth of 2.6 percent per year for the next decade, a significant increase from our earlier projection of 2.2 percent. Moreover, we identify important changes in the underlying sources of growth. On the positive side, the continued strength of technological progress and the importance of investment in IT equipment and software suggest higher trend productivity growth. On the negative side, the aging of the U.S. labor force continues to act as a drag on productivity advances as the growth in labor quality slows. On net, these developments are favorable for the U.S. economy and support the view that the technology-led productivity revival will continue.

Recent Productivity Trends

The Bureau of Labor Statistics (BLS) is the official source of data on U.S. labor productivity (output per hour worked) for the business, nonfarm business, and manufacturing sectors of the U.S. economy. Recent BLS estimates (U.S. Department of Labor 2004), released in October 2004 for the period through second-quarter 2004, show that productivity growth since 1995 has been more than twice the average of the previous two decades (Chart 1). To be precise, productivity growth increased from 1.5 percent per year in the period from fourth-quarter 1973 to fourth-quarter 1995 to 3.1 percent per year in the period from fourth-quarter 1995 to second-quarter 2004.[2]

Chart 1
U.S. Productivity Growth
U.S. Nonfarm Business Sector, 1947:4-2004:2

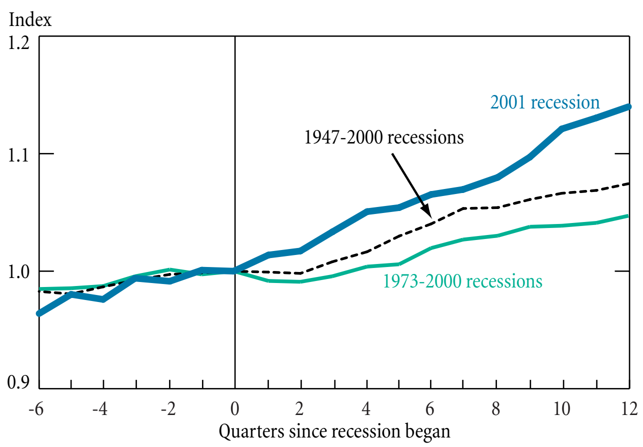


Source: U.S. Department of Labor, Bureau of Labor Statistics.

Note: The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

This sharp acceleration in productivity growth in recent years suggests a faster trend growth rate. Between the first quarter of 1969 and 2002, for example, there was no eight-year period in which productivity growth exceeded 3.0 percent. While the post-1995 period includes the boom of the late 1990s, it also includes the NASDAQ collapse in 2000, the 2001 recession, the September 11 terrorist attacks, an investment bust, corporate accounting scandals, the war in Iraq, and rising oil prices. The increasing strength of productivity through this period is nothing short of astonishing.

Chart 2
Productivity Growth over the Business Cycle
2001 Recession Compared with Averages of Earlier Recessions



Source: U.S. Department of Labor, Bureau of Labor Statistics.

Notes: Productivity series are normalized to equal 1.0 at the beginning of each recession. The thin green line represents average productivity growth over the four recessions in the 1973-2000 period; the dashed line represents average productivity growth over the nine recessions during the 1947-2000 period.

The resilience of productivity growth is also evident in its behavior around business cycle changes. In the 2001 recession, as in earlier downturns, productivity growth slowed at the onset of the economy's decline and accelerated afterwards. Significantly, however, the drop-off in productivity in 2001 was not as large as it had been in earlier recessions and the productivity recovery was much stronger (Chart 1). A closer examination of productivity performance around recent recessions confirms this finding (Chart 2): Three years after the 2001 recession began, nonfarm productivity had grown 13.1 percent, compared with post-recession gains of only 4.6 percent for the average recession from 1973 to 2000 and 7.2 percent for the average recession from 1947 to 2000.

The strength of U.S. productivity after 2001 puzzled many analysts of the business cycle. The Business Cycle Dating Committee of the National Bureau of Economic Research, for example, pointed to the gap between output and employment growth in 2002 and early 2003 as a major problem in dating the end of the 2001 recession.[3] This divergence obviously reflects strong underlying productivity growth.

Explaining U.S. Productivity Growth

We employ standard growth accounting techniques to decompose the growth of productivity into its components, or sources. Specifically, we quantify the proximate contributions of increased inputs of labor and capital services and other factors. This section briefly outlines our methodology, data sources, and empirical estimates.[4]

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 idea is that workers become more productive if they have more or better capital (equipment, structures, or land) with which to work—a faster computer for an accountant, say, or a more sophisticated numerically controlled machine tool for a manufacturing worker. The second source of labor productivity growth is a gain in labor quality, defined as an increase in labor input per hour worked. Labor quality reflects changes in the composition of the workforce: as firms shift their hiring toward workers with more experience and education, for example, average labor productivity rises. The third source is total factor productivity (TFP) growth, which reflects all labor productivity growth that is not attributable to capital deepening or labor quality gains. TFP growth is often associated with technological progress but also reflects changes in utilization rates, reallocations of resources among sectors, increasing returns to scale, and measurement error.

This framework can be extended to highlight the two channels through which information technology influences productivity growth. First, economywide TFP growth can be decomposed into the portion reflecting gains in the IT-producing industries and the portion reflecting gains in the rest of the economy. This allows us to quantify the technological progress in the production of IT equipment and software—for example, the ability to produce faster and more powerful computers at lower prices.[5] Second, aggregate capital deepening can be decomposed into the portion that reflects more intensive use of IT capital equipment such as computer hardware, software, and telecommunications equipment, and the portion that reflects investment in other types of capital.

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). We examine a more comprehensive measure of output than the one used in the official labor productivity statistics published by the BLS.[6]

Our capital service estimates are based on the BEA's Tangible Wealth Survey, which reports business investment and consumer durables purchases for detailed asset classes such as computers, office buildings, and one-to-four-family homes. We employ a broad measure of capital that includes fixed assets—buildings and equipment—owned by businesses and consumer durables assets owned by households, as well as land and inventories. The prices of capital and consumer durables services use asset-specific values for asset price changes, service lives, and depreciation rates for each type of business asset and consumer durable.

Our labor data are drawn from the population censuses for 1970, 1980, and 1990, the annual Current Population Survey sponsored by the BLS, and the NIPA. We take total hours worked for private domestic employees from the NIPA and self-employed hours worked for the business sector from the BLS. Labor input is a quantity index of hours worked that takes into account the heterogeneity of the workforce, classifying workers by sex, employment class, age, and education level. Labor quality growth reflects the difference between the growth in labor input and the growth in hours worked.

Empirical Results

Table 1 begins with the growth of private output and shows the breakdown into the growth in hours and labor productivity (rows 1-3). We examine the 1959-2003 period and three subperiods: 1959-73, 1973-95, and 1995-2003.[7] We are particularly interested in the U.S. growth resurgence that began after 1995, so we also report the difference between the average growth in 1995-2003 and 1973-95.

For the 1959-2003 period, output grew 3.58 percent per year. The post-1995 increase in output growth was 0.84 percentage point, from 3.06 percent per year for 1973-95 to 3.90 percent for 1995-2003. This increase reflects a gain in average labor productivity growth of 1.57 percentage points, partly offset by a decline in the growth of hours worked of 0.73 percentage point. Note that our data include the 2001 recession and the sluggish employment recovery that followed.

Average labor productivity growth is broken down into its sources in rows 4-10 of Table 1. For the full 1959-2003 period, ALP increased 2.21 percentage points per year. Capital deepening made the largest contribution, accounting for 1.21 percentage points of the total increase. Total factor productivity was next, contributing 0.74 percentage point, and labor quality followed with a contribution of 0.26 percentage point. This ranking, which holds for each subperiod and the post-1995 acceleration, underscores the importance of investment and capital allocation for productivity growth.

The table's final column highlights the key role that the two IT channels played in the U.S. growth resurgence. Of the 1.57 percentage point increase in ALP growth after 1995, 0.86 percentage point was due to capital deepening and 0.80 percentage point due to faster TFP growth, with a small decline in labor quality growth of –0.09 percentage point. IT production accounted for more than 35 percent of the increase in aggregate TFP, far exceeding the 5 percent share of IT goods in aggregate output. This sizable contribution reflects the

Table 1

Sources of U.S. Output and Productivity Growth

1959-2003

	1959-2003	1959-73	1973-95	1995-2003	1995-2003 less 1973-95
Private output	3.58	4.21	3.06	3.90	0.84
Hours worked	1.37	1.36	1.57	0.85	-0.73
Average labor productivity	2.21	2.85	1.49	3.06	1.57
Contribution of capital deepening	1.21	1.41	0.89	1.75	0.86
Information technology	0.44	0.21	0.40	0.92	0.52
Non-information technology	0.78	1.19	0.49	0.83	0.34
Contribution of labor quality	0.26	0.33	0.26	0.17	-0.09
Total factor productivity	0.74	1.12	0.34	1.14	0.80
Information technology	0.25	0.09	0.24	0.53	0.28
Non-information technology	0.49	1.03	0.10	0.61	0.51

Notes: Data are for the U.S. private economy. All figures are average annual growth rates. The 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.

exceedingly high rates of technological progress in IT production and is manifest in the 9.2 percent per year decline in the price of IT output in 1995-2003. Similarly, 60 percent of the increased capital deepening in 1995-2003 was attributable to IT, although information processing equipment and software accounted for only about one-quarter of private fixed investments in this period. This large contribution reflects both the rapid accumulation of IT capital as prices fell and IT capital's high marginal product.

A brief look at the economics underlying our findings may shed light on the complex role of IT. The story begins with the IT-producing industries that make high-technology equipment and software. Here, fundamental technological progress is the driving force that has allowed each generation of new equipment to outperform prior generations. This technological progress is manifest in "Moore's Law," the doubling of computer chip power every eighteen months or so. As a result, the quality of IT has improved even as prices have fallen—a change that is measured as TFP growth in IT production. In response to the enormous relative price declines for IT investment, firms have rapidly substituted IT assets for other production inputs. This massive investment in IT leads to the large contribution of IT capital deepening to labor productivity growth.

A Comparison with Earlier Productivity Estimates

By comparing our estimates of the sources of the productivity revival with earlier estimates based on data through 2000 (Jorgenson, Ho, and Stiroh 2002), we can identify changes in the makeup of the productivity revival. Table 2 juxtaposes the earlier decomposition of the productivity revival (1995-2000 less 1973-95) with our current estimates (1995-2003 less 1973-95). While this comparison reveals broad similarities, some important differences emerge.

Note first that the increase in output growth after 1995 is much smaller when the 2001 recession and recovery are included. The sluggish performance of the U.S. labor markets is apparent in the growth of hours, which now shows a large slowdown during the post-1995 period rather than an increase. Significantly, however, labor productivity now shows a larger increase—1.57 percentage points, compared with 0.92 percentage point in our 2002 estimates—reflecting relatively strong growth in 2001, 2002, and 2003, as well as revisions to the underlying data.

The change in the acceleration of labor productivity can be largely attributed to more rapid capital deepening and faster non-IT TFP growth. Both IT and non-IT capital are now larger, although this result partly reflects differences in our methodology.[8] The increase in capital deepening occurred because the growth of hours slowed more than the growth in non-IT capital services, resulting in an increase in non-IT capital per hour worked. The contribution of labor quality to the post-1995 revival is essentially unchanged. Finally, the contribution of TFP associated with IT production has not changed, while we now see a much larger contribution from non-IT TFP growth. A portion of the non-IT TFP growth is likely transitory and cyclical in nature because firms are expanding output but adding resources cautiously, so it is unclear how much should be interpreted as permanent technology and efficiency gains.

Table 2

Changes in the Sources of U.S. Productivity Growth

	J-H-S (2002) Estimates	Current Estimates	
	1995-2000 less 1973-95	1995-2003 less 1973-95	Change
Private output	1.61	0.84	-0.77
Hours worked	0.68	-0.73	-1.41
Average labor productivity	0.92	1.57	0.65
Contribution of capital deepening	0.52	0.86	0.34
Information technology	0.44	0.52	0.08
Non-information technology	0.08	0.34	0.26
Contribution of labor quality	-0.06	-0.09	-0.03
Total factor productivity	0.47	0.80	0.33
Information technology	0.27	0.28	0.01
Non-information technology	0.20	0.51	0.31

Notes: All figures are average annual growth rates. J-H-S (2002) estimates are taken from Jorgenson, Ho, and Stiroh (2002, Table 2), and current estimates are taken from Table 1.

Projecting Productivity Growth

The productivity outlook is a critical issue for the U.S. economy, but forecasting productivity growth accurately is difficult. Analysts must distinguish permanent changes from temporary shocks and make assumptions about technological progress, shifts between different types of investment and workers, and the pace of innovation. These difficulties have led to a wide range of estimates that are often substantially revised. The Congressional Budget Office, for example, has revised its ten-year projection of nonfarm business labor productivity up from 1.2 percent per year in January 1997 to 2.7 percent per year in January 2001 and down to 2.2 percent in September 2004 (CBO 1997, 2001, 2004). This section presents productivity projections based on the most recent data and compares them with our earlier estimates in Jorgenson, Ho, and Stiroh (2002).

Methodology and Data

We use the same productivity framework as in our analysis of the 1995-2003 productivity revival. In addition, we make two key assumptions that are consistent with the experience of the United States and other developed countries over time periods longer than the typical business cycle. First, to smooth fluctuations such as the investment boom of the late 1990s and the investment bust around the 2001 recession, we assume that output and the reproducible capital stock grow at the same rate. Second, we assume that hours worked 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.[9]

We must also predict 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 traditional tools, while others involve much greater uncertainty. For the variables we consider less hard to project (hours growth, labor quality growth, capital share, reproducible capital stock share, and IT output share), we present a single value. For the technology variables that are more difficult to project (IT-related TFP growth, non-IT TFP growth, and capital quality growth), we employ three sets of projections—a base case, a pessimistic scenario, and an optimistic scenario—to emphasize the inherent uncertainty.

We first discuss the variables that are held constant over all scenarios. For hours growth and labor quality growth, we draw on the demographic model of the Census Bureau to construct our projections of the trends. Thus, we break down the population by year of age, as well as by race and sex. Our estimates suggest that hours growth will be about 0.72 percent per year and that growth in labor quality will be 0.09 percent per year for 2004-14. Both growth rates are considerably lower than in our 2002 estimates because we use the more recent census population projections from 2001 and a later time period for the projection.

The capital share of GDP fluctuates, but does not show a clear trend over the past forty years, so we assume it remains constant at 42.5 percent, the average for 1959-2003. Similarly, the fixed reproducible capital share in total capital has shown no trend and we assume it remains constant at 81.5 percent, the average for 1959-2003. We assume that the IT output share stays at 4.7 percent, the average for 1995-2003.

For the variables that differ 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 1990-2003, the optimistic scenario assumes that the patterns of 1995-2003 will persist, and the pessimistic case assumes that the economy reverts to 1973-95 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 the 1995 shift in the product cycle for semiconductors from three years to two years as competition intensified.[10] Whether the shorter product cycle is permanent or transitory is critical in gauging the likely pace of TFP gains in IT production, but there is considerable uncertainty. The 2003 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 a three-year product cycle after 2004.[11] Intel, however, has recently announced its intention to maintain a two-year product cycle (Lammers 2004).

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 based on its 1990-2003 growth rate. Our optimistic projection assumes that the two-year product cycle for semiconductors continues, so that IT-related TFP growth reflects rates seen in 1995-2003. Our pessimistic projection assumes that the semiconductor product cycle reverts to the slower pace observed in 1973-95. In all cases, the contribution of IT to aggregate TFP growth reflects the 1995-2003 average output share of each IT component.

The TFP contribution from non-IT sources is more difficult to project because the post-1995 performance has been so uneven. We simply present a range of assumptions that are all consistent with the U.S. historical experience. Our base case uses the average non-IT TFP contribution observed in the full 1990-2003 period. This assumes that the myriad factors that drove TFP growth through 2003—including technological progress, innovation, resource reallocations, and increased competitive pressures—will remain. Our optimistic case assumes that the larger contribution seen in 1995-2003 will continue for the intermediate future, while our pessimistic case assumes that the non-IT TFP contribution will revert to its value during the slow-growth period of 1973-95.

The final variable is the growth in capital quality, which reflects rapid growth in computers and other types of capital with high marginal products. A key difficulty here is that the recent investment pattern, encompassing both the boom of the late 1990s and the bust that followed, is likely to be unsustainable, so recent estimates may be a poor guide. Our base case again uses the average rate for 1990-2003. Our optimistic projection ignores the belief that capital substitution was unsustainably high in the late 1990s and assumes that capital quality growth will continue at the faster pace seen in the 1995-2003 period as firms continue to shift toward relatively inexpensive IT assets. Our pessimistic scenario assumes that the growth of capital quality will revert to the rate seen in 1973-95.

Productivity Projections

Table 3 assembles the components of our projections and presents the three scenarios. The first two rows show the projected growth of output and labor productivity. Rows 3-7 report the five factors that are held constant across scenarios. Rows 8-11 report the three factors that vary across scenarios.

Our base-case scenario puts labor productivity growth at 2.56 percent per year and output growth at 3.28 percent per year for the next decade. Projected productivity growth falls short of our estimates for 1995-2003 as TFP, capital deepening, and labor quality gains moderate, while output growth faces the additional drag of slower hours growth. These projections reflect the slackening pace of technological progress in semiconductors and put the contribution of IT-related TFP slightly below that of 1995-2003 as the semiconductor industry eventually returns to a three-year product cycle. Slower growth is partly offset by a larger IT output share. Other TFP growth also makes a smaller contribution.

Our optimistic scenario, which assumes rapid technological progress, puts labor productivity growth at 3.22 percent per year and output growth at 3.95 percent per year. In particular, the assumption that the two-year product cycle in semiconductors will persist for the intermediate future drives rapid TFP growth in the production of IT equipment and software, as well as a continued shift toward IT assets and rapid growth in capital quality. In addition, non-IT TFP growth continues its rapid growth after 1995.

Finally, our pessimistic scenario—premised on a return to the sluggish growth rates of 1973-95—predicts annual growth in labor productivity of 1.35 percent. The larger share of IT, however, means that even with slower capital quality growth, slower labor quality growth, and slower TFP growth, labor productivity growth will be near the rates seen in the 1970s and 1980s.

Overall, we conclude that the U.S. productivity resurgence is likely to continue and 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—such as technological progress in information technology, a growing share of IT production, and a more competitive and deregulated economy—remain firmly in place.[12] These positive effects, however, are likely to be tempered by demographic trends. Specifically, the aging of the labor force and the tapering off of increases in workers' educational attainment may lead to a slower pace of labor quality growth and place a drag on labor productivity.

If we compare these projections to our earlier ones in Jorgenson, Ho, and Stiroh (2002), we find that our base-case estimate has risen to 2.56 percent from 2.21 percent, reflecting the continued productivity gains of recent years. These gains are partially offset by a greater drag on future labor productivity growth from demographic trends. Nonetheless, the net effect is a sizable increase in projected productivity growth, suggesting that the technology-led productivity resurgence will continue.

Table 3
Output and Labor Productivity Projections

	Scenario		
	Pessimistic	Base-Case	Optimistic
Projections			
Private output growth	2.07	3.28	3.95
Average labor productivity growth	1.35	2.56	3.22
Common assumptions			
Hours growth	0.723	0.723	0.723
Labor quality growth	0.087	0.087	0.087
Capital share	0.425	0.425	0.425
Reproducible capital stock share	0.815	0.815	0.815
IT output share	0.047	0.047	0.047
Alternative assumptions			
TFP growth in IT	8.32	9.70	11.24
Implied IT-related TFP contribution	0.39	0.46	0.53
Other TFP contribution	0.10	0.45	0.61
Capital quality growth	0.94	1.82	2.29

Notes: In all projections, hours growth and labor quality growth are from internal projections for 2004-14, the capital share and the reproducible capital stock share are 1959-2003 averages, and the IT output share is the 1995-2003 average. The pessimistic case uses 1973-95 average growth of IT-related TFP growth, the non-IT TFP contribution, and capital quality growth. The base case uses 1990-2003 averages, and the optimistic case uses 1995-2003 averages.

Conclusion

The strength and resiliency of U.S. productivity growth continue 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 vigorous and, in recent years, has even accelerated. Indeed, the U.S. economy has not enjoyed such sustained productivity growth since the 1960s.

The estimates presented here show the critical importance of IT in this productivity resurgence. Productivity gains come from both technological progress in the industries that produce IT equipment and software and an ongoing shift by firms toward the purchase of relatively cheap and highly productive IT equipment. There is also evidence of more widespread gains in total factor productivity.

Our projections suggest that U.S. productivity growth is likely to remain relatively strong over the medium term but will slow somewhat as the economy moves toward a more stable growth path and demographic trends continue. We emphasize, however, that there is considerable uncertainty in these projections. The future growth of productivity depends critically on hard-to-predict factors such as the evolution of semiconductor technology and business investment patterns. 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 observed in the 1970s and 1980s.

Notes

1. See Baily (2002), Jorgenson and Stiroh (2000), Jorgenson (2001), Stiroh (2002), Jorgenson, Ho, and Stiroh (2002), and Oliner and Sichel (2000, 2002) for estimates and references. Unless explicitly defined otherwise, productivity growth refers to the average annual growth rate of labor productivity (output per hour worked).

2. These estimates refer to the nonfarm business sector and are average annual growth rates calculated as log differences.

3. See the memo from the NBER Business Cycle Dating Committee from October 2, 2003, at <http://www.nber.org/cycles/recessions.html>.

4. Methodological details are in Jorgenson, Ho, and Stiroh (2002). Stiroh (2001) provides a broad overview of the strengths and weaknesses of growth accounting.

5. As a practical matter, we estimate IT-related TFP growth from relative price changes—that is, a fall in IT prices less input prices reflects technological progress and TFP growth in IT production.

6. We include the nonprofit sector and imputed capital service flows from residential housing and consumer durables.

7. Computer and software investment data begin in 1959; 2003 is the last year for which complete data are available.

8. Our earlier work included only business capital in IT capital deepening, while we now also include the service flow to households from IT consumer durables assets. With no change in methodology, almost all the increase in capital deepening would reflect the non-IT component.

9. These assumptions are consistent with the concept of potential growth of output in the long run.

10. The product cycle refers to the pace at which new models are introduced and supplant earlier ones on the technological frontier.

11. The report is available at <http://public.itrs.net>.

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

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About the Authors

Dale W. Jorgenson is the Samuel W. Morris University Professor at Harvard University; Mun S. Ho is a visiting scholar at Resources for the Future, an independent research institute in Washington, D.C.; Kevin J. Stiroh is an assistant vice president in the Banking Studies Function of the Research and Statistics Group.

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