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Productivity Growth: Trends and Prospects

Brian W. Cashell, Government and Finance Division

September 15, 2008

Abstract. While policymakers have at least some direct or indirect influence over many economic variables, productivity growth may be among those that remain relatively beyond the influence of deliberate economic policy. Although many policy proposals are advocated on the grounds that they will help boost productivity, it may be that productivity growth rates have a greater influence on policy than policy does on the growth of productivity. Variations in the productivity growth rate are so incompletely understood that there is no clear consensus among economists about the best way for policymakers to promote it.

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Brian W. Cashell
Specialist in Macroeconomic Policy
Government and Finance Division

Prepared for Members and
Committees of Congress

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Summary

While policymakers have at least some direct or indirect influence over many economic variables, productivity growth may be among those that remain relatively beyond the influence of deliberate economic policy. Although many policy proposals are advocated on the grounds that they will help boost productivity, it may be that productivity growth rates have a greater influence on policy than policy does on the growth of productivity. Variations in the productivity growth rate are so incompletely understood that there is no clear consensus among economists about the best way for policymakers to promote it.

Higher productivity growth means higher real incomes, which in combination with progressive income tax rates yields higher federal revenues. Productivity growth also extends the date of reckoning as far as Social Security is concerned, because the incomes of those paying Social Security taxes will grow more rapidly compared to the rate of growth of benefits.

In the mid 1990s, trend productivity growth accelerated. That was unusual in a mature economic expansion, which has suggested to more than a few observers that it was not just a short-term phenomenon, but rather a sign that there was an increase in the long-term economic growth rate.

That pickup in productivity growth has been attributed, in part, to computers and other IT equipment which have undergone dramatic technical improvements and coincidental price declines. As computer prices have fallen, more and more applications for computing power have been found. Because of falling prices it has become profitable to put computers to uses with smaller and smaller returns. There is also the prospect that it may take firms a considerable amount of time to adapt the way they do business to take advantage of their investments in IT equipment. As was the case with other historic technological advances, the productivity gains attributable to investments in IT equipment may ripple through the economy for some time.

An important question for policymakers is how much longer this surge in productivity growth might continue. Two recent studies attempted to project productivity growth based on the current understanding of post-1995 developments. Between 1995 and 2007 average labor productivity grew at an annual rate of 2.5%. The two projections suggest that in the future it is more likely to be closer to 2%. That would still be a faster rate of growth than in the years before 1995.

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There is widespread agreement among economists that beginning in 1995, the long-run trend rate of growth of productivity accelerated. That was a welcome development. The rate of growth of productivity has important consequences for policymakers. Faster productivity growth means faster economic growth and more rapid gains in living standards. Consumers can buy more of those goods and services (or leisure) that make their lives easier or more enjoyable. Even when productivity growth is limited to certain industries, everyone benefits from the lower prices for (or the improved quality of) those goods and services.

While the growth rate of productivity varies in the short run, it also exhibits relatively stable long-run trends. The budget process typically looks at least five, if not 10, years ahead in setting spending and tax policies. With respect to Social Security, the time frame is even longer. Over such an extended period of time, some insight into the outlook for productivity growth is critical to projecting other economic variables and establishing an economic baseline on which to base budget decisions.

Policymakers have some influence over productivity growth, but a significant contributor to productivity growth is the pace of technological change which may be relatively removed from the influence of deliberate economic policy. Policies that promote education and capital investment may well have some effect. However, the major shifts in long-term trends seem to have been more related to shifts in the rate of technological progress. These variations in the productivity growth rate are so incompletely understood that there is no clear consensus among economists how policymakers might go about influencing them.

Between 1973 and 1995, productivity growth was sluggish compared to what it had been during the 1960s. In 1995, trend productivity growth picked up. This report explains what productivity is and how it is measured. It examines both the cyclical and long-run characteristics of productivity growth, discusses continuing efforts to explain the post-1995 acceleration in productivity growth, and considers whether that faster rate of growth can be expected to continue.

What is Productivity?

Productivity is a ratio. It is a measure of the quantity of output produced relative to the amount of work required to produce it. Most often it is expressed as the ratio of some measure of inflation-adjusted output to the number of labor hours involved. Mathematically, it looks something like this:

$$productivity = \frac{output}{hours}$$

Labor productivity is measured in terms of average output per hour. It is a ratio of the quantity of output to the hours of work performed. If the quantity of output rises by the same proportion as the amount of work, then the economy is only producing more because there are more workers, or because workers are putting in longer hours, but there is no productivity growth. If output rises faster than hours worked, labor productivity is also increasing.

Rearranging the terms may help illustrate the significance of productivity:

$$output = productivity \times hours$$

This shows that total output is a function of both work and productivity. Any increase in output must therefore come about as the result of increases in either hours worked or productivity.

In the short run, hours worked may vary over the business cycle as the unemployment rate rises and falls. Beyond that, hours worked may vary somewhat over time as the proportion of the population in the labor force changes. But, in the long run, hours worked is primarily determined by population size. Output growth is an important policy goal, but if it only comes by increasing hours worked then living standards are unlikely to improve.[1]

Some of the sources of productivity growth are clearly understood. Increased investment and a growing capital stock raise labor productivity. Increased education and training also contribute. But aside from the contributions of human and physical capital, much less is certain. The pace of technological advance is not easily explained.

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[1] When the economy is at full employment, the combined growth rates of labor and its productivity represent a sort of speed limit. Sustained economic growth above that limit is considered likely to result in an accelerating rate of inflation. That is another reason why it is important for policymakers to be aware of productivity growth trends.

Measurement Issues

The most commonly cited measure of productivity published by the federal government is average labor productivity. It is published quarterly by the Bureau of Labor Statistics of the Department of Labor (BLS). The measure of output used by BLS in its calculation is based on real gross domestic product (GDP) in the non-farm business sector published by the Bureau of Economic Analysis (BEA) of the Department of Commerce.

Problems in Measuring Real Output. Production of goods and services is necessarily measured in terms of dollar values because that is the only unit of measure common to all of the goods and services produced. The dollar value of output, however, reflects not only the quantity of goods and services produced, but also their prices. The dollar value of output will rise with an increase in the quantity of goods and services produced, but it will also rise with an increase in their prices. Distinguishing between changes in output that are "real" (i.e., indicative of changes in quantity), and changes that are due only to variations in the general price level is a difficult problem.

Productivity measures are based on inflation-adjusted measures of output. The way in which price change is measured can thus affect measures of productivity growth. If existing price indexes understate the rate of inflation, that will cause estimates of productivity growth to be overstated.

Few goods or services stay the same from year to year. Of all the goods and services produced, computers may be changing the most rapidly from year to year. The prices of computers have been falling, and their performance has been improving dramatically. Rather than simply track changes in the price of a "computer" from one year to the next, the BEA attempts to track changes in the price of "computing power."[2] That means that it tries to take into account changes in memory, processing speed, and other features when estimating price change in successive models of computers.[3]

Productivity Growth in the Short Run

In the short run it can be difficult to tell whether a change in the rate of productivity growth is temporary or indicative of a change in the long-run trend. To economists, productivity's significance has more to do with the long run, and so variations in its long-run trend and the factors that influence it are the focus of

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[2] J. Steven Landefeld and Bruce T. Grimm, "A Note on the Impact of Hedonics and Computers on Real GDP," *Survey of Current Business*, December 2000.

[3] Some sectors of the economy may be easier to measure than others. In the case of manufactured goods there is at least a tangible product that can be counted even though there may be difficulties in assessing changes in its quality or other characteristics. In the case of services, it can be difficult even to define what is being produced. Take medical care, for example. In the case of physician services, should production be measured as the number of office visits per hour? Should success at treating various ailments be taken into account?

considerable research. Productivity, however, also tends to vary systematically over the course of the business cycle. A long-run trend would be one that persisted for more than one business cycle.

Although each business cycle has unique aspects, there are certain tendencies that are common to most of them. One of those tendencies is for productivity growth to be *procyclical*. In a recession, it is typical for productivity to decline, or grow less rapidly. As the recession ends, and the economy begins to expand, productivity growth usually picks up.[4] **Table 1** presents data for annual rates of growth in average labor productivity over the course of each of the nine complete business cycles of the post-war era.[5]

[4] At the beginning of an economic contraction, firms may be slow to lay off workers because there are costs associated with rehiring them when business recovers. If the contraction continues, firms may lay off workers who are relatively less productive. Reducing the quantity of labor employed thus tends to moderate any initial deceleration in measured productivity growth. As the contraction comes to an end, firms can put idle capital back to work as well as any under-utilized labor already on hand. This increase in output with little or no increase in hours worked results in relatively rapid productivity growth. Once increasing demand can no longer be satisfied with existing capacity, additional labor will be added. Those hired first will tend to be those relatively more experienced. As more and more labor is hired, the contribution to output of each additional hire tends to drop. As the expansion ages, productivity growth tends to slow.

[5] These data reflect productivity in the nonfarm business sector. The business cycle reference dates use here are those established by the National Bureau of Economic Research (NBER), and indicate the beginnings and endings of periods of economy-wide expansions and contractions.

Table 1. Growth in Output per Labor Hour, Nonfarm Business Sector

Business Cycle Reference Dates (year and quarter)			Average Annual Rate of Growth from: (percent)		
peak	trough	peak	peak to trough	trough to peak	peak to peak
1948:4	1949:4	1953:3	3.7	3.4	3.5
1953:3	1954:2	1957:3	0.6	2.3	2.0
1957:3	1958:2	1960:2	0.9	2.9	2.3
1960:2	1961:1	1969:4	0.2	2.9	2.7
1969:4	1970:4	1973:4	2.6	3.0	2.9
1973:4	1975:1	1980:1	0.3	1.5	1.3
1980:1	1980:3	1981:3	-1.5	2.2	1.0
1981:3	1982:4	1990:3	-0.6	2.0	1.6
1990:3	1991:1	2001:1	-1.0	2.1	2.0

Sources: National Bureau of Economic Research; Department of Labor, Bureau of Labor Statistics.

The data bear out a clear tendency for productivity growth to be procyclical. That is to say, productivity growth is higher during expansions (trough to peak) than during contractions (peak to trough). During expansion, productivity growth tends to be faster in the early stages and to slow somewhat once the economy is fully employed. **Table 2** compares productivity growth rates from the last two years of three long expansions with the preceding interval.

In the expansions of the 1960s and 1980s, there was a significant slowdown in the rate of productivity growth towards the end of the expansion. In contrast, productivity growth accelerated towards the end of the expansion of the 1990s. That was seen as reason to believe there may have been an increase in its long-run trend rate of growth, since it did not follow the typical cyclical pattern.

Table 2. Labor Productivity Growth Rates in Three Long Expansions

Expansion dates and sub-periods	**Growth rate (percent)**
1961:1 to 1969:4	2.9
1961:1 to 1967:4	3.4
1967:4 to 1969:4	1.2
1982:4 to 1990:3	2.0
1982:4 to 1988:3	2.2
1988:3 to 1990:3	1.5
1991:1 to 2001:1	2.1
1991:1 to 1999:1	2.1
1999:1 to 2001:1	2.3

Source: Department of Labor, Bureau of Labor Statistics.

Productivity Growth in the Long Run

Just as productivity growth varies in the short run, it also varies from one cycle to the next. Economists have identified particular times when the long-run rate of growth seems to have shifted. One of those was in the early 1970s, and another one seems to have occurred in the mid-1990s. **Table 3** shows those periods and the annual rates of growth in average labor productivity for each.

Table 3. Productivity Growth Rates, Long-Term Trends

Time period	**Growth rate (percent)**
1947 to 1973	2.8%
1973 to 1995	1.4%
1995 to 2007	2.5%

Source: Department of Labor, Bureau of Labor Statistics.

The Post-1973 Slowdown in Productivity Growth. For much of the post-World War II era, the United States experienced relatively rapid rates of productivity growth. Between 1947 and the 1973, output per labor hour in the nonfarm business sector grew at an annual rate of 2.8%. Between the 1973 and 1995, that rate fell to 1.4% per year. Most economists point to 1973 as the beginning of an extended period of slower productivity growth. That drop in the rate of productivity growth has been the focus of much economic research. Thus far, the slowdown remains poorly understood.

A prime suspect in that slowdown, at least initially, was the OPEC oil price hike, which in 1973 roughly doubled the price of crude oil. The mere coincidence of the productivity slowdown and the rise in price of a major input to the production of goods and services made it an attractive suspect. The theory was that, because of higher energy costs, much of the existing capital stock which relied on energy to contribute to output became obsolete.[6]

Subsequent experience, however, cast doubts on the significance of the coincidence. Between 1979 and 1981, oil prices doubled again, and then in 1986 the price of oil fell by nearly half. That only one of these large oil price changes was associated with a shift in the trend rate of growth in productivity suggested that if there was a single factor to blame for the 1973 slowdown, it was to be found elsewhere.

Another possible cause of the post-1973 slowdown was a slowdown in spending on research and development (R&D). Griliches found that R&D spending, as a percentage of GDP, declined beginning in the mid-1960s.[7] The timing of the decline would seem to implicate it, but it is hard to make a strong case out of a single instance. Moreover, other countries also experienced a decline in productivity growth without a corresponding decline in R&D spending.

Griliches also pointed out that, in the 1970s, the number of patents granted in the United States declined. That resulted in a drop in the number of patents per dollar of R&D spending. Griliches suggested that the decline in the number of patents per dollar of R&D spending may have been evidence of diminishing returns to R&D spending, and he wondered if there might be a sort of technological frontier near which opportunities for invention become relatively scarce.

Maddison examined a number of factors in an effort to account for the role each one may have played in the slowdown.[8] Maddison was able to "explain" only 41% of the total deceleration in output growth. Of 14 separate factors, the most important was found to have accounted for less than one-seventh of the slowdown.

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[6] Martin Neil Baily, "Productivity and the Services of Capital and Labor," *Brookings Papers on Economic Activity 1*, 1981.

[7] Zvi Griliches, "Productivity, R&D, and the Data Constraint," *American Economic Review*, March 1994.

[8] Angus Maddison, "Growth and Slowdown in Advanced Capitalist Economies," *Journal of Economic Literature*, June 1987.

Because the slowdown in trend productivity has been dated to a single point in time, it was suspected that a single cause for the slowdown might be found. Identifying a single cause would have been more satisfying in that policy measures might have been designed to reverse it. If the slowdown had affected different industries more or less equally, that might have favored arguments that a single cause was responsible. However, when productivity trends were examined for individual industries, some were found to have fared well in comparison with others.[9]

Gordon offered a slightly different perspective on the post-1973 slowdown. He maintained that, rather than trying to explain why productivity growth slowed in the 1970s and 1980s, the focus should instead be on why it was so rapid earlier.[10] Gordon argued that, in the 1970s, productivity growth simply fell back to its long-run trend rate, and that the growth experienced earlier in the century was unusually rapid due to a number of technological advances. Among the advances he cited were the spread of electric motors, the internal combustion engine, and the telephone and its derivatives. Gordon argued that these innovations had a much greater economic effect than the electronic computer. He went on to suggest that the economy was on a long-run curve of diminishing returns to technological advancement, and that the various modifications and improvements to devices such as computers were less important than was their initial introduction.

The Post-1995 Acceleration in Productivity Growth. Although it was not fully appreciated at the time, it became increasingly evident by the turn of the century that productivity growth seemed to have accelerated around 1995. That it can be difficult to discern shifts in productivity trends was borne out by the fact that economic forecasts underpredicted growth for five consecutive years. **Table 4** shows actual rates of economic growth between 1996 and 2001 and associated forecast errors of the Office of Management and Budget (OMB), the Congressional Budget Office (CBO), and Blue Chip Economic Indicators. The acceleration in growth was notable because it occurred late in the life of the 1990s expansion (see **Table 2**).

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[9] Robert J. Gordon, *Problems in the Measurement and Performance of Service-Sector Productivity in the United States*, National Bureau of Economic Research, Inc., Working Paper no. 5519, March 1996.

[10] Robert J. Gordon, "Comments," in Ben S. Bernanke and Julio J. Rotemberg, eds., NBER *Macroeconomics Annual 1996*, MIT Press.

Table 4. Forecasts of Growth in Real GDP, 1995 - 2000

	Actual	Forecast Errors		
		OMB	CBO	Blue Chip
1996	3.7	-1.5	-1.7	-1.5
1997	4.5	-2.3	-2.2	-2.2
1998	4.2	-1.8	-1.5	-1.7
1999	4.5	-2.1	-2.2	-2.1
2000	3.7	-0.4	-0.4	-0.1

Sources: Department of Commerce, Bureau of Economic Analysis; Congressional Budget Office; Office of Management and Budget; Blue Chip Economic Indicators.

Robert Solow, a major contributor to the theory of economic growth, has often been quoted as saying that the effect of computers can be seen everywhere but in the productivity statistics.[11] Through the 1980s and early 1990s, there seemed to have been no big payoff from the increased use of computers. That presented a puzzle to those who had anticipated significant returns.

It is now believed that computers have had much to do with the acceleration in productivity growth since the mid-1990s. Whether that is the case and how computers have affected productivity growth are important in trying to assess how durable the acceleration will prove to be.

It is widely assumed that the speed and memory capacity of those computers will continue to improve at a steady pace. This rapid rate of technological advance in the development and manufacture of computers was predicted in 1965 by Gordon E. Moore, one of the co-founders of Intel Corporation.[12] Specifically "Moore's Law" predicted that the number of transistors that could be put on a single computer chip would double every 18 months. Whether that prediction was a self-fulfilling prophecy may be open to question, but the fact is that the pace of technological advance in the manufacture of computers has vindicated Moore's Law over time.

Because of rapid innovation in the production of computer chips, the prices of computers, as well as other goods related to information processing and communications, sometimes referred to collectively as information technology (IT), have been falling steadily for some time. **Figure 1** shows the chain-weighted price index, published by BEA, for computers and peripheral equipment from 1959 through

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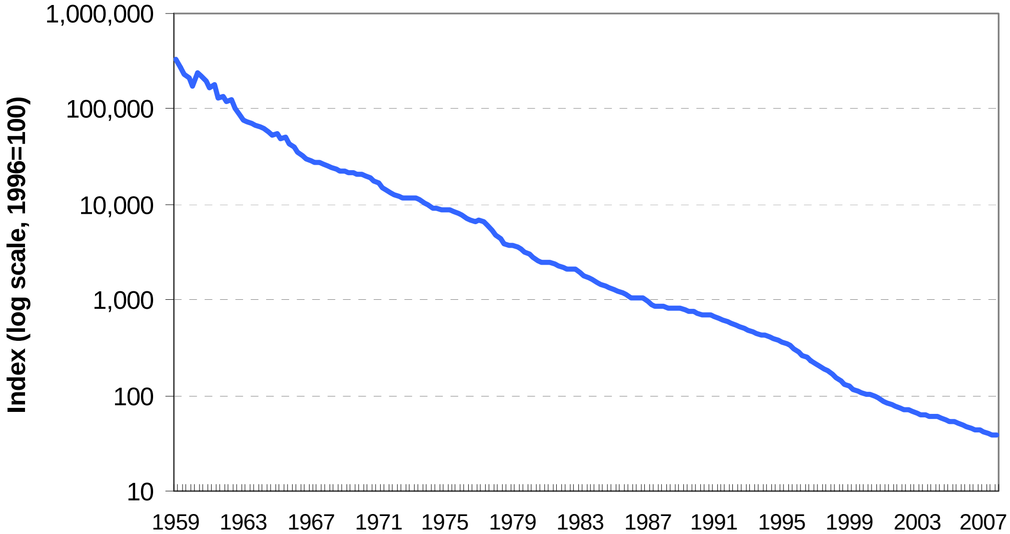
[11] Robert Solow, "We'd Better Watch Out," *New York Times Book Review*, July 12, 1987, p. 36.

[12] Gordon E. Moore, "Cramming more components onto integrated circuits," *Electronics*, vol. 38, no. 8, April 19, 1965. See the Intel website at [http://www.intel.com/technology/mooreslaw/index.htm].

2007. Because the changes are so large the chart is plotted on a logarithmic scale. Using a logarithmic scale has the added advantage that the slope of the line indicates the rate of change in the variable. In this case, the rate of change in computer prices has been fairly steady for a long time. Between 1959 and 1995, computer prices fell at an average annual rate of 17.2%, and between 1995 and 2007 prices fell at an annual rate of 16.4%.

Figure 1. Chain-Weighted Price Index for Computers and Peripheral Equipment



Source: Department of Commerce, Bureau of Economic Analysis.

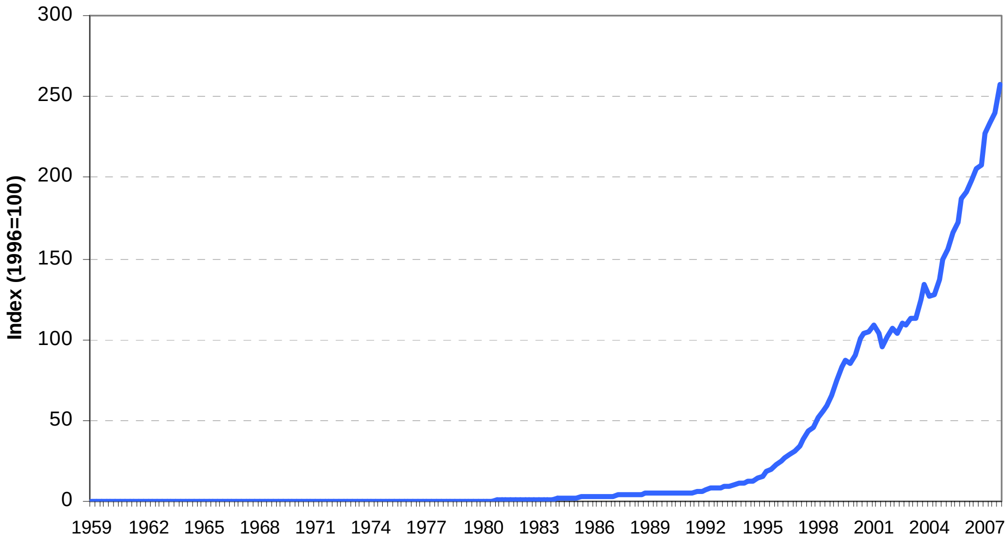
These price declines reflect substantial improvements in the quality of computers. BLS has developed procedures for estimating price indexes for goods whose characteristics are changing rapidly. These are referred to as "hedonic" price indexes. Hedonic price indexes attempt to estimate a statistical relationship between prices and a set of characteristics, such as memory and processor speed.

These price indexes are important to the measurement of productivity, because estimating price change is necessary to estimating change in real output and thus productivity. If the rate of price decline in computers is overestimated, then measures of productivity will be overstated. Most studies estimate that, in the late 1990s, prices for personal computers alone fell at an annual rate of somewhere between 30% and 40%.[13]

[13] J. Steven Landefeld and Bruce T. Grimm, "A Note on the Impact of Hedonics and Computers on Real GDP," *Survey of Current Business*, December 2000.

Rapid declines in computer prices have stimulated IT investment. **Figure 2** shows the chain-linked quantity index for investment in computers and related equipment from the national income and product accounts (NIPA). Although there are data back to 1959, production of computers was negligible until the 1980s. Thus, even though real output of IT equipment was increasing rapidly, it did not account for a very large share of total output until recently.

Figure 2. Real Investment in Computers and Peripheral Equipment



Source: Department of Commerce, Bureau of Economic Analysis.

Computers have affected growth in productivity in at least two ways. First, there has been rapid productivity growth in the *production* of computers which, as computers accounted for an increasing share of total production, tended to raise the overall measure of productivity growth. Second, the sharp drop in computer prices has stimulated increased *investment* in computers, which has contributed to an increase in the overall amount of capital available to the workforce. This is often referred to as "capital deepening." Increases in the size of the capital stock generally tend to raise worker productivity.

Two separate studies attempted to assess the contribution of computers and IT investment to the post-1995 acceleration in productivity growth. Oliner and Sichel found that, of a 0.9 percentage point increase in productivity growth from the first half of the 1990s to the latter half, all of it could be accounted for by the combined effects of advances in the production of computers themselves, and in advances in the way those computers were put to use.[14]

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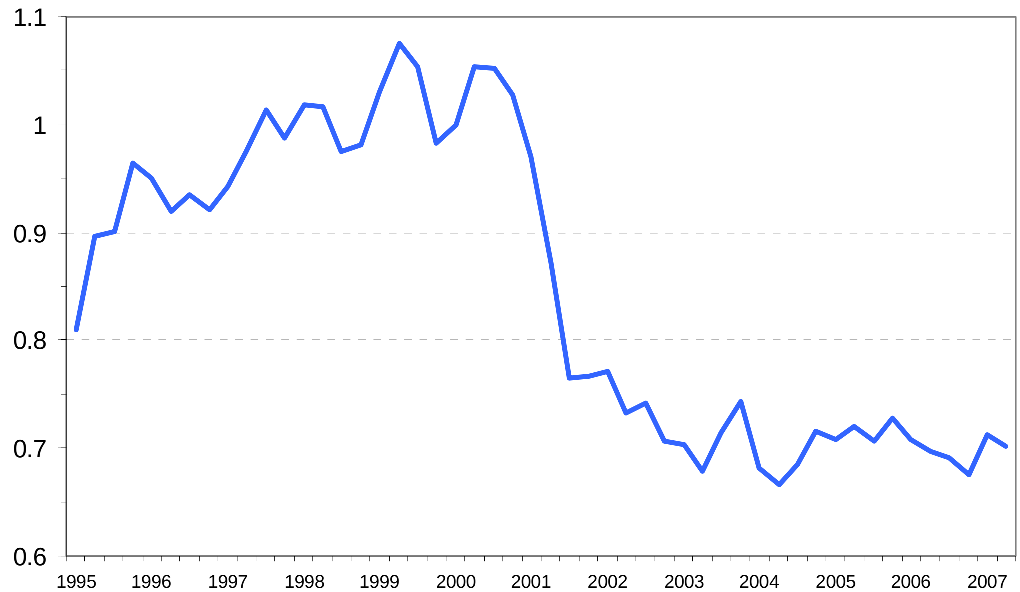
[14] Stephen D. Oliner and Daniel E. Sichel, *Information Technology and Productivity: Where* (continued...)

Jorgenson, Ho, and Stiroh came to similar conclusions. They found that investment in IT equipment together with productivity advances in the production of IT equipment could account for all of the increase in productivity after 1995 compared with growth between 1973 and 1995.[15]

Since the publication of those studies attributing much of the acceleration in productivity growth to IT investments, there was a significant decline in the share of GDP allocated to IT investments. **Figure 3** shows investment spending as a percentage of GDP since 1995.[16]

Figure 3. Investment in Computers and Peripheral Equipment as a Percentage of Gross Domestic Product



Source: Department of Commerce, Bureau of Economic Analysis.

Gordon suggested that the continuation of rapid productivity gains following the decline in spending on computers may mean that the earlier studies exaggerated the

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[14] (...continued)
Are We Now and Where Are We Going? Board of Governors of the Federal Reserve System, May 2002.

[15] Dale W. Jorgenson, Mun S. Ho, and Kevin J. Stiroh, *Lessons From the U.S. Growth Resurgence,* paper prepared for the First International Conference on the Economic and Social Implications of Information Technology, held at the U.S. Department of Commerce, Washington, DC, on January 27-28, 2003.

[16] It is possible some of the rise in IT spending was associated with the introduction of new software and equipment to deal with the "Y2K" problem. That may have served to accelerate the introduction of next generation software.

contribution of IT spending on the post-1995 acceleration in productivity growth.[17] Gordon argues that it is implausible that increased investment in IT equipment would have an immediate effect on productivity growth. According to Gordon, it took forty years for the benefits of electrification to be fully realized. Factories had to be reorganized to take advantage of electric power. In the same way, the introduction of computers has driven firms to change business practices. Those changes take time. But the reorganization, as well as worker training and other novel business practices made possible by the introduction of computers, may have contributed to productivity in ways that are difficult to measure.

More recently, Jorgenson, Ho and Stiroh have found that the IT contribution to productivity growth fell after 2000.[18] In spite of that, there was little change in the growth rate of average labor productivity after 2000. Apparently, one reason productivity growth held up was a decline in the growth rate of hours worked which tended to raise the amount of capital available to labor. That is a development that may be unlikely to persist.

One of the sectors of the economy that experienced relatively rapid productivity growth is retail trade. Retail trade may have benefitted a great deal in the use of computers and IT investments. Fernald and Ramnath cite the particular example of so-called big-box stores that have become pervasive in retailing.[19] The success of those large scale retailers may have been made possible by the introduction of computers. Computers allowed those stores to manage sophisticated distribution networks and improve inventory control, and by growing in size also benefit from economies of scale.

Baily also suspects that the contribution of IT investments to faster productivity growth might have been overstated.[20] He points out that prior to 1995, economists were unable to fully explain variations in productivity growth by simply examining variations in those factors believed to contribute to it. Given the relatively small number of observations on which the studies linking IT investments to productivity are based they might still be treated with some skepticism. He argues that it might also be the case that the increase in IT spending was motivated by the acceleration in growth.

An apparent inconsistency has caused others to ask whether the contribution of IT investments might be overstated. Many European countries did not enjoy the post-

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[17] Robert J. Gordon, "Exploding Productivity Growth: Context, Causes, and Implications," *Brookings Papers on Economic Activity*, 2:2003.

[18] Dale W. Jorgeson, Mun S. Ho, and Kevin Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives*, Winter 2008.

[19] John G. Fernald and Shanthi Ramnath, "The Acceleration in U.S. Total Factor Productivity after 1995: The Role of Information Technology," Federal Reserve Bank of Chicago *Economic Perspectives*, 1Q/2004.

[20] Martin N. Baily, "Recent Productivity Growth: The Role of Information Technology and Other Innovations," Federal Reserve Bank of San Francisco *Economic Review*, 2004.

1995 acceleration in productivity growth. Gordon compares productivity in the 1990-1995 and 1995-2003 intervals and points out that while the growth rate of output per hour increased by 0.9 percentage point after 1995, the U.S. growth rate of output per hour fell by 1.2 percentage points in the European Union.[21] Gordon argues that European government policies may have inhibited the growth of big-box retail stores and thus minimized productivity gains IT investments might otherwise have provided.

An OECD study looked at those industries that use IT equipment and found that, for the most part, countries other than the United States and Australia experienced little benefit from the use of increased investments in IT equipment after 1995.[22] This study pointed out that the increase in Wal-Mart's share of the retail market accounted for some of the post-1995 increase in productivity. It suggested that it may be more difficult for firms to expand and gain market share in some European countries than in the United States. It would seem that public policy has influenced the extent to which IT investment has contributed to the acceleration in productivity growth.

An NBER study looked at the ability of individual firms to benefit from IT investments.[23] It found a significant difference between the productivity gains experienced by U.S. firms as opposed to non-U.S. firms, and attributed it to IT spending. It seems that firm characteristics may be as important as the overall economic environment in determining the effect on productivity of IT spending.

Investments in IT equipment may contribute to productivity by either substituting for labor or by complementing it. When it is a complement to labor, the more educated the labor force is the greater the contribution is likely to be. When it is a substitute, the more educated the displaced workers are, the easier it is likely to be for them to find new jobs. In either case, more flexible capital and labor markets may increase the potential contribution to productivity of increased IT investment.

Will the Post-1995 Growth Rates Continue?

An important question for policymakers is whether or not the surge in productivity growth of the late 1990s will continue. Higher productivity growth means higher real incomes, which in combination with progressive income tax rates yields higher federal revenues. Higher productivity growth also extends the date of reckoning for Social Security because the incomes of those paying Social Security taxes will temporarily grow more rapidly relative to the growth rate of Social Security benefits. Whether or not productivity growth continues at the rate estimated for the

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[21] Robert J. Gordon, "Why was Europe Left at the Station When America's Productivity Locomotive Departed?" March 2004. Available on his website at [http://faculty-web.at.northwestern.edu/economics/gordon/P368-CEPR.pdf].

[22] Dirk Pilat, "The ICT Productivity Paradox: Insights From Micro Data," OECD *Economic Studies*, no. 38, 2004/1.

[23] Nicholas Bloom, Raffaella Sadun, and John Van Reenen, "Americans Do I.T. Better: US Multinationals and the Productivity Miracle," National Bureau of Economic Research *Working Paper* 13086, May 2007.

late 1990s is a critical concern for those making and using long-term economic forecasts.[24]

It now seems likely that most of the increase in productivity growth of the late 1990s was not a cyclical variation, but was a change in the long-run trend rate of growth.

There seems to be general agreement that the recent pickup in trend productivity is at least in part attributable to the rapid rate of decline in the prices of computers and other IT equipment. An important factor in those price declines has been innovation in the manufacture of microprocessors. Whether or not that rapid pace of innovation keeps up, and prices continue to fall will be important factors in future rates of productivity growth. However, ultimately there may be limits to the number of transistors that can be put on a single computer chip. As computer prices have fallen, computer use has become much more widespread. Because of falling prices it has become profitable to put computers to uses with smaller and smaller returns.

Two recent studies attempt to project productivity growth based on the current understanding of post-1995 developments. Jorgenson, Ho, and Stiroh point out that some of the factors that contribute to productivity are less mysterious than others.[25] Growth in labor hours, growth in the quality of the labor force, and growth in the capital stock are relatively easy to predict, for example.

In contrast, it is harder to project the rate of technological advances in the production of IT equipment. Jorgenson and his co-authors point out that beginning around 1995, the product cycle, which refers to the period of time between new product introductions, shrank from three to two years for semiconductors. That shift, the faster introduction of next generation processors, may explain some of the IT contribution to the acceleration in productivity growth. If semiconductors reverted to a three-year product cycle, that might temporarily reverse some of the IT contribution to future productivity growth.

It may be as difficult to project the other factors that contribute to productivity growth, particularly the pace of technological advance in the non-IT sectors of the economy, and improvements in the overall quality of the capital stock. Acknowledging those difficulties, Jorgenson and his co-authors suggest a range of projections for the next ten years. Their outlook for annual growth in average labor productivity stretches from a "pessimistic" 1.4% rate to an "optimistic" 2.8% rate. Based on those projections, they expect growth in total private output to range somewhere between a 2.1% and a 3.5% rate of growth over the next decade.

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[24] Paul W. Blauer, Jeffrey L. Jensen, and Mark E. Schweitzer, Productivity Gains, How Permanent? Federal Reserve Bank of Cleveland *Economic Commentary*, September 1, 2001.

[25] Dale W. Jorgenson, Mun S. Ho, and Kevin Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives*, Winter 2008.

Gordon, in a recent paper, also attempted to project productivity growth rates.[26] The critical question addressed by Gordon concerned how long a historical period should be taken into account as a basis for productivity projections. Gordon's general view is that the driving force behind productivity growth is innovation and that the frequency of important innovations tends to vary in unpredictable ways. He is also skeptical that the invention of the personal computer and the growth of the internet constitute innovations as important as the widespread availability of electricity and the development of the internal combustion engine. Given the historical record of innovation and of variations in productivity growth, Gordon feels that any long-term projection of productivity growth ought to take in at least the past 25 years rather than just the record since 1995.

Because Gordon bases his projection on the record over the past 25 years, he does not expect productivity growth in the next 25 years to match the post-1995 rate. He expects productivity growth closer to 2% than to 2.5%. Based on those expectations, Gordon projects a long-run growth rate of GDP of about 2.5%. Between 1973 and 1995 GDP grew at an annual rate of 2.8%. Between 1995 and 2007 that rate rose to 3.1%. The outlook is thus for growth to slow somewhat with more rapid productivity growth offsetting the effect of slower growth in the labor force.

In August 2008, CBO released updated long-term economic projections.[27] CBO projects a growth rate for labor productivity of 1.9% over the next 75 years. Combined with expected growth in the labor force over that period, CBO projects real GDP will grow by about 2.3% annually.

[26] Robert J. Gordon, "Future U.S. Productivity Growth: Looking Ahead by Looking Back," October 27, 2006, workshop paper available at [http://faculty-web.at.northwestern.edu/economics/gordon/Groningen_Maddison80th.pdf].

[27] Congressional Budget Office, *Updated Long-Term Projections for Social Security*, August 2008.