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Productivity Growth: Recent Trends and Future Prospects

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Updated July 9, 2003

Abstract. This report examines both the cyclical and long-run characteristics of productivity growth, discusses the recent behavior of productivity, and considers the factors that may determine its future performance.

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Productivity Growth: Recent Trends and Future Prospects

Updated July 9, 2003

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Productivity Growth: Recent Trends and Future Prospects

Summary

While there are many economic variables over which policymakers have at least some direct or indirect influence, productivity growth may be among those that remain relatively removed from 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. It seems that 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.

Nonetheless, 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. As long as Social Security operates on a pay-as-you-go basis, productivity growth also extends the date of reckoning as far as the trust fund balances are concerned because the incomes of those paying Social Security taxes will grow more rapidly than the benefits. Whether or not productivity growth continues at the rate it did in the late 1990s is a critical concern for those making and using long-term economic forecasts.

Productivity is a highly cyclical variable, so that assessing its rate of growth at any single point in time requires knowing the particular stage of the business cycle. However, it is the long run trend rate of growth of productivity that is of particular interest because that is the source of rising standards of living. Following the business cycle peak in the fourth quarter of 1973, productivity growth slowed substantially. Unfortunately, that slowdown remains poorly understood, which makes it difficult to design policies that might counteract it.

In the second half of the 1990s, however, productivity growth appears to have accelerated. This is unusual in a mature economic expansion, which 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.

The recent pickup in productivity growth is largely due to the rapid rate of decline in the prices of computers and other information technology (IT) equipment. The rapid drop in price of IT equipment stimulated substantial investment spending, raising the amount of capital per worker. 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. This report will be updated as economic developments warrant.

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Productivity Growth: Recent Trends and Future Prospects

Of all the economic variables policymakers keep an eye on, productivity growth may be one of the most important, at least over the long run, because it measures the rate of improvement in our national standard of living. Economy-wide increases in productivity indicate increases in real production and incomes which have been achieved without an increase in work. Consumers can buy more of those goods and services (or leisure) that make their lives easier or more enjoyable. Even where productivity growth is limited to certain industries, everyone benefits from the lower prices (or the improved quality) for those goods and services.

While there are many economic variables over which policymakers have at least some direct or indirect influence, productivity growth may be among those that remain relatively removed from 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. It seems that 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.

Nonetheless, productivity growth rates do have important consequences for policymakers. The budget process, for example, 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. Without at least some understanding of underlying factors, projections of productivity may simply reduce to quantifying forecaster optimism.

In the second half of the 1990s, productivity growth accelerated. That it happened well into an economic expansion was unusual, and it raised hopes that it was more than a temporary phenomenon and represented an increase in the long-run trend rate of growth. This report examines both the cyclical and long-run characteristics of productivity growth, discusses the recent behavior of productivity, and considers the factors that may determine its future performance.

The Cyclical Nature of Productivity

Distinguishing variations in productivity growth that are due to short-term economic conditions from those that might be indicative of a change in long-term trends can be difficult. Productivity is a cyclical variable, and tends to fluctuate considerably over the short run. Changes in longer-term trends can only be identified by comparing growth rates over successive business cycles.

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Productivity is most often measured by output per man-hour. It is typically procyclical. In a recession, productivity tends to decline, or grow less rapidly. As the recession ends, and the economy begins to expand, productivity growth usually picks up.

At the beginning of an economic contraction, demand for goods and services declines but firms may be slow to lay off workers both because they may have invested a considerable amount of time and money in their recruitment and training, and because there are costs associated with laying those workers off and then re-hiring them when business recovers. The other input to production, physical capital, is relatively fixed in the short run. So, at the beginning of an economic downturn, output tends to fall more rapidly than either labor or capital, and so measured productivity declines.

If the contraction continues and production falls enough, firms will begin to lay off workers. But, at first, they will tend to be those most recently hired with the least amount of training and who were relatively less productive than those hired before. Reducing the quantity of labor employed tends to moderate any initial deceleration in measured productivity growth.

As the contraction comes to an end and the economy begins to expand again, firms can increase their output initially by putting idle capital back to work and taking advantage of any under-utilized labor already on hand. This increase in output with little or no increase in either labor or capital is reflected 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. Thus, as the expansion ages, productivity growth slows from the rates earlier on in the expansion.

Measuring Productivity

Productivity is a ratio of the quantity of output produced to the quantity of inputs used in its production. An increase in the quantity of output with no increase in either labor or capital would be an increase in productivity. As long as output is rising faster than the contribution of labor and capital, measured productivity will rise.

There are two different measures of productivity published by the federal government. Both are published by the Bureau of Labor Statistics of the Department of Labor (BLS). The measure of output used by BLS in the calculation is based on data from the national income and product accounts published by the Bureau of Economic Analysis of the Department of Commerce (BEA). The first, and probably the one most often cited in press reports, is *labor* productivity. 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 done. If the quantity of output rises by the same proportion as the amount of work, then the economy is only producing more either because there are more workers, or workers are putting in longer hours, and there is no productivity growth. If output rises faster than hours worked, labor productivity is also increasing.

The second measure, known as multi-factor productivity, also referred to as total factor productivity, accounts for increases in both hours worked and growth in the capital stock. Multi-factor productivity typically rises more slowly than labor productivity because there is a more complete accounting of inputs. The difference between the two measures is mainly attributable to increases in the ratio of capital to labor.

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 factors involved. The dollar value of output, however, reflects both prices and quantities. Distinguishing between changes in output that are "real" (i.e., indicative of changes in quantity), and changes that are only due 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. Over time, most products acquire new characteristics that make it difficult to compare them with earlier models. An increase in the price of a car, for example, may reflect rising prices throughout the economy, but it may also reflect new features such as catalytic converters or airbags. Ideally, those price increases due to the addition of these new characteristics would not affect the price index for cars. Even though the same number of cars might be sold in successive periods, the newer model car might provide a better (e.g. safer or less polluting) service over its useful life. A more difficult problem is the introduction of an entirely new product because there is no price from an earlier period with which to compare the introductory price.

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 change in the price of a "computer" from one year to the next, the BEA attempts to track changes in the price of "computing power."[1] 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.

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, what should be measured as production, the number of office visits per hour? Should success at treating various ailments be taken into account?

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[1] 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, pp. 17-22.

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Some have argued that because the service sector accounts for a growing share of total national output, and because it is more difficult to measure productivity in the service sector, that overall measures of productivity have become more prone to error. At one time it was suggested that at least part of the slowdown in productivity growth that began, by most accounts, in 1973 may have been due to measurement problems associated with the increased size of the service sector.[2] More recent evidence suggests that is unlikely to have been the case. Those sectors considered to be harder to measure account for some of the larger productivity gains since 1995.[3]

Productivity Growth: Historical Patterns

How does productivity growth in the economic expansion of the 1990s compare with those of the past? Table 1 presents data for annual rates of growth in *labor* productivity between successive business cycle reference dates for the post-War era.

Two observations are apparent from the data in the table. First, there is clearly a tendency for productivity growth to be procyclical. That is to say that productivity growth is higher during expansions (trough to peak) than during contractions (peak to trough). Second, it is clear from the data that, since the business cycle peak in the fourth quarter of 1973, productivity growth has been quite a bit slower than was the case before.

In order to separate changes in long-term trends from those changes that reflect more variable short run economic conditions, analysts often compare data from similar points in successive business cycles. A look at the peak-to-peak rates of growth in productivity for past business cycles reveals that productivity growth fell by about half after 1973.

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[2] Zvi Griliches, "Productivity, R&D and the Data Constraint," *American Economic Review*, Volume 84, Issue 1, March 1994, pp. 1-23.

[3] Robert J. Gordon, *Recent Productivity Puzzles in the Context of Zvi Griliches' Research*, paper presented to meetings of the American Economic Association, Jan 5, 2002, 17 pp.

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Table 1. Growth in Output per Labor Hour, Private 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	3.6	4.4	4.2
1953:3	1954:2	1957:3	1.6	2.6	2.4
1957:3	1958:2	1960:2	2.1	3.1	2.8
1960:2	1961:1	1969:4	1.1	3.4	3.2
1969:4	1970:4	1973:4	2.9	3.2	3.1
1973:4	1975:1	1980:1	0.3	1.7	1.4
1980:1	1980:3	1981:3	-1.7	3.2	1.6
1981:3	1982:4	1990:3	-0.3	1.9	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.

For much of the post-World War II era, the U.S. experienced relatively rapid rates of productivity growth. Between the fourth quarter of 1948 and the fourth quarter of 1973, output per labor hour in the private business sector grew at an annual rate of 3.2%. Between the fourth quarter of 1973 and the first quarter of 2001, that rate fell to 1.7% per year. Most economists point to 1973 as the beginning of an extended period of slower productivity growth. This drop in the rate of productivity growth has been the focus of much economic research. Thus far, the slowdown remains poorly understood.

The economic expansion which began in March 1991 and ended in March 2001 (120 months) was the longest U.S. expansion on record.[4] Only two other expansions have been long enough to allow meaningful comparisons. The expansion of the 1960s began in February 1961 and ended in December 1969 (106 months), and the expansion of the 1980s began in November 1982 and ended in July 1990 (92 months). Figure 1 compares productivity growth in the latest economic expansion with those two earlier expansions. For each expansion represented, productivity is set equal to 100 at the initial cycle trough (i.e., the starting point of the expansion).

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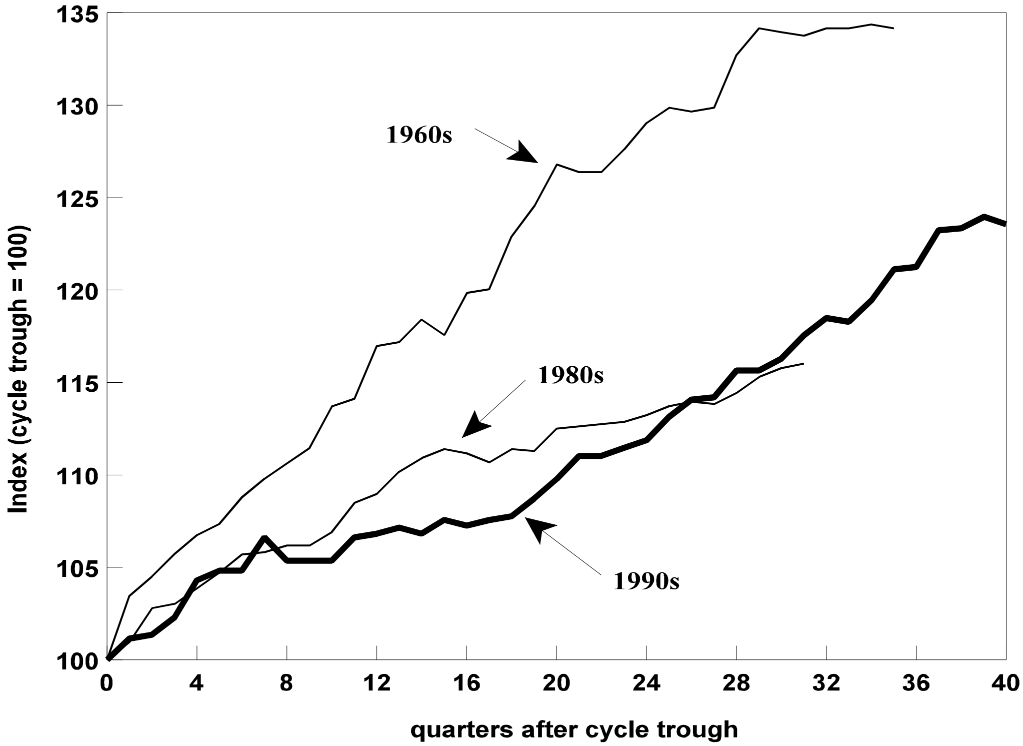
[4] The Business Cycle Dating Committee of the National Bureau of Economic Research is widely acknowledged as the arbiter of U.S. business cycle reference dates. See its website at: <http://www.nber.org/cycles.html>.

Figure 1. Labor Productivity in 3 Long Expansions



Source: Department of Labor, Bureau of Labor Statistics.

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The chart shows that the expansions of the 1960s and the 1980s followed, more or less, the typical pattern described earlier. Rates of growth tended to be more rapid earlier in the expansions than was the case towards the end of the expansion. It is also clear that productivity grew much more rapidly in the expansion of the 1960s than in the 1980s.

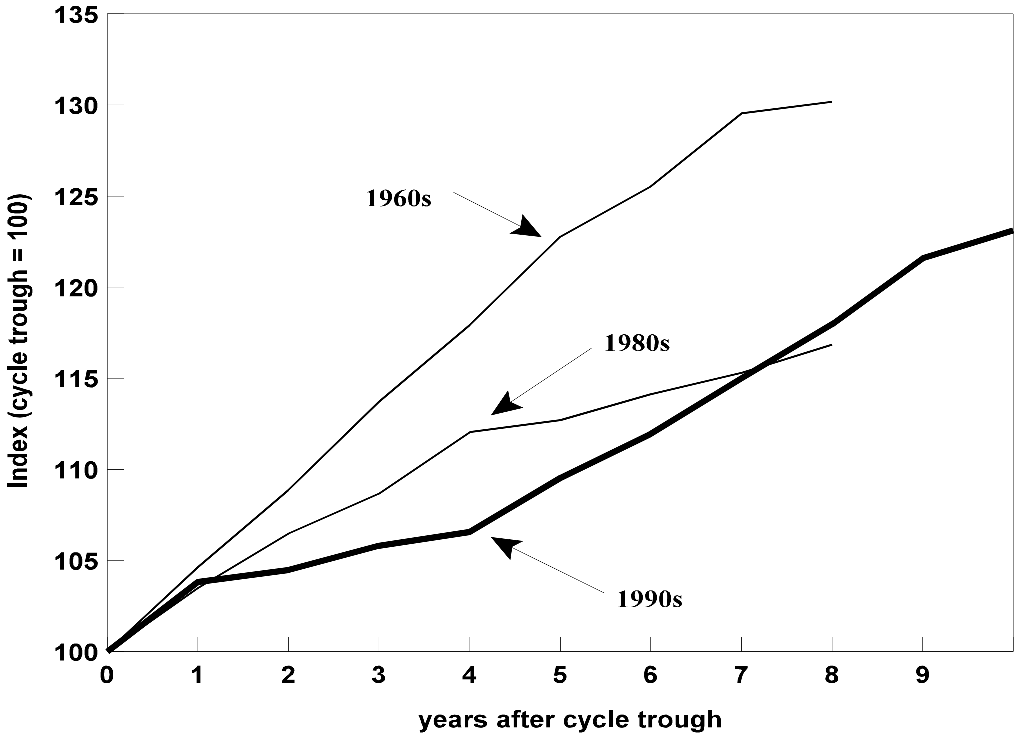
The expansion of the 1990s did not follow the typical pattern. For about the first half of the expansion it did seem to be typical with productivity growth slowing from its pace at the start. But after about four years, productivity growth unexpectedly accelerated. That productivity growth accelerated at the midpoint of the expansion has been interpreted as evidence that there has been a shift in the long-run trend.

Multi-factor productivity. BLS also publishes an alternative set of productivity measures which account not only for labor used to produce goods and services, but also for the role that capital plays in the production process – multi-factor productivity, as described above.

Capital comes in two forms, physical capital and human capital. Physical capital refers to the land, plant, equipment, and inventories that are used in the production of goods and services. Human capital results from investments in education and training which yield a more capable workforce.

In calculating the multi-factor measure of labor productivity, the input of labor takes changes in labor quality into account. In other words, an adjustment is made which reflects investments in education and training, otherwise known as human capital. Figure 2 compares growth in this measure of labor productivity in the current expansion with previous business cycles. (These data are only available annually).

Figure 2. Multi-factor Productivity – Labor



Source: Department of Labor, Bureau of Labor Statistics.

Figure 2 shows again that the expansions of the 1960s and 1980s exhibited, more or less, typical patterns of productivity growth. That is to say, growth rates were relatively more rapid early in the expansions and relatively less rapid as the expansions drew to a close. As was the case with the previous measure of labor productivity, the expansion of the 1990s was atypical. Although productivity growth was slower in the second, third and fourth year than in the first year of the expansion, productivity growth accelerated in the fifth year and continued at a relatively rapid pace.

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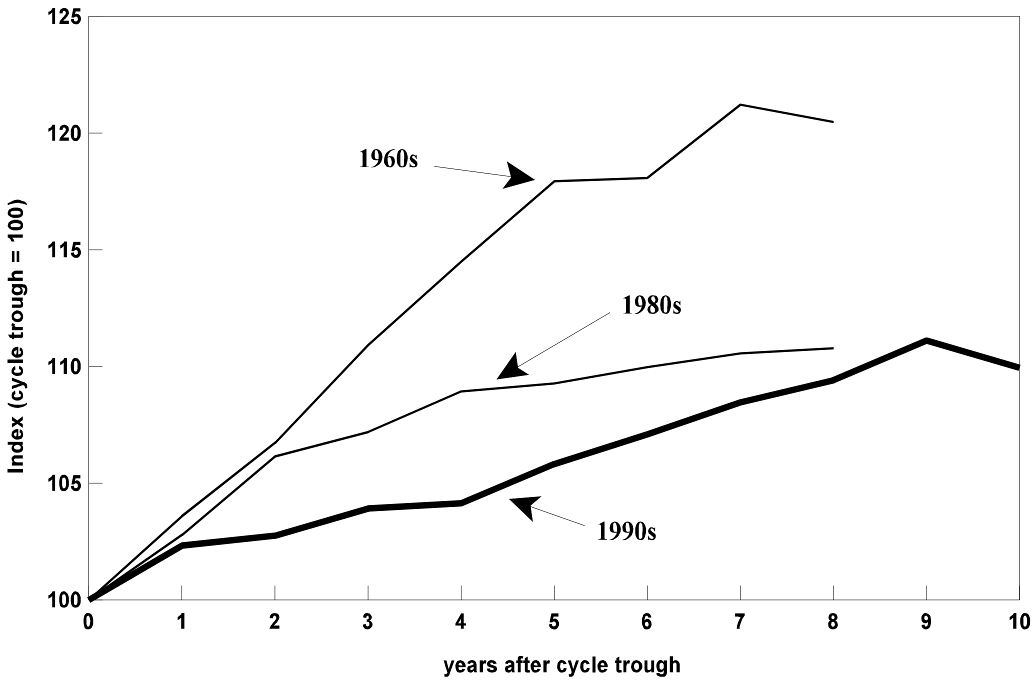
Figure 3 compares growth in multi-factor, also known as total factor, productivity over each of the three long postwar expansions. This measure accounts for contributions of both labor and capital in the production of goods and services. Because capital's contribution to the production of goods and services is also taken into account, it rises by less than do the other measures which take only labor hours into account.[5]

Figure 3. Multi-factor Productivity – Total



Source: Department of Labor, Bureau of Labor Statistics.

The chart, like the two earlier ones, shows that the expansions of the 1960s and 1980s, were fairly typical in terms of the cyclical behavior of productivity, and that productivity growth in the 1960s was much faster than it was in the 1980s. It also shows that the cyclical behavior of productivity growth in the 1990s expansion was typical through the first 4 years, but was much weaker than in the other two long expansions. After the fourth year, however, productivity growth accelerated.

The unexpected acceleration in productivity in the second half of the 1990s, exhibited by all of these measures, prompted many observers to speculate that there had been an important change that some characterized as the "new economy." It was claimed that, with the expansion of the internet and the widespread use of computers, we were on the verge of an era of much more rapid economic growth.

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[5] Remember that productivity is a ratio of output produced to the inputs used in its production. By adding capital to the inputs, the ratio falls.

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Accounting for Past Changes in Productivity Growth

The long-term trend rate of growth in productivity apparently slowed in the early 1970s. The search for causes attracted the attention of many analysts. If there is to be any hope of designing policies likely to stimulate growth in living standards, or of making projections of productivity growth, it would seem that some understanding of past variations would be critical. It would be particularly gratifying if some single dominant factor could be identified so that policies to counteract it could be designed. Unfortunately, results to date might be described as unsatisfying.

The prime suspect, at least initially, was the OPEC oil price hikes which, in 1973, roughly doubled the price of crude oil. The fact that this price "shock" was more or less coincident with the slowdown in productivity growth made it a likely candidate. The theory was that, because of the suddenly higher cost of energy, much of the existing capital stock became obsolete.[6]

Since 1973, however, there have been additional oil price shocks with no appreciable effect on the rate of productivity growth. Between 1979 and 1981, oil prices more than doubled again. In 1986, the price of oil fell by nearly half. In real terms, the average price of oil in 1998 was less than it was in 1973.[7] That only one of the large oil price changes was associated with a change in productivity growth suggests that, if there is a single factor to blame for the 1973 slowdown, it is likely to be found elsewhere.

Another potential cause which has been examined is spending on research and development. Griliches examined the role of R&D spending in the productivity slowdown.[8] He found a decline in R&D spending relative to GDP beginning in the mid-1960s. That timing would seem to make it a good suspect in the 1973 slowdown. But, other countries that also experienced productivity decelerations had no corresponding drop in R&D spending. That doesn't mean R&D played no role, but it would be easier to implicate R&D spending if there had been other instances.

Griliches also points out that, in the 1970s, the number of patents granted in the U.S. declined. That, paired with an increase in the dollar level of R&D spending, resulted in a decline in the number of patents per R&D dollar. Griliches suggests that this decline in the number of patents relative to R&D spending leaves open the possibility of diminishing returns to R&D spending and wonders if it is possible that there exists some sort of technological frontier near which the opportunities for invention become scarce.

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[6] Martin Neil Baily, "Productivity and the Services of Capital and Labor," *Brookings Papers on Economic Activity 1*, 1981, pp. 1-50.

[7] Department of Energy data available on the web at: <http://www.eia.doe.gov/emeu/aer/txt/tab0519.htm>.

[8] Zvi Griliches, "Productivity, R&D, and the Data Constraint," *American Economic Review*, March 1994, volume 84, number 1, pp. 1-23.

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In an attempt to identify causes of the post-1973 slowdown in real output growth, Angus Maddison analyzed a range of likely factors and tried to estimate the contribution of each one.[9] Maddison was only able to "explain" 41% of the 1.4% per year deceleration in real output. Of the 14 separate factors examined, the largest was found to have accounted for less than one-seventh of the slowdown.

Thus, while it might be satisfying if a single cause for the productivity slowdown could be found, it seems more likely that there are multiple factors at work. If the slowdown in productivity had affected all industries more or less equally, that might have favored the case for a single cause for the slowdown, although one factor would not necessarily be expected to affect industries to the same degree. However, when productivity trends are examined for individual industries, some are found to have fared quite well in comparison with others.[10]

Economist Robert Gordon has offered a slightly different perspective on the 1973 productivity slowdown. He maintains that, rather than explaining why productivity growth slowed in the 1970s and 1980s, the focus instead should be on why it was so rapid earlier in the century.[11] Gordon argues 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 cites are the spread of electric motors, the internal combustion engine, and the telephone and its derivatives. Gordon argues that, together, these innovations had a much greater economic effect than the electronic computer. Gordon goes on to suggest that the economy may be on a long-run curve of diminishing returns to technological advancement, and that the various modifications and improvements to devices such as computers are less important than their initial introduction.

It may be that there will always be some portion of productivity growth or variation in productivity growth that will remain unexplained. Early theoretical models of economic growth treated that part of productivity not due to capital accumulation as "exogenous," which is economic jargon for a variable which does not react to the internal influences of an economic system, but rather is external and independent.[12] If that is true, there will always be limits to the extent of influence public policy can have on productivity growth.

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[9] Angus Maddison, "Growth and Slowdown in Advanced Capitalist Economies," *Journal of Economic Literature*, volume 25, number 2, June 1987, pp. 649-681.

[10] 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 #5519, March 1996.

[11] Robert Gordon, "Comments," in Ben S. Bernanke and Julio J Rotemberg, eds., NBER *Macroeconomics Annual* 1996, MIT Press, pp. 259-267.

[12] Robert Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, volume 39, August 1957, pp. 312-320.

Computers and Productivity Growth

Robert Solow, a major contributor to the theory of economic growth, is often quoted for his remark that the effect of computers can be seen everywhere but in the productivity statistics.[13] Through the 1980s and early 1990s, there seemed to be no big payoff from the growing stock of computers. That presented a puzzle to those who expected significant returns.

But it is now believed that computers have had much to do with the acceleration in productivity growth since the mid-1990s. Whether or not 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 getting to the point where consumers expect the rapid pace of innovation in the manufacture of computers to continue. It is also 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.[14] Specifically "Moore's Law" predicted that the number of transistors that could be put on a computer chip would double every 18 months. Whether or not 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 the 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 4 shows the chain-weighted price index, published by BEA, for computers and related equipment from 1959 through early 2003. Because the changes are so large the chart is plotted on a logarithmic scale. Prices for computers have clearly been on a steady downward trend. Between 1959 and 1995, computer prices fell at an average annual rate of nearly 17%, and between 1995 and 2003 prices fell at an annual rate of 19.9%.

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

[14] Gordon E. Moore, Cramming more components onto integrated circuits, *Electronics*, Volume 38, Number 8, April 19, 1965. See also the Intel web site: [http://www.intel.com/research/silicon/mooreslaw.htm].

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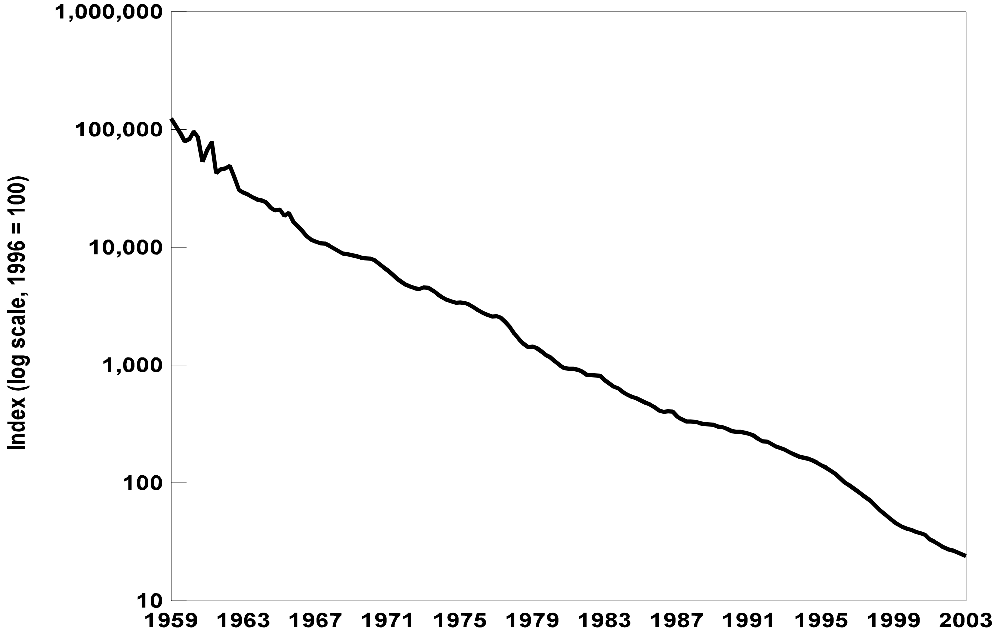
Figure 4. Chain-Weighted Price Index for Computers and Peripheral Equipment



Source: Department of Commerce, Bureau of Economic Analysis.

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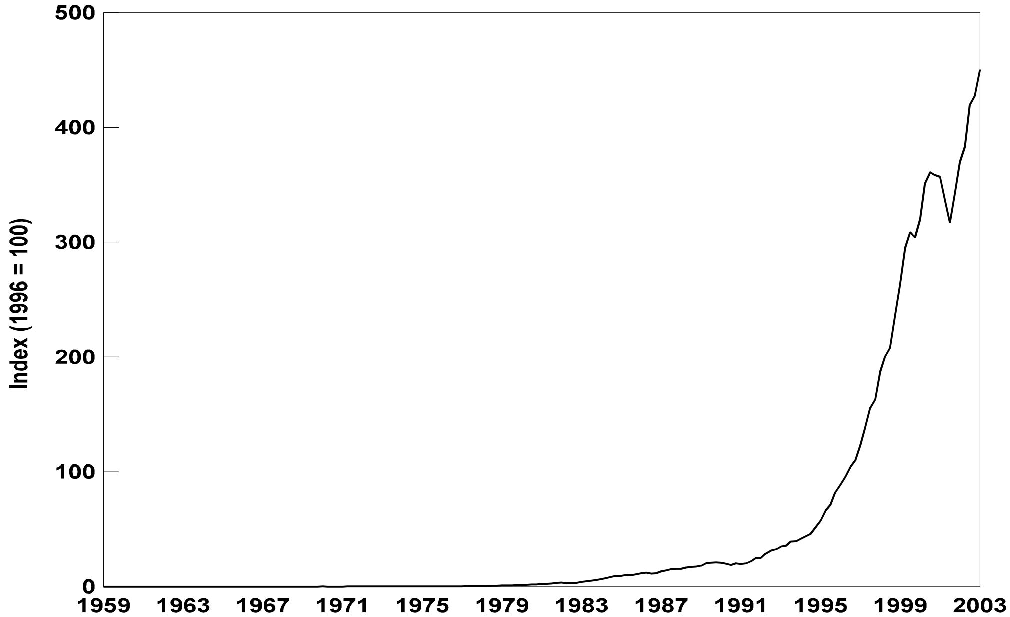
These price declines reflect substantial improvements in the quality of computers. BLS has developed a procedure for estimating price indexes for goods whose characteristics are changing rapidly. These are referred to as "hedonic" price indexes. Hedonic price indexes attempt to estimate a statistical 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%.[15]

Rapid declines in computer prices have, not surprisingly, stimulated a surge in investment. Figure 5 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.

[15] J. Steven Landefeld and Bruce T. Grimm, "A Note on the Impact of Hedonics and Computers on Real GDP," *Survey of Current Business*, Dec. 2000, pp. 17-22.

Figure 5. Chain-Type Quantity Index – Investment in Computers and Peripheral Equipment



Source: Department of Commerce, Bureau of Economic Analysis.

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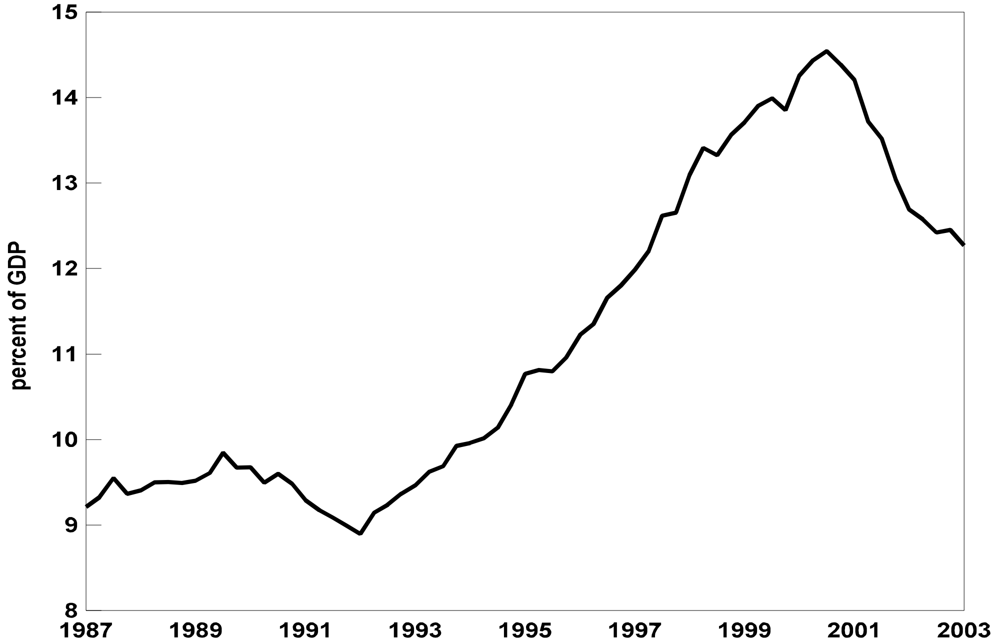
Increased investment in computers made a direct contribution to the increase in economic growth of the late 1990s. Between 1973 and 1995, real GDP increased at an average annual rate of 2.9%. Of that 2.9% growth, production of information processing equipment and software contributed 0.3 percentage points. Between 1995 and 2000, real GDP grew by an average of 3.9%, and information processing equipment and software contributed 0.7 percentage points of that growth.

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 capital stock generally tend to raise worker productivity.

In part because of increased spending on IT equipment, the overall rate of investment spending rose significantly in the 1990s. Figure 6 presents real fixed investment as a share of total GDP since 1987. Since the end of the 1990s expansion, the ratio has fallen, but it remains above its 1995 level.

Figure 6. Real Private Non-Residential Investment as a Percentage of GDP



Source: Department of Commerce, Bureau of Economic Analysis.

There remains the question, however, whether or not the acceleration in productivity growth is limited to developments in the world of information technology.

What Explains the Acceleration in Productivity Growth?

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Prior to the recent acceleration in productivity growth, most analyses found that computers were not yielding much benefit. One reason for that is that, until recently, computers accounted for a relatively small share of the total capital stock.[16]

But, that view has now changed. Although perhaps not yet embracing all of the claims of proponents of a "new economy," economists are encouraged that the acceleration in productivity growth of the late 1990s may mean that the economy is on a higher growth path and that computers have had a lot to do with it.

Two recent studies, discussed below, found considerable evidence that the computer, or more generally IT equipment, is behind most of the recent acceleration in productivity growth. There is also evidence of a modest "spillover" into other sectors of the economy. In other words, investment in computers can raise the productivity of the workers who use them, but it may also lead firms to change the way they operate leading to further productivity gains.

The first study, by Oliner and Sichel at the Federal Reserve Board, found that of a 0.9 percentage point increase in the growth rate of total factor productivity from the first half of the 1990s to the second half, all of it could be accounted for by advances in the production of computers themselves and the also by the use of those computers.[17] Table 2 presents a breakdown of Oliner and Sichel's accounting for productivity growth for selected periods since 1974.

Table 2. Contributions to Productivity Growth

	1974-1990 (1)	1991-1995 (2)	1996-2001 (3)	change (3) - (2)
Growth rate of labor productivity	**1.36**	**1.54**	**2.43**	**0.89**
Contributions from:				
Capital Deepening	**0.77**	**0.52**	**1.19**	**0.67**
Information technology capital	0.41	0.46	1.02	0.56
Other capital	0.37	0.06	0.17	0.11
Labor quality	**0.22**	**0.45**	**0.25**	**-0.20**
Multi-factor productivity	**0.37**	**0.58**	**0.99**	**0.41**
Semiconductors	0.08	0.13	0.42	0.29
Computer hardware	0.11	0.13	0.19	0.06
Software	0.04	0.09	0.11	0.02
Communication equipment	0.04	0.06	0.05	-0.01

[16] Stephen D. Oliner and Daniel E. Sichel, "Computers and Output Growth Revisited: How Big is the Puzzle?" *Brookings Papers on Economic Activity*, 2:1994, pp. 273-334.

[17] Stephen D. Oliner and Daniel E. Sichel, *Information Technology and Productivity: Where Are We Now and Where Are We Going?* Board of Governors of the Federal Reserve System, May 2002, 78 pp.

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Other nonfarm business	0.11	0.17	0.23	0.06

Source: Oliner and Sichel.

Oliner and Sichel found that of a 0.89 percentage point increase in average labor productivity between the early and late 1990s, 0.56 was due to increased investment in IT related capital (an increase from 0.46 to 1.02), and 0.35 was due to increased productivity in the production of IT equipment (an increase from 0.26 to 0.61 in the combined computer and semiconductor sectors). Thus, the contribution of IT equipment to the increase in productivity was greater than the overall increase. Oliner and Sichel also found that labor quality's contribution to productivity growth declined during the 1990s. That is likely related to cyclical factors as the unemployment rate fell and the available pool of skilled workers shrank.

Oliner and Sichel, using an economic model, attempted to assess the implications of recent developments in the technology sector for prospects for continued rapid productivity growth. They conclude that productivity growth is likely to fall somewhere in the range of 2 - 2¾% over the next ten years.

A second study, by Jorgenson, Ho, and Stiroh, came to similar conclusions.[18] Table 3 presents the results of their analysis.

Table 3. Sources of Productivity Growth

	1959-1973 (1)	1973-1995 (2)	1995-2001 (3)	change (3) - (2)
Growth rate of labor productivity	2.63	1.33	2.02	0.69
Contributions from:				
Capital Deepening	1.13	0.80	1.39	0.59
IT Capital Deepening	0.19	0.37	0.85	0.48
Other Capital Deepening	0.95	0.43	0.54	0.11
Labor Quality	0.33	0.27	0.22	-0.05
Total Factor Productivity	1.16	0.26	0.40	0.14
Information Technology	0.09	0.21	0.41	0.20
Non-information Technology	1.07	0.05	-0.01	-0.06

Source: Jorgenson, Ho, and Stiroh.

[18] 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, D.C., on January 27-28, 2003, 28 pp.

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According to Jorgenson, Ho, and Stiroh's estimates, of a 0.69 percentage point rise in average labor productivity growth during the 1990s, increased investment (capital deepening) accounted for 0.59 percentage point, and improved productivity in the IT sector itself contributed another 0.20 percentage point of the acceleration.

The evidence suggests that increased productivity in the sector producing IT equipment has had a modest direct effect on total factor productivity. By far the more important factor has been the declining price of IT equipment stimulating a surge in investment and increasing the size of the capital stock.

Remember that total factor productivity measures changes in output that are not accounted for by changes in economic inputs such as labor and capital. There is no doubt that computers are raising productivity of many firms, but, as long as economic statistics measure them correctly, the increased share of work that computers do will not show up in increased multi-factor productivity because that measure of productivity tracks the increase in output not associated with the increase in investment in computers.[19] It is unclear whether or not computers have had any "spillover" effects on multi-factor productivity beyond their direct contribution to growth in output.

There is some evidence to suggest that those spillover effects – of computers on total factor productivity – are fairly small. Jorgenson and Stiroh found that those sectors of the economy that invest most heavily in computers and IT equipment, such as financial services, had among the lowest rates of productivity growth measured.[20]

Jorgenson, Ho, and Stiroh also estimated projections of growth in average labor productivity. They projected that productivity growth would range between 1.14% and 2.38% over the next decade, with a base case of 1.78%, just below the 1995 - 2001 rate of growth.

In another study, Robert Gordon found that most of the acceleration in labor productivity was attributable to capital deepening and faster productivity growth in the production of computers and IT equipment.[21] Of the roughly 0.2 percentage point increase in total factor productivity, most was accounted for by faster productivity growth in the manufacture of durable goods. That suggests that any spillover effects of computers on the overall economy were limited.

Will the Surge in Productivity Growth Persist?

Perhaps the most important question for policymakers is whether or not the surge in productivity growth of the late 1990s will continue. Higher productivity

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19 Barry P. Bosworth and Jack E. Triplett, *What's New About the New Economy? IT, Economic Growth and Productivity*, Brookings Institution, December, 2000, 35 pp.

20 Dale W. Jorgenson and Kevin J. Stiroh, Raising the Speed Limit: U.S. Economic Growth in the Information Age, *Brookings Papers on Economic Activity*, 2000(1), volume 2, pp. 125-212.

21 Robert J. Gordon, *Technology and Economic Performance in the American Economy*, Working Paper 8771, National Bureau of Economic Research, February 2002,58 pp.

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growth means higher real incomes, which in combination with progressive income tax rates yields higher federal revenues. As long as Social Security operates on a pay-as-you-go basis, it also extends the date of reckoning as far as the trust fund balances are concerned because the incomes of those paying Social Security taxes will grow more rapidly than the benefits. Whether or not productivity growth continues at the rate it did in the late 1990s is a critical concern for those making and using long-term economic forecasts.[22]

It seems likely that the increase in productivity growth of the late 1990s was a shift to a higher long-run trend rate of growth rather than an event limited to the most recent cyclical expansion. But there is still no guarantee that faster growth will endure through the next expansion.[23]

The major difficulty in projecting productivity growth remains an imperfect understanding of past variations. 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. To a great extent, projections of productivity still reflect the optimism or pessimism of the forecaster.

It is clear however that the recent pickup in productivity is largely 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, their use has become much more widespread. Because of falling prices it has become profitable to put computers to uses with smaller and smaller returns. But, as long as recent rates of innovation in the production of computers and IT equipment continue, productivity might at least be expected to continue growing more rapidly than it did between 1973 and 1995.

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

[23] See also: CRS Report RS21527, *The Performance of Productivity During the Recent Slowdown: What Does It Mean for Future Living Standards?* , by Marc Labonte.