Has the Productivity Trend Steepened in the 1990s?

By Andrew J. Filardo

In the 1990s, conventional measures of productivity growth, or the growth in output per worker, have indicated a dramatic rise. If these measures are correct, the economic benefits are clear. In the short run, sustained, faster productivity growth would enable the economy to expand more rapidly without intensifying inflationary pressures. In the long run, sustained, faster productivity growth would boost real incomes and improve the standard of living. Since 1960, for example, productivity advances have helped the typical worker produce 70 percent more output per hour, more than doubling personal incomes.

Despite signs that productivity has recently begun to follow a steeper path, some analysts are skeptical. Episodes of faster productivity growth in the past have often reflected cyclical influences rather than fundamental trend shifts. And, the conventional productivity measure, which is based on *fixed-weighted* productivity data, has recently shown an upward bias.

To address these concerns, this article reexamines the conventional, fixed-weighted productivity measure and also uses a new *chain-weighted* measure to assess productivity growth. The first section of the article summarizes the empirical evidence and describes the theoretical arguments in support of the view that the trend of productivity has steepened. The second section challenges this view of productivity in three parts. The first part challenges the theoretical arguments. The next part suggests the standard statistical tests overstate the significance of the apparent increase in the trend of productivity because they disregard cyclical influences. The final part describes the recent bias of the conventional, fixed-weighted data and shows that statistical analysis using the new chain-weighted data sharply contradicts the steeper trend view. Based on this analysis, the article concludes that the productivity trend has not steepened in the 1990s.

ARGUMENTS SUPPORTING THE STEEPER TREND VIEW

The case for a steeper productivity trend is supported by both empirical evidence and theoretical arguments. Empirically, standard statistical tests suggest that productivity gains in the current expansion have exceeded the typical cyclical improvements in productivity. Theoretically, several factors could have caused such a fundamental shift in long-run productivity.

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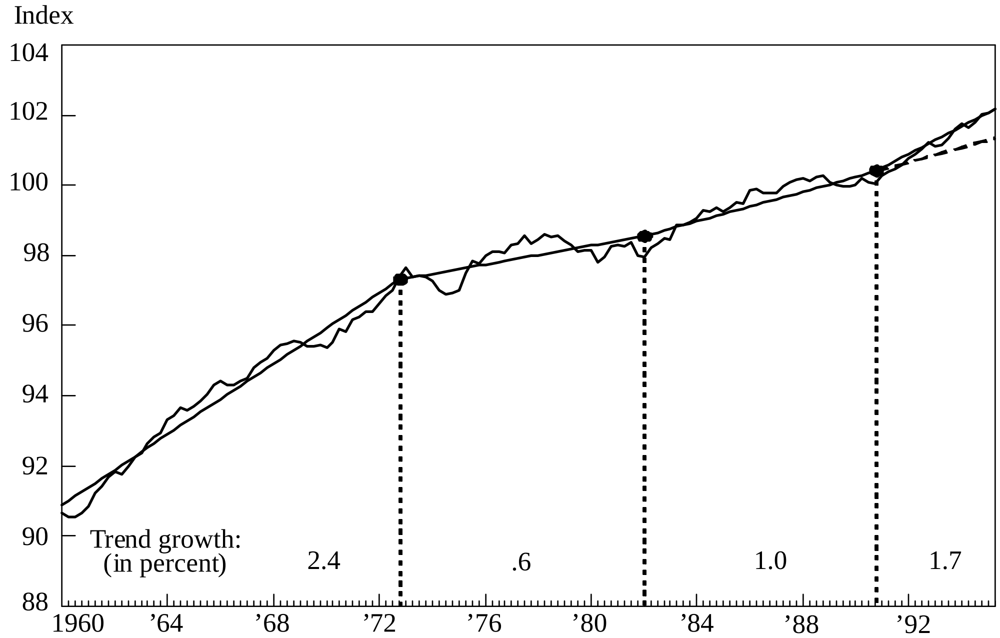
Chart 1

CONVENTIONAL, FIXED-WEIGHTED PRODUCTIVITY AND ITS FITTED TREND LINES



Sources: Bureau of Labor Statistics and author's calculation.

Statistical evidence of a steeper productivity trend

Recent data suggest that productivity may be following a new, steeper trend. Nonfarm business productivity has grown at an annual rate of just under 2 percent in the 1990s, up from the roughly 1 percent rate in the previous two decades. This growth is notable because in this expansion, which began in the first quarter of 1991, productivity growth has expanded more rapidly relative to output growth than in other postwar expansions.[1]

Formal statistical analysis supports the view that productivity has begun to follow a new, steeper trend. Chart 1 shows conventionally measured nonfarm business productivity and the estimated linear trends it has followed since 1960. The trends ignore cyclical influences and grow at different rates starting in 1972:Q4, 1982:Q1, and 1990:Q4, dates which standard statistical tests identify as statistically significant breakpoints. These breakpoints reveal four subperiods of trend productivity (see appendix for description of statistical methodology to identify breakpoints). Long-run productivity grew most rapidly before 1973, slowed dramatically in the 1970s, edged up in the 1980s, and now in the 1990s appears to be climbing moderately.[2] To highlight the steeper current trend, the dashed line in the chart extends the linear trend established in the first quarter of 1982. The divergence of the solid and dashed lines in the 1990s illustrates the apparent steeper trend of 1.7 percent currently being followed, up from a rate of 1.0 percent earlier.[3]

Factors causing the steeper productivity trend

Economists who support the steeper trend view routinely cite three factors underlying the sharp productivity rise in the 1990s. These factors are increased use of computers and computer-related equipment, stronger plant and equipment investment, and widespread corporate downsizing. Theoretically, each factor can cause productivity to increase more rapidly. Empirically, each factor has coincided with the faster pace of conventionally measured productivity.

Increased use of computers. The increased use of computers can steepen the productivity trend by improving the tools and technology that workers use in their jobs. With greater computing power, today's workers can produce more goods of higher quality than their counterparts could produce just a decade ago. Computers have given firms versatility to respond quickly to changing business conditions, thereby making them more efficient. New computers and peripherals with their improved software have enabled employees to assimilate more information in less time.[4]

Empirically, the growth in the use of computers and peripheral equipment has accelerated in the 1990s. From services to manufacturing, computers have become ubiquitous. Real investment of computers and peripherals has skyrocketed from an annual growth rate of 20 percent prior to 1991 to a rate of 32 percent rate since then. This growth has coincided with a consistent decline in computer prices of about 14 percent annually (Chart 2).

Increased use of computers, especially faster and more sophisticated computers, has also raised prospects that technological progress will proceed at a faster pace than in the recent past. These tools will also help increase and spread existing knowledge, thereby increasing the rate at which new ideas and better computers arise. The empirical record supports this view. Greater computer investment has been correlated with an increase in technological progress, especially in manufacturing industries.[5] Expenditures on information-processing and related equipment, which includes new computers and peripherals, have grown substantially for the last 25 years with a significant pickup in the late 1970s and 1980s. Over this period, technological progress, measured by multifactor productivity, has also picked up by 0.5 percentage point for nonfarm business and 2.3 percentage points for manufacturing (Bureau of Labor Statistics and Lysko).[6]

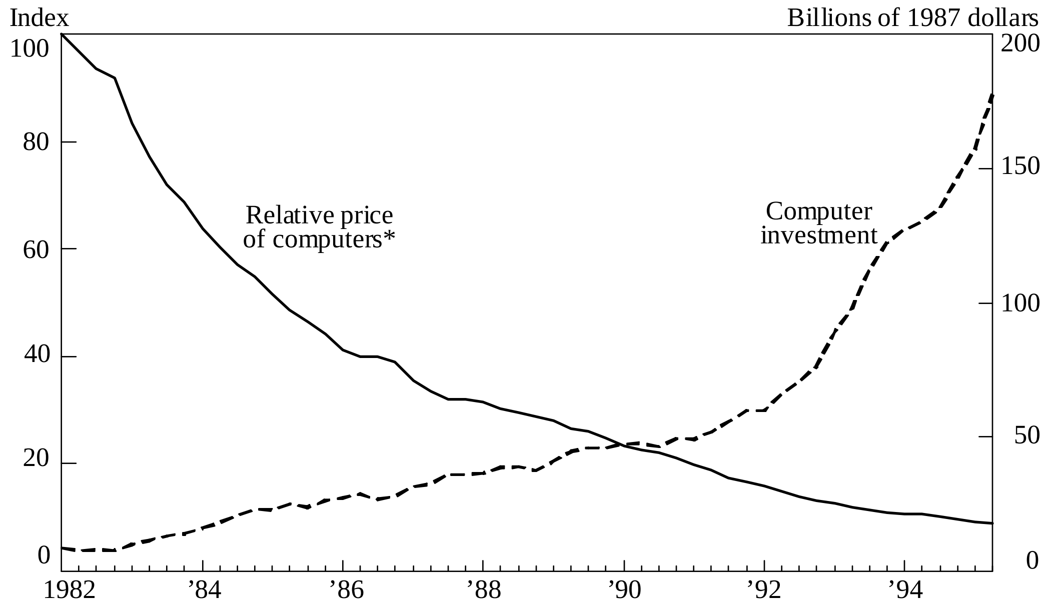
Stronger plant and equipment investment. Analysts also point to stronger plant and equipment investment as a more general factor that could have boosted productivity growth in the 1990s. Plant and equipment investment can increase productivity growth in two ways. First, plant and equipment investment adds to the existing capital stock. With a larger stock of capital, workers can increase their output per hour of effort. For example, a construction worker with a bigger dump truck can haul more dirt in a day than a worker with a smaller truck. Second, plant and equipment investment may increase the rate of technological progress.[7] Some economists argue that innovations in plant and equipment facilitate the use of existing technology and may quicken the arrival of new ideas and future technology.

The growth of gross plant and equipment investment surged in the 1990s (Chart 3). From 1960 to 1990, plant and equipment investment rose at a 3.9 percent rate but since then has more than doubled to 10.1 percent. Such a surge may help to account for the faster pace of productivity in the 1990s.

Widespread corporate downsizing. During the 1990s, corporate downsizing became an important tool to cut costs and trim excesses. A recent American Management Association (AMA) study noted that at least 72 percent of firms in their survey had downsized from 1989 to mid-1995.[8] Chart 4 illustrates an important development in corporate

Chart 2

COMPUTERS AND PERIPHERAL EQUIPMENT RELATIVE PRICE AND INVESTMENT



* Relative price of computers is the computer price index divided by the CPI-U. Index (1982:Q1 = 100).
Sources: Bureau of Economic Analysis and author's calculation.

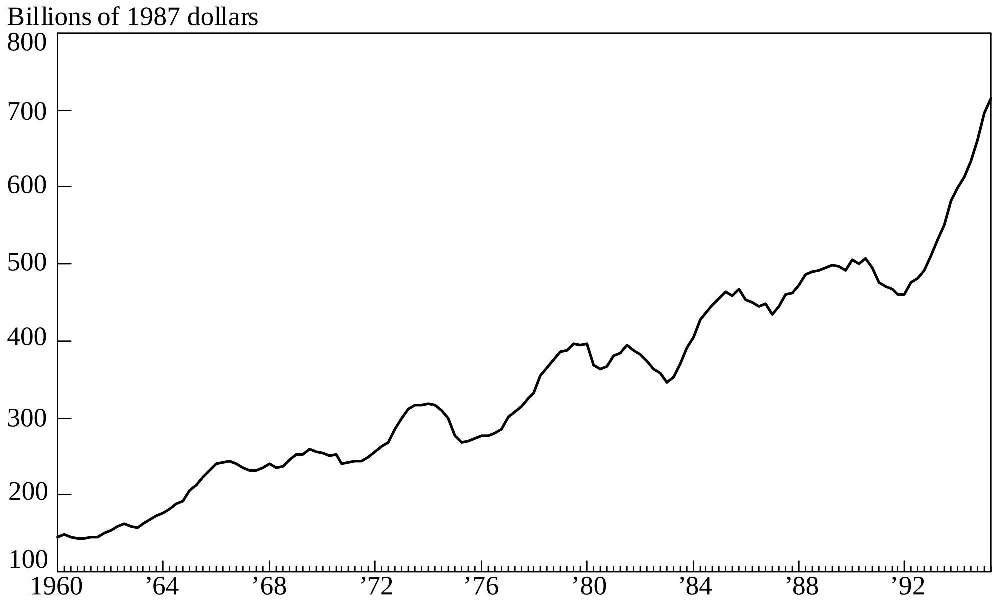
downsizing. Corporations have traditionally scaled back employment primarily during cyclical downturns. In the current business cycle, however, firms have been more willing to prune the workforce well after the cyclical trough, which occurred in 1991. In fact, 1994 was one of the top years for announced layoffs due to downsizing in the current cycle, and over half of the firms cited reasons other than cyclical downturns for the layoffs.[9]

Downsizing offers the promise of higher worker productivity. If done correctly, firms are able to cut their less productive workers and uncompetitive product lines and retain their more productive workers and profitable products. By trimming the excesses, firms can become leaner and more profitable. In fact, half of the firms that downsized from 1989 to 1994 have reaped higher profits. In the process, output per worker might be expected to rise. Thus, widespread downsizing could lead to increased aggregate productivity.

ARGUMENTS AGAINST A STEEPER TREND VIEW

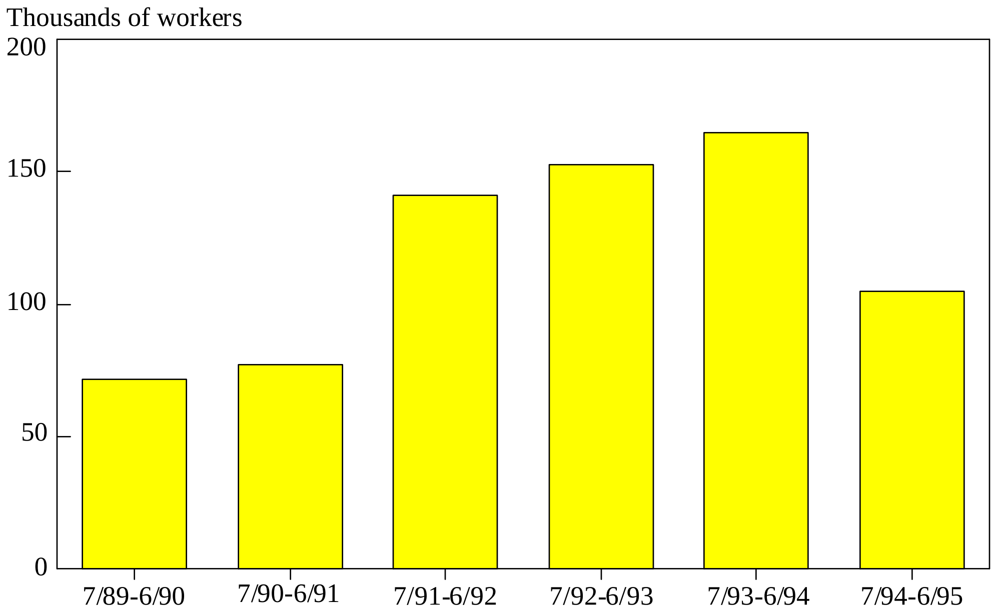
Further investigation reveals several arguments against the steeper trend view of productivity. This section first questions the importance of the link between faster productivity growth and computers, plant and equipment investment, and corporate downsizing. Next, the section challenges the accuracy of the standard statistical tests in detecting breakpoints in the trends because cyclical influences are ignored. A cycle-adjusted test is used to reexamine

Chart 3
GROSS PLANT AND EQUIPMENT INVESTMENT



Source: Bureau of Economic Analysis.

Chart 4
PERMANENT STAFF CUTS ANNOUNCED BY U.S. CORPORATIONS



Source: Challenger, Gray & Christmas, Inc.

the evidence for a break in the conventionally measured productivity trend. The section then examines the impact of bias in conventional, fixed-weighted productivity data on tests to identify the trend breaks. Chain-weighted productivity data, which correct for the known bias in the fixed-weighted data, not only paint a different picture of the productivity trends over the last 25 years, but also provide scant statistical evidence of a steeper productivity trend in the 1990s.

Role of causal factors exaggerated

Increased computer use, stronger plant and equipment investment, and widespread corporate downsizing, as indicated earlier, might have contributed to faster productivity growth in the 1990s. The theoretical links are plausible, and the correlation with faster productivity growth in the 1990s is striking. Yet, the empirical link between each factor and faster productivity growth is not strong.

Computer and peripheral equipment investment. Despite exceptional growth in their use, computers and peripherals equipment cannot account for a shift in productivity growth. To assess the quantitative importance of computers' contribution to productivity growth, a growth accounting method can be used. This method breaks down productivity growth into two sources: growth in factors of production—such as labor and capital—and technological progress. Because increased investment in computers and peripheral equipment adds to the economy's capital stock, such investment has surely contributed to productivity growth. The quantitative significance of its contribution, however, depends on the relative size of computers and peripheral equipment as a component of the capital stock.

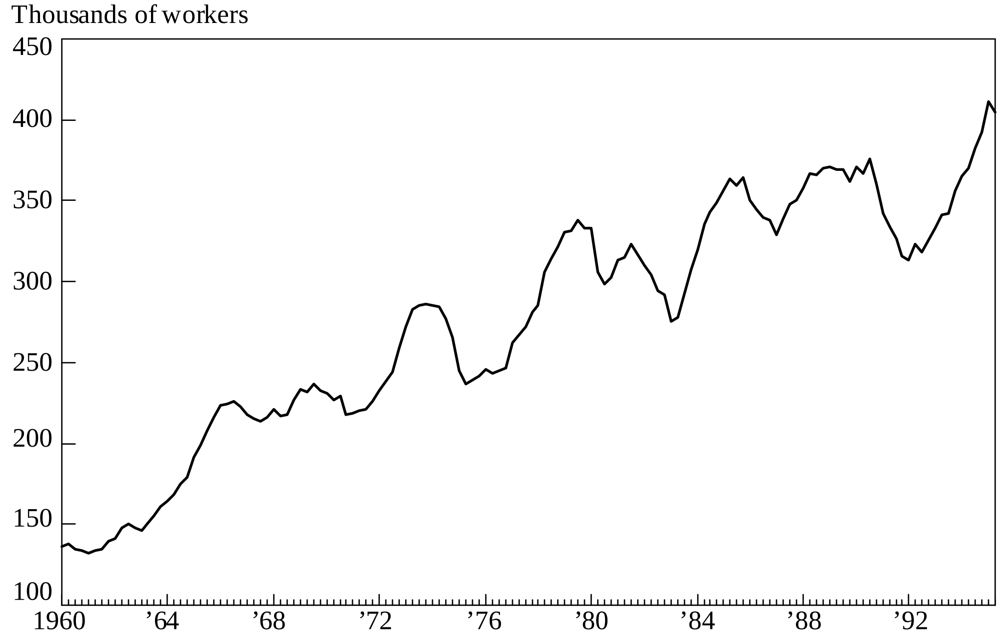
Even though the investment share of computers nearly doubled from 1991 to the first half of 1995, the share of computer and peripheral equipment investment in the capital stock of the economy was too small to significantly increase productivity.[10] In fact, computers accounted for only about 2 percent of the capital stock (Oliner and Sichel). To put this into perspective, even if all firms had increased their purchases of computers from 20 percent to 32 percent per year (with no depreciation in the existing stock of computers), the extra contribution to productivity would have been just 0.002 percent.[11] Taking depreciation into account, the net contribution of information-processing investments would have been even smaller.

Plant and equipment investment. Despite its rapid growth since 1991, plant and equipment investment, excluding information-processing equipment, appears to be showing strong cyclical behavior with no apparent shift in trend. A good portion of the growth of plant and equipment investment has been due to the growth of computer and peripheral equipment investment. Excluding these computer-related investments, the 1990-91 recession witnessed a sharp contraction in plant and equipment investment. Since 1991, the growth has surged to 9.6 percent. Chart 5 illustrates that plant and equipment investment, excluding information-processing equipment, has not exceeded its historical upward trend. Thus, it is doubtful that this factor has spurred productivity. Moreover, several studies have found that equipment investment, including information-processing equipment, has not appreciably influenced the rate of technological progress.[12]

Corporate downsizing. Even though downsizing holds the promise of increased productivity, recent survey data indicate that most downsized companies in the 1990s have not increased productivity despite increasing profits. The recent AMA survey cited earlier showed that firms downsizing between the second quarter of 1989 and 1995 have failed to witness widespread productivity gains. In fact, roughly two-thirds of the surveyed firms that downsized reported unchanged or lower productivity levels. The AMA survey links this poor productivity performance to morale problems and reorganizational snags following downsizing.[13]

Chart 5

PLANT AND EQUIPMENT EXCLUDING INFORMATION PROCESSING EQUIPMENT



Source: Bureau of Economic Analysis.

A recent plant-level manufacturing study largely corroborates the conclusions of the AMA study. Baily, Bartelman, and Haltiwanger examined the consequences of downsizing at manufacturing plants in the late 1980s. They found little systematic evidence of a link between downsizing and productivity gains at manufacturing plants. Productivity gains were found both in plants that increased and plants that decreased their work force. In addition, many downsized plants actually suffered a decline in productivity.

These two studies contradict the conventional wisdom that downsizing leads to higher productivity. Cutting the work force can have negative consequences on productivity even though the short-run effect on profits may be positive. While it is possible that future downsizing efforts may improve productivity growth as a result of lessons learned in the 1990s, the waves of downsizing to date cannot have caused aggregate productivity to increase substantially.

Statistical evidence against a steeper trend

In addition to these challenges to the theoretical arguments, further investigation of the statistical evidence raises doubts about the validity of a new, steeper trend of productivity in the 1990s. The standard statistical analysis discussed earlier lends support to the steeper trend view. The analysis, however, may have provided faulty inferences. To provide more reliable inferences about trend breaks, this section corrects the bias in the standard statistical tests for cyclical influences. This section also discusses implications of the well-known bias in the conventional, fixed-weighted data and reexamines the steeper trend view using the more accurately measured chain-weighted productivity data.

The cycle-adjusted statistical test. The standard statistical test for a trend break in the 1990s may have been affected by the business cycle recession of 1990-91. During recessions productivity typically falls below its trend. As the economy recovers, productivity typically moves back toward the trend and eventually overshoots it. This faster-than-trend productivity pace after a business cycle trough may cause the standard statistical test to falsely identify a new, steeper trend.

To address this concern, a cycle-adjusted test based on the *bootstrap* procedure is used (appendix). While the cycle-adjusted test—using conventional, fixed-weighted productivity data through 1995:Q2—still finds evidence of a break at the 5 percent confidence level, it does not find evidence at the 1 percent confidence level. Thus, taking cyclical behavior into account, the apparent steeper trend is not as strongly supported as indicated by the standard statistical test.

Further application of the cycle-adjusted statistical test raises additional doubts about the strength of the steeper trend view. Instead of using data through 1995:Q2, the modified test uses several data subsamples. Initially, the test uses data through the most recent business cycle trough (1991:Q1) and finds no statistically evidence of a trend break at the 5 percent confidence level. Quarter by quarter, the end of the subsample is sequentially extended and the cycle-adjusted test performed. The test finally finds sufficient evidence of a trend break by 1994:Q4—just three quarters ago. Thus, productivity data released since the end of 1994 are critical observations supporting the steeper trend view.[14]

The three critical observations from 1994:Q4 to 1995:Q2 suggest empirical support for the steeper trend view may be weak. If recent data have been the result of special factors or turn out to be revised downward, then the tentative conclusion of a break in the 1990s may be overturned. Moreover, these three critical observations point out the possibility of a much more fundamental problem with the steeper trend view. The statistical upward bias that has been associated with the fixed-weighted data has been particularly severe over the last three quarters. Such a bias could have affected inferences of a trend shift. To assess the impact of the bias, the statistical tests of this section can be rerun using the chain-weighted productivity data, which are not subject to the bias.

Statistical tests using the chain-weighted data. Traditionally, the Bureau of Economic Analysis (BEA) has reported on economic activity using the conventional fixed-weighted measure of real output. This fall, however, the BEA will begin featuring a chain-weighted index. The chain-weighted measure avoids the “substitution bias” associated with the fixed-weighted measure (box). Consequently, most analysts consider the chain-weighted measure a more accurate indicator of economic activity. The differences that arise from using the chain-weighted data provide further arguments against the steeper trend view.

Chain-weighted productivity data paint a picture of productivity’s historical record that differs in three ways from one using the conventional, fixed-weighted data. First, the fixed-weighted productivity bias, as measured by the gap between the chain-weighted and fixed-weighted measures, has varied systematically across time. Chain-weighted productivity grew more quickly on average than fixed-weighted productivity before 1987. For years near 1987, the two measures are virtually identical. Since then, the chain-weighted data have grown more slowly.[15]

FIXED-WEIGHTED AND CHAIN-WEIGHTED OUTPUT AND PRODUCTIVITY MEASURES

In theory, labor productivity is measured as a ratio of output per unit of labor input. In practice, to measure productivity economists have traditionally relied on fixed-weighted, nonfarm business productivity, which is the ratio of real, fixed-weighted nonfarm business output to nonfarm employee hours. This practice will change in the fall of 1995 as the Bureau of Economic Analysis (BEA) switches from featuring the fixed-weighted measure of real output to a chain-weighted measure. This box highlights some theoretical and empirical differences between the two output measures and discusses the implications for productivity measures.[16]

Theoretically, the key difference between the fixed-weighted and chain-weighted measures is reflected in their names. With the fixed-weighted method, price weights from a fixed benchmark year are used to measure real output. Currently, the conventional benchmark year is 1987. With the chain-weighted measure, price weights are chain-linked, which allows the weights to change annually.[17]

When the fixed-price weights differ significantly from the chain-price weights, the fixed-weighted output measure tends to mismeasure real output. This difference naturally occurs as one moves farther away from the fixed benchmark year because relative price changes tend to lead to changes in purchasing habits. Generally, when the prices of goods and services fall, consumers and businesses tend to substitute away from the relatively high-priced goods, thus causing the relatively low-priced goods and services to experience faster growth. Consequently, the fixed-weighted measure of real output tends to overstate the growth rate of real output because the faster growing sectors are weighted with the relatively high 1987 prices. The extent of the overstatement is called the "substitution bias."[18]

The chain-weighted measure can remedy the substitution bias by annually updating the price weights. For example, one primary factor for the substitution bias in the 1990s has been the large, persistent declines in computer prices. Each year computer and peripheral equipment prices have fallen about 14 percent. From 1987 to 1991, the declines were associated with very little bias. But, by 1995:Q2, the cumulative price declines helped to contribute 0.7 percentage point to the bias in the fixed-weighted measure. The chain-weighted measure avoids this bias by annually adjusting price weights because year-to-year relative price changes are modest when compared with cumulative multiyear changes that affect the fixed-weighted measure.

Empirically, the fixed-weighted and chain-weighted output measures paint slightly different pictures of economic growth in the three subperiods: pre-1980s, the 1980s and early 1990s, and post-1991. In the 1980s and early 1990s, the fixed-weighted and chain-weighted measures of real output historically were similar. In fact, from 1984 to 1991 the two measures were virtually identical.

FIXED-WEIGHTED AND CHAIN-WEIGHTED OUTPUT AND PRODUCTIVITY MEASURES (continued)

Before 1980, however, the fixed-weighted output tended to grow more slowly than the chain-weighted output. From 1960 to 1980, fixed-weighted output grew 3.4 percent annually while chain-weighted output grew 3.7 percent annually. Business cycles were also more muted under the fixed-weighted measure in this period.[19]

Since 1991, chain-weighted output has grown 2.8 percent annually, while fixed-weighted output has grown at a much faster 3.3 percent rate. This 0.5 percentage point difference suggests that the current expansion has been less robust than previously thought.

The chain-weighted output picture implies a different productivity picture in the postwar period. Chain-weighted productivity grew more quickly than fixed-weighted productivity when chain-weighted output grew more quickly than the fixed-weighted output. Conversely, chain-weighted productivity grew more slowly than fixed-weighted productivity when chain-weighted output grew more slowly than the fixed-weighted output. For example, since 1991, chain-weighted output has grown more slowly than conventional, fixed-weighted output. As a result, recent productivity has been overstated.

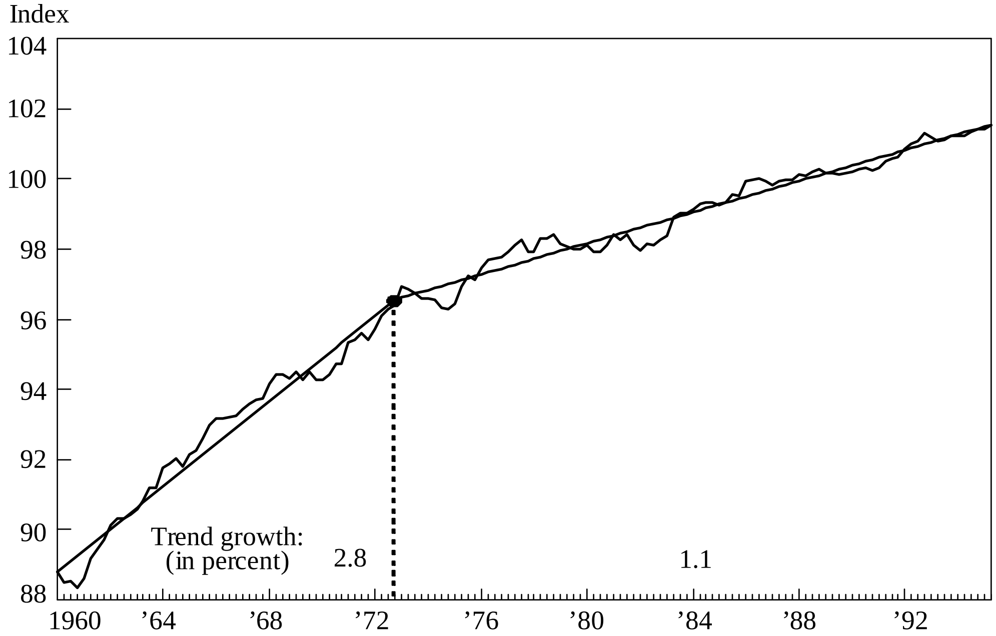
Second, the bias also has varied over business cycle swings. The chain-weighted productivity swings were more exaggerated before 1987, but more muted after 1987, than the fixed-weighted productivity swings. In the 1990s, for example, the conventional fixed-weighted productivity measure has overstated annual productivity growth by a quarter percentage point on average in the 1990-91 recession and by nearly one percentage point in the current expansion. From 1960 until the mid-1980s, in contrast, fixed-weighted productivity understated productivity growth in both expansions and recessions.[20]

Third, and most important, the bias alters the relative growth rates of the four subperiods of productivity growth. Recall that in the rapid postwar growth period prior to 1973:Q1, productivity growth was 2.2 percent using the fixed-weighted measures. Since then, fixed-weighted productivity slowed markedly to 0.6 percent from 1973:Q1 to 1982:Q1, edged up to 1.0 percent from 1982:Q2 to 1990:Q4, and since 1990:Q4 appears to have revived to 1.7 percent.

Using the chain-weighted measure, history looks different. Clearly, pre-1973 was a period of rapid productivity growth according to both measures. Chain-weighted productivity grew at 2.8 percent annually. After that period, chain-weighted productivity appears to have grown more quickly before 1987 and more slowly after 1987. Together, the upward revision in the 1970s and the downward revision in the 1990s have straightened the trends in the three subsequent subperiods; growth since 1972:Q4 has averaged about 1 percent annually in each of the subperiods. Consequently, the chain-weighted data raise the possibility there were no breaks in trend productivity in either 1982 or the 1990s.

Chart 6

ALTERNATIVE, CHAIN-WEIGHTED PRODUCTIVITY AND ITS FITTED TREND LINES



Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, and author's calculation.

Tests with the chain-weighted productivity data confirm the absence of trend breaks during the 1980s and 1990s. In contrast to conventional, fixed-weighted productivity data, chain-weighted productivity data exhibit a steady, unchanged trend since 1973. Chart 6 overlays the chain-weighted productivity data and its estimated linear trend. In the post-1972 period, long-run productivity began rising at a 1.1 percent rate with no apparent evidence of a break. Statistical tests confirm the visual impression suggested in Chart 6. Standard and cycle-adjusted statistical tests using the chain-weighted data find no evidence of a break after 1972.[21] Productivity appears to follow the 1.1 percent trend line quite closely.[22] Thus, the substitution bias in the fixed-weighted data has helped to bias standard and cycle-adjusted tests toward identifying a productivity trend break in the 1990s.

SUMMARY

This article finds no compelling evidence that trend productivity has steepened in the 1990s. Theoretical arguments supporting the steeper trend view—the increased use of computers, stronger plant and equipment investment, and widespread corporate downsizing—are qualitatively plausible, but quantitatively impotent. In addition, standard statistical tests strongly supporting the steeper trend view are misleading. The cycle-adjusted test using the fixed-weighted data provides only weak support for the steeper trend view. This test also shows that recent productivity gains have prejudiced inferences toward finding a trend break. Inferences made from the recent, conventionally measured data may be misleading because the recent strong growth in productivity has coincided with a well-documented, upward bias in these fixed-weighted data. This article evaluates the impact of the bias by considering chain-weighted productivity data that are immune to the bias and are considered more accurately measured. Using chain-weighted data, the long-run trend of productivity has remained unchanged, growing 1.1 percent annually since the early 1970s. In sum, this article concludes that the productivity trend has not steepened in the 1990s.

APPENDIX

This appendix describes the statistical analysis used in the article to test for a shift in the trend of labor productivity. A statistical linear trend model is estimated, and two testing methods are used to identify trend breaks. The first is standard statistical test and the second is a business-cycle-adjusted test, which addresses some known weaknesses in the standard test. The appendix will highlight the statistical significance of the article's results (Table A1).

Statistical model

The trend model of productivity uses a single-equation regression method. The dependent variable is the logarithm of nonfarm business labor productivity denoted by y_t. The explanatory variables include a constant, a piecewise linear time trend, T_i, and an error term, e_t.

$$y_t = constant + \sum_{i=1}^{n} a_i T_i + e_t .$$

The least square coefficients a_i are estimators of the slope of the productivity trend in each of the n subperiods. Each coefficient can be interpreted as average growth rate of productivity between the breakpoint dates.[23]

Standard statistical tests

This article uses a standard statistical test to detect shifts in the productivity trend. Technically, this test is similar to a Chow breakpoint test. Instead of choosing a candidate breakpoint to test, this method searches over all dates for possible breaks in the slope of the productivity trend. The statistical significance of a trend break is tested using critical values from an F-distribution; if the estimated model generates an F-statistic greater than the critical value, then the test indicates a statistically significant trend break.

Several tests were run to test for a break before the 1990s. Sequentially, the method searched over all possible breakpoints. When one was found by maximizing the F-statistic prior to the 1990s, the breakpoint was noted and the procedure was repeated. Using fixed-weighted nonfarm productivity, this method found trend breaks at 1972:Q4 and 1982:Q1. The trend growth rate was 2.2 percent before 1972:Q4 and 0.6 percent from 1972:Q4 to 1982:Q1.

Given these breaks, two sets of tests were run to examine a break in the 1990s. First, using data through 1995:Q2, the sequential breakpoint tests were run and yielded a statistically significant breakpoint in 1990:Q4. The growth rate from 1982:Q1 to 1990:Q4 was 1.0 percent and the trend growth rate afterward was 1.7 percent. Second, research earlier in the decade failed to find a trend break in the productivity series and thus suggested that the faster pace of productivity growth simply reflected cyclical fluctuations. To reassess this earlier research, the data series was truncated at 1991:Q1. The breakpoint test was run and verified the finding that no statistically significant evidence indicates

Table A1

STATISTICAL TREND TESTS

	Estimated	Standard error	P-value of trend break test at 1990:Q4 Standard	Alternative
Fixed-Weighted Productivity				
1948:Q1-1972:Q4	2.4	.04		
1973:Q1-1982:Q1	.6	.05		
1982:Q2-1990:Q4	1.0	.07		
1991:Q1-1995:Q2	1.7	.18	.002	.012
Chain-Weighted Productivity				
1959:Q3-1972:Q4	2.9	.04		
1973:Q1-1995:Q2	1.0	.06	.984	.787

a trend break using data up to 1992:Q4. In fact, using the 5 percent confidence levels, the F-distribution critical value was not breached until 1994:Q1. At the 1 percent confidence level, the critical value was not breached until 1994:Q4.

Business-cycle-adjusted statistical tests

The standard statistical testing methodology suffers from a well-known problem which can be addressed with the test outlined in this section. The sequential procedure in the previous section generates F-statistics that produce inconsistent inferences when compared with the standard F-distribution. In general, the critical values from the F-distribution are too low and consequently may cause faulty inferences about a trend break. One way to avoid these problems is to generate corrected critical values.

To obtain corrected critical values, this article modifies the standard methods in three ways. First, instead of using theoretical critical values, empirical critical values are computed using simulation techniques. The statistical model is simulated 25,000 times under the assumption that there was no break in the 1990s. For each simulation, an F-statistic is computed. Then, an empirical F-distribution is tabulated for the 1 percent and 5 percent critical values. Second, each simulation is run using a set of estimated shocks, instead of using shocks from a normal distribution. The set of shocks are the estimated error series, e_t. This procedure, technically referred to as a bootstrap simulation, is preferred because macroeconomic series such as productivity are at odds with the assumption of normally distributed random numbers. Third, the simulation method in this article corrects the empirical critical values for business cycle influences. In particular, the method adjusts for the 1990-91 recession. In recessions, productivity tends to fall rapidly and then during expansions tends to recover robustly. Such a pattern over a short time period could cause standard methods to identify a new trend when, in fact, the fluctuations simply reflect cyclical behavior.

Using the cycle-corrected critical values, the fixed-weighted productivity shows a break in 1972:Q4 and 1982:Q1 as before. There also appears to be some evidence of a break in the 1990s. The trend break in 1990:Q4, however, garners less statistical support. The break cannot be rejected with a p-value of 1.2 percent (whereas the break cannot be rejected using the standard statistical tests with p-value of 0.2 percent).

Further investigation using the cycle-adjusted tests shows that the p-value falls below the 5 percent level in 1994:Q4. This cycle-adjusted test result together with the associated standard statistical test results raises questions about whether evidence of the break may be partly due to the mismeasurement of the conventional, fixed-weighted data, since the fixed-weighted data have begun to show a substantial upward substitution bias over the last few years.

To examine this possibility, this article estimates the statistical model with the chain-weighted data and performs the standard and cycle-adjusted tests, instead of trying to adjust the critical values for substitution bias in the fixed-weighted productivity data. Both the standard and cycle-adjusted tests yield similar inferences. The tests find no trend break in the 1990s with p-values better than 75 percent. Testing for breaks before 1990 (not reported), this article identifies only one statistically significant break in 1972:Q4; the 1982:Q1 and 1990:Q4 breaks do not appear to be statistically significant.

ENDNOTES

[1] From the trough in 1991:Q1 to 1995:Q2, real GDP has grown 2.9 percent annually, while nonfarm business productivity has grown at a respectable 2.2 percent rate. In comparison with postwar expansions, this productivity increase is even more impressive because output growth in the 1990s was sluggish (Kahn). Comparing the current expansion to those that started in 1961, 1975, and 1982, real GDP for the first 17 quarters rose 4.5 percent annually, while productivity logged only a 2.1 percent increase.

It should also be noted that the small difference between the productivity growth rates is misleading. Special factors in the earlier expansions tend to overstate productivity growth. In particular, the decade of the 1960s was clearly a faster growth period, and the 1970s and 1980s recessions were deeper than in the 1990s.

[2] The trend growth rate of productivity declined from 2.4 percent annually to a 0.6 percent rate in the early 1970s. Since then the trend steepened from 1.0 percent between 1982:Q1 and 1990:Q4 to 1.7 percent after 1990:Q4.

Using data through 1995:Q2, the statistical model finds sufficient statistical evidence to support the steepened trend productivity view. The standard statistical tests identify a break in trend at 1990:Q4 with significance at better than two-tenths of 1 percent (test statistic of 10.3).

Note also that if the pre-1973 trend line were extended to the present, productivity would be 35.5 percent higher, which would support a much higher standard of living.

3 By 1995:Q2, productivity was 10 percent above the trend set in the 1980s, which is denoted by the dotted line in Chart 1. In contrast, productivity has typically overshot its trend by 3 percent 17 quarters into an expansion.

4 In contrast to neoclassical growth models, Romer (1990, 1994) argues that new technology becomes available endogenously. As firms invest a greater amount into research and development—like increased use of computers—the pace of technological progress is expected to quicken. In a different context, Boskin and Lau discuss the empirical complementarity between technological progress and capital investment.

5 Siegel and Griliches find a "positive correlation between productivity growth (but not acceleration of productivity) and investment in computers." Dedrick and Kraemer investigate the contribution of information technology on productivity growth in Asian countries from 1984 to 1990, and discover that stronger information technology investment leads to faster productivity growth. Using recent firm-level data, Brynjolfsson and Hitt, and Lichtenberg both find that computer equipment has had a significant impact on firm output.

6 Some economists believe that computers may have contributed more to productivity growth than has been officially reported. The unreported contribution arises because output growth—and hence productivity growth—is difficult to measure in certain sectors of the economy. Productivity in the service sector is generally thought to be understated because quality changes in output are difficult to measure. For example, grocery stores may report little productivity growth based on traditional measures. However, the increased use of computers has allowed stores to more accurately track inventories, which results in increased variety at lower prices. In addition, computers and scanners enable clerks to check out patrons more quickly than in the past. Such productivity gains go unreported by data collectors. More generally, quality changes in many sectors of the economy, especially in industries with hard-to-measure output, may go unmeasured resulting in an understatement of "true" productivity growth. Consequently, quality improvements from computers may have increased trend productivity but these improvements will not show up in the measured productivity data used in this article.

7 De Long and Summers (1992a, 1992b) argue that plant and equipment investment not only has a direct impact on productivity growth by increasing the capital stock but also has an indirect impact by increasing the rate of technological progress. In an international comparison, they show that countries that invest more in plant and equipment also experience faster productivity growth.

8 The AMA surveyed human resource managers in AMA-member companies. They sampled roughly 10 percent of 8,000 firms, which represents one-fourth of the work force. The survey has been conducted annually since 1987. For more details, see *1995 AMA Survey on Downsizing and Assistance to Displaced Workers*.

An earlier survey by the Conference Board corroborates the extent of downsizing in the economy. In the Conference Board survey, 85 percent of the 406 large firms surveyed had instituted some sort of downsizing in the previous five years.

9 According to the 1995 AMA survey, the rationale for downsizing was the following: 43.7 percent, actual or anticipated downturn; 34.5 percent, improved staff utilization; 19.1 percent, transfer of production or work; 19.7 percent, automation or other new technology; 10.4 percent, merger or acquisition; 5.0 percent, plant or office obsolescence.

10 Baily and Gordon, and Roach discuss the "productivity paradox." They find that the aggregate impact of computers and peripheral equipment in the 1970s and 1980s has been small, at best. Despite the rapid growth of computer investment and declining prices, aggregate productivity did not grow considerably faster.

Since their research was published, the growth in computers and peripheral equipment has continued to rise significantly in recent years, but the size of the sector may still be too small to appreciably affect the aggregate. For example, since 1991, computer investment's share nearly doubled, but as of the first half of 1995, computers still only accounted for 3.1 percent of aggregate output.

11 If the increase at 32 percent were sustained into the indefinite future, the contribution would be approximately 0.002 = (0.32 percent - 0.20 percent)*0.02. This is probably an upper bound since most of the increased gross investment is just offsetting depreciation of the existing capital stock.

12 Auerbach, Hassett, and Oliner dispute the earlier findings of De Long and Summers (1992a). Auerbach and others find that plant and equipment investment has led to a small increase in technological progress. Brendt and Morrison also provide a similar conclusion.

[13] Domestic and foreign outsourcing has increased as firms have downsized. Outsourcing raises the possibility that productivity growth may be overstated. Siegel and Griliches show that outsourcing appears to have little effect on aggregate productivity. Fixler and Siegel find some impact of outsourcing but argue the impact will likely be short-lived.

[14] Earlier studies found some evidence that productivity growth during the first couple years of the expansion was consistent with typical cyclical gains (Gordon); since then, however, productivity has continued to rise at a relatively fast pace. The *Economic Report of the President* (1995) argued that the trend may have steepened. Conventionally measured data have continued to grow over 3 percent in the last year.

[15] Recent evidence from the chain-weighted productivity data may affect the economic outlook of economists and policymakers, especially those who based their outlook on the conventional, fixed-weighted productivity data and the standard statistical test. One change in their outlook is that trend productivity has grown more slowly under the chain-weighted data than previously reported with fixed-weighted data. As a consequence, potential output as measured by the chain-weighted data also has grown more slowly than previously thought using the conventional data (Kahn). It should be noted, however, that slower potential output growth need not suggest that the economy has been experiencing greater resource pressures than previously thought using the conventionally measured data, because output growth under the chain-weighted measure has also been slower. Another change in their outlook is that the slower chain-weighted productivity growth translates into faster chain-weighted unit labor costs. Conventionally reported unit labor costs have been rising at a 1.5 percent annual rate, while chain-weighted measures have been rising at a 2.4 percent rate. Thus, incipient wage pressures may have been greater than previously thought, despite slower chain-weighted output growth during the current expansion. These tentative conclusions may fundamentally change views about the economy by many who have not focused on the more accurately measured chain-weighted output data.

[16] The BEA has published a series of articles that provide details of the fixed-weighted and chain-weighted output measures. These articles also provide details on the advantages and disadvantages, on how to calculate growth rates, and on scheduled revisions for price weights. See Triplett, Young (1992, 1993), and Landefeld, Parker, and Triplett.

[17] For example, the formula used to calculate the 1995 annual gross growth rate of fixed-weighted GDP (Laspeyres quantity measure) is

$$FW\ Growth\ Rate = FW_{94,95} = \frac{\sum P_{i,1987}\,Q_{i,1995}}{\sum P_{i,1987}\,Q_{i,1994}},$$

where $Q_{i,\,t}$ is the quantity of good i in year t and $P_{i,\,t}$ is the price of good i in year t. The gross growth rate for nonadjacent years is, for example, $FW_{92,95}$.

The chain-weighted or Fisher Ideal Method (base years change annually) for the 1995 annual gross growth rate is

$$CW\ Growth\ Rate = CW_{94,95} =$$

$$\sqrt{\frac{\sum P_{i,1994}\,Q_{i,1995}}{\sum P_{i,1994}\,Q_{i,1994}} \times \frac{\sum P_{i,1995}\,Q_{i,1995}}{\sum P_{i,1995}\,Q_{i,1994}}}$$

The chain-weighted measure is the geometric mean of a Paasche and Laspeyres quantity index. In contrast to the fixed-weighted measure, the gross growth rate for nonadjacent years cannot be calculated directly. Instead, the annual growth rates are chain-linked. For example, the growth rate from 1992 to 1995 is $CW_{92,93}$*$CW_{93,94}$ *$CW_{94,95}$.

[18] The table below illustrates how different base year prices can cause the fixed-weighted and chain-weighted measures of real output to diverge. A fictitious economy is constructed that has witnessed considerable change. From 1987 to 1994 the economy has increased its share of computers as the relative price of computers has fallen sharply.

A FICTITIOUS ECONOMY

	Economic data			
	1987	1992	1993	1994
Pcomputer	100	45	35	30
Pother	100	100	100	100
Qcomputer	1	1.7	2.8	3.8
Qother	100	110	112	116

	Annual growth rates	
	1993	1994
Fixed-weighted 1987 base	3.1	4.1
Chain-weighted base	2.5	3.6
Fixed-weighted 1992 base	2.5	3.6
Substitution bias	.6	.5

Calculating the real output growth rates with the fixed-weighted and chain-weighted methods demonstrates that as the composition of the economy changes, the 1987 fixed-weighted measure of real output overstates the growth rate. For example, in 1994 the 1987 fixed-weighted growth rate is 4.1 percent, considerably higher than the 3.6 percent rate measured by the chain-weighted and 1992 fixed-weighted measures. The overstatement is called the "substitution bias."

Intuitively, the 1987 fixed-weighted growth rate is biased upward because the growth in the computer industry is weighted too heavily in the calculation. Instead of a price weight close to 30 to 35, the 1987 price weight for computers is 100. In contrast, if more representative price weights were used that better reflect the 1993-94 economy, the bias is eliminated.

[19] From 1960 to 1990, the fixed-weighted measure understated growth by 0.5 percentage point in expansions and by 0.3 percentage point in recessions.

[20] From 1960 to 1982, the fixed-weighted measure understated productivity growth by 0.6 percentage point in expansions and by 0.2 percentage point in recessions.

[21] With the chain-weighted productivity data, the p-values for the tests of a trend break in the 1990s are 0.984 for standard statistical tests and 0.787 for the cycle-adjusted tests. P-values less than 0.05 provide evidence of a break at the 5 percent confidence level. These tests are more fully described in the appendix.

[22] The unchanged trend result found with the nonfarm productivity data is also corroborated using the manufacturing data. Since measures of nonmanufacturing industries are thought to underestimate productivity growth, both fixed-weighted and chain-weighted nonfarm business productivity could be downwardly biased. If so, the evidence of an unchanged trend of measured productivity does not rule out the possibility that productivity has actually started rising faster in the 1990s.

To investigate this possibility, an annual chain-weighted manufacturing series was constructed by the author using fixed-weighted and chain-weighted manufacturing gross product originating (GPO) and dividing by hours data. Manufacturing productivity, which accounts for roughly 20 percent of output, is thought to be a more reliable measure of productivity than aggregate output because manufacturing output is easier to measure. For example, the output of a car plant is much more tangible and easier to measure than the output of medical services. Moreover, quality improvements for cars can be measured relatively more accurately than quality improvements in cancer treatment.

The constructed series suffers from two drawbacks that obscure the information about trend breaks. First, the data are available only at an annual frequency. Second, the data on manufacturing GPO are available up to 1993. From 1980 to 1990, the chain-weighted manufacturing productivity grew at an annual 3.2 percent rate, and the fixed-weighted measure grew at an annual 2.9 percent rate. From 1991 to 1993, the chain-weighted and fixed-weighted measures have grown at roughly an annual 2.5 percent rate. Overall, chain-weighted and fixed-weighted productivity measures show no apparent shift in their trends in the 1990s—if any trend emerges, it is more gradual.

[23] Bai describes the econometric theory behind testing for break tests for regression coefficients. Lumsdaine and Papell, and Canjels and Watson consider the econometrics of linear time trend estimation. The autocorrelated errors in the estimated statistical trend model of this article led to simulations using an AR1 model.

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