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What Has Happened to Productivity Growth?

Martin Neil Baily

The collapse of U.S. productivity growth is the most severe and persistent of recent economic problems. Unless there is an increase in growth, American living standards will remain stagnant and problems such as the budget deficit will plaque policy-makers. Why has this happened? Among the important reasons are a failure to innovate, changing demographics, and disruptions to the economy, including oil price increases and inflation.

A persistent decline in productivity growth in the U.S. economy has prevailed since the late 1960's, and it intensified after 1973. Multifactor productivity in nonfarm business grew at 1.75% per year from 1953 to 1968. This rate dropped after 1968 and fell to only 0.32% a year by 1973 to 1979 (Fig. 1). The cumulative effect of this decline on the output of the economy was substantial. Had the pre-1968 growth rate continued, output in 1979 would have been 12% higher than it actually was, with no additional capital or labor used in production. This amount of additional output is much larger than that needed to solve many of today's economic problems, notably the budget deficit.

The nonfarm business sector of the U.S. economy includes everything except government operations, agriculture, and nonprofit organizations. Figure 1 also shows productivity growth in manufacturing, which differs from that of the aggregate economy (*1*). Productivity growth in manufacturing actually accelerated from 1968 to 1973, before slumping from 1973 to 1979.

Although the difference between manufacturing and the aggregate economy is important, a disaggregated view of the slowdown shows the pervasiveness of this decline. Productivity growth has decreased in almost all of the major sectors of the economy. Within the major sectors, the Bureau of Labor Statistics (BLS) looked at specific industry-level performance and found that three-quarters of the industries in their sample had declines in productivity growth (*2*).

The Dimensions of the Slowdown

Multifactor productivity growth is the concept favored by most economists, and now by BLS also. To calculate this measure of

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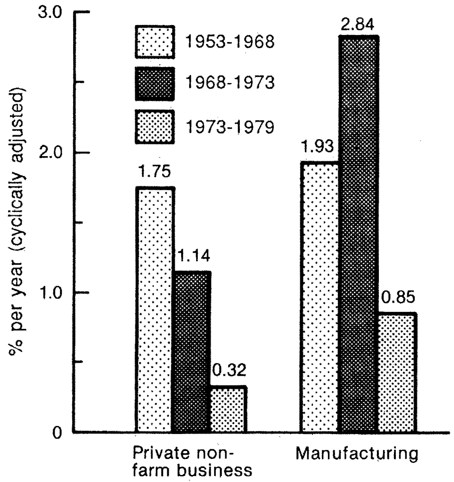
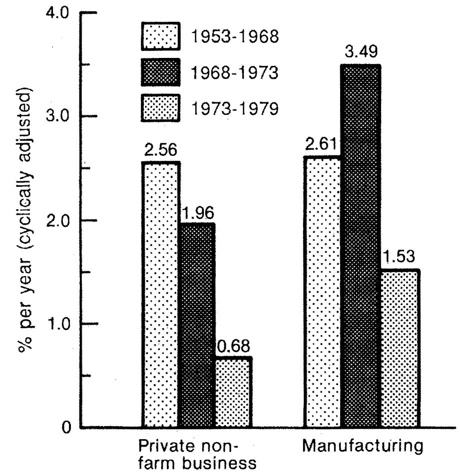


Fig. 1. Multifactor productivity growth in private nonfarm business and manufacturing.

Fig. 2. Labor productivity growth for private nonfarm business and manufacturing.



productivity growth, the rate of growth of inflation-adjusted output is used as the starting point. Then an estimate is made of the direct contribution of increases in labor input and capital input to the growth in output. The extent to which output grew over and above the amount attributable to increases in the quantity of labor and capital is called multifactor productivity growth. It measures the increase over time in the efficiency or productiveness of capital and labor that results from improved technology or better organization and management (*3*).

An alternative and simpler measure of productivity computed as the ratio of inflation-adjusted output to labor input is average labor productivity or output per hour; its growth rate over selected periods is shown in Fig. 2. The post-1973 slowdown in the nonfarm business sector is slightly greater when labor productivity is used as a measure than when multifactor productivity is used. For manufacturing the reverse is true. But, taken as a whole, Fig. 2 looks broadly similar to Fig. 1. The existence and general magnitude of the slowdown show up by using either measure.

Labor productivity increases both because of increases in multifactor productivity and because of increases in the amount of capital invested per worker. Its growth rate, therefore, usually exceeds that of multifactor productivity alone. Multifactor productivity growth is preferable because it allows a clearer separation between the contributions to growth coming from increases in the quantities of factor inputs (capital and labor) and increases in the efficiency of their use. Since the two concepts often change together, however, labor productivity remains useful, especially for comparisons of international economies, where data on multifactor productivity are often unavailable.

Figure 3 shows the growth of labor productivity in the manufacturing sectors of six major countries over the periods 1955 to 1973 and 1973 to 1979. Every country had a substantial decline in productivity growth after 1973. In fact, the absolute size of the slowdown is remarkably uniform across the countries. The growth rate fell by two percentage points in four of these six countries—Japan, Canada, West Germany, and the United Kingdom. It fell by less (1.25 points) in the United States and by only 0.87% in France.

Cyclical adjustments. All of the productivity data in Figs. 1 through 3 have been cyclically adjusted. This means that I have estimated the extent to which short-run fluctuations in demand lead to short-run variations in output and productivity. The impact of these short-run effects is then removed and the remaining data reveal the underlying productivity trends.

Cyclical adjustment is necessary because a period of strong demand always gives a temporary boost to productivity, as everyone works harder and the capital is used for extra hours. A recession always causes a temporary dip in productivity, as there is not enough work to go around and people are assigned to maintenance tasks rather than production (*4*).

The period after 1979. The data in Figs. 1 through 3 end at 1979. The period since 1979 is unique and is treated separately. The key question is whether there has been a recovery of productivity growth. The answer bears on the causes of the slowdown and on such points as whether Reaganomics is working, and it seems to be that some recovery of productivity growth is evident within the manufacturing sector. For the nonfarm business sector as a whole, however, productivity remains weak.

Explanations of the slowdown. A plethora of popular hypotheses explain why productivity growth has slowed, but the serious alternative explanations for the slowdown can be grouped into eight possibilities. A brief explanation of each and a detailed discussion of the main alternatives are presented here.

1) Labor. The level of skill and experience in the labor force may have deteriorated, or workers may not work as hard as they used to.

2) Capital. The amount of capital investment may have been inadequate to sustain the level of productivity growth, or capital investments may not have been very productive.

3) Energy and materials. The price of energy and other raw materials increased at about the same time that productivity growth slowed. In an attempt to economize on these inputs, companies may have reduced the productivity of capital and labor.

4) Output measurement. The products and services produced by the economy are diverse and do not remain constant over time. Part

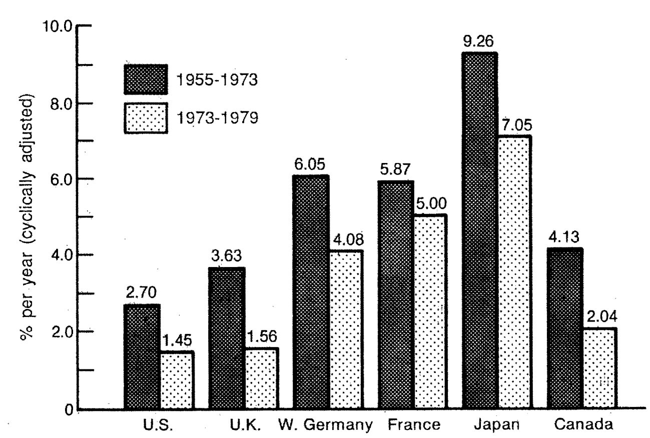


Fig. 3. Labor productivity growth of the manufacturing sector of selected countries.

of the slowdown may be a statistical illusion created by measurement problems.

5) The composition of output. The level of productivity differs greatly in the different industries of the economy. If production shifts toward low-productivity activities, such as small-scale retailing, then perhaps this will pull down average productivity.

6) Technology. A slowing of productivity growth may have resulted from a reduction in the pace of innovation.

7) Management failures. The number of people having a master's in business administration (M.B.A.) who are running companies has proliferated, even as productivity growth declined. It is said that U.S. managers have emphasized financial manipulation and short-term paper profits at the expense of sound investments and technology development. We have managed our way to decline, it is claimed.

8) Government failures. By imposing an enormous burden of regulatory requirements and by allowing high and fluctuating rates of inflation, the government, some believe, has disrupted economic efficiency.

Labor Quality and Effort

The simple productivity calculations given earlier are made by using worker-hours as the measure of labor input. This procedure gives the same weight to an hour of unskilled labor as to an hour of work by an engineer. Clearly that is not reasonable. People differ greatly in their abilities and training. The principal way in which economists have tracked changes over time in the skill level of the work force is by its education level. One economist, Darby, argued that much of the productivity slowdown can be attributed to the allegedly slow rate at which educational attainment increased in the 1970's (*5*).

Darby uses as his index of education the median years of schooling of the adult population. This number increased rapidly through the 1950's and 1960's, but it stopped growing in the 1970's. In terms of correlation, therefore, it serves well as a reason to explain the slowdown. Unfortunately, it is not a useful measure of educational attainment when determining productivity analysis. At the end of World War II the median years of schooling was about 9 years. Half the population had 9 years of schooling or more and half had 9 years or less. In the postwar period, the median rose rapidly until it hit 12 years in the late 1960's. It then stopped growing because a large fraction of the population completes only high school. This does not mean that educational attainment actually stopped rising. In 1980, 16% of the population had four or more years of college and 35% of the population had only completed high school, whereas the corresponding figures for 1970 are 11 and 31% (*6*). In other words, the time-series behavior of the median years of schooling does not correspond to the underlying reality. It is a quirk of the particular statistical measure.

Work on the impact of education on growth has been done by Fraumeni and Jorgenson (*7*) and Denison (*8*). They use estimates of the extent to which an additional year of education adds to each worker's income. This estimate puts a productivity value on what a year of schooling is worth. They also provide detailed information on the distribution of educational attainment in the work force. The quantity and value information are combined to form an estimate of the educational human capital of the work force.

Denison and Fraumeni and Jorgenson reach similar conclusions. The level of educational attainment of the U.S. work force has been rising strongly since 1948 with no decline in its growth rate in the 1970's. Denison estimated that increases in educational capital added 0.40% per year to the growth of output from 1948 to 1973 and 0.47% per year from 1973 to 1982. His figures, therefore, show a slight acceleration in the contribution of education after 1973.

Quality of education. Denison (*8*) and Fraumeni and Jorgenson (*7*) found that the U.S. work force is becoming more and more educated, but, in concluding that more education led to productivity growth, they assumed that the quality of education had remained the same. However, educational quality may have diminished, with a deleterious impact on worker productivity. One possible sign of this reduction in quality is that Scholastic Aptitude Test (SAT) scores followed a long downtrend after 1963. The cohort of students born in 1945 achieved an average score of 478 on the verbal test and 502 on the mathematical test when their scores were recorded in 1963. The cohort born in 1962 and tested in 1980 achieved only 424 on the verbal test and 466 on the mathematical.

Can this decline in SAT scores explain the slowdown? Two obstacles stand in the way of blaming the productivity slowdown on the younger generation and the decline of old-fashioned educational values. The first is that about half of the total decline in SAT scores, and virtually all of the decline over the period from 1963 to 1973, resulted from broadening the base of people taking the test (*9*). As more and more students finished high school, the bottom tail of the ability distribution lengthened.

The second obstacle is that young people do not make up a large enough fraction of the work force to cause the fairly abrupt productivity slowdown that actually took place. The SAT scores, after adjusting for the base broadening, indicate that at most a 5 to 6% decline in the quality of new labor force entrants occurred gradually after 1973. In a simulation model, I demonstrated that this could have had only a minor effect on productivity, at least through 1979 (*10*).

Demographic change. Another reason for the possible decline in labor input quality is the substantial changes in the age-sex mix of the work force. The productivity calculations assume that an hour of work is the same regardless of whether it is supplied by an experienced mature adult or an inexperienced teenager. But the wage rates of adult males are three times as large as those of teenagers and one and a half times as large as those of women. Economic theory suggests that these wage differences reflect productivity differences, because if the adult males were not more productive in proportion to their relative wages, their employers would have replaced them with cheaper alternatives.

Adult males made up 55% of employed persons in 1957; this rate had fallen to 44% by 1979 (*11*). Thus, if it is true that other demographic groups are only one-third or two-thirds as productive as adult males, this demographic shift could have had a substantial effect on productivity.

Most people are willing to accept the idea that teenagers have low relative productivities, but most people are not willing to accept the view that women are inherently less productive than men. However, differences in both wages and productivities need have nothing to do with the intrinsic abilities of the different groups. It is possible that women are confined by custom or discrimination to low-productivity jobs. And, on average, women have less work experience than men. To see the potential consequences of demographic change, I updated work by Perry and constructed an adjusted labor-input measure in which workers in each demographic group are weighted by the relative wage rate of that group (*10, 12*). As the demographic distribution shifted toward workers who earned lower wages, the adjusted labor-input series declined relative to a conventional measure of hours of work, reflecting a possible decline in skill and experience.

The results of this exercise showed that adjusted labor input grew more slowly than the conventional series over the entire period considered (1950 to 1979) and that the impact of demographic change accelerated after 1968. The changing mix of the work force reduced the effective labor input by 0.2% per year before 1968 and by 0.4 to 0.5% after 1968. The adjustment does make some difference, therefore. Demographic change may be an important reason why productivity slowed after 1968. Since there was no further shift in the trend in 1973, however, the adjustment does not explain the intensification of the slowdown after 1973.

Conclusions on labor quality and effort. For many people, either a deterioration in work effort or a decline in labor quality provides a plausible explanation for weak productivity performance. And that may be right. But the evidence for either hypothesis is thin and tends to evaporate on close inspection. The changing age-sex mix of the labor force is probably the most important quantitatively, but even this aspect explains only a part of the overall slowdown.

Capital Accumulation and Capital Services

One of the striking facts about countries with rapid productivity growth compared with countries with slow productivity growth is that the rapid growers invest in new plants and equipment at a much higher rate than slow growers. This evidence suggests that inadequate capital formation may have caused the slowdown.

Hudson and Jorgenson suggested a reason why the rate of capital formation may have slowed and pulled productivity growth down with it (*13*). The price of energy began rising in 1970 and jumped very sharply in 1973. Jorgenson argued that capital equipment uses energy to operate. Automation can be thought of as a process whereby human power is replaced by machinery that uses energy. A rise in the cost of energy makes automation less attractive and hence discourages capital investment. This hypothesis is plausible and can be extended to other countries. Energy prices went up for all the industrialized countries during the early 1970's.

The first question, however, is whether the pace of capital formation actually fell in the 1970's or was inadequate to maintain productivity growth. Table 1 provides information on capital formation. The growth rate of the capital input was unusually high from 1968 to 1973 but was at about a normal level from 1973 to 1979. A stronger case for the inadequacy of investment can be based on the observation that the ratio of capital input to labor input grew less rapidly from 1973 to 1979 than in earlier periods. There was a tremendous increase in labor supply in the United States in the 1970's as young people and women of varying ages came flooding into the labor force. In order to maintain the growth rate of the capital-labor ratio, investment would have had to rise as a share of output, and it did not.

The bottom line on the importance of capital formation to the slowdown comes from the comparison of labor productivity and multifactor productivity growth. As explained, multifactor productivity growth is computed by taking into account the effect of changes in the pace of capital formation. A slowing in capital formation cannot be an explanation for a slowing in multifactor productivity growth. At most, it can help explain a slowing in labor productivity growth.

Capital services. In a 1981 study (*10*), I suggested that part or all of the slowdown in productivity growth might be attributable to a deterioration not in the amount of capital, but rather in the ability of this capital to provide a flow of productive services. If such a decline in capital quality had taken place, but had not been reflected in conventional capital input measures, then it would have had an adverse effect on both measured labor and multifactor productivity. I proposed three reasons why a decline in capital services might have occurred. (i) The rise in the cost of energy made some of the existing energy-inefficient capital obsolete. (ii) Pollution abatement and worker safety regulations meant that part of the flow of new equipment did not add to the ability of capital to produce output. (iii) The expansion of foreign trade meant that many factories in the United States became uncompetitive and had to be closed or were underused.

Capital equipment is designed to produce a particular product in a particular way. Estimates have to be made about the future cost of the labor and raw materials that a piece of capital will use and about the pattern of demand for the product. If those predictions are wrong, then the capital is less productive. Energy-inefficient plants were costly to run after 1973. Companies that had invested in plants to produce consumer electronics in the 1960's found that these plants could not produce and sell profitably against foreign competition in the 1970's.

My hypothesis, therefore, is that even though capital formation remained fairly strong from 1968 to 1979, many investment decisions turned out to be bad ones. As a result, some capital was scrapped prematurely and, perhaps more important, some capital was never fully used.

Is there any evidence to support this view? First, capital productivity has been declining in recent years. The quantity of output produced per unit of capital actually rose by 8% between 1957 and 1968. It then fell by 3% from 1968 to 1973 and fell another 7% from 1973 to 1984 (*14*). These figures are for the nonfarm business sector. A similar result was shown even more dramatically by Bosworth for the manufacturing sector (*15*). Manufacturers report an estimate of their productive capacity to the Federal Reserve Board. Bosworth found that this capacity in 1980 was down about 20% relative to what would have been predicted from the historical relation between capacity and capital investment.

Second, the pattern of the slowdown across industries is consistent with the hypothesis that capital services declined. The manufacturing industries that suffered the worst productivity slowdowns are capital-intensive industries such as chemicals and petroleum refining (*16*). A decline in capital services affects the capital-intensive industries the most.

In addition to this supporting evidence, however, some other evidence is negative or not supportive of the idea. Gordon looked at the electric utility industry and concluded that capital obsolescence had not been a major factor (*17*). Bosworth (*15*) also found that Census Bureau figures on the book value of corporate capital showed no sudden surge in the rate at which capital was scrapped. And Wykoff estimated the effect of the energy crisis on the second-hand prices of various capital assets and found no evidence of accelerated obsolescence (*18*).

These objections are not definitive, but their cumulative effect casts doubt on the idea of widespread scrapping of capital. I believe that capital was used less and rather inefficiently in the 1970's than in earlier periods, but it probably was not scrapped.

Output Measurement and Mix

An enormous variety of goods and services are produced each year. New models of goods are introduced that may be bigger or smaller or different in various characteristics from last year's. Everything from undertakers' services to banking services has to be valued in order to compute aggregate productivity. Many totally new products and services are also introduced each year.

In the United States fairly reliable data are available on private nonfarm business output measured in current dollars. This value of output increases from year to year, but some of the increase is purely the result of inflation, and only part reflects a real increase in production. To distinguish the amount of real increase, a price

Table 1. The role of capital formation in the slowdown. Measures refer to nonfarm business, in percentages per year. Figures are not adjusted for the effect of the business cycle and therefore differ slightly from those shown in Figs. 1 and 2. [Source: Bureau of Labor Statistics]

Growth rates	1957–1968	1968–1973	1973–1979
Capital input	3.36	4.17	3.25
Capital per hour	2.09	2.44	1.13
Labor productivity	2.82	1.89	0.63
Multifactor productivity	2.03	1.05	0.25

deflator is computed by BLS, starting with changes in the prices of individual products and services that are then aggregated into the change in an overall price index. Once the aggregation has been made, real output can be calculated. For example, if the dollar value of production in the nonfarm business sector rose by 10% from one year to the next, and if the price index shows that the weighted average of the individual prices rose by 6%, then real production rose by 4%.

Problems with output measurement. One reason why overall productivity slowed after 1968 is that there was a collapse in the level of measured productivity in the construction industry. According to official data, output per hour in this industry in 1979 had fallen below the level of 1950 (*14*). Most observers doubt the validity of the data. There were important technical advances in construction methods and materials after 1968, and independent estimates made of labor requirements for various tasks in the industry showed these requirements continuing to fall after 1968 (*19*). The problem with measuring productivity for this industry is that each construction project is unique. Coming up with a price index, and hence a value for real output, is almost impossible for a large part of the industry.

The biggest general criticism leveled at output measurement is that quality change resulting from innovation and better design is not accurately measured. Inflation is overstated and real output growth understated. Even if this criticism is correct, however, it does not necessarily explain the slowdown, because the problem of output measurement has always existed. Rees, who headed a panel on productivity statistics, has argued that in order to explain the slowdown in productivity growth in terms of errors in output measurement, it is necessary to show that the errors grew worse in the 1970's (*20*). That is not true, says Rees; if anything, BLS has been doing a better job of measuring quality change.

Others disagree, however, and argue that the issue is not how well BLS is doing, but rather that the U.S. economy has become a service economy. The procedures for estimating price changes do not work well in the service economy because it is difficult to compare the services provided by a bank or a firm of architects from one year to another.

The shift to services. The above point raises a more general question of the extent to which changes in the mix of products and services in the economy may have damped either actual or measured productivity growth.

Thurow has pointed out that average labor productivity is very different in different industries (*21*). For example, in 1972 each hour of work in the chemical industry produced $10.02 worth of output compared with $5.41 for services and $5.87 for trade (*14*). The mix of employment in the U.S. economy is shifting away from high-productivity jobs in the industrial sector and toward low-productivity jobs in the service sector and retail trade, argues Thurow. If someone who is producing $10 of output per hour is put into a job producing $5 of output per hour, then average productivity is bound to decline, he says. (*21*).

The Thurow argument, which carries immense plausibility and has influenced thinking on industrial policy, is based on a big assumption; namely, that moving a worker will somehow raise or lower that worker's productivity. This is not a plausible proposition. For example, a secretary in the chemical industry is probably doing about the same work as a secretary in the furniture industry. But the issue is deeper than that because a theory of efficient market economies says that moving a worker will make no difference to overall productivity, even if the specific tasks change (*16*). Changing the industry label on a worker does not in itself have an impact.

The reason average labor productivity is so high in the chemical business is because there is so much capital used in this industry, including the technology capital generated by R&D. Making the economy more capital intensive by adding more investment will cause average labor productivity to rise, but it is adding the capital that does it. Moving workers does not. This is true whether the extra capital goes into the chemical industry or is used to make services more capital intensive.

A similar argument to Thurow's has been raised by Baumol and Wolff (*22*). It is not differences in the levels of productivity among industries, they say, but differences in their potentials for growth. As the U.S. economy matures, more and more of the work force is engaged in service activities where the potential for technological change or automation is limited. For example, a schoolteacher, a waiter, or a hotel maid are doing about the same things in about the same way as was done 20 years ago, or even 100 years ago.

Obviously, a relation exists between the Baumol and Wolff view and the measurement issues discussed earlier. They say that the shift to services has had an adverse effect on actual productivity growth. The measurement error view claims that the adverse effect is only on measured productivity. Without better measurement techniques it is hard to decide between these two, but there is evidence relevant to both ideas.

First, the magnitude of the shift to services is often exaggerated. In 1957, manufacturing, construction, and mining accounted for 40% of private nonfarm output. This rate fell to 38% by 1973 and to 35% by 1979 (*14*), not a dramatic decline.

Second, even if some shift to services has taken place, the idea that the broadly defined service sector cannot achieve productivity growth is incorrect. The supplying of telephone services, for example, is an industry with a history of above-average productivity growth that was sustained through the 1970's. Even in wholesale and retail trade and personal and business services, output per hour grew at about the same rate as it did in manufacturing over the period from 1957 to 1973.

After calculating how much of the decline in productivity growth had occurred within the major industries of the economy and how much was the result of Baumol-type shifts in industry mix (*16*), I found that no part of the slowdown could be accounted for by mix effects. Independent work by Gollop agrees with this result (*23*). It is a result that occurs mostly because the change in the mix of production has not been consistently toward sectors with low growth potential or low measured productivity growth. Parts of the service-producing sector have had good productivity growth, while parts of the goods-producing sector (construction and mining) have done poorly.

Technology and Innovation

Innovative new machinery and new materials are both driving forces behind the growth in multifactor productivity. Innovative new products also add to productivity because of their greater value or because they are designed to be easier to produce. Therefore, an explanation for the slowdown in productivity growth is that the pace of innovation or new technological development has slowed

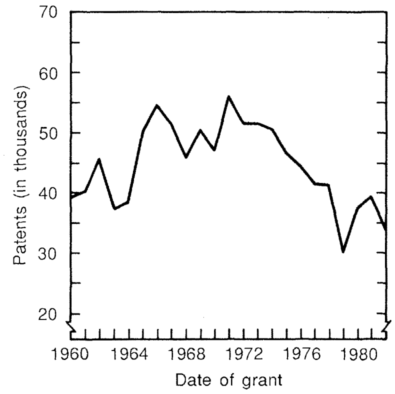


Fig. 4. U.S. patents granted to U.S. inventors. (A smaller number of patents were granted in 1979 because of a lack of funds in the Patent Office for printing and issuing patents.)

down. To many economists such an explanation seems plausible. They turn the puzzle of the slowdown around and ask why would one expect productivity growth to be constant. Schumpeter, one of the leading American economists of the interwar years, argued that technology comes in waves (*24*). A spurt in technology leads to rapid investment and high rates of growth of output and productivity. The question, therefore, is whether any independent evidence on the flow of new technology supports the idea that slow innovation was a reason for the productivity slowdown (*25*).

R&D spending. In industry, R&D is the principal mechanism for generating commercial innovations. Ways are found to use new scientific advances in commercial products or processes, or new ways to use existing knowledge are discovered. There is a substantial lag between the R&D expenditure and the introduction of innovations that will raise productivity. After adjusting for inflation, industry-funded R&D spending rose at 6.2% per year from 1960 to 1969, but this rate of growth fell to only 2.4% per year from 1969 to 1977 (*26*). Since a growth in R&D seems necessary to maintain the pace of innovation, the decline in R&D contributed directly to a fall in innovation. The decline also provides a signal that companies saw fewer opportunities to develop profitable new products and processes from 1969 to 1977.

Patents. To get a return from the costs of research and development that go into the product or process, a company must be able to prevent its competitors from copying what it has done. The number of patents granted to U.S. inventors, therefore, provides a measure of the flow of new commercial technology. Figure 4 shows that the number of patents granted to U.S. applicants peaked in 1972 but declined substantially since then. This decrease supports the belief that innovation has slowed.

Since the productivity slowdown took place in other countries also, information on patenting in other countries is relevant to the role of innovation in the slowdown. Scherer studied data for six of the major industrial countries and found that most of them paralleled the U.S. experience in that they showed a decline in the rate of patenting. The only major exception was Japan, where the number of patents granted per year continued to rise in the 1970's. Even in Japan, Scherer notes, the rate of increase in patenting declined (*27*).

Patents provide one measure of innovation, but not an ideal one. A patent is applied for early in the development stage, and often projects are abandoned because the developing company can see no commercially profitable product or process emerging. In other cases, innovations are introduced without being patented. In the electronics field, companies sometimes refrain from patenting because a patent application becomes a public record. Competing companies can review the file of patent applications and learn about the new technology. Thus, not all patents lead to innovations and not all innovations derive from patented inventions.

Innovations in two industries. To learn more about the role of technology in the productivity slowdown, I launched a research project with Chakrabarti to study innovation and productivity growth in detail in U.S. industries (*28*). This project is ongoing, and as yet we have results for only two industries. But those results are striking, and they reinforce the conclusion drawn from the patent data that a slowing in the pace of innovation may have pulled down the rate of productivity growth.

The two industries we chose in the first round of the study include one (chemicals) that had a substantial slowdown in productivity growth after 1973 and one (textiles) that had no slowdown. We collected a file of innovations introduced by surveying the technical periodicals serving each industry. Working with chemical and textile engineers, we developed criteria to determine when a new product or process that was reported or advertised in these periodicals represented a technical advance (*29*).

Our basic results are shown in Fig. 5. There was a sharp slowdown in both new product innovation and in productivity-enhancing process innovation in the chemical industry after 1973, matching its slowdown in productivity growth. In the textile industry, by contrast, there was no slowdown in the main form of productivity-related innovation, namely, the introduction of new textile machinery (*30*). This again corresponds to the productivity performance of the textile industry. Since the majority of U.S. industries had slowdowns in productivity growth that were comparable to that in the chemical industry, these results support the view that the flow of innovative new technology was less in the 1970's than in earlier years in many industries, and that this resulted in lower productivity growth.

Office innovation and automation. I have stated that the United States has been going through a period of weak innovation. That may seem to be an odd assertion, given the explosion of new computer and electronic innovations in recent years. But the computer revolution has not yet paid off in productivity growth as did the earlier generations of innovation. Much of the capital investment made in the United States in the 1970's was for

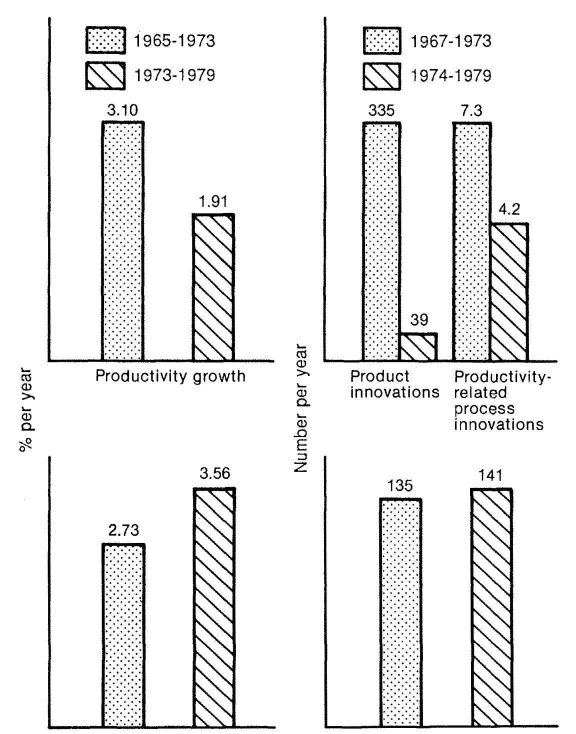


Fig. 5. Innovation and productivity both slowed in the chemical industry (upper panels), but not in the textile industry (lower panels).

computer and electronic equipment, yet most of the industries making this investment experienced slow productivity growth. In fact, the fraction of total employment that consists of white-collar workers continued to rise in the 1970's, as did the fraction of clerical workers (*31*). Within all the major industry groups of the economy, the ratio of overhead or nonproduction worker employment to total employment also continued to rise in the 1970's (*32*). It appears as if the administrative bureaucracies of the economy absorbed a large share of total investment without making corresponding improvements in efficiency.

One optimistic explanation of the pattern described could be that the impact of computerization has been to improve the quality of products and services provided and that this improvement is not being recognized. Perhaps Rees was wrong and quality change has accelerated. The problem is in productivity measurement, not productivity, and in some areas this optimistic view must be correct. For example, in financial services a broad range of new products has been offered. The credit card revolution could not have taken place without computerization, and consumers benefit from the added convenience.

There is an alternative and more pessimistic explanation, however. Office automation has differed fundamentally from factory automation. When a factory is automated, the same output can be produced with less labor or more output can be produced with the same amount of labor. The company that automates has two choices, either to cut employment or to cut prices and expand sales. Either way, productivity rises. When the office is automated, there is a third option, which is simply to generate more paper. A report may go through as many as 40 drafts (*33*). The accountants simulate the tax consequences of a variety of corporate strategies. The marketing department makes a dozen computer projections based on demographic changes and migration patterns. In principle, corporations would only do all these simulations and projections if they improved decision-making. In practice, there may be wasted resources, particularly for the society at large, if companies simply jockey for their share of the market rather than raise productivity.

The government has added to the ways in which computers are used in a manner that may not be fully productive. The tax law has become extremely complex, keeping accounting departments busy and their employment high. Also, companies must monitor a whole range of production and employment activities to make sure they conform to regulatory requirements.

Management Failures

Hayes and Abernathy, in an influential article, proposed that slow productivity growth and an inability of U.S. businesses to compete overseas were the results of serious failures by top management (*34*). The authors argued that American managers abandoned long-term technological superiority as a strategy for success and instead geared their decision making to short-term profits.

Modern management techniques are blamed for this problem. Scientific management emphasizes "analytical detachment rather than the insight that comes from 'hands-on' experience and short-term cost reduction rather than long-term development of technological competitiveness" (*34*, p. 68). Moreover, the rise of M.B.A. graduates with their management tools has promoted the idea of an "interchangeable manager," someone who can come into a company and run it without detailed knowledge of the industry and its technology. This system encourages managers to stress such things as takeovers, financial manipulation, and the setting up of profit centers in order to achieve quick results before they move on to the next industry.

The ideas expressed by Hayes and Abernathy struck a responsive chord, especially among scientific and engineering staffs in U.S. corporations. The R&D people whom I interviewed in my work on innovation frequently spoke of the frustrations they had felt in the 1970's in persuading senior management to support new product and process development. However, the argument that the productivity growth slowdown was caused by an exogenous wave of poor management is questionable.

The fact that all the major industrialized countries experienced a slowdown at about the same time has to be more than a coincidence. Yet the idea of a rather abrupt deterioration of management performance around the world after 1973 seems farfetched. Indeed, the critics of U.S. managers usually compare them unfavorably with foreign managers, notably the Japanese. But Japan also had a sharp slowdown in its productivity growth in the 1970's.

The case for poor management is not presented with serious evidence to support it. It is easy to find examples that illustrate poor management decisions, especially with the advantage of hindsight. But the advocates of the hypothesis have not yet demonstrated that a major changing of the guard really took place and that scientific managers have not actually performed as well as those relying only on experience.

Rather than postulating a sudden attack of poor management, it is far more plausible to link management failure to other explanations of the slowdown. The energy crisis, inflation, fierce foreign competition, and the drive for environmental regulation challenged managers to deal with these problems without sacrificing productivity. And they did not succeed. Office automation provided the means for reducing white-collar costs, but too often the potential gains have not been realized. Capital was not as productive in the 1970's, and management was responsible for the investment decisions and the running of the plants. Innovation slowed in some industries, and while depletion of opportunities was an important factor, courageous management might have spurred the search for new areas of opportunity. Perhaps old-fashioned managers would have dealt with these opportunities and problems more effectively than the new breed of business school–trained managers. I suspect that both old style and new style managers made their share of mistakes.

Productivity Growth Since 1979

Some optimism has been expressed about productivity because of the recent performance of the manufacturing sector. As Table 2 shows, both labor and multifactor productivity growth did well in manufacturing after 1980. Even though the economy fell into a deep recession in 1982, labor productivity in manufacturing continued to rise from 1981 to 1982, and then rose by 15% over the next 3 years of economic recovery.

The favorable experience in manufacturing does not extend to the rest of the economy, however. In the annual data on multifactor productivity there are signs of a weak recovery. But the more up-to-date data on labor productivity show that it remained stagnant from 1984 to 1986, despite continued growth in output. This pessimism is reinforced by the experience of other countries. The major industrialized countries have shown no general recovery in productivity growth; in fact, the rate in some countries has continued to decline (*35*).

The business media often paint the manufacturing sector of the U.S. economy as the one that is in trouble, while the service economy is strong. By some measures that picture is accurate. Employment growth has occurred primarily outside manufacturing, and profitability in many manufacturing industries has been squeezed by foreign competition. But the recent history of produc-

Table 2. Recent productivity performance, in percentages per year. [Source, Bureau of Labor Statistics; cyclical adjustments made by author]

Period	Actual		Cyclically adjusted	
	Nonfarm business	Manufacturing	Nonfarm business	Manufacturing
	Multifactor productivity growth			
1968–1973	1.05	2.88	1.14	2.84
1973–1979	0.25	0.71	0.32	0.85
1979–1984	0.69	1.82	0.89	2.23
	*Labor productivity growth**			
1979:2–1980:2	−1.32	−1.58		
1980:2–1981:2	1.72	3.14		
1981:2–1982:2	−0.80	1.44		
1982:2–1983:2	3.67	6.36		
1983:2–1984:2	1.64	5.14		
1984:2–1985:2	−0.38	3.26		
1985:2–1986:2	0.57	1.87		
Average	0.73	2.80		

*Annual rates of growth from the second quarter of one year to the second quarter of the following year.

tivity gives another perspective. A reason why manufacturing has exhibited slow employment growth is that it has had more rapid productivity growth than the rest of the economy. The manufacturing sector has made at least a partial recovery from the post-1973 slowdown, while the rest of the nonfarm economy clearly has not.

What Happened?

The slowdown in productivity growth that took place after 1968 was unique to the United States and can be understood in terms of causes particular to the U.S. economy. There was an influx of relatively inexperienced workers into the labor force who were employed in low-wage, low-productivity jobs. These jobs were often part-time, had little training component, and did not lead to higher wage, higher productivity jobs later on.

Within the industrial sector, there was a sharp collapse after 1968 in the levels of productivity in the construction and mining industries. These sectors had negative rates of productivity growth after 1968. The most likely explanation of construction productivity is that measurement errors made inflation-adjusted output in this industry too low in the 1970's. Part of the 1968 slowdown was not real. The decline in productivity in mining probably was real and resulted from the gradual depletion of the most available part of U.S. oil reserves (*36*).

The more serious and more widespread slowdown that took place after 1973 was caused by a combination of three forces. (i) There was a slowing in the speed with which the technological frontier was pushed out in many old-line industries. (ii) There was a series of interrelated disruptions to the economy. (iii) Rapid innovation in electronics has not resulted in much improvement in measured productivity.

The evidence of a reduction in the pace of technical change in established industries is seen in (i) a sharp reduction in the growth of R&D spending, (ii) a reduction in the flow of patents, and (iii) some case study evidence linking the flow of innovations to industry productivity growth.

The disruptions to the U.S. economy included two serious recessions in 1975 and 1982, two massive increases in energy and materials prices in 1973 and 1979 and the inflation associated with these, a rapid escalation of government regulation, and substantial shifts in the pattern of worldwide production and trade. These same disruptions affected other industrialized countries. To my knowledge, no one has shown that any one of these causes by itself was large enough to account for very much of the slowdown. But the combination of all of them was overwhelming. Business managers had to devote much of their own time and the time of their most talented subordinates and technical staff to deal with the problems. This diverted resources from productivity-enhancing activities. Moreover, corporate decision making became conservative and short term partly because companies faced so much uncertainty. In part, the reduction in the flow of innovations was a result of this uncertainty and the unwillingness of many companies to take bold new steps forward.

The failure of the electronics revolution to generate major improvements in measured productivity contributed to the slowdown from 1973 to 1979. Had white-collar activities achieved rapid efficiency gains in the period, the gains would have somewhat offset the impact of slower innovation elsewhere. However, the clearest signs of a low payoff from innovations in electronics have shown up more recently. Since 1979, several of the sources of economic disruption have disappeared. Energy and materials prices have fallen and so has inflation. There has been fairly stable growth since 1982. And productivity growth within manufacturing has improved, as one would expect since this sector was heavily affected by the disturbances of the 1970's. But productivity growth outside manufacturing remains very weak, even in areas such as financial services where the electronics revolution should have yielded rapid growth. This weakness in measured productivity reflects both poor measurement and poor performance. The BLS is not recording the increased level of service and convenience that computers allow in service industries. At the same time, the service industries, and indeed the white-collar staffs in the industrial sector also, are not benefiting from the potential gains from the new technology.

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Research Articles

Saturation Mutagenesis of the Yeast *his3* Regulatory Site: Requirements for Transcriptional Induction and for Binding by GCN4 Activator Protein

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Expression of the yeast *his3* and other amino acid biosynthetic genes is induced during conditions of amino acid starvation. The coordination of this response is mediated by a positive regulatory protein called GCN4, which binds specifically to regulatory sites upstream of all coregulated genes and stimulates their transcription. The nucleotide sequence requirements of the *his3* regulatory site were determined by analysis of numerous point mutations obtained by a novel method of cloning oligonucleotides. Almost all single base pair mutations within the nine base pair sequence ATGACTCTT significantly reduce *his3* induction in vivo and GCN4 binding in vitro, whereas changes outside this region have minimal effects. One mutation, which generates a sequence that most closely resembles the consensus for 15 coregulated genes, increases both the level of induction and the affinity for GCN4 protein. The palindromic nature of the optimal sequence, ATGACTCAT, suggests that GCN4 protein binds as a dimer to adjacent half-sites that possibly overlap.

TRANSCRIPTIONAL REGULATION OF GENE EXPRESSION IS mediated by activator or repressor proteins that bind specifically to regulatory DNA sequences. The expression of unlinked genes can be regulated in unison if they contain similar regulatory sequences that are recognized by a common activator or repressor. In prokaryotic organisms, regulatory sites are associated with palindromic sequences whose "half-sites" are seven to nine bases in length (*1–4*). This symmetry is believed to be important because these regulatory sites are recognized by dimers of the cognate DNA binding proteins (*5–9*). However, even in these well-studied regulatory sites, the structural requirements are poorly defined because they are based primarily on a relatively small number of point mutations. Positions of transcriptional control elements for some eukaryotic genes have been established but, although some inferences have been drawn from DNA sequence comparisons, the functional determinants have yet to be defined.

In bakers' yeast, *Saccharomyces cerevisiae*, the general control system coordinately regulates the expression of unlinked genes encoding amino acid biosynthetic enzymes from different pathways (*10*). That is, all genes regulated by general control are transcriptionally induced in unison above the basal level (two- to tenfold, depending on the gene) during conditions of amino acid starvation. Extensive deletion analysis of *his3*, a coregulated gene, has defined the cis-acting elements necessary and sufficient for promoter function and for regulation by general control (Fig. 1). Basal level *his3* expression requires a TATA element located 35 to 55 nucleotides upstream of the transcription initiation site and a poly(dA-dT) sequence located between −115 and −129 (*11, 12*). A separate genetic element, located between −84 and −104 is necessary for positive regulation of *his3* in response to amino acid starvation (*13*).

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