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THE DECLINE IN PRODUCTIVITY GROWTH

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Survey of the Factors Contributing to the Decline in U.S. Productivity Growth

John W. Kendrick*

Since the first half of the nineteenth century, the secular rate of growth in real gross product per labor hour in the U.S. domestic business economy gradually accelerated from about 0.5 percent a year to a maximum average annual rate of 3.5 percent in the subperiod 1948–66 (see Table 1). Since then, it declined to about 1 percent during the period 1973–78, and then fell absolutely in 1979 and will probably drop again in 1980 due largely to cyclical influences and continuing oil price increases.

The declining trend-rate of productivity growth after 1966, and the absolute declines since 1978 have become an increasing matter of concern to policy-makers and informed citizens in the United States. Since productivity gains are the chief source of increases in real income per capita, the slowing has meant lesser gains in living standards. Since increases in factor productivity are an offset to increasing factor prices, the slowing has been a significant element in the acceleration of inflation in unit factor costs and product prices. Although overall productivity changes are only indirectly involved in balance-of-payments problems, the industries whose relative productivity growth has slowed the most have had the greatest difficulties in meeting foreign competition. Clearly, policies to promote productivity would be of considerable assistance in helping this country meet some of its more pressing economic problems.

As background for policy formulation, it is essential that we understand the chief sources of productivity growth, and thus the causes of the slowdown after 1966. A convenient and useful classification of sources of economic growth in general, and of productivity growth in particular, has been provided by Edward F. Denison, together with estimates of the percentage point contributions of the various sources from 1929 through 1976.[1] I have made use of his schema, with some modifications described below, as well as many of his estimates, supplemented by my own estimates for selected variables, and for all of them in the subperiod 1973–78 since most of his series end in 1976.

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[1] See Edward F. Denison, *Accounting for Slower Economic Growth: The United States in the 1970s* (Washington: The Brookings Institution, 1979). The estimates in this volume revise, extend and supplement those in his preceding work, *Accounting for United States Economic Growth, 1948–1969* (Washington: The Brookings Institution, 1974).

Table 1
Real Gross Product, Factor Inputs, and Productivity Ratios for Selected Subperiods, U.S. Domestic Business Economy: 1800–1973 (average annual percentage rates of change)

	1800–1855	1855–1890	1889–1919	1919–1948	1948–1973
Real gross product	4.2	4.0	3.9	3.0	3.8
Population	3.1	2.4	1.8	1.2	1.5
Real product per capita	1.1	1.6	2.1	1.8	2.3
Total tangible factor input	3.9	3.6	2.2	0.8	2.4
Labor	3.7	2.8	1.8	0.6	0.7
Capital	4.3	4.6	3.1	1.2	2.5
Total factor productivity ratio	0.3	0.3	1.7	2.2	2.4
Labor	0.5	1.1	2.0	2.4	3.1
Capital	-0.1	-0.6	0.7	1.6	1.3

NOTE: The weights for capital in each of the successive periods, beginning with 1800–1855, are as follows: 0.35, 0.45, 0.34, 0.26, 0.28. The weights for labor are 1.00 minus the weights of capital.

SOURCES: 1800–1890 based on Moses Abramovitz and Paul David, "Economic Growth in America: Historical Parables and Realities," Reprint no. 105, Center for Research in Economic Growth, Stanford University, 1973, tables 1 and 2; 1889–1973 from John W. Kendrick, *Productivity Trends in the United States* (Princeton, N.J.: Princeton University Press for the National Bureau of Economic Research, 1961); estimates for 1948 forward revised and extended by the author.

The Conceptual and Analytical Framework

The sources of growth in real gross product and productivity shown in Table 2 relate to the U.S. private domestic business economy, for which largely independent estimates of outputs and inputs can be constructed. The excluded general governments, personal (households and private nonprofit institutions), and rest-of-world sectors, for which real product is assumed to move with real factor costs, comprise only about 15 percent of GNP as estimated by the U.S. Department of Commerce. It should be noted, however, that if the opportunity costs of nonmarket economic activities are estimated, the share of the nonbusiness sectors in the expanded GNP estimates rises to about one-half. But since the imputations are based on input data, they do not make possible estimates of productivity changes in the nonmarket activities. In fact, some of the official deflators for GNP, mainly banking and selected services, are based on unit factor costs, thereby imparting a small downward bias to the official real product and productivity estimates, assuming that there has been some increase in productivity in these industries.[2]

[2] See John W. Kendrick, "Expanding Imputed Values in the National Income and Product Accounts," *The Review of Income and Wealth,* Series 25, no. 4, December 1979. As of 1973, GNP adjusted to include the additional imputations was almost 64 percent larger than the official estimates. Since 1939, imputed values have grown faster than official GNP, especially when both are measured in terms of real factor costs. The Department of Commerce is currently engaged in expanding its imputations.

Table 2
Sources of Growth in Real Gross Product, U.S. Domestic Business Economy Percentage Points, Selected Subperiods, 1948–1978

Sources	1948–66	1966–73	1973–78
	Average Annual Percentage Rates of Change		
Real Gross Product	3.9	3.5	2.4
Factor Input — Total	1.1	1.9	1.6
Labor	0.4	1.4	1.3
Capital	2.6	3.3	2.3
Real Product Per Unit of Labor	3.5	2.1	1.1
Capital/Labor Substitution	0.7	0.5	0.3
Total Factor Productivity	2.8	1.6	0.8
Sources of Total Factor Productivity Growth; (Percentage Point Contribution)			
Advances in Knowledge	1.4	1.1	0.8
R & D Stock	0.85	0.75	0.6
Informal	0.3	0.25	0.2
Rate of Diffusion	0.25	0.1	—
Changes in Labor Quality	0.6	0.4	0.7
Education & Training	0.6	0.7	0.8
Health	0.1	0.1	0.1
Age/Sex Composition	-0.1	-0.4	-0.2
Changes in Quality of Land	—	-0.1	-0.2
Resource Reallocations	0.8	0.7	0.3
Labor	0.4	0.2	0.1
Capital	0.4	0.5	0.2
Volume Changes	0.4	0.2	-0.1
Economies of Scale	0.4	0.3	0.2
Capacity Utilization Rate	—	-0.1	-0.3
Net Government Impact	—	-0.1	-0.3
Services to Business	0.1	0.1	0.1
Regulations	-0.1	-0.2	-0.4
Actual/Potential Efficiency, and *n.e.c.*	-0.4	-0.6	-0.4

n.e.c. = not elsewhere classified

SOURCE: John W. Kendrick, based in part on estimates by Edward F. Denison, *Accounting for United States Economic Growth, 1948–1969* (Brookings, 1974).

Denison used estimates of real national income instead of real gross product, and confined his analysis to the nonresidential business sector. The two aggregate measures show much the same movements, but removal of the residential sector results in a slightly higher productivity change since, in effect, the real income and product from residences parallel the real residential stock estimates.

Labor input is measured by employee hours paid for plus hours worked by proprietors and unpaid family workers. There are no internal weights, so relative labor shifts among occupations, industries, age-sex groups, and groupings based on educational attainment, show up as part of the explanation of productivity changes rather than as part of labor input. This treatment is the same as that in the official estimates of the U.S. Department of

Labor. It differs from that of Dale Jorgenson, who includes all of the shift-effects in labor input as a "quality" component; and from that of Edward Denison, who adjusts labor input for age-sex shifts and for amounts of education, but counts certain labor force shifts as part of the explanation of changes in output per unit of input. In the last analysis, it is not important whether qualitative changes are counted as part of input or as part of the explanation of productivity change so long as the contribution of each component variable is separately estimated.

Similarly, capital input is assumed to move proportionately to real gross capital stocks, without internal weights by type and by industry such as are employed by Jorgenson to obtain estimates of what he calls "quality" changes in capital. In my estimates, changes in the composition of capital as well as of labor affect productivity movements. Denison distinguishes only a few major types of capital in deriving his capital input estimates. Further, he uses a weighted average of real gross and net stocks to approximate the effects of aging on output-producing capacity of capital. In my estimates, changes in average age of fixed capital are a source of changes in productivity. None of us adjusts the stock estimates for changes in rates of utilization of capacity. I do not because capital carries a real cost to the owners regardless of intensity of use. Jorgenson formerly made an adjustment, but was persuaded by Denison that the data do not permit accurate adjustments for the entire business economy.[3] Thus, changes in rates of utilization of capacity are another source of changes in productivity as measured.

To weight labor and capital inputs together, Denison uses the shares of labor compensation and of property compensation (net of depreciation charges) in national income. However, Jorgenson has persuaded me that it is preferable to use the factor shares of *gross* national income, including depreciation in property compensation. This is more symmetrical since no allowance has been made for depreciation of human capital in the labor compensation portion of national income. Jorgenson argues that Denison's approach overweights labor in relation to capital.

The table shows both the conventional output (real gross product) per labor hour and the total factor productivity measures. Since the latter is the ratio of real gross product to a weighted average of labor and capital inputs, the reconciliation between the two measures is provided by the measure of the rate of substitution of capital for labor. This is computed as the difference between the growth rates of total factor input and of labor input; alternatively by the increase in capital per labor hour, weighted by the share of capital compensation in gross national income. It is one of the sources of growth in labor productivity.

It will be noted from the table that the sources of growth in total factor productivity are divided into seven main groupings. In the next section, each of these is discussed in some detail, and their contribution to the slowdown is

[3] See the exchanges between Denison and Jorgenson, et al, in the May 1972 Supplement to the *Survey of Current Business* 52, no. 5, pt. 2, "Issues in Growth Accounting."

detailed. Here, we quickly review how our classification of sources differs from the Denison schema. In the first place, Denison estimates the contribution of advances in technological knowledge, as applied to production, as a residual. Whereas we accept his estimates through 1966, thereafter we estimate it directly as described later. Further, we subdivide the estimates into three major components.

Under "changes in labor quality," we include the components which are included by Denison as aspects of labor input: effect of increased education and changes in labor force composition (age-sex mix). The effects of training have been added to those of education, and we have added another category "health and safety," changes in which are potentially significant although the estimates indicate contributions have been modest.

"Resource reallocations" capture the effects of shifts of labor and capital among uses and industries. Since Jorgenson weights factor inputs by occupation (or type of capital) and by industry as well as by age, sex, and educational categories of labor, the shift effects show up as "quality" changes in his input estimates. Denison includes the effects of intersectoral shifts of labor, but not of capital, which appears to be inconsistent. Given differential rates of factor remuneration among uses and industries, relative shifts of resources towards those with higher productivity as reflected in rates of compensation augment growth.

Both volume factors shown in Table 2 are also recognized by Denison. Opportunities for economies of scale, through greater specialization of personnel, equipment and plants, and a reduction in the real unit costs of overhead functions, are presumed to rise or fall with changes in growth rates. "Intensity of demand" is chiefly a cyclical influence on the behavior of annual data. It affects rates of change over subperiods to the extent that ratios of actual to potential real GNP differ significantly in the beginning and end years. My estimating methodology differs somewhat from Denison's. The degree of cyclical variability during subperiods also affects productivity growth, but chiefly through its effect on capital formation, human as well as nonhuman.

Next, we try to estimate the effects of governmental actions, beyond those already of influence on the previously discussed variables. Denison estimates the negative effects of regulations on productivity as measured. But governmental actions may also have positive effects on productivity. So we attempt to arrive at the *net* impact.

Finally, the residual contribution to growth is interpreted primarily to represent the effect of changes in the ratio of actual to potential labor efficiency, any other variables not captured in the other estimates, and, of course, the net effect of possible errors in all of the other variables contained in the table. Several subcategories of the residual are detailed in the table. The only one of these included by Denison is the effect of increasing crime.

Finally, it should be emphasized that all of the sources of productivity growth shown in the table are *proximate* determinants. The influence of basic, underlying factors, such as changes in social values, institutional forms and practices, and incentive systems, exert their impact through the immediate causal forces. In the discussion that follows, I refer to changes in some of the underlying forces that may have been responsible for changes in the proximate determinants. Unfortunately, quantitative analysis can only go so far in explaining first causes, and much of the discussion must remain speculative.

It must also be acknowledged that even the estimates of the contributions to productivity growth of the proximate sources are of varying quality. Some are quite firmly based, such as the effects of interindustry shifts and estimates of the contribution of increased educational attainment. Others, such as the impact of economies of scale, are more speculative.

The ensuing discussion of causal factors follows the order of Table 2. Attention is focused particularly on the changes in contributions of the determinants between the first subperiod, 1948–66, and the third, 1973–78. The boundary years of the subperiods have been picked to represent periods of high-level economic activity. Nevertheless, there is still some effect on rates of change of differences in rates of capacity utilization (see below).

Changes in the Capital/Labor Ratio

Lines 3 and 4 of the table show that from 1948 to 1966, capital grew at a 2.4 percent average annual rate faster than labor input. In the next subperiod, the growth of the real capital stock and input accelerated, but less than the pronounced acceleration of labor input that reflected the coming-of-age of the baby boom generation. In the 1973–78 subperiod, the rate of growth of labor input remained high, but there was a marked deceleration in the rate of capital formation and the increase in the capital/labor ratio slowed further to a 1.0 percent average annual rate. When the rate of change in the ratio is weighted by the property share of gross national income, approximately one-third in the base period, the resulting "substitution" of capital for labor is seen to drop from 0.7 percentage point in 1966–78 to 0.3 in 1973–78. The difference of 0.4 percentage point is a measure of the contribution of the declining growth of capital per unit of labor input to the 2.4 percentage point deceleration in real product per unit of labor. As noted above, the rate of capital/labor substitution is also the difference between the rates of growth of total factor input and of labor input, since the former is a weighted average of labor and capital inputs, and thus provides the reconciliation between labor productivity and total factor productivity (lines 5 and 7 of the Table).

Most analysts have accorded a significant role to the slowing growth of capital per worker or per hour in explaining the productivity slowdown. In particular, in a careful study, Randy Norsworthy of the Bureau of Labor Statistics also estimated that this variable contributed a 0.4 percentage point to the slowdown between the subperiods 1948–66 and 1973–78.[4] Robin Siegel

[4] From table prepared by J. R. Norsworthy for a meeting of the Society of Government Economists and Committee for Economic Development in Washington, March 1980.

has a somewhat larger contribution of 0.6 percentage point using the subperiods 1955–65 and 1973–78.[5] Since increasing amounts of capital per workers, apart from the increasing efficiency of capital due to technological progress discussed in the next section, raise the productivity of labor, it is clear that a slowing in the growth of capital relative to labor would retard the growth of labor productivity. It is well documented that after the 1973–75 recession, the recovery of private investment was quite sluggish. From 1948 through 1974, gross private domestic investment averaged 15.6 percent of GNP; in 1974–78 it fell to 14.1 percent. The private investment ratio averaged 7.4 percent in the earlier period, falling to 4.5 percent in 1974–78. The net private saving ratio fell somewhat less, but government deficits averaged much higher after 1974, further reducing the funds available for private investment. However, the large balance-of-payments deficits in 1977–78 augmented the funds available for domestic capital formation.

The decelerating growth of capital relative to labor after 1966, and particularly after 1973, was associated with significantly lower rates of return on investment, both before and after tax, after adjustment of profits to reflect the current replacement costs of inventories and depreciation charges on fixed capital.[6] During the eight-year period 1970–77, adjusted domestic after-tax profits to U.S. nonfinancial corporations averaged 4.25 percent of their gross domestic product, compared with a 7.75 percent average for 1947–69. Computed as a rate of return on net worth the 1970–77 average was 3.55 percent compared with 5.90 for the 1947–69 period. Both as incentive and as a source of funds (after dividend payouts, which declined less), the lower profit rates must have depressed investment.

Accelerating inflation was a major cause of lower profit rates. Terborgh hypothesized that business executives were slow to adapt pricing policies to reflect fully the impact of inflation on costs, particularly the current replacement costs of inventories and capital consumed when books reflected lower acquisition costs, and that boards of directors based dividend declarations on the overstated book profits. More important, in my view, has been the use of macro-economic policies to prevent prices from rising as much as unit costs in high-level years such as 1966, 1969, 1973–74 (and again in 1978–80). This has squeezed profit margins and brought on recessions that reduced capacity utilization, further depressing inducements to invest.

The decline in measured rates of return also reflects the growing proportion of business capital stocks required by governmental regulations, primarily environmental and health/safety. Denison estimates that the percentage grew from 0.25 in 1969 to 1.53 in 1973 and 2.58 in 1975.[7] This means

[5] Robin Siegel, "Why Has Productivity Slowed Down?," *Data Resources U.S. Review*, March 1979, cited by Eli Shapiro, "Policies for Productivity Growth," (Bryn Mawr, PA.: The American College, 1979), p. 3.

[6] The estimates are from George Terborgh, *Corporate Earning Power in the Seventies: A Disaster* (Washington: Machinery and Allied Products Institute, August 1977). See also Herman I. Liebling, *U.S. Corporate Profitability and Capital Formation: Are Rates of Return Sufficient?* (Elmsford, N.Y.: Pergamon Press, Fall 1979).

[7] Edward F. Denison, *Accounting for Slower Economic Growth*, p. 58.

that the real net stock available for the production of measured output grew by 0.3 percentage point less than the total 1969–73, and by 0.5 less 1973–75, with the percentage continuing to rise thereafter.

Another factor which slowed the rate of substitution of capital for labor was the large increase after 1973 in the price of energy, particularly petroleum products. In an influential article, Jorgenson and Hudson argued that capital goods and energy are complements with a low elasticity of substitution between them, but with a high elasticity of substitution between capital plus energy and labor.[8] Thus, the huge energy price increase in 1974 promoted substitution of labor for capital, and in many industries, speeded-up the obsolescence of energy-intensive equipment, and slowed the growth of labor productivity. Denison argues that Jorgenson and Hudson, and also Rasche and Totom,[9] overestimated this effect, but it does seem plausible that the energy price increase played a role in slowing the growth of the capital/labor ratio.

Another contributor to lower capital formation which has been generally overlooked was the relative increase in prices of structures and equipment beginning in 1970, and especially after 1974.[10] This would not only reduce expected rates of return, but it accentuated the effect of a lower current dollar investment rate on real capital stock growth. The jobs tax credit, instituted in late 1975, by subsidizing employment, would also have tended to increase employment relative to capital formation. But the effect of this particular measure must have been small, given the size of the program.

Finally, the many developments accentuating business uncertainty after 1965 — war, accelerating inflation, price controls, recessions, OPEC actions, and domestic regulations of various types — tended to increase risk premiums and reduce investment demand, particularly for longer lived capital goods.

Advances in Technological Knowledge

Over the long run, by far the most important source of productivity growth is advances in technological knowledge applied to productive processes and instruments. Cost-reducing innovations in the ways and means of production are particularly important, but even the development of new products for sale to consumers and governments as well as to producers affect productivity indirectly through the learning-curve effect although GNP estimates do not adequately reflect the gains in welfare due to new and improved goods and services.

Denison estimates advances in knowledge and n.e.c. as a residual after

[8] Edward A. Hudson and Dale W. Jorgenson, "Energy Prices and the U.S. Economy, 1972–1976," *Data Resources U.S. Review*, September 1978, pp. 1.24–1.37.

[9] Robert H. Rasche and John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," Federal Reserve Bank of St. Louis *Review*, vol. 59 (May, 1977), cited in Denison, *Accounting for Slower Economic Growth*, p. 141.

[10] See Denison, *Accounting for Slower Economic Growth*, p. 56.

accounting for all other significant sources of growth. Prior to the 1970s, he considers the net effect of sources not elsewhere classified to be negligible. Thus, his estimate of a 1.4 percentage point contribution of the residual 1948–66 would signify that advances in knowledge accounted for half of the growth in total factor productivity as we measure it. Although we accept his estimate of the residual as indicative of advances in knowledge through 1966, thereafter we estimate it independently as described below. By so doing, we avoid the dilemma faced by Denison when his residual turned negative after 1973, although other evidence indicates that technology continued to advance, even if at a slower pace than in the first two decades after World War II.

First, we estimate the technological progress directly attributable to outlays for research and development (R & D). For the past half century or so, most inventions and innovational developments have emanated from formal R & D activities of teams of scientists and engineers employed by industrial laboratories, and to a lesser extent from university and governmental R & D performance — although universities and other nonprofit institutions perform the bulk of basic research, which comprises less than 10 percent of the total.

To estimate the stock of knowledge applicable to production, we cumulated real R & D outlays, with due allowance for the gestation and developmental periods between the commencement of projects and their commercial application, and for the mortality experience of process and product innovations. To the real R & D stock estimates obtained by this "perpetual inventory" approach, we applied the estimated base period social rate of return to R & D investments in order to obtain the contribution to national income and product.[11]

For decades the ratio of R & D to GNP rose, reaching a high point of 3.0 percent in 1964, before levelling out and then declining for a decade to 2.2 percent in the latter 1970s. As a result, the rate of growth of the real R & D stocks decelerated sharply from almost 10 percent per annum 1948–66 to less than 5 percent 1973–78. The estimated contribution to productivity growth fell from near 0.9 to around 0.6 percentage point between the two periods. Objections have been made that our estimates include government-financed R & D, much of which goes for defense and space, as well as R & D for development of new and improved products generally. But there are frequently civilian applications of defense and space technology. New and improved products directly increase productivity if they are producers' goods, and indirectly all product development enhances productivity through the learning-curve effect noted above. By our procedure, changes in the composition of R & D may be viewed as affecting its productivity and rate of return.

[11] My methods for estimating the contributions of R & D, and of other variables, are described in more detail in John W. Kendrick, "Productivity Trends and the Recent Slowdown: Historical Perspective, Causal Factors, and Policy Option," in William Fellner, Ed., *Contemporary Economic Problems 1979* (Washington: American Enterprise Institute, 1979), pp. 17–69.

It is true that the drop of the R & D ratio after the latter 1960s was due to the cut-back of government funding. But even the business-financed R & D ratio levelled out for a decade, and the growth of that part of the real stock also decelerated, though not as sharply as the total.

There is a reciprocal relationship between business investments in R & D and in the fixed capital goods that embody new technology. Given the lower rates of return and higher risk premiums in the 1970s, it is not surprising that managements cutback increases in R & D, as well as in plant and equipment outlays. But since one result of successful R & D is to shift business investment demand curves upwards offsetting the tendency towards diminishing returns, the reduced growth of R & D outlays probably contributed to the lower profit margins of the 1970s compared with the 1960s. It should also be noted that the increased impact of regulations in the 1970s undoubtedly diverted a portion of R & D activity from projects that would enhance productivity growth as measured to projects required to meet regulatory objectives. In estimating the contribution of R & D to growth, we use a somewhat smaller rate of return for the 1970s than the 1948–69 period, but it was, of course, applied to a larger base.

Inventive and innovative activity not captured by the R & D statistics also contributes significantly to productivity gains. This includes the work of lone-wolf and part-time inventors, but mainly the many small improvements in technology made by managers and workers in plants and offices, particularly during the "shake-down" phase of innovation. Our estimates assume that the contribution of informal innovative activity moves proportionately to that of formal R & D, which sets the pace in terms of major innovations that feed into the informal activity. The absolute contribution of this element was estimated at 0.3 percentage point during 1948–66, obtained by subtracting the R & D contribution together with that of the rapidity of diffusion of innovation, described next.

Best practices in technology and productivity of progressive firms and plants are usually well ahead of the average in most industries. Average productivity is favorably affected by a narrowing of the gap through more rapid diffusion of technological innovations. Since cost-reducing innovations are generally embodied in new capital goods, the average age of fixed capital goods is an important indicator of possible changes in the rate of diffusion. A weighted average of Bureau of Economic Analysis estimates of the average ages of structures and equipment, after rising from 1929 to 1947, fell by almost three years from 1948–66, by about one year from 1966–73, and then rose slightly between 1973 and 1978 reflecting the lower real capital formation of recent years. We estimated that this contributed over 0.2 of a percentage point to the slowdown between the 1947–66 and 1973–78 subperiods. Denison estimates that the slowing rate of diffusion would have contributed 0.1 percentage point at most to the slowdown (through 1976)[12], but there are

[12] See Denison, *Accounting for Slower Economic Growth,* pp. 57–58.

other reasons for believing that a slower rate of diffusion was a more significant element than he suggests.

There is evidence that environmental and land-use regulations have delayed new plant construction and lengthened the average period of construction, which also contributed to the decline in productivity of contract construction, noted below. Regulations affecting the introduction of drugs and other new products appear to have slowed down this type of innovation. Also, the Revenue Act of 1969, by substantially increasing the taxation of capital gains sharply reduced equity investment in small companies, which contributed disproportionately to innovation in the past. The reduction of capital gains taxes by the Steiger amendment to the Revenue Act of 1978 has increased the flow of risk capital for new firms since its enactment.

In sum, the contribution of advances in knowledge declined by 0.6 of a percentage point between 1948–66 and 1973–78, accounting for about one-fourth of the deceleration in the growth of real product per hour. Corroborative evidence on the importance of this factor is the decline in the total number of domestic patents issued annually by the U.S. Patent and Trademark Office from a double peak of 54,636 in 1966 and 55,979 in 1971 to 41,452 in 1977. Patents issued to foreign applicants continued to rise.[13]

Changes in the Quality of Labor

Of the several factors affecting labor quality shown in the table, the most important is education and training. This element interacts with technological progress, of course, since the educational system produces the scientists, engineers, and managers who are involved in invention and innovation, as well as the other members of the labor force who must operate an increasingly complex technology of production. On the other hand, the advances in knowledge and know-how that emerge from R & D and informal invention and innovation are transmitted through education and training, including learning on the job.

Denison prepared careful estimates of the contribution of increased education to growth on the basis of data on earnings differentials of workers with different levels of educational attainment, after adjustment for the effects of differing family backgrounds and ability. His estimate of 0.5 percentage point for the period 1948–66 is almost the same as mine based on a different approach. I estimated the total real stock of educational capital embodied in employed persons, and multiplied by my estimate of the average rate of return on human capital (12.5 percent in 1948–66, and 12.0 percent after 1966).[14] Estimates of the real stock and contribution of capital resulting from training programs (not included by Denison) add another 0.1 to the esti-

[13] *Science Indicators 1978* (Washington: National Science Board, 1979), Table 4-17, p. 218.

[14] Kendrick, "Expanding Imputed Values," p. 40. For a description of my various capital estimates, see *The Formation and Stocks of Total Capital* (New York: National Bureau of Economic Research, 1976).

mate. Both Denison and I calculate that the contribution of education (plus training, in my estimates) increased in the subsequent subperiods, although the increase obtained by Denison in his most recent work is somewhat larger than mine. The increase is consistent with the GNP estimates which show that the proportion devoted to public and private educational outlays has continued to rise. The estimates do not reflect changes in the quality of education and efficacy of the learning process. In this regard, the downward trend in average Scholastic Aptitude Test scores since the early 1960s is disturbing.

The average health status of persons engaged in production also affects productivity through changes in vitality, life expectancy, and time lost due to illness. The rising proportion of GNP devoted to health and medical outlays has resulted in increases in "health capital" per person that have contributed 0.1 percentage point to productivity gains in each subperiod.[15] My estimates count only half of medical outlays as being productivity-related. Other evidence on the health status of Americans, such as the upward trend in life expectancy, confirms the impression that this has been a positive factor.

The effect of a changing age-sex composition of the work force is estimated by Denison in terms of 10 groups. The different average earnings of each may be interpreted as reflecting in part different levels of experience and thus of "learning by doing." The decline in the contribution of this factor from -0.1 in 1948–66 to -0.4 in 1966–73 reflects the bulge of youthful entrants into the labor force beginning in the mid-1960s, and the accelerated increase in female labor force participation. The effect of these shifts was diminishing in the 1973–78 subperiod (and will be reversed in the 1980s).

Changes in Quality of Land

Eventual deterioration in the average quality of land and other domestic natural resources as production grows has long been recognized by economists as a potential source of declining productivity. In U.S. economic history, this tendency has been much more than counteracted by technological progress, and productivity in agriculture and mining exhibited above-average productivity gains up until the latter 1960s. Since then, productivity growth has decelerated somewhat in agriculture, and productivity in mineral industries declined absolutely after 1970. In farming, production expanded onto less desirable lands in the 1970s, and in mining there is evidence of deterioration of ores, and, in the case of oil, an increasing proportion of production has come from reserves that are much more costly to exploit.

Part of the deviation of productivity from past trends has been due to increased regulation, particularly by OSHA. We estimate that about half of the poorer performance is attributable to the deterioration of natural resources. But given the relatively small weight of extractive industries in gross private domestic business product, this reduced the overall rate of pro-

[15] Ibid., p. 41.

ductivity advance by only 0.1 percentage point from 1966–73, and 0.2 from 1973–78. The impact may well be greater in the future, however, as the United States seeks to achieve greater energy independence.[16]

Resource Reallocations

The shift of resources of given types from uses, firms, industries, and regions with lower rates of remuneration to those with higher rates increases real product and productivity. Labor and capital may be employed at less than their equilibrium prices for various reasons — lack of information, or various impediments to mobility, such as regulations, restrictive practices of firms and unions, and the monetary or psychic costs of movement.

It is relatively simple to estimate the effects of inner-industry shifts of resources by calculating what real product per unit of input would have been with an unchanging composition of labor (or capital) and comparing that with the actual productivity numbers. That type of computation with respect to labor productivity has been made in the U.S. Department of Commerce (see Table 3), with the result that 0.4 percentage point of the slowdown in growth of real product per hour between the subperiods 1950–66 and 1973–77 was due to the change in structural shift effects. The effects are due not only to shifts among industries with different levels of real product per hour in the base period, but also to the changing weights accorded the differential rates of productivity change in the various industries. This type of disaggregated analysis has been carried further by Lester Thurow, who has sought to analyze the causes of retardation of productivity growth in particular industries.[17]

In our schema, not all of the inter-industry shift effect is applicable, since some of the differences in levels of real product per hour are due to differences in average educational levels and in age-sex mix, which have already been accounted for. Accordingly, we follow Denison who estimates the effects of two major shifts that increase economic efficiency — the relative shifts of persons out of farming into the nonfarm sector, and of nonfarm self-employment into employee status. Because of the low value-added per hour of those who shift, the compositional changes (particularly out of farming) have had significant effects in the past. Between 1948–66 and 1973–78, however, the positive contribution of these shifts fell by 0.3 percentage point as the opportunities for further favorable reallocations dwindled.

While Denison does not do so, it seems to me that symmetry requires an estimate to be made of the effects of relative shifts of capital among types and industries with differing rates of return. Professors Jorgenson and Gollop,

[16] See E. F. Renshaw, "Productivity" in the Joint Economic Committee print, *U.S. Economic Growth from 1976 to 1986: Prospects, Problems and Patterns*, vol. 1, *Productivity* (October 1, 1976). Denison mentions the declining quality of land, but does not attempt to estimate the effect.

[17] Lester C. Thurow, "The U.S. Productivity Problem," *Data Resources U.S. Review*, August 1979, cited in Shapiro, "Policies for Productivity Growth," pp. 8–10.

Table 3
Average Annual Rates of Growth in Output Per Labor Hour Paid, U.S. Domestic Business Economy (Percent)

Sector	(1) 1950-66	(2) 1966-73	(3) 1973-77	Changes (2)-(1)	(3)-(2)
Agriculture	5.9	5.4	4.2	-0.5	-0.8
Mining	4.5	2.0	-4.4	-2.5	-6.4
Construction	2.9	-2.2	-0.8	-5.1	1.4
Manufacturing					
Durable Goods	2.6	1.9	1.3	-0.7	-0.6
Nondurable Goods	3.3	3.2	2.6	-0.1	-0.6
Transportation	3.7	2.9	2.1	-0.8	-0.8
Communications	5.3	4.8	6.8	-0.5	2.0
Utilities	6.1	4.0	1.0	-2.1	-3.0
Wholesale Trade	3.3	3.9	0.3	0.6	-3.6
Retail Trade	2.5	2.2	1.0	-0.3	-1.2
Finance, Insurance, etc.	0.8	-0.2	0.6	-1.0	0.8
Services	1.7	1.9	0.4	0.2	-1.5
Weighted productivity growth within major sectors	2.8	2.0	1.2	-0.8	-0.8
Unweighted average growth, Total business economy	3.4	2.3	1.4	-1.1	-0.9
Structural shift effect	0.6	0.3	0.2	-0.3	-0.1

SOURCE: U.S. Department of Commerce, Office of the Chief Economist.

using estimates for several types of capital in more than 50 industry groups, found that reallocations added 0.4 percentage point to growth in 1948–66, and somewhat more in the subsequent subperiod.[18] Using estimates for 31 industry groups in 1973–78, I found that the contribution declined to 0.2 point.

It does not appear that the degree of concentration of industry, nor of unionization of workers, changed significantly over the period 1948–78. Some economists claim, however, that with accelerating inflation changes in relative prices have served less effectively as signals for movement of resources. It is also possible that labor mobility may have been reduced somewhat by the growth of pension plans and other fringe benefits that are not vested in the workers.

Volume Changes

Productivity is affected by secular, cyclical, and erratic changes in output. Economies of scale as output grows secularly reflect increasing specialization of personnel, equipment, plants, and producing units, indivisibilities, and the spreading of overhead-type functions over increasing volume. Based

[18] Frank M. Gollop and Dale W. Jorgenson, "U.S. Productivity Growth by Industry, 1947–73," in John W. Kendrick and Beatrice N. Vaccara, eds., *New Developments in Productivity Measurement and Analysis* (Chicago: University of Chicago Press, 1980), pp. 17–136.

on Denison's rough estimating procedure that relates the gains from scale economies to the rate of growth of real product, their contributions declined from 0.4 percentage point during 1948–66 to 0.2 during 1973–78.

I use a simpler method than does Denison for estimating the effects of the cycle on productivity in the first and last years of the subperiods over which growth rates are calculated. Denison uses a complex regression procedure whereby he attempts to estimate the cyclical component of annual productivity changes from the movements of the nonlabor share of factor income. I base my estimate on the effect of changes in the ratio of actual to potential real GNP between the end years of subperiods on the rates of utilization of the relatively fixed component of real factor inputs (estimated at around 40 percent). Using the revised estimates by the Council of Economic Advisers in its 1979 Annual Report, I find a negligible effect of the cycle between 1948 and 1966, -0.1 percent for 1966–73, and -0.3 for 1973–78. Denison finds a small positive effect for 1948–66, a much larger negative effect for 1966–73, and between 1973 and 1976 he finds the effect already to be positive. He had not extended his potential real income and product estimates through 1978 in his most recent published work.[19]

Irregular or erratic factors refer to changes in weather, strike activity, and civil disturbances (not to mention wars). These may have a perceptible influence on annual changes, but Denison's estimates of the effects of the first two factors listed above indicate that the effects over the subperiods used in our analysis were negligible, and they are omitted from the table.

Net Government Impact

Some investigators analyze the negative impact of general governments on productivity, without taking account of the public services rendered to business and the community at large. We attempted to assess the positive services in terms of the growth of governmental inputs relative to business inputs (since government output data are fragmentary). On this basis, it appears that the government contribution to business productivity has been about 0.1 in the subperiods surveyed, somewhat less than pre-1948.

Denison estimates that the negative impacts of environmental, health, and safety regulations — which increase business inputs and costs without increasing measured outputs — reduced productivity growth by 0.13 during 1967–73, and 0.35 during 1973–76. We have rounded his estimates up to -0.2 and -0.4, since there are other types of regulations, although those evaluated by Denison have the most important impact on business, and since our subperiods are a bit larger than those he covered. Although Denison's estimates begin in 1967, it appears that regulatory burdens were increasing in prior years. For example, the numbers of pages of regulations published in the Federal Register gradually increased from 3,450 in 1937 (the first year of

[19] Denison, *Accounting for Slower Economic Growth*, Appendix I, "Effects of Varying Intensity of Demand on Output per Unit of Input," pp. 176–189.

publication) to 60,221 in 1975. We have entered a -0.1 percentage point impact for the subperiod 1948–66. It was probably even greater in the 1929–48 period, when New Deal economic programs burgeoned.

Residual

The residual, or difference between rates of change in productivity and in the explanatory variables offered above, has been modestly negative in all three subperiods. We interpret the residual as reflecting chiefly changes in the ratio of actual to potential labor efficiency at given levels of technology. A couple of elements affecting this ratio can be measured. For one thing, the hours estimates of the Bureau of Labor Statistics, which we use, consist 90 percent of hours paid for rather than hours worked. The downward trend of the ratio of hours worked to hours paid for, reflecting the increasing proportion of paid holidays, vacation, and sick leave, and in some cases sabbatical leaves, has been estimated by BLS to have reduced measured productivity growth in the several subperiods by about 0.1 percentage point.

There has also been a trend towards more unproductive time of workers when at work — for "breaks," the conduct of personal business, and the like. Based on a small sample, the Survey Research Center of the University of Michigan reported that the ratio of time actually worked to time at the workplace by married men was 2 percent lower in 1974–76 than in 1965–66, and even more so for married women.[20] I would guess that the average annual contribution of about -0.2 during this period of heightened social ferment was greater than it was before or after. The mere process of back-casting suggests the trend must have been less in earlier years. But more data are needed to assess the trend since 1973.

There is considerable speculation that the efficiency of hours actually worked may have declined in relation to the kind of standards or norms used in work measurement studies. There is no doubt that restrictive work rules and practices exist in many industries, but data are not available to indicate whether their negative impact has increased. Labor efficiency may also have been adversely affected since the early 1960s by some negative social tendencies, such as growing drug use and crime (see below), loosening of the work ethic, increased questioning of materialism and of various social institutions, including business. But there is no way to assess the net impact of these tendencies. My impression is that they peaked during the era of the Vietnam conflict. The fact that there is no trend in the residual suggests that their impact has not increased, or if it has, that it has been offset by other, positive developments.

The residual also includes possible effects on unit costs of changes in the social and institutional environment not captured by the proximate determinants already discussed. An example is the increase in dishonesty and crime,

[20] F. Stafford and G. Duncan, "The Use of Time and Technology by Households in the United States," (July 1977), Table 4.

which Denison estimates to have reduced productivity growth by 0.03 percentage point a year, on average, during the period 1958–75 spanned by his estimates. Other examples are changes in the degree of competitive pressures in product and factor markets (which has a cyclical component), changes in managerial efficiency, and deviations in the allocation of workers among jobs from an optimum. Finally, the residual reflects errors in the estimates of output, inputs and the impacts of explanatory variables to the extent that they are not offsetting. The small size of the final residual indicates that omitted variables and estimating errors had largely offsetting effects.

Recapitulation

The statistical explanation of the rates of productivity change in the several subperiods automatically provides a quantification of the sources of the slowdown. As may be calculated from Table 2, the 2.4 percentage point deceleration in the growth rate of real product per hour was accounted for by reduced contributions of five groups of explanatory variables, each of which contributed 0.4 to 0.6 percentage point: substitution of capital for labor, advances in technological knowledge, resource reallocations, volume changes, and the combined effect of changes in quality of natural resources and the net impact of governmental programs. Labor quality showed a minor 0.1 point increase, and the residual showed the same negative impact in both subperiods.

Concluding Comments

This concluding section offers some interpretative comments concerning the various sets of causal factors, with some reference to policy implications.

A review of the determinants makes clear the dominant role of total capital formation and the resulting growth of real capital per unit of labor. This includes not only the conventional tangible investment in structures, equipment, inventories and natural resource development, but also the "intangible" investments in R & D, education and training, health and safety, and mobility. The complementarity of these various types of investment is high. R & D raises rates of return on and demand for the tangible capital goods in which it is embodied, and tangible investment helps diffuse new technology and raise labor productivity. Technological progress upgrades the demand for labor, while the scientists, engineers and managers produced by the educational system create the inventions and innovations. Investments in health and safety improve the quality of the labor force, and increase the rate of return on human capital, particularly education, while the educational system plays a role in medical research as well as education, and in diffusing health information. Mobility is essential for labor and capital to adapt to changes in demand and supply conditions arising from technological and other dynamic forces, and thus maximize income and product. When one form of investment lags, as has R & D since the mid-1960s, the effectiveness of other types is reduced. Ideally, the principle of equi-marginal rates of return, equal to the marginal cost of funds, should be used to allocate investment among the various types and uses. More research is needed to permit better estimates of rates of return, particularly on intangible investments.

Each of the several types of investment is undertaken by both the private and public sectors. It is interesting that investments in education, training, health and safety continued to rise strongly in the 1970s, propelled by government programs directed toward welfare goals. This contrasts with the sharp cutback in government funding of R & D beginning in the latter 1960s, which created rising unemployment of scientists and engineers. The latter experience suggests the need for federal science policy involving fairly regular increases in aggregate R & D outlays, even if gradual compositional changes are considered desirable.

The chief problem with respect to private business investment was the declining rates of return in the 1970s, after adjustment for inflation effects, and the higher risk premiums associated with OPEC actions, accelerating inflation, recession, increased regulatory burdens and other controls. The fact that productivity growth also slowed down significantly in most other industrialized countries after 1973 suggests that the common factor of accelerating inflation in general, and the huge rise in oil prices that created its own distorting effects as well as triggering accelerated inflation in most countries, was particularly important in reducing the growth of capital per worker and adversely affecting other productivity determinants. Capital/labor substitution was lower after 1973 in most OECD countries than it was in the preceding decade or two.[21]

The relationship between inflation and productivity is, of course, an inverse one. While inflation impairs productivity growth, so does a retardation of the latter variable accelerate inflation through stronger cost-push. Certainly, policies to stimulate investment and otherwise spur productivity are a fundamental avenue of attack on inflation.

Since another of the papers at this conference deals with policy, I will not try to treat systematically the options available to stimulate investment. Of the tax options for so doing, I would give priority to price-indexing depreciation. A less familiar approach would be to reduce the relative price increase in capital goods industries, one aspect of which would be to target productivity-enhancing measures on the capital goods industries, particularly construction. Government can also promote investment by reducing uncertainties, particularly with respect to its own policies and actions. This brings us to a second grouping of causal forces.

Government most directly affects productivity growth through its own measures which affect business positively or negatively, and through its responsibility for relatively full employment and stable growth. With respect to the latter, skillful use of macroeconomic policies to contain economic con-

[21] Cf. *Productivity Trends in the OECD Area* (Paris: Organization for Economic Cooperation and Development, 8 October 1979, restricted).

tractions to a narrow scope and thus achieve more stable growth obviously tends to augment the rate of growth by increasing the volume of investments over the cycle. Further, the focusing of government policies in all relevant areas on promoting the growth of productivity and real product would increase the gains from economies of scale.

Reducing the inflation rate, as called for in the Humphrey-Hawkins Act of 1978, would have a positive effect on investment and productivity. As stated in the 1979 Annual Report of the Council of Economic Advisers published in the *Economic Report of the President*, p. 117:

> Perhaps the most important single contribution to this objective (increasing investment) would be lower inflation. Expectations that the inflation rate would decline steadily over the next 5 years would directly attack one of the obstacles to the recovery of business investment, since the uncertainty faced by business has been a major deterrent to investment planning. Indirectly, reduced inflation would have even larger effects on financial markets. With declining inflation, we could look forward confidently to a marked fall in short- and long-term interest rates, to strongly rising stock prices, and hence to a reduction in the cost of both debt and equity capital.

In my book, this will require further experimentation with and refinement of incomes policies to supplement traditional monetary and fiscal policies to reduce price inflation.

With regard to the net impact of government actions, the priority issue at this point is to minimize the negative effect of social regulations. Many recommendations have been made towards this end, and the Regulatory Council and the Regulatory Analysis Review Group were set up in the executive branch to coordinate and rationalize the regulatory process. It is important that these efforts plus outside analyses continue to try to increase the cost-effectiveness of those regulations that are in the public interest.[22] The positive impact of government resources used to promote business productivity can obviously be enhanced by increasing the productivity of government agencies. Beyond this, cost-benefit criteria for public investments, both in infrastructure required by business and the community at large and in capital goods that would reduce unit costs of public services, should be applied in order to ensure an adequate volume of public investment. Unfortunately, economy drives often cut out desirable capital projects that would yield a net return above cost over their lifetimes.

It would be highly desirable for the federal government to expand the staff of its National Productivity Council, which is now composed of two

[22] For example, Henry G. Grabowski and John M. Vernon, *The Impact of Regulation on Innovation* (Washington: National Academy of Sciences, 1979); and *Environmental, Health, and Safety Regulations*, Draft Report of an Advisory Subcommittee of the Domestic Policy Review Committee (Washington: National Technical Information Services, PG 290405, December 1978).

persons, so that it can do an effective job of coordinating and monitoring policies and programs of the many agencies that affect productivity, coordinate and perform research and analysis, and initiate proposals for the President to improve the nation's productivity growth rate. It is hoped that the Council, which succeeded the National Center for Productivity and Quality of Working Life in October 1978, will do on a continuing basis the kind of job the authors of the papers for this conference are doing on an ad hoc basis.

The remaining causal forces are less amenable to direct government influence. These have to do with changes in the composition of outputs and inputs, and in the ratio of actual to potential efficiency with given technology. Resource reallocations result from changes in the composition of final demand due to changes in income, relative prices, and tastes; and to changes in technology, and in the relative prices of resource inputs. The efficiency of the price system in product and factor markets depends, of course, on the legal and institutional framework, and on the enforcement of the antitrust laws and on the efficacy of economic regulations in simulating the results of competition. The degree of mobility of resources in response to price signals and associated incentives depends primarily on the self-interest of workers and property-owners, but can be influenced to some extent by public policies in the areas of manpower and finance.

Changes in the composition of the labor force (primarily the age-sex mix) primarily reflect demographic variables, but are also influenced to some degree by government policies relating to education, training, unemployment, retirement and immigration. The domestic natural resource base of the economy is largely given, but the patterns of its use are amenable to policy influence.

Changes in labor efficiency in the business sector reflect an interaction of the values and attitudes of workers and their representatives and the management practices and pay systems designed to elicit optimal performance under given technology, the rapid learning of new job content, and the eliciting of innovative cost-reducing ideas from all levels of workers. Labor laws and manpower programs can influence performance. An example of a constructive development in recent years has been a program of the Federal Mediation and Conciliation Service to aid companies and unions in establishing joint labor-management productivity teams to promote improvements in productivity. Whether governments should play a role in influencing attitudes towards work is a moot point.

In conclusion, this review of the determinants of productivity growth reveals the great scope and complexity of the subject. It makes clear that policies to promote productivity must be developed and instituted on many fronts. In October, I prepared a paper for the American Council on Education that contained around 100 proposals for accelerating the rate of U.S. productivity growth.[23] Some of these which I had drawn from the reports of

[23] John W. Kendrick, *Policies to Promote Productivity Growth* (Washington: American Council on Education, April 1980).

the subcommittees of the Domestic Policy Review Group were subsequently included in the President's industrial innovation initiatives.[24] But all of the proposed changes in tax laws and many of the other recommendations are still available for possible action. Much remains to be done to promote a much more vigorous growth of productivity in the 1980s than in the 1970s.

[24] Fact Sheet on "The President's Industrial Innovation Initiatives" (Washington: The White House, October 31, 1979).

Discussion

Lester C. Thurow*

According to Kendrick the dominant factor in declining productivity growth is a slowdown in capital formation or more accurately a slowdown in the rate of growth of the capital-labor ratio. This is an area where it is necessary to be accurate since the slowdown in the rate of growth of the capital-labor ratio springs not from a slowdown in the proportion of the GNP devoted to capital formation but from a speedup in the rate of growth of the labor force.

Using the three periods from 1948 to 1965, 1966 to 1972, and 1973 to 1979, plant and equipment investment rose from 9.5 percent of the GNP in the first period to 10.3 percent of the GNP in both of the next two periods. Plant and equipment investment is up, not down. But the rate of growth of manhours of work in the private business economy has accelerated dramatically. Manhours of work were growing 0.4 percent per year from 1948 to 1965, 1.1 percent per year from 1965 to 1972, and 2.1 percent per year from 1972 to 1979. To equip a labor force that was growing more than five times as fast in the last period as in the first period, the fraction of GNP devoted to plant and equipment investment would have had to have risen dramatically. It didn't.

The fact that it didn't, however, does not prove that there is an economic problem that needs to be solved. The market was calling for a slowdown in the rate of growth of the capital-labor ratio. If you look at the relative prices of labor (as measured by total compensation per full-time equivalent employee) and capital (as measured by the implicit price deflator for private and equipment investment), the price of labor was rising 2.7 percent per year from 1948 to 1965 relative to that of capital. Labor was becoming expensive; capital was becoming cheap.

But in the third period of time the price of labor was rising only 0.7 percent per year relative to that of capital. Thus relative prices were changing four times as fast in the first period as in the third. Using a simple Cobb-Douglas simulation with an elasticity of output of capital of 0.3, this slowdown would have reduced the rate of growth of labor productivity (due to the slowdown in growth of the capital-labor ratio) by 0.6 percent per year.

But a rising purchasing price is only one element of the total gross cost of capital. Capital investments must be financed and need energy. If energy

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costs are added into the analyses, the price of labor was rising 2.9 percent per year relative to that of capital in the 1948 to 1965 period since energy costs were falling. But in the third period the price of labor was *falling* 2.9 percent per year relative to that of capital since energy costs were skyrocketing. If interest rates and energy costs are both included, the price of labor was rising 1.1 percent relative to capital in the first period but *falling* 4.2 percent in the third period. Obviously the latter calls for a reduction in the optimum capital-labor ratio and a reduction in the optimum level of productivity. Capital is becoming expensive; labor is becoming cheap.

Looking at the relative prices of labor and capital, it is not at all clear that there is an "economic" productivity problem. A slowdown in productivity growth is exactly what the market is calling for and what is to be desired in a period when massive numbers of new workers need to be introduced into the labor force. These new workers lower wages and stop capital formation from rising, but that is what they are supposed to do in a supply and demand world.

A second major source of the productivity slowdown in Kendrick's analysis is an adverse shift in the industrial mix. But here again this adverse shift does not indicate a market failure. It merely indicates the end of an era when agriculture was declining rapidly and the beginning of an era when the service industries are growing rapidly.

Using the industrial breakdown provided by Kendrick, agriculture entered 1948 with a level of labor productivity just 40 percent of the national average. Every worker moved from agriculture to industry represented a 60 percent gain in productivity. And millions of workers were moved. From 1948 to 1965, 9.1 billion manhours were moved from agriculture to industry. And from 1965 to 1972 another 1.8 billion manhours were released. But in the period from 1972 to 1978, only 0.1 billion manhours were released. Movements from agriculture to industry had stopped and agriculture had become a small industry in regard to employment. But when this movement stopped, agriculture ceased being a major source of productivity gains.

Conversely in 1948 services had a level of productivity that was 96 percent that of the national average. Service industries were growing, but the growth did not represent any huge net drain on aggregate productivity. But service productivity growth was slow after WWII and by 1978 service productivity was only 62 percent of the national average. Thus a worker moved into services in 1978 represented a 38 percent decline in productivity. And millions of workers were moved. From 1972 to 1978, 5.7 billion manhours or 35 percent of the growth in hours of work went into services. This represented a large reduction in national productivity growth.

Where did the workers go in services? Forty-two percent of the workers went into health care (mostly nursing homes) and 27 percent into business services (consulting, lawyers, accountants). Presumably businesses were rational in their purchases of business services and the elderly need to be washed and bathed. No market failure was occurring.

Together the agriculture-service effect explains about 22 percent of the national decline in productivity growth from the first to the third period. But there is nothing that can or should be done about this source of the decline.

The decline in extractive industries explains about 10 percent of the national decline in productivity, but this is almost all accounted for by depletion in the oil industry — less oil found per well drilled. Kendrick finds declining land (agriculture) productivity, but this is a statistical artifact due to the corn blight and the re-introduction of millions of low productivity areas back into production with the removal of crop controls. These two factors caused agriculture productivity to decline from 1972 to 1973 and to reach only 1972 levels in 1974. But since 1974, agriculture productivity has grown faster than it did from 1948 to 1972. Thus there was a one-shot decline in agriculture productivity that shows up in growth accounting but it is not a cause for policy concern.

Construction productivity has now been falling for 15 years and accounts for about 17 percent of the decline in national productivity. This is a genuine mystery that is not cleared up by growth accounting. For example, while constant dollar output only grew 58 percent from 1954 to 1977, construction materials grew 133 percent. Do you really believe that the average building uses twice as many materials now?

Kendrick points to declining expenditures on R&D as one of the sources of the productivity decline. I am skeptical because of the timing. R&D expenditures peaked as a percent of GNP in the mid-1960s, but they did not really start to decline until the early 1970s. The productivity decline started much earlier and there must be a substantial time lag between R&D expenditures and measured productivity.

Once again looking at Kendrick's table on industrial productivity growth, you can see that there has been a sharp decline in the rate of growth of productivity in the utility industry. Here again the decline is easily understood as a rational market reaction. In electrical utilities, most of the manpower is located in the distribution network and marginal labor costs are well below average labor costs. Thus in periods where electricity consumption is growing very rapidly, utility productivity growth is very high. But in periods when electricity consumption is not growing or falling, utility productivity slows down or falls. This pattern can be seen by looking at the year-to-year changes in utility productivity. It is a direct function of the rate of growth of utility output. But slower growth in energy consumption is not only being called for by relative prices but is a national policy. Thus no one wants to reverse the slowdown in utility productivity growth. If anything, policies will make productivity growth even slower.

Finally there is the crime and social unrest item referred to by Kendrick. Since 1972, the U.S. economy has added 150,000 private protective service workers. These are pure negative productivity (they guard existing output rather than producing new output) as far as the indexes are concerned, but once again they are not irrational.

When you add up all of these factors, you have to ask seriously whether there is an "economic" productivity problem. Productivity growth has slowed down, but this is in response to market factors that do not indicate imperfections or failures.

What then is the productivity problem? To some extent, it is geopolitical (we do not want our standard of living to fall behind that of our industrial neighbors) and to some extent it is political (we find it difficult to operate a society where real standards of living are not rising), but it is not economic. As a result, plans to accelerate the rate of growth of productivity have to approach the problem from this perspective. We won't accelerate productivity growth by improving the performance of the market, but by introducing market "imperfections" that make the economy grow faster than individual private decision-making or the market would dictate.

Capital Accumulation and Potential Growth

Richard W. Kopcke*

From 1950 to 1965 the average annual growth of output per hour for nonfarm, nonresidential business was 2.5 percent; from 1965 to 1978 labor productivity grew only 1.5 percent per year, a decline of 1 percentage point. In manufacturing, the decline was somewhat less, .6 of a percentage point. This erosion of productivity growth suggests that the rate of expansion of potential Gross National Product (GNP) may have dropped a full percentage point in recent years—whereas potential growth was commonly believed to be almost 4 percent until the mid-1960s, many now believe it is nearer 3 percent.[1]

This study concludes that much of the slump in productivity and potential GNP growth resulted from a slower rate of capital accumulation. One-half of the decline in labor productivity for nonfarm nonresidential business is due to slower growth of the stock of plant and equipment. For manufacturing, slower capital accumulation may account for the entire drop in productivity growth.

Much of the decline in the demand for capital can be attributed to rising inflation since the late 1960s. From the mid-1950s to the early 1970s investment tax incentives increased the demand for capital, but since then rising inflation rates generally have raised business income tax burdens, thereby depressing the demand for capital.

The postwar incentives for investment caused the capital stock to grow much faster than employment, *temporarily* boosting the expansion of potential GNP. Since 1965, however, rising inflation has depressed investment incentives and the rate of capital accumulation, *temporarily* retarding the expansion of full-capacity GNP. This study's analysis suggests that a policy designed to insulate the demand for capital from high inflation could achieve a potential growth rate of 3.5 percent or more during the remainder of this century.

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[1] See, for example, various issues of the *Economic Report of the President;* the issues published in 1962, 1965, and 1979, among others, provide useful comparisons. This paper is not suggesting that 1965 is *the* year when productivity fell. Analysts first noted a slower productivity growth in the late 1960s and early 1970s. Because 1965 roughly divides the postwar period in half, separating the period of high growth from the years of slower growth, and because the pace of capital accumulation began to drop after 1965, this year provides a useful benchmark for measuring the recent productivity slump. The growth of output per hour did not drop dramatically in any single year, rather it has progressively declined over many years perhaps commencing as early as 1965.

The first two sections of this paper, particularly the second, describe this study's analytical techniques. Section III compares the growth of output with the employment of capital and labor to show how slower capital accumulation since the mid-1960s has depressed the growth of labor productivity. Sections IV and V then describe how the higher income tax burdens on capital, due to higher inflation rates since the mid-1960s, have depressed capital accumulation, thereby reducing the growth of potential output. The last section summarizes the study's principal conclusions.

I. The Production Function

Two common methods for studying the sources of productivity and output growth use either "growth accounting" or production functions. Growth accounting assumes that the earnings of each factor of production equals the value of its product when it is fully employed.[2] Output growth may then be attributed to labor or capital by weighing the growth in hours worked and the expansion of the capital stock by their respective earnings. For many well-known reasons, though, the earnings of labor and capital may seldom match the value of their product, even in years of "full employment," so growth accounting may poorly describe the sources of productivity growth.[3]

The production function compares output with the employment of labor and capital services directly to isolate the sources of productivity growth. Accordingly, output is a function of labor and capital inputs.

$$Q = F(K, L).$$

This approach shares one weakness with growth accounting: it is difficult to measure the overall quantity of labor and capital services because differences in quality among people or plants are difficult to assess.[4]

According to the production function, current engineering knowledge determines the maximum, or potential, output per "unit" of material input that can be produced with a given stock of labor and capital. The growth of potential output is then determined by the expansion of the labor force and

[2] In many cases, it is the marginal product which presumably equals the factor cost.

[3] First, the market value of corporate capital (essentially the prospective value of its product) seldom equals its replacement cost. In many respects, skilled labor and managers, like plant and equipment, represent an investment whose product may also seldom match its cost. Second, a growing business may hire more labor and capital than it needs to satisfy current orders if it is preparing to increase future capacity. Third, businesses often do not know in advance how much of their product they can sell at particular prices; consequently, the value of labor's product, for example, may sometimes exceed its wage, and, at other times, this product may fall short of labor's wage. Wages may not even match the average value of labor's product because risk-averse firms may hire labor only so long as the expected value of its product exceeds the wage by some protective margin. Fourth, whenever businesses or labor do not merely passively supply their products or services at market prices over which they exert no influence, the earnings of capital and labor are not determined solely by their productivity. For these reasons, among others, factor earnings reflect more than factor productivity alone.

[4] I do not use a "weighted" measure of the labor force for example. See footnote 3.

the capital stock as well as by the pace of technical progress that enables a given stock of labor and capital to produce more output from a given flow of material inputs. If the flow of output is compared to the use of only one factor of production—labor, for example—then its *productivity* depends not only on overall technical progress but also on the employment of the other factors of production—the more capital labor uses, the more output labor can produce. The growth of output per hour worked, therefore, depends on technical progress and the growth of the capital stock.

The specific production function used in this study is translogarithmic:

$$(1)\quad \ln(Q/H) = \alpha_o + \alpha_e \ln(E/H) + \alpha_s \ln(S/H) + \beta_{ee} \ln(E)^2 + \beta_{es} \ln(E)\ln(S) + \beta_{eh} \ln(E)\ln(H) + \beta_{es} \ln(E)\ln(S) + \beta_{ss} \ln(S)^2 + \beta_{sh} \ln(S)\ln(H) + \beta_{eh} \ln(E)\ln(H) + \beta_{sh} \ln(S)\ln(H) + \beta_{hh} \ln(H)^2 + \alpha(T),$$

E: the stock of producers' durable equipment;
H: hours;
Q: value-added;
S: the stock of nonresidential structures;
$\alpha(T)$: productivity and technical change.

where:

$$\beta_{eh} = -\beta_{ee} - \beta_{es}$$
$$\beta_{sh} = -\beta_{es} - \beta_{ss}$$
$$\beta_{hh} = +\beta_{ee} + 2\beta_{es} + \beta_{ss}$$

The function, as defined above, has constant returns to scale, and the last term is intended to represent Hicks-neutral technical change and secular variations in total factor productivity.[5]

II. Estimation of the Production Function

Using a Bayesian technique, the parameters of the production function are estimated from postwar data. The stochastic representation of (1) is:

$$(2)\quad \ln(Q/H) = \alpha_o + \alpha_e \ln(E/H) + \alpha_s \ln(S/H) + \beta_{ee}(\ln(E)^2 + \ln(H)^2 - 2\ln(E)\ln(H)) + \beta_{es}(\ln(H)^2 + \ln(E)\ln(S) - \ln(H)\ln(E) - \ln(H)\ln(S))^2 + \beta_{eh}(\ln(S)^2 + \ln(H)^2 - 2\ln(S)\ln(H)) + \alpha_1(T) + \alpha_2(T)^2 + \alpha_3(T)^3 + \epsilon,$$

where T represents a time trend.[6]

[5] Energy is not a factor of production for value-added. See the extensive discussion in Appendix A.

[6] T is unity in 1950:1 and 116 in 1978:4.

(3) $y = X\gamma + \epsilon \quad \epsilon_t = \rho\,\epsilon_{t-1} + \upsilon_t \quad \upsilon_t \sim N(O,\sigma^2)$,

where y is a vector of n observations on ln(Q/H), X is a matrix comprised of observations on the right-hand-side variables of (2), and y contains the parameters of the production function. The errors, ϵ_t, may be represented by a first-order Markov process driven by a normal random variable, υ.[7]

The prior distribution for γ is normal with mean g_1 and precision matrix (inverse of the variance matrix) N_1. The conditional posterior distribution for γ is defined by the following statistics for each of ten discrete values for $\rho(\rho = .1i, 1 = O, ..., 9)$:

$$(4) \quad \text{let } R = \begin{bmatrix} \sqrt{1-\rho^2} & 0\,0 \ldots 0 \\ -\rho & 1\,0 \ldots 0 \\ 0\rho - & 1 \quad 0 \\ 0 & 0\,0 \ldots 1 \end{bmatrix}$$

$$\text{then } N_2 = (X^tR^tRX/\sigma^2 + N_1)$$

$$g_2 = N_2^{-1}(X^tR^tRy/\sigma^2 + N_1 g_1),$$

where $\hat{\sigma}^2$ is the mean squared residual from the normal projection of Ry onto RX.

For a given value of ρ, then, the posterior is conditional on both ρ and $\hat{\sigma}^2$

[7] Rather than estimate the more common share equations, the production function is estimated directly. The share equations impose strong assumptions about the pricing policy of business, and, having imposed these assumptions, these share equations suffer from "simultaneous equations problems" at least as severe as the production function itself. For example, a rise in business tax rates will depress capital's share of after-tax value-added, ceteris paribus, while it raises the marginal user cost of capital. In response to this tax increase, the demand for capital will tend to fall and capital's share will tend to recover. The common share equations cannot describe this process: both observed factor shares and factor stocks are endogenous variables, and the share equations do not consistently represent any behavioral or technological relationships, unless one assumes: (a) firms are price takers, (b) average factor shares adjust "immediately" to equal required or marginal factor shares, and (c) firms are almost always on their production frontiers. Of course, if these assumptions obtain, the factor share equations should be expressed with the shares on the right-hand side.

For well-known reasons dictated by the theory of contracts, the theories of decision-making under uncertainty (factors will be paid less than their marginal product by risk averse firms), intertemporal production planning, oligopoly/oligopsony behavior, the distortions of possible discrimination, etc. firms may seldom pay factors of production a return which corresponds to their prevailing marginal product, and firms may seldom be on their "efficient" production frontier. Furthermore disequilibrium conditions—for example, the market value of corporate capital seldom equals its replacement value—may also cause the "list prices" used in estimating factor returns to be misleading indicators of factor productivity. As suggested by Hall and Jorgenson, even if one is willing to accept competitive market theory, factor demands are functions of prevailing and of past marginal user costs. In any case the share equations succumb to at least as many statistical problems as does the production function itself, yet fitting the production function has the considerable atribute of being more direct.

(Zellner, pp. 70 ff. and p. 243) and this distribution is normal with mean g_2 and precision N_2.

The marginal posterior distribution for ρ is proportional to (Zellner, Chapter X.):

$$(5) \quad \hat{\sigma}^{-n} N_2{}^{-.5} \exp(-.5(y^tR^tRy/\hat{\sigma}^2 - g_2{}^tN_2g_2) \; f_1(\rho),$$

where $f_1(\rho)$ is the prior distribution for ρ. Therefore the "unconditional" posterior distribution for γ is a weighted sum of the normal distributions defined in (4); the weight for each distribution is proportional to the quantity defined by (5).

According to the prior mean, the rate of Hick-neutral technical change is 2 percent per year, and while the matrix of cross elasticities, β, is zero, the elasticity of output per hour with respect to both equipment and structures (α_e and α_L) is 15 percent.

The prior's covariances among the coefficients of (2) are zero, except for that between α_e and α_s and those among β_{ee}, β_{es}, and β_{ss}. The variances and covariances for these two groups of parameters were selected according to the following method. First a preliminary variance matrix for each of the sets of coefficients, (α_e, α_s, α_h) and (β_{ee}, β_{es}, β_{eh}, β_{ss}, β_{sh}, β_{hh}), is chosen. The sum of α_e, α_s and α_h is "known" to be unity, and the three restrictions shown in (1) are "known" to constrain the coefficients β. Denoting the set of coefficients, α or β, by δ, its preliminary variances by Σ, and the restriction on δ by $R\,\delta = c$, then (Anderson, pp. 27–30):

$$\mathrm{Var}(\delta | R\,\delta = c) = \Sigma - (R\Sigma)^t(R\Sigma R^t)^{-1}(R\Sigma).$$

In this manner the variance matrices for each of the two sets of coefficients have the appropriate singularities. The initial variances for (α_e, α_s, α_h) were (.0033, .0033, .0066), and for (β_{ee},β_{es}, β_{eh}, β_{ss}, β_{sh}, β_{hh}) the initial variances were (.00097, .00019, .00019, .00097, .00019, .00097). The correlation coefficient among β_{ee}, β_{ss}, β_{hh} is .8 and the correlation coefficient between β_{eh}, and β_{sh} is .5. The prior probability for each of the 10 values of ρ is .1.

This prior distribution and the posterior distribution defined by expressions (4) and (5) are used in the sequel to estimate production functions for nonfarm, nonresidential business, and all manufacturing business.

III. Labor Productivity and the Growth of the Capital Stock

Nonfarm, Nonresidential Business

From 1950 to 1965, the average annual expansion of output per hour was 2.5 percent for nonfarm, nonresidential business firms, but from 1965 to 1978 however, labor productivity grew only 1.5 percent per year, a decline of 1 percentage point.[8] This drop in productivity growth supports speculation that the rate of expansion of potential GNP may have dropped a full percentage point in the last 15 years. The causes of this decline are often attributed to rising energy prices, a diminution of innovation, a changing composition of the labor force, or other "structural changes" in the economy. According to this view, we must learn to accept a slower expansion of real living standards until these (often vaguely defined) structured impediments to growth have been surmounted.

The estimated relation between labor productivity and capital accumulation tells another story. Of the 1 percentage point drop in the expansion of labor productivity since the mid-1960s, 50 percent, or .5 of a percentage point, is due to a slower expansion of the capital stock, and the remainder can be attributed to other, unspecified structural changes.[9] Half of the slump in productivity and potential GNP growth, therefore, can be attributed to a decline in the demand for capital rather than forces beyond the grasp of traditional macroeconomic policy.

As shown in charts 1 and 2 (the solid lines), the capital-labor ratios for nonfarm business generally increased from 1950 to 1978, rising especially rapidly until the late 1960s. Whereas the average annual growth of the stock of equipment exceeded hours by 2.8 percentage points before 1965, the growth of equipment, on average, surpassed hours by only 2.2 percentage points thereafter. From 1973 to 1978 the annual expansion of equipment exceeded hours by only 1 percentage point. The slump is even more pronounced for structures. Before 1965 the stock of nonresidential structures grew, on average 2.8 percentage points per year faster than hours worked; after 1965, however, the average annual growth of structures exceeded hours by only 1 percentage point. From 1973 to 1978 the expansion of the stock of structures only matched the growth of hours. Altogether, then, the expansion

[8] As discussed in the first footnote, 1965 only divides the years of faster productivity growth from those of slower growth. In fact, both the declining rate of capital accumulation since 1965 and the nonlinear trend for technical change in the production function indicate that productivity growth did not decline in one consummate step, it eroded slowly during the late 1960s and 1970s.

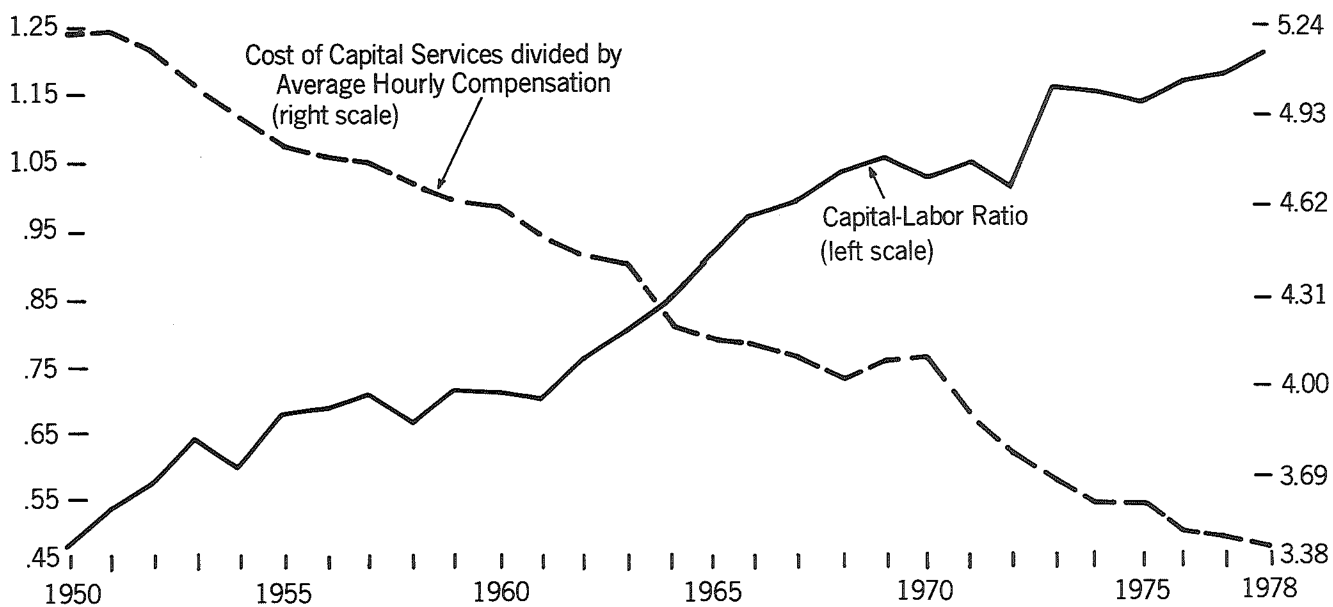
According to the estimates shown in expression (6) the pace of technical progress has fallen throughout the postwar-period for nonfarm, nonresidential business. The rapid accumulation of capital offset the modest decline in the growth of technical change in the 1960s, but in the 1970s slower capital accumulation coupled with a more rapid decline in the growth of technical change severely depressed the growth of labor productivity.

[9] Some research attributes much of the change in productivity growth to a changing industrial mix that undoubtedly is included in the "unexplained residual" here. Anticipating an argument from the next section of this paper, however, just as the capital-labor ratio changes with investment incentives so may the mix of industries. The same incentives that encourage any industry to hire more labor than capital also favor the growth of labor-intensive industries.

Furthermore, research and development spending and worker training programs are natural complements to capital expansion. Thus, the same incentives that encourage capital formation also stimulate investments in people and ideas.

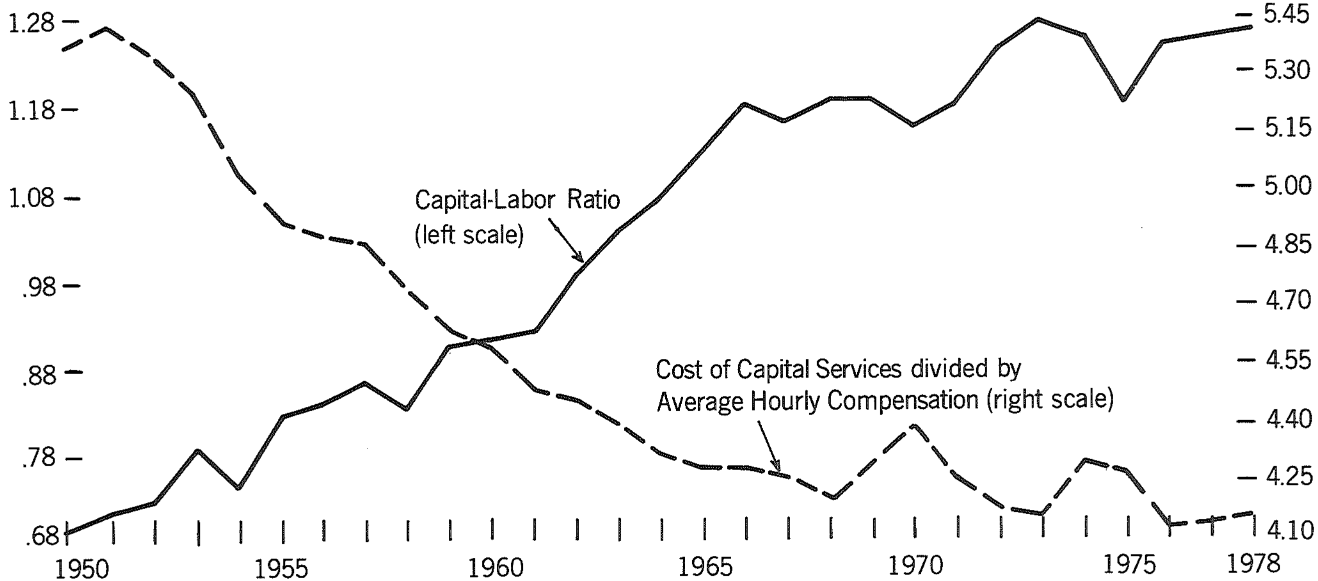
For these reasons perhaps more than half of the productivity slump can be addressed by traditional macroeconomic policies that stimulate investment spending.

Chart 1 Ratio of Equipment to Manhours and the Relative Cost of Capital — Nonfarm Nonresidential Business



Source: Bureau of Economic Analysis and Bureau of Labor Statistics. See Technical Appendix.

Chart 2 Ratio of Structures to Manhours and the Relative Cost of Capital — Nonfarm Nonresidential Business



Source: Bureau of Economic Analysis and Bureau of Labor Statistics. See Technical Appendix.

of the capital stock surpassed the growth of hours by 2.8 percentage points before 1965, but during the 1970s the rate of capital accumulation barely exceeded the growth of hours worked. Though postwar demographic and social changes caused the labor force to expand much more rapidly in the late 1960s and 1970s than it had previously, there has been no comparable surge in fixed investment spending for want of adequate incentives.

In the context of the estimated production function for nonfarm, nonresidential business (using the mean of the posterior distribution),

$$
\begin{aligned}
(6)\quad \ln(Q/H) = {} & 1.41 + .132 \ln(E/H) + .139 \ln(S/H) \\
& - 2.89E{-}3 \ln(E)^2 + 5.61E{-}4 \ln(E)\ln(S) \\
& + 2.33E{-}3 \ln(E)\ln(H) \\
& + 5.61E{-}4 \ln(E)\ln(S) - 2.81E{-}3 \ln(S)^2 \\
& + 2.25E{-}3 \ln(S)\ln(H) \\
& + 2.33E{-}3 \ln(E)\ln(H) + 2.25E{-}3 \ln(S)\ln(H) \\
& - 4.58E{-}3 \ln(H)^2 \\
& + 4.46E{-}3\, T - 1.06E{-}6\, T^2 - 4.99E{-}8\, T^3,
\end{aligned}
$$

the falling rate of capital accumulation has accounted for half of the 1 percentage point drop in labor productivity growth after 1965. In addition, the overall rate of technical change has fallen at an increasing rate every year since 1950. This slump accounts for the remainder of the decline of labor productivity.

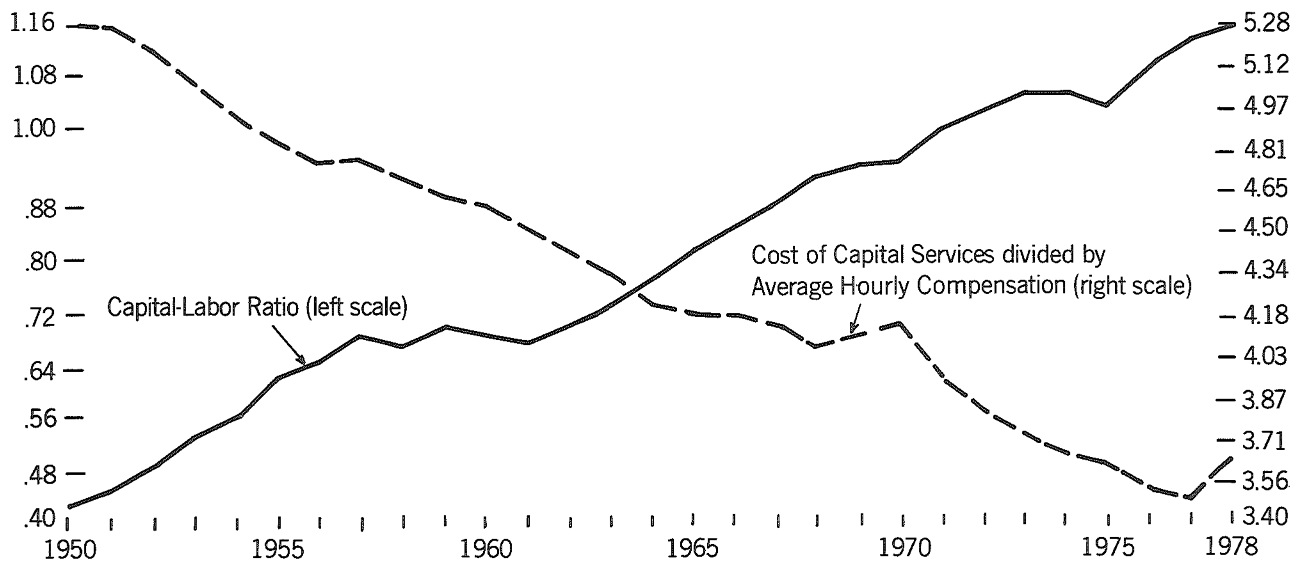
Manufacturing Business

If the slower accumulation of capital has been so detrimental for labor productivity growth, the effect should be especially important for manufacturing businesses which are generally capital intensive.

From 1950 to 1965, the average annual expansion of output per hour was 2.7 percent for manufacturing firms, but from 1965 to 1978 labor productivity grew only 2.1 percent per year, a decline of .6 of a percentage point. According to the estimated production function, the slower expansion of capital since the late 1960s has depressed the growth of manufacturing productivity by .7 of a percentage point. In other words, slumping investment incentives have accounted for all of the decline in manufacturing output per hour—in fact, slower capital formation may have even masked a small increase in productivity due to technical progress.

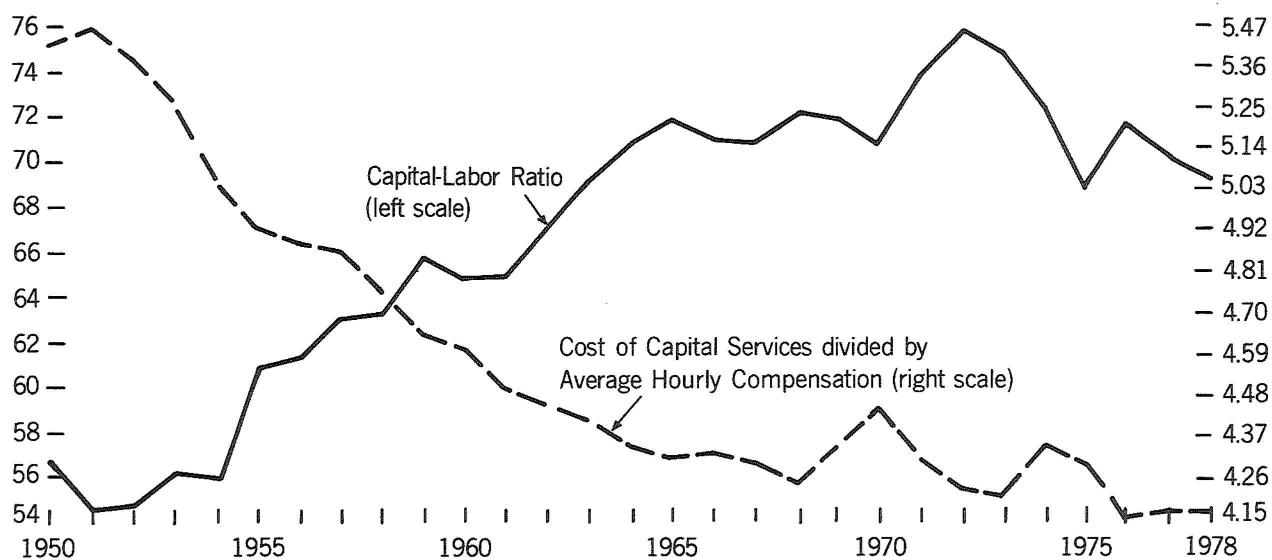
As shown in charts 3 and 4, the capital-labor ratios for manufacturing firms generally increased from 1950 to 1978, rising especially rapidly until the late 1960s. Throughout the postwar period, the average annual growth of the stock of equipment exceeded hours by a relatively constant 2.6 percentage

Chart 3 Ratio of Equipment to Manhours and the Relative Cost of Capital — Manufacturing



Source: Bureau of Economic Analysis and Bureau of Labor Statistics. See Technical Appendix.

Chart 4 Ratio of Structures to Manhours and the Relative Cost of Capital—Manufacturing



Source: Bureau of Economic Analysis and Bureau of Labor Statistics. See Technical Appendix.

points. Before 1965 the stock of nonresidential structures grew, on average, 1 percentage point faster than hours worked; after 1965, however, the average annual growth of structures only matched the growth of hours. From 1973 to 1978, the expansion of the structures was 1 percentage point less than the growth of hours. Altogether, for manufacturing the expansion of the capital stock surpassed the growth of hours by 2 percentage points before 1965, but during the 1970s the rate of capital accumulation exceeded the growth of hours worked by only 1 percentage point.

In the context of the estimated production function for manufacturing,

$$
\begin{aligned}
(7)\quad \ln(Q/H) = {} & -1.87 + 2.43 \ln(E/H) + .300 \ln(S/H) \\
& - 9.08E{-}3 \ln(E)^2 + 2.67E{-}3 \ln(E)\ln(S) \\
& + 6.41E{-}3 \ln(E)\ln(H) \\
& + 2.67E{-}3 \ln(E)\ln(S) - 1.07E{-}2 \ln(S)^2 \\
& + 8.03E{-}3 \ln(S)\ln(H) \\
& + 6.41E{-}3 \ln(E)\ln(H) + 8.03E{-}3 \ln(S)\ln(H) \\
& - 1.44E{-}2 \ln(H)^2 \\
& + 3.80E{-}3\, T + 8.30E{-}6\, T^2 - 3.51E{-}8\, T^3,
\end{aligned}
$$

the decline in capital accumulation relative to hours worked has reduced the average annual growth of output per hours by .7 of a percentage point after 1965, essentially the entire drop in manufacturing productivity growth. According to the estimates in equation (7), the pace of technical progress for manufacturing increased each year from 1950 to 1969; since then, the growth of technical change has declined. This recent slump has been sufficiently modest, however, that the average annual growth of technical change since 1965 exceeded its growth before 1965 by .1 of a percentage point.

IV. Inflation and the User Cost of Capital

Although rising material prices may have been responsible for a considerable portion of the recent drop in potential growth, much of the slump can be attributed to the failure of the income tax codes to measure and tax business income accurately during periods of high inflation. In fact, rising energy prices may have indirectly depressed the demand for capital through the income tax codes to the extent these prices have been a cause of inflation. Economic policy may not be able to restore the relative price of energy to levels that prevailed in the 1960s, but it can measure and tax business income more realistically.

Because capital assets, plant and equipment, are consumed during production, a portion of the price paid for these assets is included in production costs throughout their "service lives." During periods of rising prices, however, the current replacement cost of plant and equipment exceeds the *original* purchase price; consequently, the value of capital assets consumed in production exceeds depreciation allowances tied to original purchase prices. Thus, business profits apparently rise when the inflation rate increases because illusory "depreciation profits" arise from the underestimate of capital consumption costs.[10]

These "depreciation profits" are taxed like any other business income so rising inflation increases the income tax burdens for business. The effective income tax rate increases most for those firms using the most capital-intensive production methods, and during periods of inflation the prospective costs of business expansions or renovations increase, the more capital-intensive the project, the more its expense rises. Rising inflation rates, therefore, increase the relative cost of capital services as long as depreciation allowances are tied to capital assets' original purchase prices. The costs of structures and other longer lived assets have risen most rapidly due to inflation: Because depreciation allowances for these assets are allocated over many years, the gap between these allowances and actual capital consumption costs can become especially large before the assets are retired.

It is a common belief that businesses, as debtors, reap gains from inflation that offset the taxation of "depreciation profits." In the article cited below, I reported that business has not benefited from purchasing-power holding gains on long-term debt because purchasing-power losses on pension fund reserves have been at least as large. Yet it is important to distinguish past from prospective investments. For prospective projects, *expected* inflation erodes the real value of depreciation allowances, but *expected* inflation does not necessarily offer borrowers any holding gains on newly issued debt, partly because debt yields will include an inflation premium. High expected inflation rates, therefore, discourage investment spending, and the yet unknown errors in these inflation forecasts cannot influence the demand for new capital, even though these unknown forecast errors eventually will influence the return on these capital assets after they have been purchased and installed.[11]

Charts 1 through 4 not only show capital-labor ratios for all domestic nonfarm business and for manufacturing firms (the solid lines), they also

[10] "Service lives" are often dictated by statutory schedules rather than useful economic lifespans. Though the economic life of an asset may exceed its service life, rising inflation rates increase the cost of capital services nonetheless.

[11] To some analysts, the inflation premium embedded in current debt yields is unrealistically low so they reason that inflation may indeed offer business substantial purchasing-power gains on debt. Today's "low" nominal yields may imply that real yields on debt are also "low" according to the simple theory of inflation premiums; yet these low yields may not stimulate investment if the prospective growth of sales is depressed or if managers believe business risks are now great. Nevertheless, assuming that debt finances one-third of the cost of new investment projects and that the loan principal is retired by amortization or by a sinking fund (both are common arrangements), the higher present value of purchasing power gains on debt today when compared to the 1960s (using a 1 percent after-tax real rate of discount) only offsets about one-fifth of the drop in the present value of depreciation allowances. This calculation also assumes the expected longer run rate of inflation has increased from 1 percent to 6 percent from the early 1960s to the

show the cost of capital services relative to the cost of labor services (the dashed lines). The cost of capital services for producers' durable equipment for nonfarm, nonresidential business fell 7.3 percent per year from 1950 to 1965; since then, capital costs fell only 5.7 percent per year. From 1973 to 1978, these costs declined, on average, only 4.9 percent annually. The cost of capital for nonresidential structures fell, on average, 7.5 percent per year before 1965; since then, however, these costs declined only 1.2 percent per year. The cost of capital for manufacturing behaved almost identically to that of all nonfarm business.

It is no coincidence that capital accumulation was most rapid when capital costs were declining most swiftly, from 1950 until the late 1960s, and that investment has waned recently now that these costs are no longer declining so rapidly. Furthermore, Chart 5 shows that the changing mix of business's capital assets—equipment compared with structures—closely corresponds to changes in the relative costs of these assets. From the mid-1950s to the early 1970s tax credits, accelerated depreciation, and lower corporate income tax rates increased the demand for capital, especially equipment after 1962. Since 1973, however, rising inflation rates generally have retarded the decline in the cost of capital services, thereby depressing the demand for capital assets, especially structures.

The Cost of Capital Services

Table 1 shows how the changes in the relative cost of capital services can be allocated to the changing price of capital goods relative to labor compensation, required rates of return, and business income tax burdens. These components are not entirely independent, of course. For example, a higher tax burden will depress the demand for capital, and as a result (depending on the pricing practices in capital goods markets) the price of new capital assets may decline, perhaps offsetting much of the higher tax burden. In this event, how-

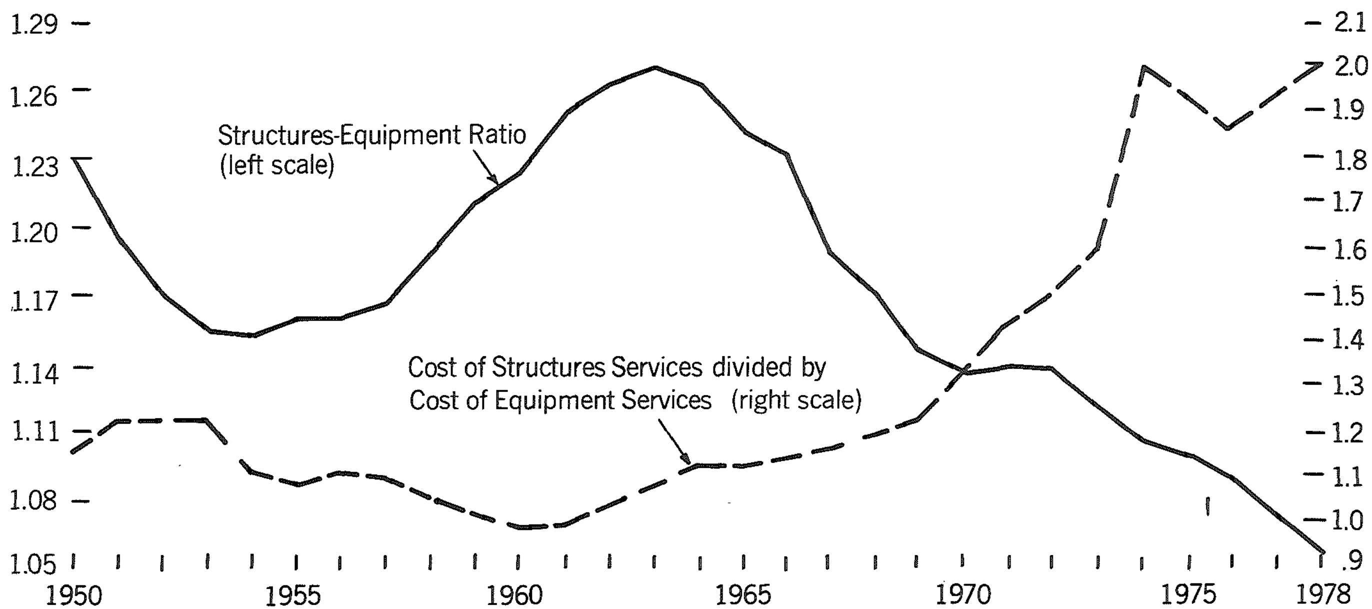
1970s. Therefore, today's debt yields do not assuage the high tax burden on business, contrary to William Nordhaus's observation that "the ratio of the sum of positive incentive due to interest deductibility and negative incentive due to illiberal depreciation allowance to true profits" has risen since World War II. (See "Policy Responses to the Productivity Slowdown," in this volume.)

In my user cost of capital (see Appendix B), I have assumed that market rates of interest—the relevant opportunity cost—are the most defensible discount rates for depreciation allowances and debt service charges. If I were to discount debt servicing at rates exceeding market yields, I would also have to discount depreciation allowances more severely than I have done in this paper.

See Richard Kopcke, "Are Stocks a Bargain?," *New England Economic Review,* May/June 1979, pp. 13–15; P. J. Corcoran, "Inflation, Taxes, and the Composition of Business Investment," Federal Reserve Bank of New York *Quarterly Review,* vol. 4 no. 3 (Autumn 1979), pp. 13–34; and T. N. Tideman and D. P. Tucker, "The Tax Treatment of Business Profits under Inflationary Conditions," in H. J. Aaron, editor, *Inflation and the Income Tax* (Washington: Brookings Institution, 1976).

Unlike "depreciation profits," "inventory profits" arise whenever goods or materials are stockpiled whether the production process is labor-intensive or capital-intensive, so the tax burden of "inventory profits" presumably does not influence the capital intensity of production.

Chart 5 Ratio of Nonresidential Structures to Equipment and the Relative Cost of Capital— Nonfarm Nonresidential Business



Source: Bureau of Economic Analysis. See Technical Appendix.

Table 1
Decomposition of the Relative Cost of Capital Services for Nonfarm Business

A. Producers' Durable Equipment

	Relative Price of Equipment[1]	Required Yield[2]	Corporation Income Tax Burden[3]
1950	100	.26	1.06
1951	93	.25	1.18
1952	87	.25	1.18
1953	82	.25	1.19
1954	80	.24	1.05
1955	77	.23	1.03
1956	75	.23	.98
1957	73	.23	1.00
1958	71	.23	1.00
1959	68	.22	1.00
1960	65	.22	1.00
1961	62	.22	.98
1962	60	.22	.92
1963	57	.22	.87
1964	54	.22	.82
1965	52	.22	.82
1966	49	.22	.85
1967	46	.22	.87
1968	43	.22	.87
1969	40	.22	1.00
1970	37	.23	1.06
1971	34	.22	.95
1972	32	.22	.90
1973	29	.22	.90
1974	26	.23	.89
1975	25	.23	.92
1976	23	.23	.93
1977	22	.23	.95
1978	20	.24	.97

[1] The relative prices are the relevant capital goods deflator divided by the compensation of labor (index, 1950 = 100).

[2] The required yield is the relevant depreciation rate (.05 for structures, .15 for equipment) plus the sum of the dividend-price ratio on equity and a constant growth rate, .04.

[3] The corporate tax burden is defined in detail in the Technical Appendix. It represents the value of tax credits and depreciation allowances to businesses buying capital goods. When the values in this column decline, the tax law effectively offers business a greater "discount" or "rebate" for purchasing capital assets.

Table 1, continued
Decomposition of the Relative Cost of Capital Services for Nonfarm Business

	B. Nonresidential Structures		
	Relative Price of Structures[1]	Required Yield[2]	Corporation Income Tax Burden[3]
1950	100	.16	1.14
1951	97	.15	1.31
1952	92	.15	1.31
1953	87	.15	1.23
1954	81	.14	1.13
1955	78	.13	1.12
1956	78	.13	1.08
1957	74	.13	1.08
1958	69	.13	1.08
1959	65	.12	1.10
1960	61	.12	1.08
1961	58	.12	1.08
1962	56	.12	1.03
1963	54	.12	1.03
1964	51	.12	1.03
1965	50	.12	1.00
1966	48	.12	1.02
1967	46	.12	1.05
1968	44	.12	1.06
1969	42	.12	1.19
1970	41	.13	1.29
1971	39	.12	1.24
1972	38	.12	1.21
1973	36	.12	1.21
1974	36	.13	1.26
1975	34	.13	1.32
1976	30	.13	1.32
1977	28	.14	1.35
1978	27	.14	1.37

[1] The relative prices are the relevant capital goods deflator divided by the compensation of labor (index, 1950 = 100).

[2] The required yield is the relevant depreciation rate (.05 for structures, .15 for equipment) plus the sum of the dividend-price ratio on equity and a constant growth rate, .04.

[3] The corporate tax burden is defined in detail in the Technical Appendix. It represents the value of tax credits and depreciation allowsances to businesses buying capital goods. When the values in this column decline, the tax law effectively offers business a greater "discount" or "rebate" for purchasing capital assets.

ever, even though the cost of capital rises less than its tax burden alone, the lower relative price of capital depresses the supply of new investment goods. Thus, falling market prices for equipment and structures cannot maintain capital formation when business income tax burdens are rising.

Higher tax burdens that ultimately depress capital accumulation may also increase the discount rate, especially in the short run. If the tax liability on "depreciation profits" rises sharply due to an unanticipated increase in the inflation rate and if inflation rate forecasts are received with less conviction, then investors may discount future earnings more severely, and the risk premium embedded in discount rates may rise substantially. In other words, high and variable tax rates, due to high and variable inflation rates, depress current after-tax returns to capital while tarnishing the prospects for future returns; one manifestation of such bearish sentiments is a higher discount rate as investors seek more lucrative and secure projects. Of course, inflation itself is not necessarily the only source of investor insecurity: attempts to "fight inflation" with recessions may have increased business risks while diminishing prospective rewards.[12]

According to Table 1, capital goods prices relative to labor compensation (column 1) fell fairly steadily from the early 1950s to 1978: the relative price of equipment declined, on average, 5.6 percent per year while the price of structures fell 4.7 percent. While these falling relative prices contributed to the rapid decline in the cost of capital services until the late 1960s, they surely cannot explain the more moderate decline in capital costs since then. The explanation lies elsewhere.

Estimates of the contribution of income tax liabilities to the user cost of capital are shown in the third column. For equipment, investment tax credits, accelerated depreciation, and lower corporate income tax rates generally reduced the tax burden from the early 1950s to the mid-1960s. In 1954 a revised income tax code first permitted businesses to use accelerated depreciation allowances—sum-of-the-year's-digits and double declining-balance schedules—in place of straight-line and 150 percent declining-balance schedules. In 1962, the service lives of producers' durable equipment were generally reduced 30 or 40 percent, and equipment first became eligible for a 7 percent investment tax credit. The maximum corporate income tax rate was also reduced from 52 percent in the early 1950s to 50 percent in 1964 and 48 percent in 1965. By 1965 the contribution of income tax liabilities to the cost of capital services was 15 percent lower than it was in the mid-1950s.

Although equipment service lives were reduced another 20 percent in 1971 and the investment tax credit was raised to 10 percent in 1975, inflation has generally raised the tax burden on equipment since the late 1960s. In 1978 the contribution of income tax liabilities to capital costs was almost as high as it was in the mid-1950s.

[12] Because the empirical estimates of the discount rate rely heavily on stock prices, the figures appearing in the second column of the table probably reflect these sentiments about inflation, real returns, and growth in recent years.

Because nonresidential structures were generally ineligible for investment tax credits, the tabulated tax burden decreased less for these assets than it did for equipment from the 1950s to the 1960s.[13] Moreover, after 1969 structures were no longer eligible for accelerated depreciation allowances, so the rising inflation of the late 1960s and 1970s has pushed the tax burden on structures to new postwar peaks. In 1978 the contribution of income tax liabilities to the user cost of capital for structures was more than 30 percent higher than in the 1950s and early 1960s. Because the figures in the third column essentially use an average of past inflation rates in lieu of management forecasts, it is conceivable that recent tax burdens may even exceed the numbers shown in the table.

Summary

These estimates of the income tax burden on capital show that tax incentives generally encouraged capital formation, especially for equipment, until the end of the 1960s. These tax incentives, coupled with declining relative capital goods prices and falling discount rates, encouraged a rapid expansion of the capital stock. During the 1970s, however, rising inflation reduced business's after-tax return on investment, and frequent recessions made investors more cautious; consequently, the user cost of capital fell less rapidly after 1973 and the rate of growth of the capital stock declined. If higher rates of inflation had not raised the income tax burden on plant and equipment after 1965, the cost of capital services would have declined more than one-third during the last 13 years. Accordingly, the rapid expansion of the capital stock would have been encouraged, not arrested.

V. Potential Growth and Capital Accumulation

The rapid decline in the relative cost of capital services during the 1950s and early 1960s helped boost potential GNP growth as high as 4 percent because the use of capital services increased much faster than hours. Declining relative prices, discount rates, and tax liabilities all contributed to the lower capital costs that were responsible for the more rapid accumulation of capital.

If the relative cost of capital services were constant, potential output would expand as fast as the growth of hours plus technical change would permit. In this case, the estimates of the production function for nonfarm, nonresidential business suggest that "potential" growth was 3 percent throughout the postwar period. From 1950 to 1965 hours worked increased

[13] Structures that do qualify for investment tax credits are typically owned by businesses in regulated industries, such as utilities. Regulatory commissions often take these tax incentives into account when allowing rate increases so that the after-tax rate of return on investment may not increase despite a more generous tax credit. In fact, some utilities use "flow through" accounting that passes these credits (and the benefits of accelerated depreciation allowances) on to the rate payers.

1.2 percent per year while the estimated annual technical change was 1.7 percent; after 1965, however, hours increased 1.8 percent per year, while annual technical change was only 1.2 percent.

The actual average annual expansion of nonfarm, nonresidential business output exceeded 3.6 percent from 1950 to 1965, more than .6 of a percentage point higher than the "potential" growth rate defined above. Because the relative cost of capital services fell substantially during this period, the ensuing aggressive investment in plant and equipment enabled production to expand faster than hours and technical change alone would have allowed. Since 1965, the more moderate accumulation of capital and other impediments to productivity growth allowed nonfarm business product to grow, on average, only 3.2 percent per year. More recently, persistently high rates of inflation may have depressed this growth rate still further, to 3 percent or less.

From 1950 to 1965, the tax burden on structures declined .9 percent annually while the burden on equipment fell 1.7 percent annually. From 1965 to 1978 the tax burden rose 2.3 percent and 1.3 percent respectively for structures and equipment. These figures imply that the weighted cost of capital services (the weights for structures and equipment are .33 and .67) before 1965 fell approximately 1.4 percent annually faster than it would have otherwise, and, afterward, capital costs rose approximately 1.6 percent faster than otherwise. The potential annual growth of the capital stock, therefore, was increased 1.4 percentage points before 1965 and was depressed 1.6 percentage points afterward by the shifting tax burden. The estimated production functions imply that a 1 percentage point increase in the growth of capital adds approximately .26 of a percentage point to the growth of potential output; consequently, the declining tax burden on capital may have temporarily added as much as .3 or .4 of a percentage point to "normal" potential growth before 1965, and the rising tax burden may have temporarily subtracted .4 of a percentage point from "normal" potential growth afterward.

Due to response lags and bottlenecks, the growth of the capital stock did not respond fully to the falling tax burdens before 1965 nor has capital fully adjusted to the rising tax burdens since then. Therefore, the actual swing in annual potential growth, due to shifting tax burdens, was less than .7 or .8 of a percentage point. If tax burdens (Table 1, column 3) had not increased since 1965, the annual potential rate of growth could have been .5 of a percentage point higher since 1965.

VI. Conclusion

Accelerated depreciation allowances, reduced corporate income tax rates and investment tax credits all combined to raise the demand for business capital from the mid-1950s to the mid-1960s, *temporarily* adding as much as .3 or .4 of a percentage point to the annual growth of potential output. Substantially higher inflation rates since then generally have reduced the demand for capital more than enough to offset the benefits of these tax incentives. This erosion of investment incentives not only rescinded the additional growth potential before the economy could fully exploit it but also *temporarily* reduced potential growth another .4 of a percentage point. So far, this reversal of incentives for investment spending has reduced the growth of output approximately .5 of a percentage point since 1965.

Although rising material prices may have been responsible for a considerable portion of the recent drop in potential growth, much of the slump also can be attributed to the failure of the income tax codes to measure and tax business income accurately during periods of high inflation. In fact, rising energy prices may have indirectly depressed the demand for capital through the income tax codes to the extent these prices have been a cause of inflation. Economic policy may not be able to restore the relative price of energy to levels that prevailed in the 1960s, but it can measure and tax business income more realistically. If tax reforms had insulated the cost of capital services from today's high inflation rate, current estimates of potential GNP growth could have been as high as 3.5 percent. Of course, if the necessary tax reforms eventually are adopted or if the inflation rate falls dramatically, the ensuing rapid decline in capital costs would, once more, encourage rapid capital accumulation and *temporarily* lift the potential growth rate perhaps as high as 4 percent.

Although reduced capital accumulation has accounted for half of the drop in labor productivity growth in nonfarm, nonresidential business since 1965, one may not infer that the remaining half of the productivity slump is all that is left for higher energy prices, worker training, research and development, etc. to explain. The productivity puzzle may not be neatly broken into a number of mutually exclusive pieces. For example, our high inflation rate may be attributed partly to rapidly rising energy prices and perhaps partly to lower worker skills, less active research and development efforts, or other impediments to technical progress, as I have measured it. Thus, there may be a variety of "explanations" for the relatively slow rate of capital accumulation, explanations that are themselves the ultimate causes of that part of the productivity slump attributed to this relatively slow growth of capital. If these other influences have depressed the demand for capital through a high inflation rate, their ability to depress productivity growth would wane with tax reform. Conversely, if relatively weak investment incentives have also discouraged the attendant investment in human skills and ideas, tax reform would accomplish more than the installation of additional steel or mortar.

APPENDIX A

Measuring Output and Productivity

GNP is a measure of the quantity of final good and services produced by domestic businesses. From the GNP accounts, the product of a firm, by definition, is its value-added—the value that the firm *adds* to raw materials and intermediate goods as it transforms these inputs into output. Thus, the product of an automobile manufacturer is the quantity of autos manufactured by the firm less the quantity of steel, rubber, glass, oil, and other materials from which the autos are fabricated. This value-added is distributed among the factors of production that combine to produce GNP.

Value-added is the appropriate measure of product because it eliminates the "double-counting" associated with a gross output measure of production. For example, when a steel mill sells its product to an auto manufacturer, the value of this steel is counted in gross output. If the value of this steel were not then deducted from the output of the auto manufacturer, the product of the steel mill's labor and capital would be counted twice: once when the steel is sold to the auto company, and again when the steel embodied in the automobile is sold to the consumer. If, instead, the steel were produced by the auto manufacturer for itself, no such "double-counting" would occur, and gross output would be lower even though the total production of steel and automobiles had not changed. Therefore, value-added is the appropriate measure of the nation's product because gross output would overstate production, and changes in gross output would not necessarily reflect changes in total national product.

Accounting identities require that factor product must equal factor income. Because value-added is the difference between gross output and material input, it comprises the returns earned by the factors of production: part is paid to landowners as rent, part is paid to laborers and managers as wages and salaries, and the remainder is paid to those who own or finance inventories, machines and buildings—capital assets—as profits and interest.[1] Hence, GNP, or factor product, equals the compensation of labor, the returns to capital and the earnings of renters, factor income.

Energy, however, is *not* a factor of production like capital or labor; it is a produced material input like iron ore, water, or wood. This does not imply that the growth of output and labor productivity are insulated from energy price changes, however. Material prices may have a considerable influence on GNP growth, but this influence does not arise from any material's role as a factor of production for GNP.

As defined in U.S. National Income and Product Accounts, GNP equals the compensation of labor, the return to capital, and the earnings of rentiers. The "returns to gasoline" are not part of national product or income; in fact, gasoline is itself produced by labor and capital and, as such, the contribution of capital and labor to gasoline is part of value-added. If gasoline and other material inputs, nevertheless, were considered factors of production, then business payments to these "factors" would have to be included both in income and output; otherwise, the accounting identity requiring that factor product equals factor income would be violated. In other words, if analysts insist that energy or other materials are factors of production, then for logical consistency they must no longer measure output by value-added, they must use gross output—the total value of the automobile, the steel, and the iron ore at each sale.

Yet, gross output, for reasons described above, is a questionable measure of output. Because

[1] Though land is a factor of production, a lack of official, reliable estimates of the value of domestic land resources precludes its consideration here. Some useful, unofficial estimates are available, but they tend to tie the value of land mechanically to the value of structures. If these procedures are valid, then the consideration of structures alone entails little loss of generality because this component, structures, is essentially an index for total real estate.

Inventories are not "factors" of production like equipment and structures. The efficient use of labor and capital often entails the creation of inventory stocks — goods in process, materials and warehouses, and final products depots —, but, for the most part, inventories cannot technically substitute for machine tools or engineers in producing value-added. To the extent, however, that *innovations* in communications or data processing have enabled business to reduce inventory without depressing value-added, my production function underestimates technical progress.

of its "double-counting," not only does gross output overstate production, but changes in gross output do not necessarily represent changes in final output. Furthermore, defining product as gross output, rather than value-added, in order to introduce energy and other materials as factors of production creates unacceptable anomalies that violate the notion of "productivity." For example, if technical progress causes labor and capital to become more efficient, so that they require less material input to produce the same value-added, the "productivity" of labor and capital would fall because gross output (value-added plus material input) would decline while these factor services do not. Ironically, then, because labor and capital become more efficient, the gross output measure of their "productivity" declines.[2]

Gross output "production functions" are not simply analogous to the more familiar production functions for value-added. If the gross output "production function" were written

(1) $GQ = G(K, H, M)$,

where K, H, and M represent the employment of capital, labor, and materials, then value-added would be

(2) $Q = G(K, H, M) - P_M M$,

where P_M is the price of materials relative to the deflator for value-added.

Expression (2) is curious in two respects. First, unless G (K, H, M) can be written G* (K, H, M) + $P_M M$, then (2) claims that value-added is somehow depressed by rising relative material prices even though the employment of K, H, and M do not change and the technology remains the same. Although rising material prices certainly can depress output in full macroeconomic equlibrium, expression (2) is more controversial: higher material prices reduce the technical ability to supply value-added even if nothing else changes including the consumption of resources. It is difficult to illustrate this implication by example.

The second curious feature of (2) is that, unless G (K, H, M) can be written F (K, H) + $P_M M$, constant returns to scale for gross output and its inputs, K, H, and M (a common assumption), implies decreasing returns to scale for value-added and its factors of production, K and H. Such a function may also imply that value-added is increased by altering the flow of material inputs even though the use of labor and capital services does not change and no technological innovations have occurred. One laborer working with one machine, at full capacity, can produce one widget per hour, after paying for materials, with supplies of one pound of resources per hour. Supplying the same laborer and machine with two pounds of resources per hour cannot increase widget production unless, perhaps, preventive maintenance is postponed and the laborer taxes his talents. Ordinarily, potential output cannot be increased (except, perhaps, for a short time, and then, only at considerable cost) by increasing the flow of raw materials available to labor and capital.

This study, like the National Accounts, defined product as value-added. The production function for value-added (from expression (2) and the ensuing discussion) is

(3) $Q/M = F(K/M, H/M)$, for
$M \leq \overline{M}$ $\overline{M} = H(\overline{K},\overline{H})$.

Potential output is not increased once the supply of materials exceeds the maximum flow that the existing stock of capital and labor can process. Of course, if the flow of materials is not sufficient to keep the existing stock of capital and labor fully employed, potential output will decline and redundant factors of production eventually will be discharged.[3]

[2] This problem is not rectified by defining product as value-added plus energy input only, instead of total gross product. If technical change allows labor and capital to produce the same value-added with less energy, once again measured factor productivity declines: the use of energy declines, so total "product" falls while labor and capital services do not.

[3] In any recession, whether a result of inadequate demand for final products or a result of inadequate resource supplies, business does not immediately discharge redundant factors of production. Accordingly, the growth of labor productivity usually drops sharply when the growth of GNP declines.

If the production function in expression (3) exhibits constant returns to scale, then output per hour is determined by the capital-labor ratio and the technology embedded in the production function.[4]

(4) $Q/H = f(K/H)$.

Although gasoline is not a factor of production for GNP, the price of gasoline and other material inputs can influence the growth of potential output and productivity. First, in the long run, the relative price of gasoline, iron ore, water, or wood can influence the choice of production technique or the place of technical change. If the price of materials should rise, for example, business may discard the technology that required one laborer using one machine and one pound of resources per hour to produce one widget per hour, after paying for the resources. Business may favor instead a technology that required two laborers using two machines and one-half pound of resources per hour to produce one and one-half widgets per hour, after paying for the resources. This new technology, requiring more factors of production yields more value-added per pound of resources. Low resource prices may not have warranted the use of this new technology, but high resource prices make the "substitution" of capital and labor for resources more lucrative. After this technical change, the production function shown in (4) becomes, for example,

(5) $Q/H = .75f(K/H)$;

the ability to substitute capital for labor has not changed, but overall factor productivity is lower. (Incidentally, this example notwithstanding, nature does not require overall factor productivity to decline when one technology supplants another due to higher material prices.)

To consume fewer resources, the new technology might favor the use of two workers and one machine to produce one and one-half widgets per hour using one-half a pound of resources. In this second example, total factor productivity may not have changed, but the ability to substitute capital for labor is altered. If (4) could have been written

(6) $Q/H = A(K/H)^{.25}$,

then the new production function might be

(7) $Q/H = A(K/H)^{1}$.

In the first example the production function was only shifted by higher resource prices; now the shape of the function is altered. Because the coefficients of the production estimated in this study—α_e, α_s, β_{ee}, β_{es}, β_{ss}—are not themselves functions of material prices (an assumption common to almost all such studies), only the first type of technical innovation is considered here.

The relative price of materials may also influence potential output and productivity by changing the relative costs of factors of production. For example, rising gasoline and heating oil prices will increase the cost of employing labor: not only will wages tend to increase but the expense of heating and cooling work spaces will rise. In a similar manner, rising material prices will increase the cost of buying and operating machinery. Rising energy prices could also raise the cost of using capital to the extent they are a cause of the currently high rate of inflation that has reduced the value of depreciation allowances for prospective investors. Businesses consider relative factor costs when choosing the mix of capital and labor they wish to employ. Therefore, even though material prices may not have changed production technology, rising material prices, for example, could raise the relative cost of capital, thereby depressing the growth of the capital stock.

Materials are not factors of production for value-added. (See expression (3) and the discussion following expression (2).) Some studies, nevertheless, have included materials among the

[4] As mentioned in footnote 3, business cycles also may temporarily influence productivity growth. However, business cycles do not alter the rate of *potential* productivity growth unless they change the pace of technical change, the growth of the capital stock, or the expansion of the labor force.

factors of production for value-added to show that potential GNP is altered by changing the relative price of resources in a more "direct" manner than those described above. Let Q denote value-added (output) and K, H, and M denote possible factors of production. Q = F(K, H, M). The optimal mix of "factors," given prevailing prices, is denoted K*, H*, and M*; thus, Q* = F (K*, H*, M*) is the solution to the profit maximization problem:

(8) $\max P(F(K, H, M)) - rK - wH,$

where P, r, and w are the price of output (value-added), the cost of capital services, and the wage rate. M*, in this context, is not a function of material prices, because the "returns to materials" are not components of national income or value-added. The business will choose M* to obtain the maximum profit from its capital and labor, given the prevailing prices P, r, and w.

If a rising relative price of materials were to warrant reducing M* and increasing H*, then for this adjustment to not reduce profits the "marginal product of materials" must be negative—"$\partial F/\partial M$" must be negative. If p (the price of *value-added*), r, and w do not change, the firm could earn the same profits after the cost of materials rises as it had before, if it does not alter its employment of K, H, and M. If the "marginal product of materials" is positive, then reducing materials "employment" to favor greater employment of labor reduces profits; therefore, the swapping of materials for either K or H is efficient only if the "marginal product" of materials is negative. If rising material prices, on the other hand, alter r/w or initiate macroeconomic policy which alters P/w, then a new mix of K and H is optimal.

Materials and capital (or labor) are neither substitutes nor complements within a given production function for value-added. The production function describes a particular technology, which, perhaps, allows some substitution between capital and labor services: capital may be swapped for labor to produce a *given* GNP. The exchange of capital for labor may alter the flow of materials consumed, but it is capital that is swapped for labor, and within a *given* technology the attendant consumption of resources is determined by the employment of capital and labor alone. The attempt to swap materials for capital (or labor) on any other terms can only reduce value-added unless production technology changes.

Materials and capital (or labor) may be "complements" or "substitutes" over the set of potential production technologies. The varieties of technology, however, may be rich enough so that some innovations would increase the use of labor relative to capital to reduce the consumption of materials while other innovations would offer more capital-intensive production techniques to reduce the consumption of materials. Considering the entire set of potential technologies, whether materials and the factors of production are substitutes or complements may be unresolved. In any case, this issue cannot be settled by treating energy as a factor of production, like capital and labor, in a production function for value-added, as many studies have done. How the consumption of materials may be swapped for the employment of capital services depends on the specific technical change, which generally requires a *change* in the production function for value-added.

Appendix B

The Data Sources

The stock of equipment and nonresidential structures, E and S, are the net constant dollar estimates provided by the Department of Commerce, less pollution abatement capital and the capital of nonprofit business, multiplied by the Federal Reserve manufacturing capacity utilization rate, UCAP. UCAP is useful in this study because firms alter the length of the workweek for their plant and equipment (and labor) as they temporarily adjust production schedules to accommodate cyclical movements in demand.

The propriety of using UCAP in this manner is questionable to some analysts. UCAP is derived from the experience of manufacturing industries only, so its application to all nonfarm, nonresidential business introduces some error. More fundamentally, some believe that capacity utilization should not be a part of capital input measurement for any industry. Because I am using a production function, however, the role of UCAP is important. When demand for autos declines, the auto industry furloughs some laborers and reduces the workweek for others, and all analysts agree that we should consider only the actual number of hours worked, not the potential number of hours that the autoworkers could supply, in measuring productivity. In a sense, we consider the capacity uilization rate of the work force. Similarly, when capital is furloughed or operated at less than full capacity, consistency requires that we also consider the capacity utilization rate of plant and equipment in measuring productivity. If not, then if low demand caused auto firms to produce 75 percent of the autos that they now produce by furloughing 25 percent of their work force and "closing" 25 percent of their plants, we would erroneously believe that the capital-labor ratio had risen by 25 percent in the auto industry. We would also erroneously believe that factor productivity had fallen because we would have overstated the capital services used by the auto industry. In fact, the productivity of employed factors has not changed at all.

Ernst Berndt, in his paper "Energy Price Increases and the Productivity Slowdown in United States Manufacturing," (this volume) argues: "if one uses cyclically adjusted capital data, then one must be very cautious indeed in arguing that investment incentives are needed in order to stimulate capital formation and growth in labor productivity; in U.S. manufacturing 1973–1977, sufficient capital was already in place and the problem for productivity and growth evidently was one of lack of growth in demand for manufacturing output, not deficiency in supply of available capital." Some labor and capital may be idle when the demand for output is depressed, but *potential* labor productivity or the actual productivity of employed labor depends on the willingness of business to employ capital relative to labor. Accordingly, the problem of fully employing both labor and capital resources may be considered separately from the problem of raising the employment of capital relative to labor. Although business cycles may temporarily influence measured labor productivity (see footnotes 3 and 4 to Appendix A), the productivity growth for employed labor ultimately depends on investment incentives and the demand for capital services relative to labor services whatever the capacity utilization rate, whatever the demand for output.

Hours worked are the Bureau of Labor Statistics data; they are not adjusted for age, sex, or education. (See footnotes 3 and 7.)

Measures of output, prices and compensation are also published by the Department of Commerce and the Bureau of Labor Statistics. For nonfarm business, output does not include the value of housing services.

The cost of capital services, from Hall and Jorgenson, for example, equals

$$P_k/w \cdot (\delta+\rho) \cdot (1\text{-ITC-t Dep}) / (1\text{-t})$$

where P_k/w is the price of capital relative to the compensation of labor
δ is the depreciation rate of capital
ρ is the discount rate
ITC is the investment tax credit
t is the statutory corporate income tax rate
Dep is the present value of depreciation allowances, using Salomon Brothers' yield on

newly issued, deferred call Aa utility bonds, after taxes. The three factors above correspond to the three columns of Table 1.

The discount rate in Table 1, column 2, equals the Standard and Poor's dividend-price ratio plus 4 percentage points. The 4 percentage points represent expected real growth of domestic business. The depreciation rate for equipment is 15 percent and for structures it is 5 percent. In column 3, the tax lifetime for equipment declines from 17.5 to 10.5 years over the postwar period, while for structures it drops from 28 years to 23 years. The schedule of depreciation allowances for equipment and structures shifts from straight-line to sum-of-the-years' digits in 1954; and from 1966:4 to 1967:1 and from 1969:3 to the present the schedule of depreciation allowances for structures is 150 percent declining-balance. The discount rate for depreciation allowances equals 2 percent plus the average inflation rate for the previous five years.

ITC is the investment tax credit: zero before 1962; in 1962:1, .03 and increases by constant steps to equal .055 in 1963:3; constant at .055 until 1966:4; zero from 1966:4 to 1967:1; .055 from 1967:2 to 1969:1, zero from 1969:2 to 1971:1; .04 in 1971:2; .05 in 1971:3; .055 from 1971:4 to 1974:4; finally, .087 for 1974 and later.

REFERENCES

Anderson, T. W. *An Introduction to Multivariate Statistical Analysis.* New York: John Wiley and Sons, Inc, 1958.

Berndt, E. R. and L. R. Christensen. "The Translog Function and Substitution of Equipment, Structures, and Labor in U. S. Manufacturing, 1929–1968," *Journal of Econometrics,* vol. 1 (March 1973), pp. 81–114.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau. "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics,* vol. 55 (February 1973), pp. 28–45.

Clark, P. K. "Capital Formation and the Recent Productivity Slowdown," *Journal of Finance,* vol. 33, no. 3 (June 1978), pp. 965–975.

Denison, E. F. "Effects of Selected Changes in the Institutional and Human Environment upon Output per Unit of Input," *Survey of Current Business,* vol. 58, no. 1 (January 1978), pp. 21–42.

———. "Explanations of Declining Productivity Growth," *Survey of Current Business,* vol. 59, no. 8, part II (August 1979), pp. 1–24.

Fisher, F. "The Existence of Aggregate Production Functions," *Econometrica,* vol. 37, no. 4 (October 1969), pp. 457–69.

Gollop, F. M. and D. W. Jorgenson. "U. S. Productivity Growth by Industry, 1947–1973," in J. W. Kendrick, and B. N. Vaccara, editors, *New Developments in Productivity Measurement and Analysis.* Chicago: University of Chicago Press, 1980, pp. 17–136.

Hall, R. E. and D. W. Jorgenson. "Tax Policy and Investment Behavior," *American Economic Review,* vol. 57, no. 3 (June 1967), pp. 391–414.

Hudson, E. A. and D. W. Jorgenson. "Energy Prices and the U. S. Economy, 1972–1976," *Data Resources Review,* vol. 7, no. 9 (September 1978), pp. 1.24–37.

Jorgenson, D. W. "Econometric Studies of Investment Behavior: A Survey," *Journal of Economic Literature,* IX, pp. 1111–47.

Kopcke, R. W. "The Public Debt and Tax Incentives for Business Investment." in U. S. House of Representatives, Subcommittee on Oversight of the Committee on Ways and Means, *A Review of Selected Tax Expenditures: Investment Tax Credit.* Hearing. 96 Cong. 1 Sess. Washington: Government Printing Office, 1979, pp. 393–407.

Morgenstern, O. *On the Accuracy of Economic Observations.* Princeton, N.J.: Princeton University Press, rev. ed. 1963.

Nordhaus, W. D. "The Recent Productivity Slowdown," *Brookings Papers on Economic Activity* 3:1972, pp. 493–526.

Norsworthy, J. R. and M. J. Harper. "Productivity Growth in the 1980s: Labor, Capital and Energy," Bureau of Labor Statistics, 1980, processed.

Norsworthy, J. R., M. J. Harper, and K. Kunze. "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity* 2:1979, pp. 387–432.

Perry, G. L. "Potential Output, and Productivity," *Brookings Papers on Economic Activity* 1:1977, pp. 11–47.

Rasche, R. and J. Tatom. "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," Federal Reserve Bank of St. Louis, *Review*, vol. 59, no. 5 (May 1977), pp. 2–12.

____. "Energy Resources and Potential GNP," Federal Reserve Bank of St. Louis, *Review*, vol. 59, no. 6 (June 1977), pp. 10–23.

Solow, R. "Resources and Economic Growth," *American Economist*, vol. 22 (Fall 1978), pp. 5–11.

Thurow, L. "The U. S. Productivity Problem," *Data Resources Review*, vol. 7, no. 8 (August 1979), pp. 1.14–19.

Zellner, A. *An Introduction to Bayesian Inference in Econometrics*. New York: John Wiley and Sons, Inc., 1971.

Discussion

Edward F. Denison*

It is useful to look at the behavior not only of the amount of capital per labor hour worked, upon which Kopcke concentrates, but also of the total capital stock. Let me begin by citing some growth rates for 1950–65 and 1965—78, the periods Kopcke uses. They are based on capital stock data from the Bureau of Economic Analysis, and most are computed directly from series published in my latest book.[1]

In the nonresidential business sector, the growth rate of the gross stock of structures and equipment *increased* from 3.15 percent in 1950–65 to 3.95 percent in 1965–78. The growth rate of the net stock also *increased*, from 3.60 percent to 4.05 percent. The gross stock is the better measure of input, but the services provided by capital goods may diminish to some degree as the goods age. In my own work I have recognized this tendency by weighting growth rates of gross and net stock to measure capital input, with gross stock weighted three and net stock one. The growth rate of the input of fixed capital so measured *increased* from 3.26 percent in 1960–65 to 3.97 percent in 1965–78. However one chooses to combine net and gross, the growth rate of fixed capital rose handsomely. I may note in passing that the growth rate of the stock of inventories, which Kopcke does not recognize as capital input, also rose, though much less — from 3.30 percent to 3.37.[2]

Growth rates of gross and net stock of structures and equipment also rose in manufacturing, which Kopcke analyzes separately. The growth rate of gross stock rose from 2.79 percent in 1950–65 to 3.02 in 1965–78, that of net stock from 2.40 percent to 3.15, and that of my capital input from 2.69 percent to 3.05.

Under these circumstances it seems impossible to maintain, as Kopcke appears to do in the first part of his paper, that slower growth of capital was responsible for half of an alleged one point decline in the growth rate of potential GNP and for all of a decline of 0.6 points in the growth rate of potential manufacturing GNP. Capital clearly was working toward a higher growth rate in 1965–78 than in 1950–65. These data do not exclude pollution abatement capital or adjust for changes in capital utilization, as Kopcke does.

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[1] Edward F. Denison, *Accounting for Slower Economic Growth: The United States in the 1970s*, Washington, D.C.: The Brookings Institution, 1979.

[2] These rates include farming whereas Kopcke analyzes the nonfarm sector.

I don't think they should, but in any case the first is a partial indicator of regulatory costs while a lower rate of utilization would hardly signal a growing shortage of capital.

The ratio of fixed capital to hours worked may have contributed something to slower growth of output per hour in the nonresidential business sector. The growth rate of fixed capital per hour worked was lower in 1965–78 than in 1950–65 as a result of very fast expansion of total hours worked in 1976–78. But it was not much lower, and I have trouble seeing how it could have been a major factor affecting output per hour. The decline in the growth rate of gross stock per hour worked was 0.1 percentage points, of net stock 0.5 points, and of fixed capital input 0.2 points. Fixed nonresidential business capital gets a 10 percent weight in my calculation of total input in nonresidential business NI. Consequently, a 0.2 percentage point drop in the growth rate of fixed capital causes a decline estimated at only 0.02 percentage points in the growth rate of business NI per hour worked. Even if Kopcke's estimate that 26 percent is the proper gross weight for fixed capital is accepted, this would yield a drop in the growth rate of GNP in nonresidential business of only 0.05 percentage points. The paper gives the impression of a much more drastic change. Also to be noted is that the entire drop in the growth rate of capital per hour worked from 1950–65 to 1965–78 was due to the very fast increase in employment of 1977 and 1978. Capital per hour worked grew quite as fast from 1965 to 1976 as from 1950 to 1965.

Most baffling of all is Kopcke's finding that the decline in the growth rate of output per hour in *manufacturing* was entirely due to a slower growth rate of capital per hour worked. I have already quoted BEA data showing that *total* fixed capital grew more rapidly in 1965–78 than in 1950–65. In manufacturing, unlike the business sector as a whole, total hours worked grew at a much lower rate in the later than in the earlier period. Both BEA and Bureau of Labor Statistics estimates show the growth rate of hours worked in manufacturing fell by about 0.4 percentage points. With capital growing faster and hours growing slower, capital per hour worked grew much more rapidly in 1965–78 than in 1950–65. The growth rate of my measure of capital input per hour, based on BLS hours, rose from 1.46 percent in 1950–65 to 2.20 percent in 1965–78, an increase of 0.74 percentage points or more than half. The increases were 0.61 points for gross stock and 1.12 points for net stock. This is enough to contribute significantly toward a higher growth rate of output per hour worked in manufacturing in the later period. How Kopcke obtains results that enable capital to explain a lower growth rate I cannot imagine. Unless, that is, one reads the last full paragraph on page 34 of his paper in such a way that the last sentence refers to a different time period from the first.

Thus far I have looked at 1950–65 and 1965–78 because Kopcke's paper features these periods, but I do not think they are of particular interest. I would now like to say briefly how the picture looks to me. I shall draw from my *Accounting for Slower Economic Growth*, where all the estimates are described.

During the postwar era periods of fast growth of total national income in the economy as a whole have alternated with periods of slow growth. On a potential output basis a very high 1948–53 growth rate of 4.7 percent was followed by a much lower rate of 3.2 percent in 1953–64, another very high rate of 4.5 percent in 1964–69, and then a rate of 3.8 percent, about the postwar average to that time, in 1969–73. Then came the unfinished period from 1973 to the present time when growth of potential national income fell to the neighborhood of 2 percent.

Differences among the *first four* of these five periods were due almost entirely to fluctuations in the growth rate of total factor input. The fluctuation in the contribution of total factor input, in turn, was due mainly to labor input. Capital also played a part but not a large one. The contribution of capital was only 0.2 percentage points larger in the two periods of fastest growth than it was in the two periods of slower growth. The contribution of labor, on the other hand, fluctuated widely. It was 2.2 percentage points in the first fast-growth period, 1948–53, and 2.0 points in the second, 1964–69. It was 1.0 percentage point in the 1953–64 period of relatively slow growth and 1.6 points in the medium growth period of 1969–73. Employment, average hours, and age-sex composition dominated changes in labor input growth.

Output per unit of input was responsible for very little of the fluctuation in the postwar growth rate of potential output up to 1973. It contributed 1.7 percentage points to the growth rate in the two fast-growth periods and 1.6 points in the two periods of slower growth.

The growth rate of the residual showed little change and certainly no deceleration during 1948–73. Growth of capital input in the form of nonresidential structures and equipment was not slow up to 1973 or, indeed, up to 1975. What we did experience was a 1964–69 period of very fast growth of fixed nonresidential business capital, a rate widely recognized at that time as nonsustainable. The 4.8 percent growth of nonresidential structures and equipment input in 1964–69 compares with about 3.7 percent over the whole 1948–69 or 1948–73 periods, and only 2.2 percent over the entire 1929–76 period. Growth of fixed capital slackened in 1969–73, as expected, but only to the still high rate of almost 4.0 percent. Even in 1973–75, the time when productivity sagged so badly, the rate eased back only to 3.7 percent and it thus averaged 3.9 percent over the whole span from 1969 to 1975. At 3.9 percent the growth rate from 1969 to 1975 was the same as the rate during 1948–63, which rate had been the highest in any period since 1926 except for 1964–69. Not until 1976, by which time the deepest postwar recession had cut sharply into fixed investment, did the rate of increase in capital input drop much. But even the 1973–78 rate, which includes these years, was about the same as the rate from 1948 or 1950 to 1964.

It is true that the growth rate of actual output per hour has been falling since 1965, as Kopcke says. The growth rate of potential NI per person employed has been falling even longer — indeed, throughout the whole postwar period. But focus on these persistent declines is not helpful if one seeks to analyze our current productivity dilemma. Before 1974 the slackening in productivity growth was not particularly disturbing. In part, the drop in growth of productivity on an actual basis was the consequence of a drop in the intensity of use of employed labor and capital from a peak reached in 1965–66. The rest resulted from developments that were inevitable or even welcome, such as the exhaustion of a large pool of surplus labor in farming and the employment of greatly increased numbers of women and young people. It was the far bigger drop in the growth of productivity after 1973 that should concern us.

In contrast to the four periods preceding 1973, when fluctuations in the growth rate of total potential national income reflected changes in input growth, the drop in the growth rate of potential output *after* 1973 occurred despite a large increase in the growth of total factor input. Output per unit of input actually declined, and its growth rate dropped even more than that of total output. The increase in the growth rate of total input was due to labor input. The growth rate of capital input fell, and this contributed to the decline in the growth rate of potential output. The question, however, is how much?

I shall compare estimates of the contribution of capital in 1973–78 with its contributions in the 1948–73 period for a number of series. The contributions of capital to the growth rates of *total* potential national income and total actual national income in the whole economy are necessarily the same. They fell 0.14 percentage points. Capital contributed more, 0.19 points, to the drop in the growth rate of actual national income per person actually employed. Capital contributed most, 0.35 percentage points, to the drop in the growth rate of potential national income per person potentially employed. In each case, results are about the same for the nonresidential business sector separately. Only one-ninth to one-sixth of the decline in the growth of the various output series was ascribable to capital. Capital's contribution to the *decline* in the growth rate of these series was generally less than its contribution to the growth of the series from 1948 to 1973, so capital played a disproportionately small part in the retardation.

Let me now return to Kopcke's paper for a number of quick comments.

First, I agree with him that it is desirable to stimulate investment if we can find acceptable means to do so. But I admit to some skepticism as to our ability to affect investment a great deal through incentives to invest, and I am very skeptical that we know how to do so by affecting incentives to save. The best way to stimulate investment, and simultaneously to provide additional government and private saving to finance it, would be to gain sufficient control over inflation to allow us to run the economy at a higher level. But we don't seem to know how to do this either.

But suppose we *can* raise investment. I think that Kopcke believes the effect on the growth rate of increasing investment would be much larger than I do. One way to make the calculation follows. In the postwar years up to 1973 net private investment averaged about 7½ percent of net output. Suppose it had been higher. At, say, 1969 output levels, each additional 1 percent of the national income invested would have provided $7.7 billion of additional capital. Net earnings of capital, before tax, equaled 8.0 percent of net asset value. If the rate of return would also have been 8.0 percent for the additional capital, then each 1 point increase in the investment ratio would have raised the annual national income by 8.0 percent of $7.7 billion. This comes to $0.6 billion or 0.08 percent of the national income. If the extra capital were all allocated to nonresidential business, where the ratio of earnings to assets was highest, 10.4 percent, the national income would have been raised more — by 10.4 percent of $7.7 billion, or 0.11 percent of the national income. Let us not only assume this more favorable allocation of the extra investment but also raise the 0.11 percent to 0.12 to allow for economies of scale. Under these favorable conditions, a continuing increase in the net investment ratio of 1 percentage point, or nearly one-seventh, would be needed to raise the growth rate of national income by 0.12 percentage points. An increase of 0.12 points in the growth rate is very worthwhile, but it would go only a small way toward restoring pre-1973 growth.

Second, in any close comparison of Kopcke's results and mine, it is necessary to take into account that his analysis pertains to gross product and mine to net product. This affects nearly all magnitudes, but it is not responsible for the major differences in our appraisals.

Third, I think capital per hour is probably a less useful indicator of capital available to labor than capital per worker — perhaps with employment computed on some type of full-time equivalent basis.

Fourth, Kopcke omits both land and inventories as inputs into his production function. It is easy to see why correlation analysis does not yield results for the effects of changes in these inputs, but their omission is nevertheless an important deficiency.

Fifth, I doubt that many analysts would agree with Kopcke that the response of output to a change in one input can be obtained better by correlation analysis than by use of income shares. Certainly I do not. The use of income shares relies on the incentive for business to combine factors in such a way as to minimize costs reenforced by the pressure to do so that competition imposes.[3] This I believe to be a very powerful force. The responses of output to changes in individual inputs that are obtained by correlation analysis are much less reliable. They also vary widely from study to study. Most analysts using this method check the reasonableness of their results by comparing them with income shares. With constant returns to scale imposed, Kopcke's estimate that in nonfarm nonresidential business a 1 percent increase in structures and equipment raises output by 0.26 percent seems much too high, even though the 0.26 includes an increase in capital consumption. The only way even to approach so high a figure from income shares is to assume that all of the weight of the missing inputs — inventories and land — was and should be assigned to fixed capital, rather than allocated proportionately to fixed capital and labor. Kopcke does not suggest he means to do this, and I can't think of any reason that he would.

[3] See D. J. Daly, "Combining Inputs to Secure a Measure of Total Factor Input," *The Review of Income and Wealth*, March 1972 (Series 18, no. 1), pp. 27-53.

Sixth, I do not think it is correct to distinguish between production functions and growth accounting as Kopcke does in his text. Rather, the distinction is between production functions estimated by growth accounting techniques and those fitted by correlation analysis.[4] Even this statement is too strong, because neither is likely to rely exclusively on one technique. Correlation analysis enters into some estimates that are used in growth accounting, while Kopcke sets the sum of his coefficients for labor and fixed capital at one without regard to correlation analysis.

Seventh, I am happy to end on a point of agreement. Kopcke's Appendix A states that value-added is the appropriate measure of product because it eliminates the double-counting associated with a gross output measure of production; and that energy is a material input, not a factor of production like capital and labor. I agree. I wish Kopcke would go one step further and deduct the consumption of fixed capital as well as of materials, so as to eliminate this type of duplication from his measure.

[4] M. I. Nadiri, "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey," *Journal of Economic Literature*, December 1970, pp. 1137-77.

Energy Price Increases and the Productivity Slowdown in United States Manufacturing

Ernst R. Berndt*

I. Introduction

Greater energy conservation, continued increases in productivity and real wages, and sustained economic growth are goals pursued today by almost all national governments. Since the 1973 OPEC energy price increases, however, disappointing economic trends in the United States, Canada and elsewhere have focused attention on the extent to which these goals are compatible. In particular, the post-1973 slowdown in the rate of growth of labor productivity is viewed by many as contributing considerably to recent acceleration of price inflation.[1] In this paper I examine the role of energy price increases in the productivity slowdown in U.S. manufacturing, 1973–77. The manufacturing sector is of particular interest since it is energy-intensive and important; in 1974 it accounted for 23.4 percent of U.S. gross domestic product, but consumed 36.2 percent of total U.S. energy.[2]

Although post-1973 energy market developments have heightened professional interest in energy-economy interactions, this issue is by no means new. More than a century ago in 1865 a melancholy William Stanley Jevons reckoned

> A rise in the price of coal, whether from taxation or scarcity, must levy open and insidious contributions upon us in a manner with which no other tax whatever can compare.[3]

Indeed, because he feared England would lose her superior command of coal, Jevons lamented ". . . we must not only cease to progress as before — we must begin a retrograde career."[4]

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[1] See, for example, U.S. Council on Wage and Price Stability [1979].

[2] John G. Myers and Leonard Nakamara [1978], p.4.

[3] William Stanley Jevons [1865], p. 444.

[4] Jevons [1865], p. 201.

A symmetric argument — that lower energy prices increase economic growth and productivity, albeit modestly — was made by Herbert A. Simon in 1950:

> . . . we have considered the effects of the introduction of cheap atomic power, available anywhere, upon the economy of a nation or a region. . . . The principal short-run effect upon an economy like that of the United States would be a modest increase in productivity, and a consequent increase in income; it does not seem likely it will be more than 1%. . . . Long-run effects of larger magnitude might be produced over a number of years if the increase in income resulted in a more rapid accumulation of capital, thus further increasing the productivity of the economy.[5]

Simon's conjecture was examined a decade later by Sam H. Schurr and Bruce Netschert, who speculated that

> . . . the marked acceleration in the increase in labor and capital productivity after World War I is attributable in some degree to the new methods of organizing production made possible through the growing electrification of industrial operations.[6]

Few would argue today that post-1973 energy price increases are likely to lead to a dramatic reversal of the historic electrification process in industry. Nonetheless, some distinguished economists believe these energy price increases will have an enormous negative effect on industrialized economies in the long run, though not necessarily a highly visible or dramatic one. Dale W. Jorgenson, for example, argues

> It will be difficult to come to terms with the impact of the OPEC cartel at an intellectual level until much time has passed. If the impact of the Great Depression of the 1930s was like a nuclear explosion in its devastating force, the impact of the OPEC cartel is like a mild but persistent form of radiation. Its effects are slow and insidious but ultimately equally devastating. The effects of higher energy prices are not easy to detect for quarter-to-quarter fluctuations in the national income and product accounts. In the short and intermediate term, we can expect the full gamut of "special factors" will be brought into play by economic commentators to explain the growing departure between current economic developments and past historical experience. . . . But in the long run, presumably when we are all dead, there is at least a modest probability that the most significant economic reversal since the Great Depression of the 1930s will be seen to be the slowdown in economic growth brought about by the establishment of the OPEC cartel.[7]

[5] Herbert A. Simon [1950], pp. 246–247.

[6] Sam H. Schurr and Bruce Netschert [1960], p. 189. On this issue, also see Richard B. DuBoff [1966].

[7] Dale W. Jorgenson [1978], pp. 23–24.

In the Jorgenson framework, increased energy prices reduce capital formation in energy- and capital-intensive sectors, resulting in a smaller capital stock being passed on to future decades, thereby reducing future potential output. Moreover, and even more important empirically, since relative prices of the more energy-intensive goods rise by a greater proportion, energy price increases induce a shift in the composition of final demand to more labor-intensive sectors, thereby depressing in particular aggregate national labor productivity growth.[8] Total factor productivity growth at the national level is not affected as greatly, unless of course energy price-induced compositional shifts in final demand favor sectors with below average rates of growth in total factor productivity.[9]

While not necessarily denying that rising energy prices might eventually have a negative effect on measured productivity growth, Edward F. Denison believes that recent price increases have not had much of an impact yet, at least over the relatively short 1973–76 time period. Hence Denison concludes that "I do not believe that much of the productivity slowdown can be ascribed to energy prices."[10] However, after examining two more years' data (through 1978), J.R. Norsworthy, Michael J. Harper and Kent Kunze [1979] reckon that

> The 1973–78 slowdown is dominated by the effects of reduced capital formation. Some effect is also attributable to interindustry shifts in labor and capital. The sharp rise in energy prices may show up in a framework such as ours through its impact on capital formation and may help explain the relative weakness in capital formation in recent years.[11]

This brief survey of energy-economy interactions amply indicates a lack of consensus on the role of post-1973 energy price increases in the recent productivity slowdown. Hence in this paper I focus attention on how energy price increases might affect growth rates of measured labor and total factor productivity. The data I shall use, provided me by J.R. Norsworthy and Michael J. Harper, are for total U.S. manufacturing 1958–77. However, an essential part of the story I shall tell involves distinguishing production ("blue collar") from nonproduction ("white collar") labor; I gathered this disaggregated labor data for total manufacturing from published BLS sources.

In Section II, I provide a noneconometric analysis of these 1958–77 data, and point to evidence suggesting that a good portion of the productiv-

[8] The indirect compositional effect is typically found to be considerably larger than the direct impact; see the simulations reported in Edward A. Hudson and Dale W. Jorgenson [1974, 1978a, b].

[9] Dale W. Jorgenson and Barbara M. Fraumeni [1979] also noted that if the fixed bias of technical change in a given sector is energy using, then increases in energy prices will reduce total factor productivity within that sector. Such an approach, however, does not permit the energy-using bias of technical change to vary in response to dramatic changes in energy prices.

[10] Edward F. Denison [1979], p. 138.

[11] J. R. Norsworthy, Michael J. Harper, and Kent Kunze [1979], p. 421.

ity slowdown in U.S. manufacturing might be attributed to a slowdown in the rate of growth of output without a corresponding reduction in capital formation and growth of white collar employment; these latter two inputs can of course be viewed as quasi-fixed factors. In Section III, I discuss a dynamic model of factor demands that allows for both variable and quasi-fixed inputs, and then in Section IV I report econometric results and implications for 1973–77 productivity trends. In particular, I address five empirical issues concerning possible means by which energy prices might affect productivity trends: (i) How has the economic capacity output Y* varied from the actual rate of output Y, i.e., what does an economic measure of capacity output, dependent on energy prices, look like over the 1958–77 time period? (ii) To what extent can the small total factor productivity growth rates 1973–77 be attributed to increased divergence of actual from economic capacity output? (iii) By how much do increased energy prices affect the optimal level of output? (iv) By what amount do higher energy prices affect Tobin's q? and (v) How do variations in output and capacity utilization affect the productivity of individual inputs? Finally, in Section V I provide some concluding remarks on the role of energy price increases on measured productivity trends.

II. Examination of Factors Coinciding with the Productivity Slowdown in U.S. Manufacturing

The economic theory of productivity measurement is closely related to the theory of cost and production. Denote the quantity of aggregate capital services as K, aggregate labor L, energy E, nonenergy intermediate materials M, gross output Y, and the state of technology A. Let there be a constant returns to scale production function with traditional neoclassical curvature properties,

$$Y = Af(K,L,E,M). \qquad \ldots .(2.1)$$

A logarithmic differential of (2.1) can be written as

$$\frac{d\ln Y}{dt} = \frac{\partial \ln Y}{\partial \ln K} \cdot \frac{d\ln K}{dt} + \frac{\partial \ln Y}{\partial \ln L} \cdot \frac{d\ln L}{dt} + \frac{\partial \ln Y}{\partial \ln E} \cdot \frac{d\ln E}{dt} + \frac{\partial \ln Y}{\partial \ln M} \cdot \frac{d\ln M}{dt} + \frac{\partial \ln Y}{\partial \ln A} \cdot \frac{d\ln A}{dt}. \qquad \ldots .(2.2)$$

The partial derivatives

$$\frac{\partial \ln Y}{\partial \ln K}, \quad \frac{\partial \ln Y}{\partial \ln L}, \quad \frac{\partial \ln Y}{\partial \ln E} \text{ and } \frac{\partial \ln Y}{\partial \ln M}$$

are of course output elasticities; under competitive market conditions they equal input cost shares in the value of output. Denote these cost share as S_K, S_L, S_E and S_M. Since

$$\frac{\partial lnY}{\partial lnA} = 1, \text{ writing } \frac{\partial lnY}{\partial t} = \frac{1}{Y}\frac{\partial Y}{\partial t} \equiv \frac{\dot{Y}}{Y},$$

and analogously for each of the inputs, we have from (2.2) that

$$\frac{\dot{Y}}{Y} = S_K\frac{\dot{K}}{K} + S_L\frac{\dot{L}}{L} + S_E\frac{\dot{E}}{E} + S_M\frac{\dot{M}}{M} + \frac{\dot{A}}{A}. \quad \ldots.(2.3)$$

Total factor productivity $\frac{\dot{A}}{A}$ is obtained by rearranging (2.3),

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - S_K\frac{\dot{K}}{K} - S_L\frac{\dot{L}}{L} - S_E\frac{\dot{E}}{E} - S_M\frac{\dot{M}}{M}, \quad \ldots.(2.4)$$

i.e., total factor productivity is growth in output minus growth in aggregate input, where aggregate input is the share-weighted growth of individual inputs. Since $S_K + S_L + S_E + S_M = 1$, we can rewrite (2.4) as

$$\frac{\dot{A}}{A} = S_K\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right) + S_L\left(\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}\right) + S_E\left(\frac{\dot{Y}}{Y} - \frac{\dot{E}}{E}\right) + S_M\left(\frac{\dot{Y}}{Y} - \frac{\dot{M}}{M}\right) \quad \ldots(2.5)$$

which states simply that total factor productivity is a share-weighted average of the single factor productivity measures.

Finally, in order to provide an interpretation of factors affecting aggregate labor productivity $\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}$, we substract $\frac{\dot{L}}{L}$ from the left hand side of (2.3) and $(S_K + S_L + S_E + S_M)\frac{\dot{L}}{L}$ from the right hand side of (2.3), collect terms, and obtain

$$\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L} = \frac{\dot{A}}{A} + S_K\left(\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right) + S_E\left(\frac{\dot{E}}{E} - \frac{\dot{L}}{L}\right) + S_M\left(\frac{\dot{M}}{M} - \frac{\dot{L}}{L}\right) \quad \ldots.(2.6)$$

Equation (2.6) is very useful, for it states that growth in labor productivity is the sum of total factor productivity and the weighted growth rates of inputs relative to labor, where the weights again are cost shares.

In the context of the role of energy in labor productivity measurement, Equation (2.6) tells us that even if substantial energy conservation took place so that $\frac{\dot{E}}{E} - \frac{\dot{L}}{L}$ changed from its traditional positive value to negative, energy conservation is unlikely to have a substantial direct negative impact on measured labor productivity, since the cost share of energy is typically quite small, and thus $S_E\left(\frac{\dot{E}}{E} - \frac{\dot{L}}{L}\right)$ will tend to be negligible. Energy price increases could have indirect effects. If, for example, E and K were complementary inputs, increasing energy prices could result in reduced rates of capital formation, thereby decrease the $\left(\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right)$ term, alter the cost shares, and reduce labor productivity accordingly. Such an effect could be offset, however, if the $\left(\frac{\dot{M}}{M} - \frac{\dot{L}}{L}\right)$ and S_M terms increased due to E − M substitutability and energy price increases.

In the following pages I shall use relations (2.4), (2.5) and (2.6) to provide a framework for analyzing productivity movements in U.S. manufacturing. Since these equations are essentially continuous rather than discrete, I employ the Törnqvist discrete approximation[12] to the continuous Divisia index of (2.4),

$$\ln(A_t/A_{t-1}) = \ln(Y_t/T_{t-1}) - \overline{S}_{K,t}\ln(K_t/K_{t-1}) - \overline{S}_{L,t}\ln(L_t/L_{t-1}) - \overline{S}_{E,t}\ln(E_t/E_{t-1}) - \overline{S}_{M,t}\ln(M_t/M_{t-1}) \quad \ldots. (2.7)$$

where $\overline{S}_{i,t}$ is the arithmetic mean of the ith cost share in periods t and t−1, i.e.,

$$\overline{S}_{i,t} = \tfrac{1}{2}(S_{i,t} + S_{i,t-1}), \quad i = K, L, E, M. \quad \ldots. (2.8)$$

Data for total U.S. manufacturing, 1958–77, were generously provided me by J. Randolph Norsworthy and Michael J. Harper at the U.S. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology. Since an important portion of the analysis in this paper deals with labor disaggregated into production (hereafter, B) and nonproduction (W) labor, it was necessary to obtain additional data for these two labor types from published BLS sources.[13] Aggregate labor L was then constructed as a Divisia index of B and W.

Following other researchers, I have taken the "peak capacity" years of 1965 and 1973 as years separating subperiods, and therefore have broken the 1958–77 time span into three distinct intervals — 1958–65, 1965–73, and

[12] For a further discussion of properties of this index number, see W. Erwin Diewert [1976].

[13] These data were constructed using procedures and sources discussed in the Data Appendix of E. R. Berndt and C. J. Morrison [1980], except that no adjustment was made for changes over time in educational attainment.

1973–77.[14] Mean cost shares of the K, L, B, W, E, and M inputs for these subperiods are presented in Table 1 below.

A few comments should be made regarding the entries in Table 1. First, the cost share of energy is very small — around 1½ percent until 1973 and less than 2½ percent in 1977.[15] One important implication of this small energy cost share is that variations in energy prices or quantities will not weigh heavily in productivity calculations in U.S. manufacturing, at least not directly. Secondly, the share of capital costs in total value of output is approximately 10 percent, and has declined slightly in the 1973–77 time period. In the Norsworthy-Harper data capital income is calculated essentially as the nonlabor portion of manufacturing value-added. Thus this capital share includes not only the returns to producers' durable equipment and nonresidential structures, but also those accruing to land, inventories and other working capital.[16] Third, the share of aggregate labor is approximately 25 percent; production labor constitutes about 15 percent, and nonproduction labor 10 percent. Since 1973, the production labor share has fallen more than that of nonproduction workers.[17] Finally, the predominant factor share is that of nonenergy intermediate materials — roughly 60 percent until 1973 and slightly more after 1973. The M data are based on establishment surveys and censuses, and include sales between establishments within the manufacturing sector, as well as those between manufacturing and nonmanufacturing firms.

Before proceeding with a discussion of alternative measures of productivity trends, I list in Table 2 the average annual growth rates of quantities of gross output and inputs. The most striking feature is the dramatic slowdown in the average annual growth rate of gross output Y — from 5.411 and 3.827 percent in 1958–65 and 1965–73 to just 1.030 percent in 1973–77. Although aggregate labor input L actually fell 0.702 percent per annum in the 1973–77 time period, this reduction is due entirely to a decrease in production hours at work (B), which fell at an annual average rate of 1.451 percent; nonproduc-

[14] In section IV below I examine the empirical validity of this particular sub-period classification.

[15] This cost share for energy is considerably less than the 4–5 percent figures for U.S. manufacturing in 1947–71 published by Jack Faucett Associates [1973] and used in the studies of Ernst R. Berndt and Dale W. Jorgenson [1973], Edward A. Hudson and Dale W. Jorgenson [1974, 1978a, b], and Ernst R. Berndt and David O. Wood [1975, 1979].

The Faucett energy data include estimates of self-generated electricity and also include crude petroleum inputs into the petroleum refining sector. In the Norsworthy-Harper U.S. census data, crude petroleum is treated as M rather than E, and energy is confined to purchased energy used for heating, lighting, and motive power. See John G. Myers and Leonard Nakamura [1978] for further discussion.

[16] Using U.S. Department of Commerce, Bureau of Economic Analysis data on stocks of producers' durable equipment and nonresidential structures, and Jorgensonian rental prices for these two capital asset types, I compute that the value of capital plant and equipment services as a fraction of the total value of capital services in U.S. manufacturing varies from about one-half to two-thirds.

[17] These data include pay for time at work and supplementary benefits.

Table 1
Mean Cost Shares of K, L, B, W, E, and M Inputs in U.S. Manufacturing Based on Norsworthy-Harper and BLS Data, 1958–1977

Year	S_K	S_L	S_B	S_W	S_E	S_M
1958–65	.1195	.2724	.1688	.1036	.0153	.5929
1965–73	.1161	.2764	.1710	.1054	.0145	.5930
1973–77	.0928	.2504	.1536	.0967	.0210	.6358

Notation: K — aggregate capital
L — aggregate labor
B — production labor
W — nonproduction labor
E — aggregate energy
M — aggregate nonenergy intermediate materials

Table 2
Average Annual Growth Rates of Quantities of Gross Output and Inputs U.S. Manufacturing — Percentage Points

Time Periods	Y	K	L	B	W	E	M
1958–65	5.411	2.400	2.190	2.532	1.630	4.893	4.900
1965–73	3.827	3.905	1.022	0.763	1.440	3.815	3.893
1973–77	1.030	1.818	-0.702	-1.451	0.541	1.841	1.080

tion hours at work (W) actually increased slightly (0.541 percent per year).[18] The smaller reduction in growth of W than B may reflect a certain amount of labor hoarding of relatively skilled "overhead" labor over the business cycle; this and other possible hypotheses will be discussed later.

Using Equation (2.5), extended to allow for L being disaggregated into B and W, I then calculate total factor productivity as a share-weighted average of individual factor productivities. These results are presented in Table 3.

A substantial recent slowdown in total factor productivity for manufacturing is indicated by the entries in the final column of Table 3. However, this slowdown is not really new or dramatic. More specifically, total factor productivity fell by more than half from an annual average growth rate of 1.495 percent (1958–65) to 0.707 percent (1965–73), and then fell again by more than half to 0.340 percent (1973–77). Evidently the slowdown of total factor productivity has been going on for some time. Total factor productivity deceleration in manufacturing is not a dramatic new development coinciding with the OPEC-induced energy price increases of 1973–74.

It was noted in Equation (2.5) that total factor productivity is a share-weighted average of the individual factor productivities. The first six columns

[18] Note that the B and W series measure hours at work, which have grown at a slower rate than hours paid for, due to the increasing relative importance of supplementary benefits to B and W workers.

Table 3
Alternative Measures of Productivity Growth in U.S. Manufacturing
Average Annual Growth Rates (in Percentage Points)

Time Periods	$\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}$	$\frac{\dot{Y}}{Y} - \frac{\dot{B}}{B}$	$\frac{\dot{Y}}{Y} - \frac{\dot{W}}{W}$	$\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}$	$\frac{\dot{Y}}{Y} - \frac{\dot{E}}{E}$	$\frac{\dot{Y}}{Y} - \frac{\dot{M}}{M}$	$\dot{A}/A$
1958-65	3.152	2.807	3.720	2.940	0.494	0.487	1.495
1965-73	2.777	3.040	2.353	-0.075	0.011	-0.064	0.707
1973-77	1.745	2.518	0.487	-0.773	-0.796	-0.049	0.340

of Table 3 provide some interesting information on differing trends in these single-factor productivities. The Y/L series indicates that a rather sharp decline occurred after 1973 in output per unit of aggregate labor input — from 3.152 percent (1958–65) and 2.777 percent (1965–73) to a considerably smaller 1.745 percent (1973–77). Hence growth in aggregate labor productivity fell more during 1973–77 than growth in total factor productivity. Columns 2 and 3 show, however, that this trend in aggregate labor productivity masks very distinct patterns in output per unit of production labor at work ($\dot{Y}/Y - \dot{B}/B$) and output per unit of nonproduction labor at work ($\dot{Y}/Y - \dot{W}/W$). Production labor productivity has varied only slightly — 2.807 percent (1958–65), 3.040 percent (1965–73) to 2.518 percent (1973–77), while nonproduction labor productivity has fallen much more steeply to 0.487 percent (1973–77). Hence the slowdown in aggregate labor productivity is primarily reduced productivity growth of nonproduction workers.

The other input whose average productivity has recently fallen considerably is capital; growth in $\dot{Y}/Y - \dot{K}/K$ fell from 2.940 percent per year (1958–65) to -0.075 percent (1965–73), and then to -0.773 percent (1973–77). Stated in a slightly different way, capital-output ratios in U.S. manufacturing have increased slightly since 1965, contrary to the earlier 1958–65 pattern. The reader should note that the capital quantity data are not adjusted for cyclical utilization, i.e., they are not multiplied by an index of capacity utilization such as that of the Federal Reserve Board. Nor was the data on white collar or overhead labor multiplied by such an index. Reasons for not adjusting the capital data by capacity utilization are well known.[19] It might also be noted that the Norsworthy-Harper data include capital expenditures on pollution abatement. Based on unpublished BEA data, Norsworthy, Harper and Kunze [1979, p. 405] calculate that if these pollution abatement capital expenditure data were removed from the capital stock series in U.S. manufacturing, the rate of growth of the net capital stock would be reduced negligibly prior to 1965, would decrease by 0.29 percent per year from 1965 to 1973, and by 0.69 percent per year from 1973 to 1978. Hence, even if the capital data were fully adjusted in this way for pollution

[19] For a review of this issue, see the Jorgenson-Griliches and Denison exchange in the U.S. Department of Commerce, *Survey of Current Business* [1972].

abatement, the rate of growth of $\dot{Y}/Y - \dot{K}/K$ would still be much smaller in 1965–77 than in 1958–65. I should add that if one were to adjust the data consistently for "nonproductive" or "noncapacity increasing" pollution abatement activities, one would also want to modify the L, E and M series. For example, Myers and Nakamura [1978, p. 11] state that in certain manufacturing industries, 2 to 3 percent of total energy consumption is due to pollution control, much of it being installed between 1973 and 1976.

Table 3 shows that the behavior of average energy productivity since 1973 has been especially disappointing. Given substantial energy price increases from 1973 to 1977,[20] one would have hoped that average energy productivity would have improved since 1973. Indeed, elsewhere I have shown that, other things equal, the percent increase in average energy productivity divided by the percent increase in energy prices is the negative of the traditional own price elasticity of demand for energy.[21] Thus data in Table 3 could be interpreted to reflect an extremely low price elasticity of demand for energy — perhaps even of the wrong sign, if all other things were equal. However, in addition to the fact that a substantial increase in energy consumption during 1973 to 1976 may be due to installation of regulation-induced pollution abatement capital, a good portion of energy use, especially that for space heating and lighting and to some extent that for process heating — is of an overhead character not closely related to short-run variations in output. This implies that there are short-run increasing returns to energy, much like the well-documented short-run increasing returns to labor,[22] and that the disappointing growth in energy productivity since 1973 may reflect regulatory effects and unusually small growth in output occurring during the same time period rather than miniscule price responsiveness.

Earlier in this section I noted that it was possible to rearrange the basic total factor productivity Equation (2.4) to highlight factors related to movements in labor productivity. In (2.6), for example, growth in labor productivity was shown to be the sum of total factor productivity and the weighted growth rates of inputs relative to labor, where the weights are cost shares, i.e.,

$$\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L} = \frac{\dot{A}}{A} + S_K\left(\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right) + S_E\left(\frac{\dot{E}}{E} - \frac{\dot{L}}{L}\right) + S_M\left(\frac{\dot{M}}{M} - \frac{\dot{L}}{L}\right) \qquad \ldots\ (2.6)$$

When labor is disaggregated into hours at work of production (B) and non-

[20] The Norsworthy-Harper data indicate that over the 1973–77 time period, the real price of energy rose at an average annual rate of 12.4 percent (a 22.3 percent increase in nominal energy prices minus the 9.9 percent increase in the price of gross output).

[21] See E. R. Berndt [1978].

[22] For further discussion and quantitative estimates, see C. J. Morrison and E. R. Berndt [1979].

production (W) workers, the following analogous expressions can be obtained:

$$\frac{\dot{Y}}{Y} - \frac{\dot{B}}{B} = \frac{\dot{A}}{A} + S_K\left(\frac{\dot{K}}{K} - \frac{\dot{B}}{B}\right) + S_W\left(\frac{\dot{W}}{W} - \frac{\dot{B}}{B}\right) + S_E\left(\frac{\dot{E}}{E} - \frac{\dot{B}}{B}\right) + S_M\left(\frac{\dot{M}}{M} - \frac{\dot{B}}{B}\right) \quad \ldots. (2.9)$$

and

$$\frac{\dot{Y}}{Y} - \frac{\dot{W}}{W} = \frac{\dot{A}}{A} + S_K\left(\frac{\dot{K}}{K} - \frac{\dot{W}}{W}\right) + S_B\left(\frac{\dot{B}}{B} - \frac{\dot{W}}{W}\right) + S_E\left(\frac{\dot{E}}{E} - \frac{\dot{W}}{W}\right) + S_M\left(\frac{\dot{M}}{M} - \frac{\dot{W}}{W}\right) \quad \ldots. (2.10)$$

In a sense, these relations "explain" movements in the productivity growth of labor. However, one must be careful in interpreting the right-hand side variables as "causes" and the left-hand side variable as "effect," since (2.6), (2.9) and (2.10) are all basic rearrangements of the same total factor productivity identity.

With these caveats in mind, in Table 4 I report quantitative magnitudes of the labor productivity Equation (2.6). Recall that Y/L growth fell slightly from 3.152 percent per year (1958–65) to 2.777 percent (1965–73), and then fell by more than 1 percentage point to 1.745 percent per year (1973–77). The initial drop in Y/L growth between the 1958–65 and 1965–73 time periods coincides with a substantial drop in total factor productivity (1.495 percent in 1958–65 versus 0.707 percent in 1965–73); the slowdown in growth of labor productivity would have been larger had not the capital-labor ratio increased at a rapid rate of 2.883 percent per year.[23]

What is more surprising, however, is that growth in the capital-labor ratio has continued at a rapid rate — 2.520 percent per year, 1973–77 — even while labor productivity growth dropped substantially. Hence the argument that the recent slowdown in labor productivity growth has coincided with reduced rates of capital formation[24] does not appear to be borne out by the data, at least for the U.S. manufacturing sector 1973–77.[25]

However, some authors, Peter K. Clark [1978] and John A. Tatom [1979a,b] among others, have concluded that reduced rates of capital formation have recently occurred. Part of the divergence of views, I submit, is due

[23] This point has been made earlier by J. Randolph Norsworthy and Michael J. Harper [1979a] and J. Randolph Norsworthy, Michael J. Harper and Kent Kunze [1979], and conflicts with earlier findings by Peter K. Clark [1978]. See the first paper for further discussion.

[24] This argument has been made by, among others, Burton G. Malkiel [1979].

[25] See, however, the earlier discussion on pollution abatement capital, which if excluded could indicate a greater slowdown in rates of capital formation per hour at work.

Table 4
Factors Coinciding with Growth in Labor Productivity, U.S. Manufacturing Average Annual Growth Rates (in Percentage Points)

Time Periods	$\frac{\dot{K}}{K} - \frac{\dot{L}}{L}$	$\frac{\dot{E}}{E} - \frac{\dot{L}}{L}$	$\frac{\dot{M}}{M} - \frac{\dot{L}}{L}$	$\dot{A}/A$	$\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}$
1958–65	0.210	2.703	2.710	1.495	3.152
1965–73	2.883	2.793	2.871	0.707	2.777
1973–77	2.520	2.543	1.782	0.340	1.745

to measurement and classification issues. Data trends for the private business sector analyzed by Clark may differ from those of the manufacturing sector examined in this paper. Potentially even more important however, is the fact that Clark and Tatom multiply their capital input series by the Federal Reserve Board measure of capacity utilization in the manufacturing sector in order to obtain cyclically adjusted measures of capital services. When this adjustment is made to the Norsworthy-Harper data, a rather different picture emerges. During the 1958–65, 1965–73 and 1973–77 intervals, the Federal Reserve Board measure of capacity utilization in U.S. manufacturing grew by 2.534 percent, -0.282 percent and −1.668 percent per year, respectively.[26] If these figures are added to the K/L entries of Table 4, the revised K/L growth rate figures are 2.744 percent, 2.601 percent, and 0.852 percent for 1958–65, 1965–73 and 1973–77. These revised series accord better with the view that growth in capital per hour at work has fallen considerably since 1973, and that as a consequence, labor productivity growth has decelerated. Which view is "correct" depends partly on where one wishes to place the slowdown of output growth in the productivity accounting scheme. Edward Denison[27] has argued persuasively that utilization ought to be treated separately from input measurement. In any case, it is clear that if one uses cyclically adjusted capital data, then one must be very cautious indeed in arguing that investment incentives are needed in order to stimulate capital formation and growth in labor productivity; in U.S. manufacturing 1973–77, a growing capital stock was put in place and the problem for productivity evidently was one of lack of growth in demand for manufacturing output, not deficiency in supply of available capital plant and equipment.

In Table 5 I report growth rates of input quantities relative to production hours at work (the top half of Table 5) and relative to nonproduction hours at work (bottom half). Capital per production hour at work grew at virtually the same rate during 1965–73 and 1973–77 — around 3.2 percent per year. Although Y/B growth did not fall substantially in 1973–77 relative to earlier periods, as noted earlier Y/W growth dropped sharply and significantly. The

[26] The FRB capacity utilization data are taken from the Economic Report of the President [1980], Table B-42, p. 251.

[27] See Denison's paper and comments in U.S. Department of Commerce, *Survey of Current Business* [1972].

Table 5
Factors Coinciding with Growth in Productivity of Production (B) and Nonproduction (W) Hours at Work in U.S. Manufacturing
Average Annual Growth Rates (in Percentage Points)

Time Periods	$\frac{\dot{K}}{K}-\frac{\dot{B}}{B}$	$\frac{\dot{W}}{W}-\frac{\dot{B}}{B}$	$\frac{\dot{E}}{E}-\frac{\dot{B}}{B}$	$\frac{\dot{M}}{M}-\frac{\dot{B}}{B}$	$\frac{\dot{A}}{A}$	$\frac{\dot{Y}}{Y}-\frac{\dot{B}}{B}$
1958-65	-0.132	-0.902	2.361	2.368	1.495	2.807
1965-73	3.142	0.677	3.052	3.130	0.707	3.040
1973-77	3.269	1.992	3.292	2.531	0.340	2.518

Time Periods	$\frac{\dot{K}}{K}-\frac{\dot{W}}{W}$	$\frac{\dot{B}}{B}-\frac{\dot{W}}{W}$	$\frac{\dot{E}}{E}-\frac{\dot{W}}{W}$	$\frac{\dot{M}}{M}-\frac{\dot{W}}{W}$	$\frac{\dot{A}}{A}$	$\frac{\dot{Y}}{Y}-\frac{\dot{W}}{W}$
1958-65	0.770	0.902	3.263	3.270	1.495	3.720
1965-73	2.465	-0.677	2.375	2.453	0.707	2.353
1973-77	1.277	-1.992	1.300	0.539	0.340	0.487

bottom row of Table 5 shows that all inputs grew at a smaller rate relative to W in 1973–77 than in earlier periods; alternatively, W grew relatively more rapidly. Why this occurred is not clear. Nonproduction workers may be relatively fixed inputs in the short run, and thus their impact on aggregate productivity trends could be particularly negative when output grows at a rate smaller than expected. This hypothesis will be examined further in Section III of this paper. An alternative hypothesis, which will not be examined, is that the very slow growth in Y/W since 1973 reflects increased costs of regulation — paperwork, monitoring, etc. whose incidence falls in particular on the services of nonproduction laborers. *A priori,* it seems that such an effect would be of relatively small magnitude. Yet another possible hypothesis is that growth of W employment reflects the changing composition of output in manufacturing, which requires high-skill workers. Why this output change would become so pronounced during 1973–77 is unclear, however.

In summary, then, energy price or quantity variations since 1973 do not appear to have played a significant direct or indirect role in the slowdown of labor productivity in U.S. manufacturing, 1973–77. There are two principal reasons for the small direct effect: (i) energy costs are a very small portion of total cost, and thus energy variations do not weigh heavily in productivity calculations; and (ii) energy variations have been small, i.e., energy-output ratios have not changed much since 1973, in spite of substantial energy price increases. Nor have indirect effects of energy price increases appeared in the data, such as sharply reduced K/L ratios. Analysis of the data indicates instead that (i) total factor productivity growth has been decreasing for some time — at least since 1965 — and deceleration in its growth does not appear to be greater since the 1973 OPEC energy market developments; (ii) aggregate labor productivity growth has fallen more sharply since 1973 than has total factor productivity; however, disaggregation of aggregate labor into production hours at work (B) and nonproduction hours at work (W) reveals that growth of Y/B has been remarkably stable over the entire 1958–77 time period, while Y/W growth has fallen considerably, especially since 1973; (iii) if one assesses capital formation effects on productivity by examining changes in K/L or K/B ratios, one finds that there has been no great slowdown in capital formation since 1965; however, if one adjusts the capital data by the Federal Reserve Board capacity utilization index, K/L and K/B ratios fall significantly after 1973; (iv) the above data analysis suggests to me that the slowdown in productivity growth in U.S. manufacturing 1973–77 may be due in large part to the coincident reduction in the growth rate of output. Since inputs such as W and K tend to be fixed in the short run, and since a substantial portion of energy input may also be of an overhead nature, productivity trends since 1973 may have been much less gloomy had output grown at its 1958–73 rate of around 4½ percent per year, rather than at its much lower 1 percent rate from 1973–77.

III. A Dynamic Model of Factor Demands: Implications for Productivity Trends

In the previous section I speculated that U.S. manufacturing data point to the possibility of certain inputs being quasi-fixed in the short run, and that this relative fixity might have adversely affected productivity growth during the 1973–77 time period when output grew at an unusually low rate. This hypothesis — that productivity growth is procyclical due to quasi-fixity of certain inputs — is of course a much studied issue, particularly in the context of short-run increasing returns to labor.[28] The new wrinkles to be examined here involve a more complete theoretical specification of the dynamic cost-minimization process when nonproduction labor (W) and total capital (K) are fixed in the short run, the explicit incorporation of energy (E) into the production framework, and a closer examination of implications for total factor and labor productivity. I now proceed with a brief theoretical discussion of a dynamic model of factor demands incorporating internal costs of adjustment; for a more complete treatment, see E. R. Berndt, M. A. Fuss, and L. Waverman [1979], C. J. Morrison and E. R. Berndt [1979], and E. R. Berndt, C. J. Morrison and G. C. Watkins [1980].

Define the production function of a firm as

$$Y = F(v,x,\dot{x},t) \qquad \ldots . (3.1)$$

which represents various efficient combinations of variable inputs v and quasi-fixed inputs x that can be used to produce output Y at time t. If levels of the quasi-fixed inputs vary ($\dot{x} \neq 0$), output falls for any given amount of x and v, because of the necessity to devote resources to changing the stock rather

[28] For a recent review of this literature, see C. J. Morrison and E. R. Berndt [1979].

than producing output. This diminution in output brought about by $\dot{x} \neq 0$ constitutes "internal costs of adjustment."[29]

In the short run, firms can be viewed as maximizing restricted variable profits (revenue minus variable costs) conditional on variable input prices $\hat{w}_j$ $(j=1, \ldots, J)$, output price P, levels of the quasi-fixed inputs x_i and changes in these quasi-fixed input levels $\dot{x}_i$. Alternatively, one can view firms as minimizing normalized variable costs

$$G = \sum_{j=1}^{J} w_j v_j, \quad w_j = \hat{w}_j/\hat{w}_1,$$

conditional on

$$w_j, Y, x_i, \dot{x}_i .$$

The normalized restricted cost function

$$G = G(w, x, \dot{x}, Y, t), \qquad \ldots . (3.2)$$

where t is intended to represent the state of technology, can be shown under reasonable regularity conditions on F, to be increasing and concave in w, increasing and convex in $\dot{x}$, and decreasing and convex in x.

Two properties of G are especially important for empirical implementation. First, the partial derivative of G with respect to the normalized price of any variable input w_j equals the short-run cost-minimizing demand for v_j, i.e.,

$$\frac{\partial G}{\partial w_j} = v_j, \quad j = 2, \ldots, J. \qquad \ldots . (3.3)$$

Second, the partial derivative of G with respect to the quantity of any quasi-fixed input equals the negative of the normalized shadow cost or normalized rental price of the quasi-fixed input, i.e.,

$$\frac{\partial G}{\partial x} = -u_i, \quad i = 1, \ldots, N. \qquad \ldots . (3.4)$$

where $u_i = a_i(r+\delta_i)$, and where a_i is the normalized asset or acquisition price of the i^{th} quasi-fixed input, r is the rate of return, and δ_i is the rate of depreciation.

The long-run or dynamic economic problem facing the firm is to minimize the present value of the future stream of costs,

$$L(0) = \int_0^{\infty} e^{-rt}\left(\sum_{j=1}^{J} \hat{w}_j v_j + \sum_{i=1}^{N} \hat{a}_i z_i\right) dt \qquad \ldots . (3.5)$$

where $z_i = \dot{x}_i + \delta_i x_i$

[29] For an intuitive discussion of internal adjustment costs, see Robert E. Lucas [1967], F. P. R. Brechling and Dale T. Mortenson [1971], Michael Rothschild [1971], and S. J. Nickel [1978, Chapter 3].

is the gross addition to the stock of the i[th] quasi-fixed factor. This minimization problem is solved by choosing the time paths of the control variables v(t), $\dot{x}(t)$ and the state variable x(t) that minimize L(0), given initial conditions x(0) and v(t), x(t) > 0.

Since the normalized restricted variable cost function G incorporates the solution to the short-run cost minimization problem, i.e., it yields the optimal demand for the variable factors conditional on the values of the quasi-fixed factors, we can substitute (3.2) into (3.5). When the resulting function is integrated by parts, we obtain

$$L(0) + \sum_{i=1}^{N} a_i x_i(0) = \int_0^{\infty} e^{-rt} \left\{ G(w, x, \dot{x}, Y, t) + \sum_{i=1}^{N} u_i x_i \right\} dt. \qquad \ldots (3.6)$$

This can be interpreted as follows: since G assumes short-run optimization behavior conditional on Y(t), w(t), x(t) and $\dot{x}(t)$, the optimization problem (3.5) facing the firm is to find among all the possible G(w(t), x(t), $\dot{x}(t)$, Y(t)) combinations that time path of x(t), $\dot{x}(t)$ which minimizes the present value of costs.

A solution to (3.5) can be obtained using either the Euler first order conditions or Pontryagin's maximum principle. Assuming static expectations with respect to normalized factor prices and output, we can write the Hamiltonian as:

$$H(x, \dot{x}, \mu, t) = e^{-rt} \left(G(w, x, \dot{x}, Y, t) + \sum_{i=1}^{N} u_i x_i \right) + \mu \dot{x} \qquad \ldots (3.7)$$

When μ is eliminated from the necessary conditions, we obtain

$$-G_x - rG_{\dot{x}} - u + G_{\dot{x}}\ddot{x} + G_{x\dot{x}}\dot{x} = 0 \qquad \ldots (3.8)$$

where the x, $\dot{x}$ subscripts denote derivatives and $\ddot{x}$ is the second partial derivative with respect to time. The steady-state (long-run) solution satisfies

$$-G_x(w, x^*) - rG_{\dot{x}}(w, x^*) - u = 0, \qquad \ldots (3.9)$$

x* being unique as long as

$$|-G^*_{xx} - rG^*_{x\dot{x}}| = 0,$$

where * indicates evaluation at x = x* and $\dot{x}$ = 0. Equation (3.9) can be rewritten as

$$-G_x(w, x^*) = u + rG_{\dot{x}}(w, x^*), \qquad \ldots (3.9a)$$

and interpreted as follows: the left-hand side is the marginal benefit to the firm of changing quasi-fixed inputs (e.g., the reduction in variable costs brought about by purchasing capital equipment or hiring additional non-production workers), while the right hand side is the marginal cost (user cost plus the marginal adjustment cost) of a change in the amount of capital or skilled labor services at $\dot{x} = 0$. In long-run equilibrium, marginal benefits must equal marginal costs.

The internal cost of adjustment model outlined above is attractive in that it yields clearly defined short-run variable input demand Equations (3.3), and is based on explicit dynamic optimization. Arthur B. Treadway [1969] has linked this type of model to the "flexible accelerator" or "partial adjustment" literature by showing that $\dot{x}$ can be generated from (3.8) and (3.9) as an approximate solution (in the neighborhood of $x^*(t)$) to the multivariate linear differential equation system

$$\dot{x} = M^*(x^* - x), \qquad \text{.... (3.10)}$$

where M^* is determined from the solution to the quadratic form

$$-G^*_{\dot{x}\dot{x}}M^{*2} - rG^*_{\dot{x}\dot{x}}M^* + G^*_{xx} + rG^*_{x\dot{x}} = 0. \qquad \text{.... (3.11)}$$

In the special case of only one quasi-fixed input, Treadway has shown that

$$\dot{x}_l = M^*_l(x^*_l - x_l), \qquad \text{.... (3.12)}$$

where at the stationary point when $G^*_{x\dot{x}} = 0$,

$$M^*_l = -\frac{1}{2}\left(r - (r^2 + 4G_{x_l x_l}/\ G_{\dot{x}_l \dot{x}_l})^{1/2}\right). \qquad \text{.... (3.13)}$$

It should be noted that M^*_l varies inversely with r, and is not constrained to be constant, as is the case with typical partial adjustment models. However, if G were quadratic so that $G_{x_l x_l}$ and $G_{\dot{x}_l \dot{x}_l}$ were constant parameters, and if the discount rate r were relatively stable, M^*_l would also tend to be quite stable.

Once one specifies a functional form for G and alters the continuous time model into a discrete time specification, one can obtain short-run demand equations for variable inputs ("utilization" equations) using (3.3) and net accumulation equations for the quasi-fixed inputs using (3.9) and (3.10). From these demand equations, expressions for short, intermediate and long-run price and output elasticities can be derived which completely summarize the dynamic time paths of factor demands. In particular, following the Marshallian tradition, short-run elasticities can be defined as those obtained when x is fixed, intermediate run as the impact when x has adjusted partially as determined by M^*, and long-run as the response when x has adjusted fully to x^* and $\dot{x} = 0$. Short, intermediate and long-run average total cost curves can be defined in a perfectly analogous manner.

The above discussion, though largely theoretical, has several important implications for productivity measurement. First, the measure of total factor productivity will depend on the extent of short-run disequilibrium. To see this, recall that according to the classic Wong-Viner envelope theorem, average total cost (ATC) follows the inequality

$$ATC_{SR} \geq ATC_{IR} \geq ATC_{LR} \qquad \text{....(3.14)}$$

with the equality holding only when the firm initially is in long-run equilibrium. This occurs because with output fixed, the firm is constrained in the short run by its fixed inputs, but in the long run it can adjust all inputs to long-run equilibrium levels. Total factor productivity $\dot{A}/A$ will as a consequence generally be smaller in the short than long run, i.e.,

$$\left(\frac{\dot{A}}{A}\right)_{SR} \leq \left(\frac{\dot{A}}{A}\right)_{IR} \leq \left(\frac{\dot{A}}{A}\right)_{LR} ; \qquad \text{....(3.15)}$$

the equality again holds only when initially the firm is in long-run equilibrium. If, for example, the year 1973 was one with firms very close to long-run equilibrium, but if in 1977 the combination of dramatic energy price increases and reduced growth rates of output left firms considerably further away from their long-run equilibrium factor demands, then the 1973–77 estimate of total factor productivity growth would be altered, and comparison between 1965–73 "peak" years with 1973–77 could be misleading.

This problem — that total factor productivity growth measures may be procyclical — has occupied the attention of productivity accountants for some time, and has been the source of considerable controversy. One possible approach is to make some allowance for disequilibrium by using, say, the Wharton or the Federal Reserve Board measure of capacity utilization, adjusting some or all of the inputs (or perhaps output) by this index, and then calculating a "cyclically adjusted" $\dot{A}/A$. A basic problem with such a procedure is that the Wharton and FRB capacity output measures are essentially unrelated to an economic notion of capacity output, defined as that level of output Y^* which minimizes short-run average total costs.[30] In particular, if energy price increases shift economic capacity Y^*, then economic capacity utilization ratios Y/Y^* would be affected, which in turn would influence $\dot{A}/A$ measures. Such input price effects on capacity output cannot be captured by the mechanical formulas typically used to compute the Wharton and FRB capacity utilization rates.

One attractive feature of the theoretical framework outlined above is that it permits calculation of an economic measure of capacity output Y^*, and also allows one to determine how Y^* would be affected by changes in input prices. In the case of a single quasi-fixed input, say capital K, an increase in the price of a variable input will increase (decrease) Y^* if the

[30] This capacity output notion is consistent with long-run constant returns to scale. If the long-run ATC curve is U-shaped, however, then capacity output is that level of output on the short-run ATC curve tangent to the long-run ATC curve. See L. R. Klein [1960] for further discussion.

variable input and K are complements (substitutes).[31] Hence if energy and K are complements, recent energy price increases may have increased Y^*, thereby reducing capacity utilization ratios Y/Y^*; such a phenomenon is unlikely to be captured by the Wharton or FRB capacity utilization indices, which could therefore be biased upward in recent years.

Short- and long-run productivity growth rates for individual inputs are also affected by the extent of disequilibrium. Unlike the case for total factor productivity, however, single factor productivity measures do not follow any general inequality but instead depend on substitutability-complementarity relations among fixed and variable inputs. Suppose again there is only one quasi-fixed input, K. In response to an exogenous increase in Y, short-run "overshooting" (defined as short-run demand for a variable input being larger than long-run demand) or short-run "undershooting" occurs for an input if that variable input and K are substitutes or complements, respectively.[32] It follows, then, that if nonproduction labor W is complementary with the fixed input K, then if output falls, demand for W will not fall by as much, and average productivity of W will fall more in the short run than in the long run. Since the econometric literature contains numerous discussions of capital-skill complementarity,[33] a plausible hypothesis helping to explain the sharp drop in Y/W productivity growth rates 1973–77 is that W and K are complementary, and since output grew at an unexpectedly small rate in this period, growth in demand for W did not fall proportionally.

To illustrate the above remarks, let us now specify a functional form for the variable restricted cost function G with short-run nonhomothetic properties but with long-run constant returns to scale imposed. For a single quasi-fixed input K,[34] an attractive functional form is

$$
\begin{aligned}
G &= B + P_W W + P_E E + P_M M \\
&= Y(\alpha_0 + \alpha_{0t} t + \alpha_W P_W + \alpha_E P_W + \alpha_M P_M + \tfrac{1}{2}(\gamma_{WW} P_W^2 \\
&\quad + \gamma_{EE} P_E^2 + \gamma_{MM} P_M^2) + \gamma_{WE} P_W P_E + \gamma_{WM} P_W P_M + \gamma_{EM} P_E P_M \\
&\quad + \alpha_{Wt} P_W t + \alpha_{Et} P_E t + \alpha_{Mt} P_M t) + \alpha_K K_{-1} + \gamma_{EK} P_E K_{-1} + \gamma_{WK} P_W K_{-1} \\
&\quad + \gamma_{MK} P_M K_{-1} + \alpha_{Kt} K_{-1} t + \tfrac{1}{2}(\gamma_{KK} K_{-1}^2) + \tfrac{1}{2}(\gamma_{\dot{K}\dot{K}} \dot{K}^2 / Y) \qquad \ldots . (3.16)
\end{aligned}
$$

where all prices are normalized by P_B, the price of production labor.

[31] Surprisingly, not much has been written on this issue. The only paper of which I am aware is an unpublished one by Robert H. Rasche and John Tatom [1977c], which restricts attention to the case of a single quasi-fixed input.

[32] For further discussion, see C. J. Morrison and E. R. Berndt [1979].

[33] See, for example, Zvi Griliches [1969].

[34] Generalization to two quasi-fixed inputs is straightforward, although constraining M^* to be diagonal appears necessary. C. J. Morrison and E. R. Berndt [1979].

Using (3.3), one can obtain short-run demand equations for variable inputs. For nonproduction labor, the short-run demand equation is

$$W/Y = \alpha_W + \alpha_{Wt}t + \gamma_{EW}P_E + \gamma_{WW}P_W + \gamma_{MW}P_M + \gamma_{WK}K_{-1}/Y \quad \ldots. (3.17)$$

When W and K are complements, γ_{WK} is positive and W/Y varies directly (average W productivity varies inversely) with the capital-output ratio K_{-1}/Y. Similar short-run demand equations occur for other variable inputs. The net accumulation or net investment equation turns out to be of the flexible accelerator form. Using (3.14) we have

$$\dot{K}_t \equiv K_{t+1} - K_t = M^*_{KK,t}(K^*_t - K_t) \quad \ldots. (3.18)$$

where

$$K^* = (Y/\gamma_{KK})(\alpha_K + \gamma_{WK}P_W + \gamma_{EK}P_E + \gamma_{MK}P_M + \alpha_{Kt}t + u_K),$$

where u_K is the rental price of capital P_K normalized by P_B and where

$$M^*_{KK} = -\tfrac{1}{2}[r_t - (r_t^2 + 4\gamma_{KK}/\gamma_{\dot{K}\dot{K}})^{1/2}]. \quad \ldots. (3.19)$$

By appropriately differentiating G/Y from (3.16), we can solve for that level of output Y* which minimizes short-run average total costs of production. This yields the economic capacity output Y*,

$$Y^* = -(\gamma_{KK}K^2_{-1} + \gamma_{\dot{K}\dot{K}}\dot{K}^2_{-1})/(\alpha_K K_{-1} + \alpha_{Kt}K_{-1}t + \gamma_{WK}P_W K_{-1} + \gamma_{EK}P_E K_{-1} + \gamma_{MK}P_M K_{-1} + u_K K_{-1}) \quad \ldots. (3.20)$$

which indicates very clearly what are the factors affecting an economic notion of short-run capacity output.

In the next section of this paper I present some estimates of how post-1973 energy price increases might have affected Y*, and how reductions in growth of Y might have affected total and individual factor productivity measures during the turbulent 1973–77 time period.

Before doing that, I want to digress briefly and comment on one other aspect of the dynamic factor demand model sketched above. Earlier I noted that Burton G. Malkiel [1979], among others, has argued that a slowdown in capital formation has recently taken place, that this adversely affects labor productivity, and that one element negatively influencing investment activity has been the low value of Tobin's q, defined as the market value of a firm divided by the replacement cost of its physical capital stock. Recall also that in Section II I noted that the U.S. manufacturing data 1973–77 did not indicate a significant slowdown in the growth of the capital-labor ratio, unless one adjusted the capital data by the FRB index of capacity utilization. Nonetheless, it is of some interest to examine whether energy price increases could have negatively affected Tobin's q, and if so, by how much.

Tobin's q was originally presented in the context of a financial portfolio model.[35] A slight variant of q with more "real" than "financial" structure has been developed by Andrew Abel [1978, Essay IV] and John Ciccolo and Gary Fromm [1979]. In its amended form, q is the shadow price of installed capital goods divided by the tax-adjusted price of uninstalled capital goods. Abel used a dynamic optimization framework similar to that above and showed that investment was an increasing function of the shadow price of this amended q. In the present context for the i^{th} quasi-fixed input, q_i can be defined as

$$q_i = \frac{-\partial G/\partial x_i}{u_i}, \qquad \ldots . (3.21)$$

i.e., the ratio of the shadow price of installed capital (the reduction in variable costs due to increasing the stock of the quasi-fixed input) divided by the normalized rental price of that input. In long-run equilibrium, $q_i = 1$. Net accumulation of the i^{th} input will be positive (negative) when q_i is greater (less) than unity. Using (3.16) in the model with K as the only quasi-fixed input, we obtain

$$q_k = -\frac{(\alpha_K + \gamma_{WK}P_W + \gamma_{EK}P_E + \gamma_{MK}P_M + \alpha_{Kt}t + \gamma_{KK}K_{-1}/Y)}{u_K} \qquad \ldots . (3.22)$$

Note that if E and K are complementary inputs ($\gamma_{EK}>0$), then increases in energy prices will reduce q_K. Whether E–K complementarity is sufficient to explain the sharp reduction in Tobin's q since 1973 is an empirical issue.

IV. Econometric Results for Dynamic Models

In this section I present preliminary econometric results for U.S. manufacturing 1958–77 based on the model with a single quasi-fixed input K discussed in the previous section, as well as preliminary results based on an analogous model with two quasi-fixed inputs (W and K). The results are preliminary in that the energy and capital data in particular need to be reconciled with those of other studies.[36] Estimation was carried out using the nonlinear maximum likelihood algorithm in TSP at the University of British Columbia.

The empirical issues I address in this section include the following: (i) How has the economic optimal capacity output Y* varied with the actual rate

[35] See James Tobin [1969], and earlier works, including James Tobin [1961] and William C. Brainard and James Tobin [1968].

[36] See the discussion in Section II above.

of output Y, i.e., what does an economic measure of capacity utilization look like over the 1958–77 time period? (ii) To what extent can the small total factor productivity growth rates 1973–77 be attributed to increased divergence of actual from economic capacity output? (iii) By how much do increased energy prices affect the optimal level of output? (iv) By what amount do increased energy prices affect Tobin's q_K? and (v) How do variations in output and capacity utilization affect the productivity of individual inputs? In order to keep the text of this conference paper reasonably concise, I omit the standard complete presentation of parameter estimates, t-statistics, etc. and instead move directly to a discussion of issues.

Economic measures of capacity utilization for the one and two quasi-fixed input models are presented in the second and third columns of Table 6, respectively; for purposes of comparison, in the next two columns I reproduce the Wharton and FRB measures. A number of comments are in order. First, the economic measures are always greater than unity, whereas the Wharton and FRB figures are always less than unity. To some extent, this can be interpreted simply as a scaling convention, particularly since Wharton and FRB measures approaching 90 percent are often viewed as being very near "full capacity." On the other hand, that the economic measures are greater than unity is informative, for it indicates that production is to the right of the minimum point of the short-run average total cost curve, thereby inducing cost-reducing positive net investment. In the last two columns of Table 6 I present estimated ratios of short-run marginal cost to long-run average total cost evaluated at the actual level of output.[37]

The one quasi-fixed input model predicts positive net investment in all years, although the predicted positive amount is very small in 1958, 1959 and 1974. The two quasi-fixed input model performs about the same as the single fixed factor model in predicting $\dot{K}$, but somewhat surprisingly, the estimated single fixed factor model with W–K complementarity predicts correctly all negative accumulations in W; the two quasi-fixed input model correctly predicts negative $\dot{W}$ in 1969 and 1970, but misses the net reductions in 1960 and 1974.

The economic measures of capacity utilization compare reasonably well with the FRB index, but considerably less so with the Wharton measure.[38] Both economic measures of capacity utilization indicate relative peak years in 1965, 1973 and 1977, while peak years for the FRB index are 1966, 1973 and 1977. The Wharton relative peaks are in 1966, 1969, 1973 and 1977. Economic capacity utilization measures are lowest in 1958–59, 1970–71, and

[37] The calculation assumes that inputs are elastically supplied; when input supply curves are upward sloping, these figures likely understate the ratio of SRMC to LRAC. For a discussion of the effects of upward sloping supply curves of labor on a calculation of potential output, see Jeffrey M. Perloff and Michael L. Wachter [1979].

[38] For the single (two) fixed factor model, simple correlations between the economic measure and the FRB index are .419 (.523), while those between the economic measure and the Wharton index are only .244 (.140); the simple correlation between the Wharton and FRB index is .605.

Table 6
Alternative Measures of Capacity Utilization, and Ratio of Estimated Short-Run Marginal Cost to Long-Run Average Total Cost
U.S. Manufacturing, 1958–77

Year	Capacity Utilization Model with K Fixed	Capacity Utilization Model with W,K Fixed	FRB Measure	Wharton Measure	SRMC/LRAC Model with K Fixed	SRMC/LRAC Model with W,K, Fixed
1958	1.106	1.091	0.752	0.742	1.015	1.026
1959	1.110	1.118	0.819	0.789	1.013	1.030
1960	1.171	1.131	0.802	0.769	1.024	1.035
1961	1.177	1.130	0.774	0.737	1.026	1.036
1962	1.197	1.145	0.816	0.765	1.027	1.038
1963	1.224	1.167	0.835	0.777	1.031	1.044
1964	1.226	1.164	0.856	0.795	1.031	1.042
1965	1.232	1.190	0.896	0.842	1.030	1.045
1966	1.214	1.170	0.911	0.882	1.027	1.040
1967	1.184	1.129	0.869	0.869	1.026	1.033
1968	1.178	1.119	0.871	0.892	1.024	1.030
1969	1.169	1.108	0.862	0.902	1.025	1.029
1970	1.111	1.036	0.793	0.841	1.018	1.012
1971	1.110	1.052	0.784	0.827	1.017	1.015
1972	1.204	1.139	0.835	0.879	1.033	1.037
1973	1.240	1.185	0.876	0.932	1.040	1.049
1974	1.092	1.079	0.838	0.905	1.012	1.018
1975	1.160	1.096	0.729	0.798	1.030	1.026
1976	1.259	1.170	0.795	0.860	1.051	1.048
1977	1.267	1.183	0.819	0.887	1.055	1.052
Mean	1.182	1.130	0.827	0.834	1.028	1.034

1974–75, essentially coinciding with low points of the Wharton and FRB measures, although the latter both indicate slight downturns in 1961.

The economic capacity utilization measures differ from the Wharton and FRB values in one very important respect, however. According to the FRB measure, the relative peak years of 1973 (.876) and 1977 (.819) were considerably smaller than the 1966 all-time peak (.911), whereas for the economic measures the peaks are essentially equal. In particular, the economic measures for 1973 and 1977 are virtually identical. The Wharton index differs slightly; its all time peak is 1973 (.932), and the 1966 (.882) and 1977 (.887) peaks are about equal but smaller than that in 1973.

One implication of this for total factor productivity measurement is that if one believes the economic measures, then comparisons between 1965–73 and 1973–77 are quite legitimate, since the peak years 1965, 1973, and 1977 represent basically equal levels of capacity utilization. In particular, on the basis of these data it appears that the 1973–77 slowdown in total factor productivity relative to 1965–73 cannot be attributed to the end year 1977 being one of unequal capacity utilization.

A third empirical issue to be considered concerns the effects of increased energy prices on the economically optimal level of output Y*. Recall that in the earlier discussion I noted that if E and K were complementary inputs, then increases in P_E would increase Y*. Although E–K complementarity occurs in both the single and two quasi-fixed input models (the 1977 long-run cross price elasticities for ϵ_{EK} are -0.086 and -0.065, respectively, while those for ϵ_{KE} are -0.029 and -0.022), the effect of increased energy prices on Y* is estimated to be quite small. For example, the estimated 1977 elasticity of Y* with respect to an increase in P_E is 0.021 for the single quasi-fixed factor model, and 0.047 for the model with two quasi-fixed inputs. These small positive estimates contrast sharply with those of Robert H. Rasche and John A. Tatom [1977a, b] and John A. Tatom [1979a, b] who use a Cobb-Douglas model and estimate that the elasticity of Y* with respect to P_E is negative and about -.10. On the basis of these data, however, I conclude that energy price increases since 1973 are unlikely to have affected capacity output significantly.

The fourth empirical issue to be examined is the effect of increased energy prices on Tobin's amended q_K, defined in Equation (3.22). In Table 7 I compare "actual" values of Tobin's q for the U.S. manufacturing sector[39] with those estimated by the dynamic models; all three measures are indexed to unity in 1973. Both dynamic models predict sharp drops for q_K in 1974, but the actual drop is much larger than that predicted; moreover the q_K in 1977 are predicted to be larger than in 1973, though such a recovery did not in fact take place. Rising energy prices during the 1974–77 time period are not predicted to have had a substantial effect on q_K; indeed, in 1977 the estimated elasticity of Tobin's q_K with respect to an increase in P_E is -0.030 in the single-fixed factor model, and -0.031 in the two quasi-fixed factor specification. The principal reason underlying the predicted increase in q_K since 1974 is that q_K is very responsive to output increases and therefore is predicted to recover along with output. The estimated elasticities of q_K with respect to output in 1974 are 1.031 (K fixed) and 1.379 (W, K fixed). Hence, whatever it was that contributed to the sharp fall in q_K since 1973, the analysis undertaken here suggests that rising energy prices cannot be named as the principal villain.

The fifth and final empirical issue considered in this section is the effect of variations in output and capacity utilization on the average productivity of individual factors. In both the single and two quasi-fixed factor models, long-run constant returns to scale imply that the elasticity of demand for each input with respect to output is unity. In the short run when certain inputs are fixed, however, these output elasticities may be greater or less than unity, depending on the substitutability-complementarity relationships among variable and fixed inputs.

Short-run elasticities of demand for production labor with respect to output are estimated as slightly greater than unity (around 1.2) in both the K fixed and W, K fixed models; in the K fixed model, the corresponding elasti-

[39] Taken from Daniel M. Holland and Stewart C. Myers [1980], Table 2.

Table 7
Tobin's Amended q_K in Selected Years
U.S. Manufacturing

Year	Model with K Fixed	Model with K,W Fixed	Actual Value[1]
1973	1.000	1.000	1.000
1974	0.738	0.703	0.491
1975	0.880	0.798	0.591
1976	1.085	1.019	0.618
1977	1.111	1.043	0.618

[1] Taken from Daniel M. Holland and Stewart C. Myers [1980]. Entries from all columns are normalized to unity in 1973.

city for nonproduction labor is only about 0.6, while the W, K fixed model assumes that this short-run elasticity is zero. These results imply that as output fell from 1973 into 1974–75, the average productivity of production labor should have increased slightly, but that the average productivity of nonproduction labor should have decreased more sharply. Then as output increased considerably again in 1976–77, average productivity of B should have fallen or at least risen less rapidly, while that of W should have risen more sharply.

This predicted pattern of year-to-year variations within the 1973–77 time frame is consistent with the observed data. Although the K fixed model performs quite well in predicting differences in growth rates of B and W productivity during the 1973–77 time period, it substantially overestimates the absolute growth rate levels; predicted annual average growth rates are 3.972 percent and 1.889 percent, while actual rates were 2.518 percent and 0.487 percent, respectively. The model with W and K both fixed in the short run substantially overpredicts growth in B productivity (4.186 percent), but slightly underestimates growth in W productivity (0.238 percent). Incidentally, both models are unable to predict the slowdown in 1973–77 total factor productivity; estimated growth rates for 1965–73 and 1973–77 are equal at 0.87 percent per year for the K fixed model, and are 0.86 and 0.90 percent respectively in the W, K specification. In summary, then, for labor productivity the dynamic models are reasonably successful in predicting differences in growth rates of B and W productivity, but are unable to account for the sharp drop in absolute growth rate levels during 1973–77.

With respect to energy, both the K fixed and W, K fixed models find that short-run elasticities of demand for E with respect to output are less than unity (about 0.5 in the former and 0.8 in the latter); this helps explain the disappointing energy productivity trends over the 1973–77 time period. However, even with these small output elasticities and relatively low short-run energy price elasticities (about -0.20 in the K fixed and -0.15 in the W, K fixed model), both models predict modest growth in average energy productivity during 1973–77 of around 1 percent per year; actual energy productivity fell

0.8 percent per year, although in the latter portion (during 1975–77) it rose at an annual rate of around 2.6 percent, somewhat greater than the predicted growth rates of about 2.0 percent.

V. Concluding Remarks on the Role of Energy Price Increases on Measured Productivity Trends

In this paper I have examined the role of energy price increases in the productivity slowdown in U.S. manufacturing, 1973–77. Energy price or quantity variations since 1973 do not appear to have had a significant direct role in the slowdown of aggregate labor productivity in U.S. manufacturing, 1973–77. Two principal reasons were cited for this small direct effect. First, energy costs are a very small portion of total cost, and thus energy variations do not weigh heavily in productivity calculations. Second, observed energy quantity variations have been very small since 1973; for example, energy-output ratios have remained basically unchanged in 1977 from their 1973 levels, in spite of substantial energy price increases.

However, one way in which energy price increases could have affected labor productivity more significantly is through indirect effects, such as price induced reductions in capital-labor and energy-labor ratios. Such reductions would be consistent with E–K complementarity and E–L substitutability. As indicated in Table 4, however, there has been only a very slight slowdown in the rate of growth of the K/L ratio from 1965–73 (2.883 percent per year) to 1973–77 (2.520 percent), and in the rate of growth of the E/L ratio — 2.793 percent in 1965–73 versus 2.543 percent during 1973–77. Moreover, *a priori* it would seem that if rising energy prices were to reduce capital formation and induce substitution of workers for machines, this effect would be greater for production laborers (B) than for nonproduction workers (W). However, examination of U.S. manufacturing data disaggregated into B and W indicates that the growth rate of capital per production hour at work *increased* slightly from 3.142 percent (1965–73) to 3.269 percent (1973–77) per year, while that of capital per nonproduction hour at work *decreased* from 2.465 percent per year (1965–73) to 1.277 percent (1973–77). Even more surprising, although aggregate labor productivity fell significantly during the 1973–77 time period, growth in output per production hour at work was remarkably stable over the entire 1958–77 time period at 2½ to 3 percent per year; in contrast, growth in output per nonproduction hour at work fell from 3.720 percent per year (1958–63) to 2.353 percent (1965–73), and then fell much more sharply to only 0.487 percent per year (1973–77). In summary, then, empirical evidence in support of the hypothesis that energy price increases reduce capital formation within the manufacturing sector and induce substitution of machines for workers, thereby significantly reducing labor productivity growth, is not very convincing — at least based on these data for U.S. manufacturing through 1977. While the evidence could be viewed as being consistent with energy price increases very modestly reducing rates of capital formation in manufacturing, it does not appear to be as supportive of the energy-labor substitutability hypothesis, the latter hypothesis advanced ironically both by E–K complementarity and E–K substitutability advocates.[40] Moreover, as seen in Section IV energy price increases are unlikely to have negatively affected Tobin's q significantly.

That the evidence on the E–K and E–L relationships remains unsettled is regrettable. It should be noted that the Jorgenson interpretation of effects of rising energy prices on aggregate national rates of capital formation, labor productivity growth, and economic growth relies only partially on E–K complementarity and E–L substitutability within manufacturing, and depends considerably more on price-induced compositional changes among sectors in final demand. Evidence on such a general equilibrium hypothesis has not been examined in this paper.[41]

But if energy price increases were not responsible for the 1973–77 productivity slowdown, what were the principal causes? Based on the evidence in Section II, since inputs such as W and K tend to be fixed in the short run, and since E might also be somewhat insensitive to output variations in the short run, I conjectured that the slowdown in productivity growth in U.S. manufacturing 1973–77 may have been due in large part to the coincident reduction in the growth rate of output. This hypothesis was formulated more rigorously within the context of dynamic models of factor demands that included not only K and W but also B, E and M inputs. Econometric results, presented in Section IV, disclosed that economic measures of capacity utilization were about equal in 1965, 1973, and 1977, implying that the 1973–77 total factor productivity slowdown could not be attributed to the choice of these particular years for the 1965–73 and 1973–77 comparisons. Although the dynamic models fared quite well in predicting *differences* among B, W and E productivity growth rates during 1973–77, the models consistently overpredicted *absolute* productivity growth rates of the inputs. In brief, the dynamic models were unable to explain the 1973–77 slowdown in total factor productivity.[42]

In summary, energy price increases are unlikely to have played a major direct or indirect role in the 1973–77 productivity slowdown in U.S. manufacturing. However, to the extent that energy price increases reduce future rates of capital formation, their effect on labor productivity in the 1980s may be more substantial than in the brief 1973–77 time period. What caused the 1973–77 productivity slowdown regrettably remains a question for which we do not yet have a satisfactory set of answers.

[40] See, for example, James M. Griffin and Paul R. Gregory [1976] and Ernst R. Berndt and David O. Wood [1975, 1979].

[41] For alternative partial and general equilibrium specifications, see William Hogan and Alan Manne [1977] and John Solow [1979].

[42] The model would of course have fared better if time had been entered in squared form (t^2) rather than simply as a linear term. Such an exercise, however, would be less than satisfying and convincing intellectually.

REFERENCES

Abel, Andrew B. [1979], *Investment and the Value of Capital*, New York: Garland Publishing, Inc. (Ph.D. dissertation submitted at the Massachusetts Institute of Technology, Department of Economics, May 1978).

Berndt, Ernst R. [1978], "Aggregate Energy, Efficiency, and Productivity Measurement," *Annual Review of Energy*, Vol. 3, pp. 225-273.

——, M.A. Fuss and L. Waverman [1979], "A Dynamic Model of Costs of Adjustment and Interrelated Factor Demands, with an Empirical Application to Energy Demand in U.S. Manufacturing," Vancouver: University of British Columbia, Dept. of Economics, Discussion Paper 79-30, November.

—— and Dale W. Jorgenson [1973], "Production Structure," Chapter 3 in Dale W. Jorgenson et al., eds., *U.S. Energy Resources and Economic Growth*, Final Report to the Ford Foundation Energy Policy Project, Washington, D.C.

—— and Catherine J. Morrison [1980], "Income Redistribution and Employment Effects of Rising Energy Prices," *Resources and Energy*, forthcoming.

——, Catherine J. Morrison and G. Campbell Watkins [1980], "Dynamic Models of Energy Demand: An Assessment and Comparison," Vancouver: University of British Columbia, Resources Paper No. 49, February.

—— and David O. Wood [1975], "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, Vol. 56, No. 4, August, pp. 59-68.

—— and David O. Wood [1979], "Engineering and Econometric Interpretations of Energy-Capital Complementarity," *American Economic Review*, Vol. 69, No. 3, June, pp. 342-354.

Brainard, William C. and James Tobin [1968], "Pitfalls in Financial Model Building," *American Economic Review*, Vol. 59, No. 2, May, pp. 99-122.

Brechling, F. P. R. and Dale T. Mortenson [1971], "Interrelated Investment and Employment Decisions," paper presented at the 1971 Winter Meetings of the Econometric Society, New Orleans, December.

Ciccolo, John and Gary Fromm [1979], " 'q' and the Theory of Investment," *Journal of Finance*, Vol. 34, No. 2, May, pp. 535-547.

Clark, Peter K. [1978], "Capital Formation and the Recent Productivity Slowdown," *Journal of Finance*, Vol. 33, No. 3, June, pp. 965-975.

Denison, Edward F. [1979], *Accounting for Slower Economic Growth*, Washington, D.C.: The Brookings Institution.

Diewert, W. Erwin [1976], "Exact and Superlative Index Numbers," *Journal of Econometrics*, Vol. 4, No. 2, May, pp. 115-145.

DuBoff, Richard B. [1966], "Electrification and Capital Productivity: A Suggested Approach," *Review of Economics and Statistics*, Vol. 48, No. 4, pp. 426-431.

Jack Faucett Associates [1973], "Data Development for the I-0 Energy Model: Final Report," Chevy Chase, Maryland: Jack Faucett Associates, Inc., May.

Griffin, James M. and Paul R. Gregory [1976], "An Intercountry Translog Model of Energy Substitution Responses," *American Economic Review*, Vol. 66, No. 5, December, pp. 845-857.

Griliches, Zvi [1969], "Capital-Skill Complementarity," *Review of Economics and Statistics*, Vol. 51, No. 4, November, pp. 465-468.

Hogan, William W. and Alan S. Manne [1977], "Energy-Economy Interactions: The Fable of the Elephant and the Rabbit?" in Charles J. Hitch, ed., *Modeling Energy-Economy Interactions: Five Approaches*, Washington, D.C.: Resources for the Future, pp. 247-277.

Holland, Daniel M. and Stewart C. Myers [1980], "Profitability and Capital Costs for Manufacturing Corporations and All Nonfinancial Corporations," *American Economic Review*, Vol. 70, No. 2, May, pp. 320-325.

Hudson, Edward A. and Dale W. Jorgenson [1974], "U.S. Energy Policy and Economic Growth, 1975-2000," *Bell Journal of Economics*, Vol. 5, No. 2, Autumn, pp. 461-514.

—— and Dale W. Jorgenson [1978a], "Energy Policy and U.S. Economic Growth," *American Economic Review*, Vol. 68, No. 2, May, pp. 118-123.

—— and Dale W. Jorgenson [1978b], "Energy Prices and the U.S. Economy, 1972–1976," *Natural Resources Journal*, Vol. 18, No. 4, October, pp. 877-897.

Jevons, William Stanley [1865], *The Coal Question*, First Edition. Third Edition reprinted by Augustus M. Kelley, Publishers, New York, 1965.

Jorgenson, Dale W. [1978], "Energy and the Outlook for the U.S. Economic Growth," Harvard University, Department of Economics, xerolith, 24pp. The essence of this paper was published in slightly revised form as "Energy and the Future U.S. Economy," *The Wharton Magazine*, Vol. 3, No. 4, Summer 1979, pp. 15–21.

—— and Barbara M. Fraumeni [1979], "Substitution and Technical Change in Production," Paper presented at the NSF Conference on Natural Resource Substitution, Key Biscayne, Florida, December 13–14.

Klein, Lawrence R. [1960], "Some Theoretical Issues in the Measurement of Capacity," *Econometrica*, Vol. 28, No. 2, April, pp. 272–286.

Lucas, Robert E. [1967], "Adjustment Costs and the Theory of Supply," *Journal of Political Economy*, Vol. 75, No. 4, August, pp. 321–334.

Malkiel, Burton G. [1979], "The Capital Formation Problem in the United States," *Journal of Finance*, Vol. 34, No. 2, May, pp. 291-306.

Morrison, Catherine J. and Ernst R. Berndt [1979], "Short-Run Labour Productivity in a Dynamic Model," Vancouver: University of British Columbia, Department of Economics, Discussion Paper 79-39, November.

Myers, John G. and Leonard Nakamura [1978], *Saving Energy in Manufacturing: The Post-Embargo Record*, Cambridge, Mass.: Ballinger Publishing Company.

Nickell, S.J. [1978], *The Investment Decisions of Firms*, Cambridge: Cambridge University Press.

Norsworthy, J. Randolph and Michael J. Harper [1979a], "The Role of Capital Formation in the Recent Productivity Slowdown," Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, Working Paper 87, January.

——, J. Randolph and Michael J. Harper [1979b], "Dynamic Models of Energy Substitution in the U.S. Economy," paper presented at the NSF Conference on Natural Resource Substitution, Key Biscayne, Florida, December 13–14.

——, J. Randolph, Michael J. Harper and Kent Kunze [1979], "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, 2:1979, pp. 387–421.

Perloff, Jeffrey M. and Michael L. Wachter [1978], "Alternate Approaches to Forecasting Potential Output, 1978–1980," *Proceedings of the 1978 Business and Economics Section*, American Statistical Association, pp. 104–113.

Rasche, Robert H. and John A. Tatom [1977a], "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," Federal Reserve Bank of St. Louis *Review*, Vol. 59, No. 5, May, pp. 2–12.

—— and John A. Tatom [1977b], "Energy Resources and Potential GNP," Federal Reserve Bank of St. Louis *Review*, Vol. 59, No. 6, June, pp. 10–24.

—— and John A. Tatom [1977c], "Firm Capacity and Factor Price Changes," xerolith, not dated.

Rothschild, Michael [1971], "On the Cost of Adjustment," *Quarterly Journal of Economics*, Vol. 85, No. 4, November, pp. 604–622.

Schurr, Sam H. and Bruce Netschert [1960], *Energy in the American Economy, 1850–1975*, Baltimore: Johns Hopkins Press for Resources for the Future.

Simon, Herbert A. [1950], "The Effects of Atomic Power on National or Regional Economies," Chapter 13 in Sam H. Schurr and Jacob Marschak, eds., *Economic Aspects of Atomic Power*, Princeton: Princeton University Press for the Cowles Commission for Research in Economics, pp. 219–247.

Solow, John [1979], "A General Equilibrium Approach to Aggregate Capital-Energy Complementarity," *Economics Letters*, Vol. 1, No. 2, pp. 91–92.

Tobin, James [1961], "Money, Capital and Other Stores of Value," *American Economic Review*, Vol. 51, No. 2, May, pp. 26–37.

____ [1969], "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit and Banking*, Vol. 1., No. 1, February, pp. 15–29.

Tatom, John A. [1979a], "Energy Prices and Capital Formation: 1972–1977," Federal Reserve Bank of St. Louis *Review*, Vol. 61, No. 5, May, pp. 2–11.

____ [1979b], "The Productivity Problem," Federal Reserve Bank of St. Louis *Review*, Vol. 61, No. 9, September, pp. 3–16.

Treadway, Arthur B. [1969], "On Rational Entrepreneurial Behavior and the Demand for Investment," *Review of Economic Studies*, Vol. 36, pp. 227–239.

United States Council of Economic Advisers [1980], *Economic Report of the President*, Transmitted to the Congress, January, Washington, D.C.: U.S. Government Printing Office.

United States Council on Wage and Price Stability [1979], *Productivity: A Report Submitted to the Congress*, July 23, Washington, D.C.: Executive Office of the President.

United States Department of Commerce, Bureau of Economic Analysis [1972], *Survey of Current Business*, Special Issue on the Measurement of Productivity, Vol. 52, Part 2, May, pp. 3–111.

Discussion

Paul R. Gregory*

I suspect I was invited to comment on Mr. Berndt's paper because of work co-authored with Jim Griffin arguing that energy and capital are substitutes. Perhaps it was anticipated that Berndt would argue that K-E complementarity was a contributory factor to the post 1973 productivity slowdown — a position I would then dispute. In Berndt's paper, K-E complementarity is not at all crucial; thus, this conference is deprived of one source on controversy.

I find myself in agreement with Berndt's major conclusions — an uncomfortable position for a discussant. The major issue addressed by Berndt is: Did the acceleration in the relative price of energy since 1973 play a significant role in the slowdown of labor productivity and total factor productivity in U.S. manufacturing? As Berndt demonstrates, if one attacks this question with the conventional tools of growth accounting and production functions, it is difficult to place much blame on a single factor (energy) that accounts for 1 to 2 percent of gross input costs. One must therefore search for indirect effects that are less obvious and more difficult to quantify.

Mr. Berndt is to be congratulated on his thoughtful exploration of the direct and indirect avenues through which energy affects productivity. The most innovative feature of his work is the estimation of a capacity utilization index (CU) that captures the impact of factor price changes on productivity. At the end of this discussion, I shall suggest additional approaches that Berndt may wish to consider, but I doubt that their pursuit would alter his basic findings.

Mr. Berndt's conclusions are: 1) Energy productivity has declined, but the energy share is too small to be an important explanation of the productivity decline. 2) The rise in the relative price of energy has not led to significant changes in factor proportions. There is little evidence of K-E complementarity (unless K is adjusted by a mechanical capacity utilization index). The rise in K/L has, in fact, prevented the labor productivity decline from being greater. 3) Changes in capacity utilization in a regime where K and white collar workers are quasi-fixed do not account for the productivity decline. 4) Indirect energy price effects working via Tobin's amended q_k are small and do not explain the marked decline in q_k noted by other researchers.

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5) The major factors in the productivity decline are the declines in K productivity and the productivity of white collar workers. Berndt argues that both of these factors are quasi-fixed.

To the student of growth accounting, the first conclusion is entirely expected. The second conclusion rules out the extreme effects on K/L ratios predicted by other researchers. Given conclusion 5, declines in capacity utilization appear to suggest a convenient scapegoat for the productivity decline, but Berndt's CU index shows no real change in CU in the base and terminal years of his sub-periods. Berndt's CU index does explicitly incorporate the short-run disequilibria effects of changing relative prices when K and white collar workers are quasi-fixed, thus ruling out an indirect energy effect on CU. In view of the innovative nature of Berndt's CU measure and the importance of CU, I suggest that Berndt elaborate his results beyond the limited discussion in his text.

A brief technical comment before proceeding to more substantive issues: Apparently Berndt has estimated K by deflating the K cost share by the rental cost. Yet during periods of low capacity utilization, the short-run shadow price of K falls below the rental cost, and variations in the ratio of the shadow price to the rental price of K will be attributed to K. It would appear appropriate to test the model using direct measures of capital stock as Berndt has done in previous work.

The most substantive question is whether Berndt's model could be modified using realistic assumptions to reverse his conclusion that energy was not a significant factor in the post 1973 productivity decline. One way to alter Berndt's conclusion is to abandon his approach entirely and to model energy's impact on inflation (an exogenous supply shock) and then inflation's impact on productivity. This matter has been brought to the attention of this conference already, and I leave it to wiser heads than mine for elaboration. Also one could turn to other sectors (utilities, for example) where energy is a more important input. If one remains within the confines of manufacturing and of Berndt's own cost function model, several experiments suggest themselves.

The first experiment would be to fit the model over a shorter period (concentrating, say, on the 1970s) to test for changes in economic structure. A Chow test on a split sample of 1958–73 and 1974–77 would be appropriate.

A second experiment would be to drop the assumption of a homogeneous capital stock. This may allow one to account for the failure of energy demand to decline as rapidly as predicted. Insofar as energy usage is tied to the engineering characteristics of the capital stock, substantial declines in energy demand may require substantive changes in the capital stock, and such changes occur slowly over time. Moreover, a heterogeneous capital stock allows one to link rising energy prices and Tobin's q_k. The rising price of energy may reduce the shadow price of existing capital, which now earns less quasi rent because it is an unwanted vintage. The decline in q_k means less new investment and thus less technological progress embodied in the production process.

I would be surprised if any of these modifications (short of going to a macro inflation model) would alter Berndt's basic point that energy has not played an important role in the productivity decline experienced by U.S. manufacturing, but Mr. Berndt may wish to deal with them in his further work on this subject.

Regulation and Productivity Growth

Robert W. Crandall*

In recent years, it has become increasingly fashionable to attribute a myriad of our economic and social difficulties to excessive government regulation. If we are to believe the rhetoric, government regulation is partly or largely to blame for soaring inflation, lagging growth in GNP, declining productivity growth, the decline in the value of the dollar, and even general reductions in the animal spirits of entrepreneurs. While many of these claims may eventually be shown to have some validity, the evidence linking regulation to these various national economic maladies is presently very weak.

The reaction against regulation which has developed in the past few years reflects the confluence of two different forces: (i) a growing concern that "economic" (rate-setting, entry-restricting) regulation overly restricts competition and protects regulated firms from new technologies and new competitors; and (ii) the view that newer "social" (health-safety-environmental) regulation directs too many resources to controlling various hazards, excessively reducing privately traded goods and services. These newer forms of regulation are generally the inspiration for the charge that business is over-regulated and thus unable to discharge its function of aggressively exploiting new technologies and bringing new products to the market as it once did. The result is declining productivity, a stagnant economy, and perpetual inflation.

It is not very difficult to see how this connection between stagflation and regulation has developed. Prior to the 1970s, the economy managed to grow at a rather satisfactory rate without bouts of major peacetime inflation. While we are discovering that productivity growth may have been declining throughout the post World War II period,[1] it did not begin its catastrophic decline until 1973.[2] Inflation surged in 1974 after the relaxation of price controls only to decline briefly, but then to surge ahead to double-digit levels by 1979. Given that the Occupational Safety and Health Administration, the Environmental Protection Agency, the National Highway Traffic Safety Administration, the Consumer Product Safety Commission, and the National Environmental Policy Act had their origins between 1969 and 1972 it is not surprising that many observers see a link between pervasive regula-

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[1] See Norsworthy *et al.* (1979)

[2] See Denison (1979) for a detailed analysis of this decline.

tion and stagflation. But this case has not been substantiated by thorough empirical work, and much of it may in fact not withstand careful scrutiny.

Even at a superficial level, it is difficult to place the blame for lagging productivity growth and inflation upon regulation. The 1970s were not tranquil years in other respects. The commodities boom of 1973 preceded the oil embargo and the subsequent surge in world oil prices. Price controls were in place for almost three years, and during part of this period macroeconomic policy was excessively stimulatory. Labor force participation rose at an unexpected rate. And the economy shifted gears from a fairly major war to virtual peacetime production. The confluence of these forces could be expected to have seriously disruptive effects upon the economy, and it would be naive to associate our ills solely with one of them.

In this paper, I can only review the evidence linking productivity growth and a few of the more extensive forms of regulation — environmental and worker-safety programs. I shall argue that whatever the effects of these policies upon recent productivity growth, there is a danger that the future effects may be more pronounced. This conclusion flows from the form which these policies take — a form dictated by political forces. Unfortunately, it will be very difficult to measure these future impacts upon capital formation and productivity growth, and by the time we are able to detect them it may be very difficult to alter course.

I. The New Social Regulation

The number of regulatory programs which affect input choices and production decisions in American business is staggering. A partial listing of the most important of these programs (and the agencies responsible for them) would have to include:[3]

Water pollution (EPA)	Employee safety — mining (MSHA)
Air pollution (EPA)	Employee safety — nonmining (OSHA)
Toxic substances (EPA)	Employee health — nonmining (OSHA)
Hazardous wastes (EPA)	Land use and surface mining (BLM)
Noise (EPA and FAA)	Food and drug safety (FDA and USDA)
Radiation (EPA and NRC)	Consumer product safety (CPSC)
	Automobile safety (NHTSA)

[3] For the noncognoscenti:
EPA = Environmental Protection Agency
FAA = Federal Aviation Administration
NRC = Nuclear Regulatory Commission
MSHA = Mine Safety and Health Administration
OSHA = Occupational Safety and Health Administration
FDA = Food and Drug Administration
BLM = Bureau of Land Management (Department of the Interior)
USDA = Department of Agriculture
CPSC = Consumer Product Safety Commission
NHTSA = National Highway Traffic Safety Administration

This is only a partial list, and it fails to account for the myriad of programs within each category. For instance, toxic substances may be regulated by EPA under FIFRA, RCRA, or TSCA.[4] In each instance, the criteria imposed by legislation are different, and firms must respond accordingly.

In virtually all of these regulatory programs, a standard-setting process is utilized to control the undesired externality. These take the form of "performance standards" — requiring, for instance, that regulated entities discharge no more than x parts per million into the air, water, workplace, or final product — or engineering standards — requiring the installation of specific control equipment or the use of specific production techniques. While economists have often been critical of the standards-setting approach to regulation because of its inefficiency,[5] it is likely to continue to be the predominant mechanism for instituting the newer social regulation. An important reason for this is that it suggests to the public that the particular problem is being addressed to the maximum extent feasible.

An unfortunate part of the standards-setting process is the tendency to saddle new facilities, products, or firms with tighter standards than those facing existing entities or products. This practice exists for a number of reasons. First, there is a popular view that new facilities or products can be designed more economically to limit the generation of undesired externalities than controls upon facilities or products already in existence. Retrofitting old facilities or redesigning existing products is more difficult than designing them *de novo*. Second, this practice conforms with a notion of "forcing technology." Setting ambitious goals for future products or plants will unleash engineers and scientists to create technological solutions heretofore thought impossible. Third, it is often impossible to enforce standards for older facilities or products, but simple to set very stringent standards and enforce them on newer facilities or products. Fourth, the political forces generally operate in favor of lenient treatment for existing products or plants.[6] Obviously, existing assets and products are likely to be more heavily represented in political decision-making than products or plants yet to be built. Finally, a regulatory process biased against new development and growth addresses a commonly expressed concern that market forces overexploit certain common-property resources such as air, water, and land. Slowing growth through regulation is one method — if an imperfect one — for managing these resources.

The pervasiveness of the bias against new facilities or products in federal government regulation cannot be demonstrated with precision. One would have to undertake a thorough review of all major regulatory programs, a task quite beyond the scope of this paper. Nevertheless, a few

[4] Federal Insecticide, Fungicide, and Rodenticide Act of 1972, Resource Conservation and Recovery Act of 1976, and Toxic Substances Control Act of 1976.

[5] The classic statement is in Weitzman and in Spence and Weitzman.

[6] See Crandall (1979) for some evidence.

important examples might provide the reader with sufficient evidence to form an *a priori* case that the bias exists:

- The Congress requires EPA to establish "best available control technology" standards for all *new* stationary sources of air pollution, but existing sources often escape regulation altogether because of inadequate state emissions inventories or insufficient funds for enforcement.
- As the Congress has set increasingly stringent air-pollution standards for new automobiles, it has steadfastly refused to require states to pursue retrofitting policies for older vehicles.
- Although enforcement of standards for conventional water pollutants from existing industrial sources has been incomplete, tighter "best available control technology" standards for new sources have been enforced by EPA.
- In order to protect less developed regions of the country from environmental degradation (and more developed regions from loss of economic activity), Congress has required EPA to set tighter air pollution standards in the less populated regions of the country.
- In regulating chemicals under the Toxic Substances Control Act, EPA requires premarket notification and testing of new chemicals, but it lacks the resources to provide similarly thorough analyses of all chemicals already on the market.
- In determining the efficacy and safety of nonprescription drugs, FDA is moving much more slowly on older drugs which are already on the market than on new introductions.
- Congress has required EPA to mandate flue-gas desulfurization systems on all new power plants using coal, regardless of the coal's sulfur content. This was required to prevent midwestern utilities from substituting low-sulfur coal from new western surface mines for higher sulfur coal from older Appalachian mines.
- The National Highway Traffic Safety Administration's safety standards for automobiles apply only to new automobiles, not to used vehicles.
- HUD has proposed a rule requiring developers to submit "urban-impact statements" demonstrating that new shopping malls will not damage older shopping districts in downtown locations when federal funds are involved.
- The Department of Energy has proposed strict new energy-conservation building codes for new buildings, but is not proposing the retrofitting of older buildings.

This list is not intended to be exhaustive, but it provides some evidence of the new-source bias in environmental, health, safety, and energy regulation. Similar lists could be compiled for traditional entry-restricting, rate-setting regulation. The CAB, ICC, and FCC have required licenses to be obtained for new facilities, and each has found itself confronted with the pressure from existing regulated carriers to resist these applications. Large freight cars, larger commuter airline planes, and satellite business systems have been delayed as regulatory procedures are extended by intervening competitors or other interested parties.

Given the central role of technological progress in improving productivity, these regulatory biases against new products and facilities must have some effect upon productivity growth. This is particularly true if one accepts the view that much of technology is embodied in new assets and cannot be adapted easily to older assets. In some cases, this regulatory bias is damaging even if retrofitting is possible. "New sources" of pollution are generally defined to include older facilities which are temporarily closed for renovation. Thus, one would expect environmental policy to be reducing the rate of technological diffusion in basic pollution-intensive industries. To the extent that other regulatory policies (some of which are enumerated above) share this bias, productivity growth will be further reduced.

Note that the above argument concerning the relationship between regulation and productivity is quite different from that generally addressed by students of productivity growth such as Denison, Kendrick, or Norsworthy. Productivity growth is reduced in their empirical analyses by a diversion of productive resources away from the production of private goods and services towards mandated health, safety, or environmental facilities. These resources are used to *produce* less noise, more safety, or less pollution. New facilities are foregone only because resources are diverted to these compliance requirements. I am arguing that investments are foregone not simply because resources are invested in complying with regulations but because the regulations themselves discourage what would otherwise be productive investments. Savings are thereby diverted to less productive investments in other sectors of the economy, and productivity growth declines.

II. Regulation and Productivity Growth — The Crude Evidence

A useful point of departure for a survey of the effects of regulation on productivity growth is a sectoral breakdown of productivity trends since World War II. If regulation were responsible for much of the recent decline in productivity, one would expect to observe sharper declines in mining, utilities, and manufacturing than in, say, trade or services. In fact, Table 1 drawn from Norsworthy et al. displays some rather puzzling trends.

The rate of growth of labor productivity in the private business sector has clearly been declining since World War II; moreover, the rate of decline has been accelerating. Productivity growth in manufacturing is declining at a more moderate rate than the average for the economy while productivity in mining and construction has been actually *falling* at a precipitous rate. It is interesting, however, that two traditionally regulated sectors — communications and finance — have evidenced rising trends while the labor-intensive sectors, such as trade, services, and construction, have suffered declines in productivity growth. Since none of the latter three sectors has been heavily impacted by environmental, health, and safety regulations, it is clear that the new forms of regulation can hardly be the sole culprits in our postwar productivity slide.

Table 1
Trends in Labor Productivity by Major Sector (1948–1978)

	Average Annual Rate of Growth of Output per Manhour		
	1948–65	1965–73	1973–78
Private Business	3.2	2.3	1.1
Sectors with rising productivity trends:			
Communication	5.5	4.8	7.1
Finance, Insurance and Real Estate	1.0	-0.3	1.4
Sectors with modestly declining productivity trends:			
Agriculture	5.5	5.3	2.9
Manufacturing	3.1	2.4	1.7
Sectors with sharply declining productivity trends:			
Mining	4.2	2.0	-4.0
Trade	2.7	3.0	0.4
Utilities	6.2	4.0	0.1
Construction	2.9	-2.2	-1.8
Services	1.5	1.9	0.5
Transportation	3.3	2.9	0.9

Source: Norsworthy et al.

The only clear indictment of regulation as the source of productivity declines which emerges from Table 1 is in the mining sector. The decline in labor productivity in mining occurred precisely in the year in which much more stringent mine-safety legislation was enacted, 1969.[7] For instance, in the previous 10 years, productivity in coal mining was growing at 5.8 percent per year. Thereafter, it *declined* at a rate of 3.2 percent per year.[8] While other forces may have been at work, it is difficult to avoid the conclusion that a heightened concern for worker safety had much to do with this stunning reversal.

The sharp decline in utilities suggests, however, that two other major influences may be at work — the sharp rise in energy prices in 1973–74 and the deep recession of 1974–75. In fact, the timing of an absolute decline in utilities' labor productivity in 1974 and 1975 provides further evidence of the importance of these forces.

Why has manufacturing held up so well? If we look in detail at manufacturing, we see major differences in productivity growth trends across industries. Moreover, as Table 2 shows, the industries with the sharpest decel-

[7] Federal Coal Mine Health and Safety Act of 1969.

[8] U.S. Department of Labor, Bureau of Labor Statistics, *Productivity Indexes for Selected Industries, 1979 Edition,* Bulletin 2054.

Table 2
Pollution & Worker-Safety Capital Outlays and Productivity Growth—Selected Industries (1959-77)

Industry	SIC *Code*	Pollution Control Capital Expenditures 1973-77 (million $) *BEA*	*Census*	Employee Health and Safety Capital Expenditures 1973-77 *(million $)*	Value-Added 1976 *(million $)*	Average Increase in Output per Employee Hours (% per year) *1959-70*	*1970-77*	*1959-73*	*1973-77*
Grain Milling	204	—	158	—	6083	3.9*	3.9	3.3**	5.3
Pulp Mills	261		393		975				
Paper Mills	262	2328	1124	276	4878	4.2	3.3	4.5	1.5
Paperboard Mills	263		640		3128				
Bldg. Paper Mills	266		17		240				
Inorganic Chem.	281		689		6165	3.4	2.5	4.0	-0.2
Plastics Mat.	282	3058	531		6648	3.7	8.1	5.5	4.9
Indus. Org. Chem.	286		1434	854	11348	5.6	3.2	6.4	-1.4
Misc. Chemicals	289		169		3119	0.7	3.9	1.5	3.6
Petroleum Refining	291	5069	2041	1053	11410	5.0	3.7	5.6	0.7
Hydraulic Cement	324	—	318	—	1461	3.8	2.5	4.1	0.4
Steel	331	1791	1987	358	17274	1.3	1.9	2.5	-1.4
Copper, Lead, Zinc	3331,2,3	2369	652***	436	1051	1.5	3.5	2.5	1.4
Aluminum	3334		317		1466	2.6	0.6	2.5	-0.4
Total, Above Industries		14615	10470	2977	75,245	3.5	3.4	4.2	0.8
		(47.0%)	(65%)	(21.9%)	(14.7%)				
Total, All Manufacturing		20106	16108	7000	511,471	2.6	2.8	2.9	1.8
		(64.6%)	(100%)	(51.4%)	(100%)				
Total, All Mfg. less Above Industries		5491	5638	4023	436,226	2.4	2.7	2.7	2.0
		(17.7%)	(35%)	(29.5%)	(85.3%)				
Mining		414	—	563		3.9	-3.4	2.9	-5.9
		(1.3%)		(4.1%)					
Electric and Gas Utilities		8987	—	887		5.9	2.3	5.3	1.3
		(28.9%)		(6.5%)					
Total, Above Industries		24016	—	4427		—	—	—	—
		(77.2%)		(32.5%)					
All Industries		31105	—	13617		2.3	1.7	2.4	0.9
		(100%)		(100%)					

* — 1963-1970
** — 1963-1973
*** — *Excludes spending by SIC 3331 and 3333 in 1977.*
Source: See fns. 8-11. Productivity Data for SIC 28 are unpublished BLS Data.

eration in productivity growth are those which account for most of the pollution-control and worker-safety outlays.

Expenditures for either pollution control or worker safety include capital outlays and current operating expense. Unfortunately, there are no cross-sectional data on the operating costs of mandated occupational safety and health measures. McGraw Hill publishes rough two-digit industry breakdowns of capital outlays on worker health and safety.[9] Similarly, BEA has published estimates of capital spending for pollution control by major industry categories since 1973,[10] and the Census publishes detailed manufacturing-industry data on both capital outlays and operating expenditures for pollution control.[11] To provide rough comparability, I have reproduced in Table 2 only the capital outlays for 1973–77 for pollution control and worker safety in the most affected industries.

A very small number of manufacturing industries, comprising about one-seventh of total manufacturing value-added, account for nearly two-thirds of pollution capital spending in manufacturing and nearly half of all such expenditures by private industry. These same manufacturing industries — mainly paper, chemicals, refining, and primary metals — also account for almost one-half of manufacturing capital outlays for worker safety. Have these outlays affected productivity growth, as measured by the rate of increase in privately traded output per employee hour?

As Table 2 demonstrates, the rate of productivity growth in the regulation-impacted manufacturing industries has slowed considerably since 1970 and drastically since 1973. While the average manufacturing industry showed a slight increase in productivity between the 1959–70 and 1970–77 periods, the average rate of growth slowed somewhat for the regulation-impacted industries. But the difference between 1959–73 and 1973–77 is more dramatic. Average manufacturing productivity growth declined by almost 40 percent between these two periods — from 2.9 percent per year to 1.8 percent. Productivity growth in the heavily regulated industries fell from a level of nearly 50 percent above the manufacturing average in 1959–73 to less than 1 percent per year in 1973–77. Some high productivity growth industries became negative growth industries in the years after 1973. The implication is clear — regulation appears to be associated with sharp declines in productivity growth in certain manufacturing industries, electric utilities, and mining. But is it the causal agent? And, if so how does this causation operate? We turn to these issues after pausing to examine the quality of the available data.

III. The Problem of Measurement

At present, our sole measure of the stringency of regulation is the estimate of compliance costs available through Census, BEA, or McGraw Hill.

[9] Annual McGraw Hill Survey — *Investment in Employee Safety and Health.*

[10] U.S. Department of Commerce, Bureau of Economic Analysis, *Capital Expenditures for Pollution Abatement.* (Published annually in the *Survey of Current Business.*)

[11] U.S. Department of Commerce, Bureau of the Census, *Pollution Abatement Cost and Expenditures,* annual issues.

Companies report compliance costs for pollution control or worker safety, but it is far from clear that these estimates are very accurate or unbiased. Given the form of regulation, a standards-setting process in which administrators are encouraged or instructed to be "reasonable," there is likely to be an upward bias to reported compliance costs.

Equally important is the difficulty in separating compliance costs from other costs of doing business. If pollution control simply means installing a device to capture a residual from the production process which is then buried safely or disposed of by some other firm, the measurement of the costs of compliance might be straightforward. But few pollution or worker-safety problems lend themselves to so neat a solution. Different materials might be used so as to reduce the externalities problem. If utilities switch to low-sulfur coal, how are compliance costs to be measured? The utilities will observe a bidding up of low-sulfur coal prices and a decline in higher sulfur coal prices. How can they know what prices would have been in the absence of regulation?

Another problem derives from the fact that the residuals captured are often fairly valuable. Hydrocarbons or sulfur captured through the treatment of exhaust gases obviously have value, but it is not clear that the sales of these products or the internal use of them is netted out of compliance costs.

Any new investment in a cleaner production facility will produce some efficiency gains. Building a new steel mill which captures more of the energy byproducts and exhaust gases will reduce pollution. But the added investment in pipes and related equipment will also reduce the energy required to make a ton of steel. How much of the exhaust gas system should be credited to pollution control and how much to improved efficiency?

Finally, there are major problems of double counting across regulatory programs. Anything which reduces the discharge of hazardous substances into the environment is also likely to reduce the risk to workers. Are these expenditures reported both to BEA as "pollution" capital expenditures and to McGraw-Hill as worker-safety investments? For example, the refurbishing or reconstruction of a coke oven battery will clearly reduce the discharge of hazardous particulate emissions. But the investment in lower emissions also reduces the risk to workers and is likely to help satisfy OSHA's standard. How can we be sure that the share of the investment in "productive" equipment is separated from "pollution-control" investment and "worker-safety" investment?

To test for the possibility of bias in reported estimates of capital spending for regulation is simply not possible. How do we know what is actually spent in pursuit of regulatory compliance? If we had a more rational regulatory scheme, we would at least have benchmarks against which to assess reported control costs. For instance, if pollution were rationed by price or if discharge rights were tradable, we would have some basis for estimating the incremental costs of control. Or if EPA or OSHA employed civil penalties scaled to the degree to which a firm was generating harmful externalities, we would have a similar measure. Unfortunately, given the enormous array of administratively determined standards and the apparent difficulty in enforcing them, one cannot deduce anything from existing regulatory procedure about costs. Nor do EPA and OSHA have an accurate inventory of dangerous externalities generated before controls were employed; hence, even if we knew the incremental cost of control, we cannot know how much total control each source has employed. It is therefore impossible to make some assumptions about the shape of the incremental cost of control function and to integrate it to obtain a measure of total costs.

In another paper, I have made a mild attempt at estimating potential bias in reported pollution-capital spending data.[12] The Business Roundtable[13] employed Arthur Andersen and Company to carry out a very detailed analysis of regulatory costs for 48 major firms. These data may still be subject to an upward bias, but at least the framework for collecting and tabulating them was developed in advance with the assistance of outside experts. Moreover, the approach should be consistent across all firms — a consistency which may be lacking in other series. Extrapolating from these 48 firms to all industry is obviously hazardous given that the Roundtable firms comprised only 2 to 59 percent of investment outlays and 9 to 30 percent of sales in their two-digit industries. Nevertheless, an extrapolation based upon 1977 sales results in an estimate of pollution-control investment which is 14 percent lower than the corresponding BEA data for the relevant industries. Using the share of total investment accounted for by the reporting firms generates an even lower estimate of pollution capital spending, almost 20 percent below the BEA estimate for 1977. (See Table 3.)

In short, there is reason to believe that we do not have very good estimates of the size of these outlays and that the reported investment may be biased upward. Were this the only problem in measuring the effects of regulation, some thorough cost accounting reviews by government statistical authorities might improve the accuracy of the numbers. Unfortunately, there are other problems.

IV. Reduction of Productivity Growth through the Diversion of Capital

It is clear that the manufacturing industries most heavily impacted by regulation have suffered the steepest declines in productivity growth. Similar conclusions hold for the mining and utilities sectors. But how could regulation cause this effect? The most straightforward explanation — that adopted by Denison and Norsworthy et al. — is that resources devoted to regulatory compliance are resources which cannot be utilized to produce privately traded goods and services. Denison measures the total factor costs of such compliance while Norsworthy et al. simply remove pollution-control capital outlays from the capital stock to estimate the potential effect upon produc-

[12] See Crandall (1979)
[13] Business Roundtable, *Cost of Government Regulation Study*, 1979.

Table 3
Comparison of Business Roundtable and BEA Estimates of Incremental Capital Outlays for Pollution Control (millions of $)

Industry (1)	Industry Shares of Reporting Firms: Sales (2)	Investment (3)	Estimated Environmental Capital Outlay for Reporting Firms (4)	Estimated Industry Totals Using for Divisor Sales (5) = (4) (2)	Investment (6) = (4) (3)	BEA Estimates (7)
26	.09	.16	81	474	267	468
28	.21	.42	565	1418	709	701
29+13	.14	.18	182	685	533	1167
33	.09	.13	222	1300	900	927
35	.13	.32	40	162	66	104
36	.24	.21	40	88	100	111
37*	.30	.59	726	167	85	163
38**	.14	.24	20	75	44	—
49	.05	.02	81	853	2134	2300
TOTAL (Excluding SIC 38)				5147	4794	5941

* Excludes motor vehicle program costs.
** BEA data cover wider industry definition.
Source: BEA and The Business Roundtable, *Cost of Governmental Regulation Study*, 1979.

tivity. The latter approach is generally found in popular discussions: capital devoted to regulatory compliance can only come at the expense of "productive" investment (assuming the saving rate is held constant). Therefore, capital deepening is slowed and the embodiment of new technology in plant and equipment is retarded with obviously deleterious effects upon productivity.

The standard explanation of the effects of diverting capital from productive investments to regulatory compliance is obviously correct as far as it goes. The only possible counter-explanation strains credulity for it suggests that businessmen are goaded into more efficient production techniques by all-knowing regulators. According to this argument, the pollution control in a pulp mill may be a free lunch since the EPA mandated standards reveal to engineers in the paper industry a new method of making pulp of which they had been ignorant. This new technology so strongly dominates the old that it allows the management to retrofit old facilities, install pollution control devices, and produce paper at unit costs which are as low as or lower than preregulatory costs.

As I have suggested earlier, however, the simple measurement of resources diverted to regulatory controls may not suffice in estimating the social costs of regulation. But it is likely during the formative years of environmental, health, and safety policy that actual outlays on compliance are likely to be the most important sources of lost output due to regulation. Can this deduction be borne out by the evidence? If regulation leads to a diversion of capital resources from productive investments and if these industries evidence sharply declining rates of productivity growth, one might expect capital formation (net of pollution capital) to have slowed substantially in the 1970s in these heavily impacted industries. In fact, as Table 4 demonstrates, this did not occur during the 1973–76[14] period (when productivity growth declined most rapidly), in the manufacturing industries identified in Table 2.

Using BLS methodology for calculating the gross capital stock, I removed pollution-control investments from the gross and net capital stock data for the heavily impacted industries in our sample. Unfortunately, data do not exist for years prior to 1973; hence, the capital-stock growth estimates for years prior to 1973 include pollution-control capital. While it would have been nice to eliminate worker-safety outlays as well, the data are not disaggregated sufficiently to permit such a calculation.

The pattern of capital-stock growth exhibited by the pollution-control impacted industries is surprising to say the least. As Table 4 shows, these industries showed very little decline in 1973–76 compared to their 1959–73 rates. Since BLS does not report manufacturing capital stock series without pollution-control capital, the 3.7 and 3.5 percent growth rates for all manufacturing for 1973–76 must be adjusted downward. Given the share of investment going to pollution control in 1974–76, this downward adjustment is about 0.8 percentage points. Hence, in 1973–76, the average manufacturing industry showed lower capital-stock growth than those investing heavily in pollution control even after netting out all pollution-control capital!

A few caveats to the above analysis are in order before moving to other topics. First, the average rate of growth of the capital stock for all manufacturing shows little deceleration in the 1970s and none since 1973. This is in sharp contrast to the results of Norsworthy et al. The reason is that Norsworthy et al.'s capital stock data are translog weighted estimates of the capital stock for 1973–78. I have used simpler BLS estimation methods for a shorter period, 1973–76.

Denison argues that one should use a weighted average of the gross and net measures, heavily weighted towards the gross stock. This is not the place to attempt to resolve such a difference of opinion over methodology, but I favor Denison's approach because of the difficulties in interpreting depreciation rates.

Second, any attempt to draw conclusions concerning 1973–76 must be viewed as hazardous at best. Given the sharp commodities boom in 1973, the oil-price rise in 1974, and the deep recession in 1975, it would be difficult to make much of three years' data on capital growth. How, for example, are we to treat the excessive investment by some steel companies in raw materials processing occasioned by the 1973–74 boom? Given the forced closure of aluminum smelting capacity because of energy shortages, what is the meaning of capital stock in this industry? Might the continued growth in capital stock and declining productivity not simply be the reflection of a recession following so closely on the heels of a commodity boom?

[14] Capital-stock data by industry are available only through 1976.

Table 4
Capital Formation in Pollution-Control Impacted Industries (1959-76)
(Excluding Pollution-Control Capital — 1973-76)

Industry	SIC	1959-70	1970-76	1959-73	1973-76
		(Annual Growth Rate in Gross Capital Stock)			
Grain Milling	204	3.3	4.2	3.4	4.5
Pulp Mills	261	-1.3	-1.6	-1.6	-0.4
Paper Mills	262	6.5	0.4	5.4	-0.3
Paperboard Mills	263	5.8	5.6	5.2	7.8
Bldg. Ppr. & Bd. Mills	266	2.8	2.8	2.6	3.5
Inorganic Chem.	281	3.2	1.3	2.6	2.0
Plastic Material	282	7.2	4.6	6.6	5.0
Ind. Organic Ch.	286	6.1	5.0	5.5	6.6
Misc. Chemicals	289	3.8	4.0	3.6	5.0
Petr. Refining	291	1.1	5.0	1.6	6.6
Hydraulic Cement	324	-0.2	1.2	-0.1	1.8
Steel	331	3.3	-0.3	2.4	0.2
Copper	3331	9.2	3.2	9.1	-2.4
Zinc	3333	-1.2	-0.7	-1.5	1.5
Aluminum	3334	3.0	-0.8	2.5	-2.4
Total of Above		4.0	2.4	3.5	3.2
All Manufacturing (*Including* Pollution Control Capital)		3.6	3.3	3.5	3.7
		(Annual Growth Rate in Net Capital Stock)			
Grain Milling	204	3.1	4.3	3.3	4.7
Pulp Mills	261	-3.0	-0.3	-2.7	1.1
Paper Mills	262	6.4	-1.1	5.0	-2.0
Paperboard Mills	263	5.6	5.6	5.0	8.6
Bldg. Ppr. & Bd. Mills	266	2.7	2.7	2.6	3.4
Inorganic Chem.	281	2.8	1.1	2.2	2.0
Plastic Material	282	7.2	4.0	6.4	4.5
Ind. Organic Ch.	286	6.2	4.7	5.5	6.8
Misc. Chemicals	289	3.8	4.0	3.6	5.1
Petr. Refining	291	1.9	5.3	2.3	6.9
Hydraulic Cement	324	-1.9	2.6	-1.1	3.3
Steel	331	3.5	-1.3	2.3	-0.6
Copper	3331	9.7	1.2	9.3	-5.9
Zinc	3333	-1.9	-0.2	-2.0	2.1
Aluminum	3334	1.9	-1.4	2.1	-3.7
Total of Above		4.0	2.0	3.3	3.0
All Manufacturing (*Including* Pollution Control Capital)		3.7	3.1	3.5	3.5

Source: BLS

V. A Review of the Published Estimates of the Effects of Regulatory Expenditures

Most of the recent research on the effects of regulation upon productivity have centered on environmental policy. Denison's study[15] is an exception, but his recent updating of his 1978 study[16] involves only pollution-control spending. Norsworthy et al.[17] have examined only the effects of pollution-capital outlays upon productivity by major sector. Finally, I have attempted to measure the impact of pollution control spending — capital and operating costs — on productivity in a recent paper.

Denison's study of the effects of regulation upon the recent growth in productivity is clearly the most exhaustive and painstaking of the empirical analyses. He attempts to measure the incremental costs of pollution-control and worker safety (as well as protection against crime) for the private business sector. Excluded from his analysis, therefore, are environmental outlays by government (such as municipal sewage expenditures) and by households (on their automobiles, for instance). He provides a clear explanation of how *increases* in the value of resources devoted to these pursuits reduce the rate of increase in productivity. Since these expenditures were rising rapidly in the mid-1970s, their reduction of potential productivity growth peaked in 1975 at 0.35 percentage points. Between 1975 and 1978, Denison finds that the environmental component of these costs was reducing productivity growth by only 0.08 percentage points per year, down sharply from 0.22 points in 1975, because environmental control outlays were rising less rapidly after 1975 than before.

Norsworthy et al. measure the impact of environmental policy on productivity growth solely through its diversion of capital inputs. In the 1973–78 period, pollution control reduced the growth of capital inputs in productive activity from 2.31 to 2.05 percent for the entire private business sector and from 2.16 to 1.47 percent per annum in the manufacturing sector. The net effect of this reduction in capital input was to lower labor productivity growth by 0.1 percent per year in the private business sector and 0.2 percent per year in manufacturing.

The Denison and Norsworthy et al. approaches to measuring the effects of regulation upon productivity growth have been criticized by Smith and Kopp[18] and by Christiansen, Gollop, and Haveman.[19] They contend that such approaches fail to take into account the effects of regulation upon optimal factor proportions. Moreover, Christiansen et al. argue that Denison's approach provides an upper bound estimate to the effect on productivity because (in addition to factor-choice changes) regulation may draw from underemployed resources or it may result in a higher marginal productivity of

[15] Denison (1978)
[16] Denison (1979a)
[17] Norsworthy et al., (1979)
[18] Smith and Kopp (1980)
[19] Christiansen, Gollop, and Haveman (1980)

resources which remain in the private sector for nonregulatory goals. While these effects would seem to be small if not negligible, the criticism of ignoring changes in factor proportions appears well taken. Note, however, that changes in factor proportions may actually lead to an *underestimate* of compliance costs. Bidding up the price of low-sulfur coal or substituting electric furnaces for blast furnaces and oxygen furnaces in steel production may generate improvements in regulatory compliance without measured outlays on pollution control.

There is a more important reason why Denison and Norsworthy et al. may underestimate the effects of regulatory policy upon productivity growth. Recall the argument in Section I, above. Regulatory policy is strongly biased against new sources of the undesirable externality for a large number of reasons. This bias translates into regulatory discouragement of investment in new facilities and particularly in growing areas of the country. The loss in output from foregone opportunities may well become more important than the opportunity cost of resources required to meet regulatory standards. In the extreme case, one could imagine, for example, that EPA would simply refuse to license any new utility plants or manufacturing facilities but fail to enforce standards on existing facilities. Air and water quality might improve even though "compliance costs" were zero! But opportunities to install highly efficient new aluminum pot lines or fluidized bed combustion facilities would be foregone. Productivity growth would be stunted by this repressive policy, industry could be insulated from new thrusts of entry, and the administrator of EPA would boast that the "cost" of regulation had been reduced to zero. Thus, Christiansen et al. are incorrect when they argue that Denison's estimate of the effects of regulatory policies is likely to be an upper limit of the actual effects of regulation on productivity growth.

In Denison's recent book, *Accounting for Slower Economic Growth*,[20] he argues that much of the decline in productivity growth is due to a reduction in the contribution of advances in knowledge and other unexplained sources. This effect is reflected in a decline in the size of the "residual" — which remains after accounting for changes in input quantity and quality — from 1.4 percent per year in 1948–73 to -0.8 percent in 1973–76. According to Denison, very little of this decline in the residual could have occurred because of the slowdown in capital formation after 1973. While some of the improvement in knowledge cannot be utilized until it becomes embedded in new capital facilities, Denison argues that the new investments embodying the greatest improvements will be those most likely to be funded when capital market conditions are unfavorable. As capital formation slows, the projects embodying the smallest advances in knowledge will be those postponed or cancelled.

Denison's argument is sound for those situations in which investment projects are rationed by a market. But when regulators intervene to prevent new facilities from being built, there is no guarantee that they will act so

[20] Denison (1979)

benignly. Discouraging new petrochemical facilities in the Southwest or forbidding new power plants in the West may result in substantial reductions in the embodiment of new knowledge in the capital stock. Certainly, EPA's new source performance standards which discourage steelmakers from adopting the newest technology in existing plants must have such an effect.

There are no other conclusive studies of the effects of regulation per se upon productivity growth. There is, however, a lively debate concerning the impact of a reduced rate of capital formation upon productivity growth and, in turn, the causes of the reduction in capital formation itself. Clark[21] argues that reduced capital formation caused nearly all of the deceleration in productivity in 1965–73, but appears to agree with Denison that other factors must have been responsible in 1973–76. Similarly, Norsworthy et al. find that reduced capital formation may have been a major culprit in 1965–73, but not in 1973–78. On the other hand, Hudson and Jorgenson[22] argue that increased energy prices reduced capital formation in the 1972–76 period, inducing a substitution of labor for capital *cum* energy. Labor productivity was reduced by 2.6 percent between 1972 and 1976 from this energy-induced effect upon the capital-labor ratio, per their analysis. Denison, of course, argues that reduction in the growth of capital inputs accounted for a very small percentage of the reduction in productivity growth.

It is neither possible nor necessary to resolve differences of opinion concerning the effect of capital-stock growth upon the recent productivity slide in this paper. It is sufficient to point out that the size of the effect is uncertain, that the connection between regulation and reduced capital formation is far from conclusively demonstrated, but that capital devoted to controlling various externalities must reduce potential output of traded goods and services. Recent speculation concerning the effect of regulation on uncertainty, lead times for new projects, or the length of time to complete the projects may well turn out to be correct.[23] At present, however, regulation remains indicted in the literature, not convicted.

VI. Some Limited Cross-Sectional Evidence

If outlays on pollution control or worker safety are responsible for slowing productivity growth, we should be able to detect such effects in a cross-sectional analysis of industries which face different compliance requirements. Ideally, we would like to have a large sample of industries from which to draw observations and a considerable period of time over which to observe the effects of regulation. Unfortunately, we have neither. The intersection of the set of manufacturing industries for which published productivity data are available and the set of industries for which capital-stock data exist is only 18. Another 11 industries are available if one wishes to use unpublished produc-

[21] Clark (1979)
[22] Hudson and Jorgenson (1978)
[23] See Malkiel (1979) and Quarles (1979)

tivity series, but the output data on which these latter series are based are unreliable. Moreover, capital-stock data are available from BLS only through 1976 although with some effort these data could be extended forward to 1977 or 1978. Unfortunately, that effort was beyond the scope of this paper.

In previous work,[24] I have attempted crudely to measure the effect of pollution control costs on productivity growth by estimating the effects of changes in capital-labor ratios, energy intensity, and industry output upon the deviation of productivity from its long-term industry trend. The results of this analysis were, at best, inconclusive.

In this section, I attempt to estimate a more conventional form of a productivity growth equation, employing data from the 18- and 29-industry samples alluded to above.[25] In (1), the growth in labor productivity, measured as the percentage change in output per manhour between 1973 and 1976, is related to weighted changes in the growth of capital, labor, and regulation inputs. Specifically, the equation takes the form:

$$(1) \quad \dot{q}/l = a_o w_k \dot{l} + a_2 w_k \dot{k} + a_3 w_k \dot{r}$$

where the lower-case letters with dot superscripts represent percentage changes during the 1973–76 period, q is output, l is labor input, k is capital input, and r is regulatory cost.

To estimate (1), I use BLS estimates of the industry's gross capital stock (K_g) or net capital stock (K_n), excluding pollution-control capital. For the labor input, I use total manhours as reported in the *Annual Survey of Manufactures*. For the regulatory input, I use the *operating* costs of pollution control facilities (POL), as reported by the Census Bureau. Finally, capital's share of value added is obtained from the *1976 Annual Survey of Manufactures*. An additional variable for worker-safety capital outlays was included, but the results were inconclusive due the absence of sufficiently disaggregated data in the McGraw-Hill survey.

The results of estimating (1) are reported in Table 5. As expected, the precision of the estimates is greater for the 18-industry sample than for the 29-industries. The coefficients of the weighted labor input and capital stock variables are of the expected (opposite) signs, and they are statistically significant in the 18-industry regression when gross capital stock is employed. Moreover, the percentage change in pollution-control costs reduces productivity growth as expected. Given an average value of w_k of approximately 0.5 in the 18-industry sample, the results suggest that a doubling of pollution-control costs reduces productivity growth by 7 percentage points.

[24] See Crandall (1979)

[25] The industries in the 18-industry sample are: (SIC) 203, 205, 2421, 2434 and 2436, 251, 2611 & 2621 & 2631 & 2661, 2851, 291, 3011, 314, 322, 3241, 325, 331, 332, 3334, 341, 371. The 29-industry sample includes the above plus 204, 264, 265, 281, 2821, 286, 287, 3331, 249, 289, and 329. These industries include most of those in Table 2, which in turn are the most pollution-control impacted industries.

Table 5
Regression Estimates for Percentage Change in Productivity, 1973-76, Selected Manufacturing Industries (t-statistics in parentheses)

		Wghtd. Percentage Change, 1973-76, in:				
Sample Size	Constant	Gross Cap. K_g	Net Cap. K_n	Emp. Hrs. L	Pol. Costs POL	$\bar{R}^2$
18	0.800	0.6286		-0.9199	-0.1399	0.351
		(2.51)		(2.02)	(2.01)	
29	3.065	0.3008		-0.6785	-0.0838	0.180
		(1.50)		(1.74)	(1.61)	
18	1.574		0.4615	-0.8755	-0.1219	0.251
			(1.90)	(1.77)	(1.64)	
29	2.906		0.2779	-0.7724	-0.0807	0.166
			(1.33)	(1.75)	(1.54)	

Neither the worker-safety capital outlay growth variable nor an energy-utilization growth variable added to the explanatory power of equation (1). When a variable representing the deviation of industry output in 1976 from its long-term (1960–73) trend was introduced, however, it reduced the precision of the estimates of the other variables, particularly the pollution-cost variable. This occurs because of an inverse correlation between industry growth in the sample and pollution-cost growth. In short, it appears that rising pollution-control costs increase unit costs and output prices, thereby reducing demand for the industry's product. Of course, to "explain" flagging productivity growth by a variable which captures slower output growth is a bit circular; hence, the result is not reported.

VII. Concluding Comments

It is clear that we have not yet begun to explore the effects of the new "social" regulation upon economic performance. The casual evidence that worker-safety and pollution-control programs reduce productivity growth is abundant, but it is more difficult to demonstrate this effect with precision once one delves into disaggregated data. In part, this may be due to poor data and too short an historical period over which to search for the effect. In addition, if regulation operates by discouraging new projects or products, there is no very good indicator of the severity of regulation across industries. It is very difficult to measure opportunities foregone.

There are continuing criticisms from the proponents of stricter regulation that analyses of the cost of regulation or of its effect upon productivity ignore the benefits of regulation. If all output were counted, they contend, productivity might actually be shown to be increasing. Unfortunately, the evidence on the "benefits" of environmental and worker-safety regulation is even more scarce than data on the costs or privately traded output effects. There is no conclusive evidence, other than the mine-safety example alluded to above, that the standard environmental programs and OSHA policies have cleaned up the air or water or improved worker safety. The full effects upon output of our recently conceived regulatory policies are therefore unknown. The danger exists, however, that by the time we understand these effects we will have so discouraged investment in new facilities in basic industries that revival of these sectors will be difficult. Owners of tired old (overvalued) assets will be as potent a force against regulatory change as taxi medallion owners in New York or small refineries have proven to be in other regulatory arenas.

REFERENCES

The Business Roundtable. *Cost of Government Regulation Study*, 1979.

Christiansen, Gregory; Frank Gollop; and Robert Haveman. *Environmental and Health/Safety Regulations, Productivity Growth and Economic Performance*, Report prepared for Office of Technology Assessment, January 30, 1980.

Clark, Peter K. "Issues in the Analysis of Capital Formation and Productivity Growth," Brookings Papers on Economic Activity, 1979:2.

Crandall, Robert W. "Is Environmental Policy Responsible for Declining Productivity Growth?" Paper delivered at Annual Meeting of the Society of Government Economists, Atlanta, December 28, 1979.

Denison, Edward (1978). "Effects of Selected Changes in the Institutional and Human Environment upon Output per Unit Input," *Survey of Current Business*, January 1978, pp. 21–44.

—— (1979). *"Accounting For Slower Economic Growth,"* Washington, D.C.: The Brookings Institution, 1979.

—— (1979a). "Pollution Abatement Program: Estimates of Their Effect Upon Output per Unit Input," *Survey of Current Business*, August 1979. Part I, pp. 58–59.

Hudson, Edward H. and Dale W. Jorgenson. "Energy Prices and the U.S. Economy, 1972-76," *Data Resources Review*, September 1978.

Malkiel, Burton. "Productivity — The Problem behind the Headlines," *Harvard Business Review*, May–June 1979.

Norsworthy, J.R., Michael J. Harper, and Kent Kunze. "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, 1979:2.

Quarles, John. *Federal Regulation of New Industrial Plants*, 1979.

Smith, V. Kerry and Richard Kopp. "Productivity Measurement and Environmental Regulation," in Thomas Cowing and Rodney Stevenson (eds), *Productivity Measurement in Regulated Industries*, Academic Press, forthcoming.

Spence, Michael and Martin Weitzman. "Regulatory Strategies for Pollution Control," in Ann Friedlander (ed.), *Controlling Air Pollution*, MIT Press, 1977, pp. 219–239.

Weitzman, Martin. "Prices vs. Quantities," *Review of Economic Studies*, October 1974, pp. 477–491.

Discussion

Hendrik S. Houthakker*

Here is another fine paper in the series, each of which deals with one particular aspect of the economic slowdown, except for John Kendrick's paper which was more of an overview. By way of preface I would like to emphasize that this partial approach has its limitations. There is some tendency, heard yesterday and again today, of saying: Well, what I looked at is really not very important. It must be something else. That, of course, raises the question of whether the slowdown has one cause or many causes. If there are many causes, which is at least possible and was also suggested by the work of Kendrick and Denison, then we cannot reject any of them on the ground of being small. The fact that they are small means they are to be supplemented by other explanations.

This is a problem also with Bob Crandall's fine paper. Mostly I gathered two things from his paper. In the first place, he collected some very interesting data; although he has emphasized their limitations, there is something there. Second point, from a more theoretical view is the effect of grandfather clauses, the unwillingness of the legislative and administrative processes to bear down too heavily on existing polluters and the impact this will have on new construction. These are very important points. For the rest, Bob does not make great claims for his analysis and this I think is due in large part to the insufficiency of the data. The kind of regulation he deals with is a rather new phenomenon and the evidence as yet is inadequate for econometric estimation. He tried some cross-sectional analysis but the results are not really very conclusive, nor is this something for which he can be blamed. We just have to wait a few more years before we can do that kind of analysis better than we can now.

I would like to make a few comments on the regulatory issue. In the first place, Bob Crandall has focused on what one might call the new regulation, of which the environmental regulation and work safety are principal examples. The old regulation also has interesting relations with productivity. I myself have played around a lot with data by industry covering the entire economy. As we all know, there is much more documentation on manufacturing in the United States than on other sectors of the economy yet manufacturing accounts for less than one-quarter of GNP. There is a danger of being misled by this one well-documented but basically not very important sector at the expense of much larger sectors about which we know much less.

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I'll come back to that in a moment. Now as it turns out, the regulated sectors have generally had a pretty good productivity performance. The highest productivity growth over the postwar period in the United States is found in two regulated sectors, airlines and communications. This was something of a caution to me because I have always been opposed to the old type of regulation. It turns out I may have been wrong. The question is: is the good performance due to regulation or not? I frankly don't know. One could go at length into the old question of economies of scale which was the purported justification for much of the regulation we have had. This works well in industries like communications where there probably are economies of scale although they may not have been conclusively demonstrated. It does not help you in an industry like trucking which also has good performance by the usual criteria and this is an especially difficult one to live with.

Now, I would like to say something in this connection on utilities. There has been a slowdown in utilities. This I think also points to the importance of economies of scale. What has happened in utilities is that their product became much more expensive as a result of fuel price increases. Previously the industries with economies of scale benefited from growth much of which they had to pass on to their customers in the form of lower prices. That's how the regulatory mechanism worked. When their growth was interrupted by higher fuel prices, their performance deteriorated very severely. As with other aspects of utilities, it also meant their construction programs became severely upset. Another reason was that the electric utilities, in particular, never recognized such a thing as price elasticity, unlike, say, the telephone companies. To the electric utilities it was an article of faith that the demand for their product was independent of price, and they suddenly discovered that wasn't true. I could say more about this but I just wanted to say this because the old regulation also has interesting relations with productivity.

On the new regulation, as Bob Crandall points out in passing, the emphasis on standards has really been very detrimental to the economy as a whole and probably also to pollution control. The environmental movement took the wrong turn, I think, about 1971–1972 when the sulfur tax was rejected by Congress. Since then the whole emphasis has been on standard-setting. Standard-setting, I believe, has been a source of severe distortions including the grandfather clause distortion that Bob has pointed out. It also has probably not had a major effect on the level of pollution in the United States as a whole. If we had given taxes a try, we might by now have something to show for all the effort.

I also wanted to comment briefly on some other points in Bob's paper. At one point, he mentions the apparently improved performance of the financial sector which to be exact is finance, insurance, and real estate. I would like to point out that in this sector there are severe data problems, not so much because of lack of knowledge but rather because of the very peculiar ways this sector is handled by national accountants. The banking sector is largely in the realm of fantasy when it comes to gross product. There is a so-called banking imputation which I have never understood, although I have tried very hard. If you take it literally, the banks in this country hand out $150 in free services per annum to every man, woman, and child, and this sum has been growing rapidly. This doesn't correspond to anything in reality so one cannot infer much from the data for the banking sector.

The real estate sector also is subject to severe limitations because of the convention that owner-occupied dwellings are owned by entrepreneurs who happen to live in the same building. This is also not a very good way of looking at it, especially because the deflator for this owner-occupied sector is assumed to be the same as the deflator for rented dwellings, yet we all know that rented dwellings are generally different in kind from owner-occupied dwellings. Therefore the data for the financial, insurance, real estate sector really should not be taken seriously.

Talking about data, I would like to make a plea while I have the floor for a considerable improvement in data outside the manufacturing sector. There is a great deal to be done in beefing up these data, and especially in explaining what there is. Not only are the data not as accurate as they could be, but we need to know better what we have. B.E.A. and B.L.S. should put a much greater effort in describing the nature of their series. Some years ago the British Central Statistical Office put out a rather thick volume describing in great detail what their series mean. Nothing like this has ever existed for the United States; it should be a matter of high priority to have such a book so that we could also know what it really is we are dealing with, say, in the case of industry data. It is very hard to find out how much of this is based on double deflation. One can get general statements that manufacturing usually is based on it and nonmanufacturing usually isn't, but it is very hard to find out for sure except by talking to the individual who actually does the work.

Now mentioning the British leaves me with one final remark having to do with international comparison. There is a slightly provincial flavor in the kind of analyses we have gone through here on the productivity slowdown. The question has not yet been raised, is this a phenomenon peculiar to the United States or has it happened in other countries as well? As it turns out, it is not exactly peculiar to the United States but neither is it universal. I was at a conference at the American Enterprise Institute on the French economy a couple of weeks ago, in which it appeared that the French productivity performance in recent years has been good not only by our standards but also by French historical standards. There may even have been some improvement in recent years. The same is true for some other European countries, although it is not the case everywhere. That is why it might be very revealing to do more work on international comparison with the view to seeing what exactly the differences are, say, between France and United States; what was it in the French economy that permitted them to maintain and even improve their productivity growth whereas we have had this marked slowdown. This project could be done with relatively modest resources and might be a useful supplement to the papers we have here.

The Productivity Slowdown: A Labor Problem?

Jeffrey M. Perloff and Michael L. Wachter*

Introduction

This paper addresses two related questions. First, what effect have demographic shifts and cyclical fluctuations had on the productivity slowdown?[1] Second, what labor market policies ameliorate the productivity problem? The answers to both questions are shown to depend critically on how one measures productivity. We conclude that most labor market policies are unlikely to increase the best productivity growth rate measures without creating other major problems.[2]

In the first section of the paper, several approaches to measuring productivity are described. The standard approach is to use the average product of labor as measured by the Bureau of Labor Statistics (BLS). An obvious adjustment is to weight the manhours of different demographic groups differently so as to compensate for the changing composition of the labor force. A second approach is to use an estimated production function to calculate marginal products instead of relying on average products. It is also possible to break labor into submeasures corresponding to skilled and unskilled labor so as to obtain two or more average (or marginal) product of labor measures. Other measures discussed include cyclically adjusted labor productivity series, total productivity series, and the trends in Hicks neutral technological progress.

In Section II, measures of the productivity of the labor aggregate are examined. Although all the labor productivity measures show a slowdown has occurred over the past 15 years, the magnitude and the timing of the slowdown vary across the measures.

In Section III, separate measures for youths and adults are examined. The pattern of decline differs dramatically between older and younger

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The authors added the appendix after the conference.

[1] For evidence of the existence of a productivity slowdown, see, for example, Denison (1979). For a discussion of productivity in earlier periods, see Kendrick (1969).

[2] Because other papers at this conference deal with issues of regulation, energy, and capital, we have restricted this paper to those issues and policies which are primarily related to the labor market. One relevant, overlapping issue is the compositional effect on productivity, as discussed by Nordhaus (1972) and Okun (1973), which we do not discuss in this paper. This issue is briefly discussed in Perloff and Wachter (1980).

workers. Moreover, the total factor productivity measure of the overall productivity growth rate of the economy shows a much less pronounced slowdown between 1965 and 1979 than do the labor productivity measures.

Two general policy issues are raised with respect to the productivity slowdown in Section IV. The first is how the slowdown can be stopped or reversed. The answer to this question depends upon which productivity measure is used as a target by policymakers. The second issue concerns the need to set the productivity debate in the broader context of unemployment, inflation and income distribution.

I. Alternative Measures of Productivity

In studies of the productivity decline of the past decade the average productivity of labor is the most widely used measure.[3] It is calculated by dividing output or GNP by the total manhours (or employment multiplied by average hours of work). This variable has numerous serious, if not quite fatal conceptual flaws. Its appeal is that it can be calculated, without making any statistical adjustment, using government published data. The flaws in this measure can be organized into five categories.

First, average productivity is misleading during periods when the composition of the labor force is rapidly changing. Since this measure treats all manhours equally regardless of skill level, in a period when young workers or workers with little specific training or skills are an increasing percent of the labor force, measured productivity falls. Even if the productivity of each skill level or type of worker remained constant over time, the entry of the baby boom cohort into the labor force during the 1960s and 1970s would have lead to a decline in average productivity due to the increased percentage of youths in the labor market. Similarly, any labor market policy which succeeded in increasing the employment of the poor or the unemployed would lower average productivity. If average productivity were treated as a target by policymakers, successful manpower policies would incorrectly signal a productivity problem according to this measure.

It is important to create an index which would not be confused by compositional shifts. Weighting each demographic or skill group by its wage rate yields a productivity measure with manhours (approximately) measured in efficiency units.[4] Such an index would not be sensitive to purely composi-

[3] Some authors, however, have used other measures of productivity. See for example Berndt and Khaled (1979), Clark (1978), Gollop and Jorgenson (1980), and Norsworthy, Harper and Kunze (1979).

[4] If each worker is paid a wage equal to the value of his marginal product, then the wage ratio of two types of workers equals the ratio of their marginal products. Thus, our weighting scheme gives high productivity (high wage) workers greater weight. Specifically, our new employment index is

$$L = \sum_i W_i L_i$$

where L_i is the total nonagricultural, nongovernmental employment of the i-th demographic group and W_i is the corresponding weight formed by taking the ratio of full-time, year-round, total money income of males age 25–64. The demographic groups are: males 16–19, males 20–24, males 25–64, males 65+, females 16–19, females 20–24, females 25–64, and females 65+. The adjusted labor series L is divided into output to obtain the adjusted average product.

tional shifts in the labor force. Hereafter, such an index is referred to as a demographically adjusted measure of productivity.

A second problem with average product is that it is an imperfect proxy for the marginal product of labor. Presumably policymakers are concerned about the productivity growth rate because it is correlated with a fall in real wages. In a competitive world, the real wage is equal to the value of the marginal product and not to the average product. To obtain a measure of marginal productivity, however, requires the estimation of a production function. The measures of marginal product reported below are derived from two cyclically sensitive translog production functions estimated for the overall economy for the period 1955–78.[5] In one, the inputs are demographically adjusted labor, capital, and energy; while in the other, labor is disaggregated into youth and adult measures.[6]

The marginal product is more sensitive to substitution effects than is the average product. Since the average product is the ratio of output to labor, a relative increase in the use of other factors will increase this measure since output will grow relative to labor. If the economy is Cobb-Douglas, the marginal product is a constant multiple of the average product and hence is equally sensitive to substitution effects. If the economy can be approximated by a (non-Cobb-Douglas) translog production function, the marginal product is not a constant multiple of the average product. Instead, the marginal product equals the average product multiplied by a term which depends on relative factor proportions.[7] Thus the marginal product is more sensitive to input fluctuations than is the average product. As a result, the large supply increases in the 1970s, the energy reduction after 1974, and the dramatic capital accumulation slowdown in the 1970s had a greater effect on marginal products than average products.

Typically when a factor has an exogenous increase in supply, such as that induced by the entrance of the baby boom into the labor market, the average product will decline by more than the marginal product. The impact of rapidly increasing labor force and employment on labor productivity is tempered by the ability of the production process to shift to more labor intensive techniques (or products).

A third problem in using the average product (or the marginal product) to discuss the productivity slowdown is its sensitivity to cyclical fluctuations. Due to labor hoarding and other factors, average (or marginal) productivity tends to decline during recessions and increase during expansions. One

[5] See Perloff and Wachter (1979a) for a description of the estimation technique used.

[6] The single labor measure is the demographically adjusted one described in footnote 4. When two labor series are used, a similar adjustment process is used within a group, where males age 20–24 are taken as the base group for the youths' labor measure, and males age 45–64 are the base group for the adults.

[7] The marginal product of the i-th factor is

$$MP_i = \frac{Q}{i}(\alpha_i + \Sigma_j \gamma_{ij} \ln j)$$

where Q is output and α_{ij} and γ_{ij} are parameters of the translog production function (see Perloff and Wachter (1979a). If $\gamma_{ij} = 0$ for all i and j, then the production functions is Cobb-Douglas and the marginal product is a constant (α_i) multiple of the average product (Q/i).

method to control for cyclical factors is to use potential productivity measures which are constructed by assuming that the economy is at its equilibrium unemployment rate (U*).[8] The potential marginal and average product reported below were calculated by adjusting both output and labor to levels consistent with an economy in equilibrium (at U*). The potential output (Q*) is calculated using a cyclically sensitive translog production function.[9] Thus, the potential average and marginal productivity growth rates are the trend rates of growth with the cyclical fluctuation smoothed.

The fourth problem with the average product (and other adjusted and unadjusted productivity measures discussed above) is that it cannot be used to discuss distributional effects among different labor groups. For example, the baby boom could be expected to affect youth and adult labor groups' productivity and wages differently, unless these two types of labor are perfect substitutes. If the two groups are perfect substitutes, the demographic adjustment described above will fully control for compositional shifts.[10]

According to the cohort overcrowding model youths and adults are imperfect substitutes and may even be complements.[11] As a result the baby boom should have a differential impact on these two different age groups: reducing the productivity (and wage) growth rate of younger workers relative to adult workers.

The disaggregated labor inputs can be used to examine the effects of the post-1973 energy price increases. If energy is a substitute for young workers and a complement for adult workers, the post-1973 energy shortage should have slowed the productivity growth rate of adults relative to young workers.[12]

A fifth problem with the average product or (marginal product) of labor measure is that is does not reflect overall income and welfare. For example, if the United States were a closed economy, the nonlabor inputs would be completely owned by individuals in the United States. Nonwage income, which does total approximately one-third of national income, depends upon the wages (marginal products) of the other inputs. Gains in labor productivity which are offset by declines in the productivity of other inputs would have very different welfare implications from increases in the productivity of all inputs. The income effects of exogenous shifts in factor supplies may be determined by measuring the productivity growth rates of all factors or the growth rate of total factor productivity.

Thus, a number of measures are useful for examining problems related to the productivity slowdown. Average product measures have the advantage of being easy to calculate, but also have several disadvantages. A demo-

[8] See Wachter (1976a) and Perloff and Wachter (1979a) for a discussion of U* measures.

[9] This technique is explained in Perloff and Wachter (1979a,b). For an alternative view, see Perry (1977) and Rasche and Tatom (1979).

[10] The adjustment method described in footnote 4 implicitly assumes that different types of labor are perfect substitutes in the sense that they vary only in a "labor-augmenting" way.

[11] See, for example, Easterlin (1968) and Wachter (1972, 1976b).

[12] Actually, in a many-factor production function, this assertion should be phrased in terms of net substitutes and complements. See Berndt and Wood (1979).

graphic adjustment of the average product based on relative wages reliably corrects for distortions induced by compositional shifts if different labor groups are perfect substitutes. A better compositional adjustment may be made by separating the labor input into several groups (e.g., youths and adults).[13] With an estimated production function, it is also possible to obtain marginal product estimates instead of average products. Further, estimation techniques can be used to control for cyclical fluctuations. Finally, total productivity measures can be used to examine overall national income effects.

II. The Productivity Slowdown Using a Single Labor Input Model

From 1948 to 1965, average productivity of labor, as measured by the Bureau of Labor Statistics, rose by 2.7 percent per year. For the 1968 to 1978 period, the rate of increase fell to 2.0 percent. During 1973 and 1974, there was an absolute decline in productivity of almost 5 percent, and for the next five years (1973 to 1978), productivity growth has averaged about 1 percent per year.

A. The Changing Composition of the Labor Force

A number of major economic developments have occurred over the past 15 years and these have affected the rate of productivity increase. The most significant labor market "exogenous shock" was the entrance of the huge baby boom cohort into the labor market.[14] This demographic shift, the increase in the ratio of youth to prime age workers, is one of the most dramatic in magnitude in U.S. history. Since the young are relatively unskilled and inexperienced, output per worker has declined as their relative employment increased.

The recent demographic swings, however, suggest that the cohort of new workers in the 1965 to 1979 period had a different impact from the cohort that entered the labor market between 1950 and 1965. Even if both groups were of equal skill and education, the more recent cohort would have had a lower marginal product simply because the baby boom cohort was so large. With imperfect substitution between old and new workers, cohort overcrowding, which occurred between 1965 and 1978, contributed to the decline in the productivity of new workers.

We can partially correct the distortion created by the shift in the com-

[13] Hammermesh and Grant (1979) have noted (p. 518): ". . . future research should concentrate on substitution among various workers disaggregated by age, education, or sex rather than by the blue-collar—white-collar distinction used in most work that has little use in policy analysis."

[14] The following table shows the impact of the baby boom. The numbers are the percent average annual rates of growth by age group:

	16–24	25+	16+	(16–24)/16+
1957–1965	3.56	0.71	1.19	2.34
1965–1972	0.48	2.21	1.90	−1.39
1972–1978	7.53	0.81	2.15	5.27

position of the labor force by measuring labor in "efficiency" units where workers are weighted by their relative wage, which is a proxy for a worker's relative productivity.[15] Using this measure a new average product can be calculated which controls for compositional effects. Similarly, using this measure with capital and energy we can estimate a cyclically sensitive translog production function, with quarterly data for 1955 to 1978.[16] The production function estimates can be used to calculate a marginal product of labor which controls for compositional effects. The changes in these adjusted average and marginal products series, ΔAPL and ΔMPL, are shown in Table 1.

Table 2 shows the average change in these series and the unadjusted BLS average product for the three subperiods 1960–1964, 1965–1973, and 1974–1978. While the unadjusted BLS series shows a slowdown of 0.39 percent from 2.51 percent in 1965–1973 to 2.12 percent in 1956–1964, the adjusted APL series shows only a 0.16 percent reduction. Even more striking, the adjusted MPL shows a 0.12 percent increase. The compositional adjustments do not affect the rate of growth of the APL in 1974–1978, but the adjusted MPL series shows an even greater slowdown in this recent period (2.38 percent) than the unadjusted APL series (1.28 percent).

This type of subperiod analysis, however, can be misleading. The data in Tables 1 and 2 indicate the importance of the choice of years in dividing the period. For example, the years 1965 and 1966 have two of the three largest productivity gains over the past 25 years. Hence, changing the dating of the middle period from 1965–1973 to 1967–1973 makes a significant difference. The overall marginal productivity growth rate for 1967–1973 is only 2.13 percent, down from 3 percent for 1956–1966: the unexpected productivity speedup becomes a more traditional slowdown.

It is, however, reasonable to start this period in 1965. Besides corresponding to a point in the business cycle where U is approximately equal to U* (which is also true of 1956 and 1973), the year 1965 corresponds to a point in the demographic cycle when the baby boom cohort first entered the labor force in large numbers. (The oldest members of the baby boom cohort began to enter the labor market around 1960.)

Although a demographic adjustment for age and sex can explain the decline in productivity between 1965 and the early 1970s, this adjustment does not explain the major slowdown that began during the early 1970s. Indeed, the success of the demographic explanation in the early period compared with its lack of significance in the latest period implies an even more pronounced slowdown after the early 1970s than is shown by an unadjusted productivity series.

[15] This method is described in footnote 4.

[16] The estimates are reported in Perloff and Wachter (1979a). By cyclically sensitive we mean that the parameters are allowed to vary with the cyclical measure. For example

$$\alpha_i = \alpha_i^0 + \alpha_i \text{UGAP},$$

where α_i is a production function parameter in the standard translog, and UGAP is a measure of the deviation of the unemployment level from U*.

Table 1
Percentage Changes of Demographically Adjusted Average and Marginal Products

Year	Average Product (ΔAPL)	Marginal Product (ΔMPL)
1956	1.29	0.80
1957	2.51	2.37
1958	1.17	1.82
1959	4.23	3.88
1960	1.45	1.17
1961	2.27	1.93
1962	5.25	4.88
1963	3.45	3.09
1964	3.71	3.67
1965	4.53	4.78
1966	4.40	5.27
1967	2.02	2.28
1968	3.51	4.48
1969	1.46	2.17
1970	-0.12	-3.48
1971	2.59	0.82
1972	3.34	4.25
1973	2.60	4.41
1974	-2.52	-3.94
1975	1.17	-3.45
1976	2.90	3.87
1977	1.90	2.89
1978	0.73	2.61

Sources: The average product figures are based on a labor series which is adjusted for demographic composition: see Wachter (1976a). The marginal product series are presented in Perloff and Wachter (1979b), based on the production function estimated in Perloff and Wachter (1979a).

Table 2
Productivity Growth Rates

	Rate of Change of		
Years	Unadjusted BLS APL	demographically adjusted APL	demographically adjusted MPL
1956-1978	2.04	2.34	2.19
1956-1964	2.51	2.81	2.62
1965-1973	2.12	2.70	2.78
1974-1978	0.84	0.84	0.40

Sources: See the references in Table 1.

An important result is that adjusting the labor input series for age and sex compositional shifts alters the timing but not the size of the productivity slowdown. The onset of any significant slowdown appears to be delayed until the early 1970s. A gradual slowdown in the productivity growth rate is transformed into a dramatic collapse. As seen in Table 2, the ΔMPL series increases at a 2.62 rate from 1955 to 1964, and at a 2.78 rate from 1965 to 1973, but it grows at only a 0.40 rate from 1974 to 1978.

B. The Cyclical Adjustment

A second major economic development of the past decade has been the increasing length and depth of the cyclical swings relative to the prior two decades. Since we are primarily interested in the secular trends in productivity, we calculated potential average and marginal product series using our cyclically sensitive, three-factor translog production function, which used labor measured in efficiency units.[17] Since our potential output series represents the level of output which could have been produced if the unemployment rate had been at its equilibrium rate, the *potential* average and marginal product series, denoted APL* and MPL* respectively, are *cyclically corrected* productivity series. The percentage changes in these series, ΔAPL* and ΔMPL*, are presented in Table 3. The labor inputs in both the ΔAPL* and ΔMPL* series are adjusted for demographic as well as cyclical factors.

A comparison of the ΔMPL and ΔMPL* series in Tables 1 and 3 yields several striking results. First, if only a demographic correction is made (ΔMPL) productivity growth actually increases between the 1956–1964 and 1965–1973 periods. However, if both demographic and cyclical adjustments (ΔMPL*) are made, productivity appears to decrease slightly. As indicated in Table 4, the MPL* series grew by 2.81 percent during the 1955–1964 period and then slowed to 2.47 percent in 1965–1973.

Second, the cyclical adjustment correction, in comparison to the unadjusted series, yields a productivity growth rate which is three times higher in the most recent period. While MPL grew at 0.40 percent per year, MPL* grew at 1.17 percent between 1974 and 1978. Moreover, the MPL* series growth rate is also higher than the unadjusted BLS average product series. Although the cyclical correction yields a significant upward revision of the productivity growth rate, it is still the case that a productivity growth rate of 1.17 percent is very low by historical standards.

Third, the ΔMPL* series is useful for analyzing turning points in the productivity growth rate. The timing of the productivity slowdown has been a focal point of the current debate. The recent years have been broken into

[17] Potential series were calculated by using our cyclically sensitive translog production function. The cyclically sensitive parameters were set at the equilibrium levels and the labor series was adjusted to the level consistent with the equilibrium level of unemployment (L*). The resulting output (Q*) and L* are then used to calculate potential average product (Q*/L*) and potential marginal product. Since average unemployment over the 1955–1978 period roughly equaled our measure of U*, our actual and potential average productivity growth rates are approximately equal to each other over these years. During expansions, potential average productivity growth rates are lower than the actual rates and the reverse is true during contractions.

Table 3
Percentage Changes of Potential Average & Marginal Products

Year	Potential Average Product (ΔAPL*)	Potential Marginal Product (ΔMPL*)
1956	3.51	3.39
1957	3.33	3.15
1958	2.73	2.56
1959	2.85	2.87
1960	2.80	2.71
1961	2.71	2.57
1962	2.73	2.65
1963	2.79	2.66
1964	2.78	2.71
1965	3.05	2.95
1966	3.43	3.23
1967	3.24	3.01
1968	2.85	2.73
1969	2.77	2.65
1970	2.50	2.30
1971	1.63	1.54
1972	1.98	1.98
1973	1.87	1.86
1974	1.45	1.36
1975	1.08	0.89
1976	1.41	1.45
1977	1.40	1.43
1978	0.63	0.74

Source: See Table 1

Table 4
Growth Rates of Potential Average and Marginal Products

	ΔAPL*	ΔMPL*
1956–1978	2.41	2.32
1956–1964	2.91	2.81
1965–1973	2.59	2.47
1974–1978	1.19	1.17

Source: See the references in Table 1.

numerous subdivisions in an attempt to isolate the onset of the recent slowdown. For example, the view that the increase in energy prices has been the major causal factor requires that the significant decrease in productivity growth developed after 1973. While the post-1973 ΔAPL* and ΔMPL* figures are very low, both series declined below the historical average rate (approximately 2.3 to 2.4 percent) as early as 1970, as shown in Table 3.

Hence it appears that the demographically and cyclically corrected productivity measures show that the slowdown started around 1970 and then accelerated after the energy crisis in late 1973. Indeed a case could be made that the major drop started in 1970 or 1971. Misallocations created by the Nixon price controls program and the expansion of government regulatory efforts (e.g., EPR and OSHA) may have been important causes of this early slowdown.

III. The Two Types of Labor Input Model

A. The Compositional Adjustment Once Again

The approach used in Section II to control for compositional effects by weighting demographic groups' labor by their relative wages is fully appropriate if such units of measure are perfect substitutes for each other. An important assumption of the Easterlin and Wachter cohort-overcrowding model is that younger and older workers are imperfect substitutes for each other. If these groups were perfect substitutes, an increase in the rate of growth of younger workers would not have led to a reduction in their wages or their marginal products relative to those of older workers. In this section, two labor series, workers 16 to 24 (Y for youths) and those over 25 years old (A for adults) are used. Tests for aggregation reject the single input approach.

With both younger and older workers entered as separate inputs, we have a four factor translog production function.[18] The growth rates of the average products and the marginal products (which are based on this four factor production function) are shown in Table 5. The growth rate of the average product of younger workers is actually negative for the overall period

Table 5
Average Productivity Growth Rates

	Youths	Adults	Capital	Energy
1955–1978	-.34	2.74	.04	.66
1955–1964	-.15	3.18	.22	1.42
1965–1973	-1.07	3.07	-.52	.02
1974–1978	.29	1.31	.67	.31

Marginal Productivity Growth Rates

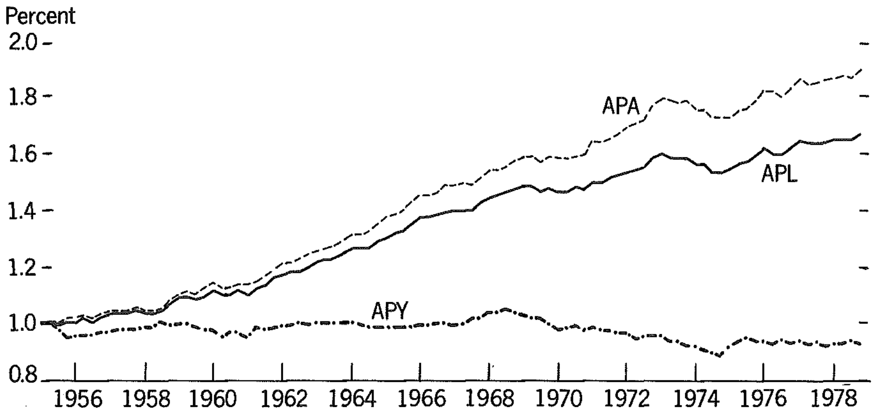
	Youths	Adults	Capital	Energy
1955–1978	1.62	2.30	.38	1.68
1955–1964	2.04	2.67	.69	3.05
1965–1973	2.19	2.75	-.54	-1.60
1974–1978	-.21	.77	1.44	5.09

[18] The four-factor cyclically sensitive translog production function is calculated using demographically adjusted youth and adult labor measures (as described in footnote 6). See the Appendix for details.

1955–1978; that is, the level of APY (average product of young workers) is lower in 1978 than it was in 1955. Only for the latest subperiod, 1974–1978, does APY increase, which is a reflection of the aging of the baby boom cohort. Since the birth rate peaked in 1958 and then remained on a high plateau through 1962, this large cohort's age ranged from 18 to 22 in 1980. As Figure 1 shows, APY has in general grown more slowly than APA (the average product of adults) and, as a result, it has also increased more slowly than the BLS average product of labor measure, APL.

Table 5 shows that marginal products capture input substitution better than average products. A comparison of average and marginal products

Figure 1 **Average Products**



APA is an index (equal to one in 1955:3) of the average product of adults.
APY is the comparable index for youths.
APL is the comparable index for all labor.

shows that the economy shifts techniques to accommodate suddenly plentiful resources. Although the average productivity growth rate is negative for youths, the marginal productivity growth rate for younger workers is above 2 percent per year for the 1955 to 1973 period. On the other hand, although youth marginal productivity increases over most of the period, the marginal productivity growth of adult workers is always higher. The economy can adjust to the oversupply of a given resource to some extent, but that input will have consistently lower marginal productivity growth.

Table 5 also substantiates the results of the previous section that the productivity slowdown does not begin until the early 1970s. Indeed, for both youths and adults, the average and marginal productivity growth rates are slightly higher in the 1965 to 1973 period than in the 1955 to 1964 period. The 1970 productivity slowdown is strongly felt by both younger and older workers. In terms of average products, older workers suffer a larger decline in the 1974–78 period than do younger workers. This relative slowdown effect results from the slower growth of youth employment in recent years (compared to the years of very rapid growth associated with the baby boom cohort). In this recent period, both age groups' marginal products declined by roughly 2 percentage points.

B. The Capital and Energy Inputs

We have also presented in Table 5 the average and marginal product growth rates for both energy and capital. They suggest that the rapid growth in both labor groups' marginal products in the 1965 to 1973 period was associated with a surfeit of capital and energy inputs. The average products for capital and energy, which reflect resource employment, indicate a large growth in K and E inputs relative to total output. Indeed, the marginal product growth rates for both K and E are negative between 1965 and 1973.

After the early 1970s, the input cycle was reversed. The capital investment boom of the 1960s was followed by a relative reduction in capital investment in the 1970s. With the OPEC embargo, oil production cutbacks and energy price increases after 1973, the energy input also grew slowly. The result was an unprecedented growth rate in the marginal productivity of energy and, to a somewhat lesser extent, capital. These data are consistent with the widely held view that the labor productivity slowdown in the early 1970s was due to a reduction in the supply of capital and energy.

Table 5 dramatizes the degree to which trends in labor productivity *do not match* productivity growth rates for other inputs. Labor does well when capital and energy are in abundance and the manhours growth rate is low. That is, the current productivity problem is a labor productivity problem and one solution would involve an increase in the supply of capital and energy. A continuing shortfall in energy will lead to a slow growth rate for the other factors. A partial solution is to encourage changes in techniques which economize on energy usage. Presumably one such method is to allow the price mechanism to work.

C. Potential Productivity Measures

The potential productivity series reflect the pure trend rates of growth since the cyclical components have been removed. The cyclical correction of adults' marginal product makes little difference except in the most recent period where it measures the growth rate from 0.77 percent to 1.26 percent, as can be seen by comparing Tables 5 and 6. Similarly, the cyclical correction only increases youths' marginal product growth rate in the most recent period (from –0.21 to 0.43 percent).

Since the potential marginal rates are corrected for cyclical and demographic effects and allow for substitution effects among inputs, they are perhaps our most reliable indication of secular productivity trends for the different inputs. They illustrate that the declining growth rate of labor productivity during the last five years was associated with increasing growth rates for the potential marginal products of capital and energy.

Table 5 and 6 are also consistent with the widely held view that energy is a substitute for capital and skilled workers, but a complement for unskilled workers. That is, increases in the price of energy cause firms to substitute toward unskilled workers and away from capital and skilled workers. Such a substitution effect results in higher potential marginal rates for energy and young workers and lower rates for capital and adult workers than the corresponding potential average products. On the other hand, the energy substitution effect is not strong enough to reverse the impact generated by each factor's individual supply: the potential marginal growth rate increases for capital and declines for young workers between 1965–73 and 1974–78. The capital shortfall overcomes the substitution impact on productivity growth of the higher energy prices. Similarly, both young and adult workers' potential marginal products decline between these periods.

Table 6
Potential Average Productivity Growth Rates

	Youths	Adults	Capital	Energy
1955–1978	-.29	2.77	-.03	.60
1955–1964	.05	3.06	-.07	1.16
1965–1973	-.26	3.15	-.66	-.13
1974–1978	-.10	1.51	1.21	.83

Potential Marginal Productivity Growth Rates

	Youths	Adults	Capital	Energy
1955–1978	1.68	2.40	1.98	1.02
1955–1964	2.14	2.69	.24	1.52
1965–1973	1.87	2.71	-.33	.11
1974–1978	.43	1.26	1.06	1.69

To evaluate these substitution arguments directly, we calculated the elasticities of substitution using the cyclically sensitive translog production function. They indicate that young and adult workers are complements. In addition young workers are substitutes for energy, while older workers are complements with energy.[19] Further, tests of separability of the labor inputs rejects the aggregation of the labor inputs at the 0.05 level.

The complementarity in production between young and adult workers has important distributional implications. During the 1960s and early 1970s the older cohort benefited from the entry of the large baby boom cohort of the 16 to 24 years olds. The youth group, in turn, was penalized by its own relative size. In the 1980s and 1990s, this large cohort will be in our adult worker category. Hence the baby bust cohort, which will be entering the 16 to 24 age group, will benefit from its own scarcity of members as well as the abundance of older workers. To the extent that the energy shortage continues — in the sense that growth rate of energy usage continues below its earlier trend rate — the labor demand and the marginal productivity of the baby bust cohort of young workers will increase further relative to that of the baby boom cohort of older workers.

D. Total Productivity

While the growth of the actual and potential marginal products is interesting because of what it tells us about relative factor wages, it is of limited value for understanding the pure productivity effects. Two factors contribute to the observed growth rates of the marginal products. First, biased or unbiased technological change can increase the marginal products. Second, increases in an input's supply will tend to lower its own marginal product and raise or lower those of others depending upon whether they are complements or substitutes.

Two alternative approaches shed light on the productivity issue while down-playing the substitution effects. Table 7 shows actual and potential total product and Hicks neutral technological progress.[20] Actual total product is calculated by taking the ratio of output to the estimated translog input index. Potential total product represents the ratio of potential output to the potential input index. The Hicks neutral technological change measure represents the values of the time trend terms multiplied by their coefficients from the production function equation where time, time squared, and time cubed are included in the equation.[21]

These series show less of a change over time than the series discussed above. However, all show a slowdown. The potential total product series indi-

[19] Griffin and Gregory (1976) and Berndt and Wood (1979) present estimates of energy-labor elasticities of substitution. Berndt and Wood point out the dangers in estimating these elasticities using production functions which are assumed separable in energy. White and Berndt (1979) present substitution elasticities based on a five-factor production function: production and nonproduction workers, capital, energy, and materials.

[20] See Solow (1957) for an excellent discussion of technological progress. For more recent discussions see Brinner (1978) and Berndt and Khaled (1979).

[21] The higher order time trends allow for a slowdown.

cates that the slowdown was less severe from the early (1955:1–1964:4) to the middle period (1965:1–1973:4) than the actual series (0.45 percent compared to 0.77 percent), but more severe later (1974:1–1978:4) than the actual series (0.54 percent compared to 0.16 percent). The Hicks neutral progress series is quite close to the potential total product series, but shows slightly faster growth in the early and late periods, which indicates that factor supplies limited growth in these periods.

E. Productivity, Wages and Income

As was argued in Section II, the marginal product of labor is more closely related to wages than is the average product. Both are more highly correlated with wages than with incomes.

Table 8 shows the growth rates of real wages. By comparing these figures to the marginal product figures in Table 5, it can be shown that they follow similar growth patterns (and both wages and marginal products growth rates deviate substantially from those of the average product). As Table 8 shows, however, income of full-time workers moves somewhat independently of wages (and marginal products), since income is more sensitive to supply fluctuations and nonlabor earnings. For example, where youths' real wages fell, on average, by 0.05 percent per year during the last five years, their real income rose by almost 0.1 percent per year. Similarly adults' wages rose by 1.4 percent while their incomes fell by almost 0.5 percent per year during the same period.

Table 7
Growth Rates

	Actual Total Product	Potential Total Product	Hicks Neutral Progress
1955–1978	1.73	1.78	1.85
1955–1964	2.22	2.16	2.34
1965–1973	1.45	1.71	1.64
1974–1978	1.29	1.17	1.27

Table 8
Growth Rates

	Real Wages*		Real Income*	
	Youths	Adults	Youths	Adults
1955–1978	1.59	2.68	1.01	1.812
1955–1964	1.96	3.00	1.06	2.304
1965–1973	2.35	3.04	1.50	2.60
1974–1978	-0.05	1.39	0.07	-0.47

* Real series created by using the implicit GNP deflator.

IV. Policy Issues

Two general types of policy issues are frequently raised in the policy debate on the productivity slowdown. The first is how productivity growth rates can be increased. As we have indicated, the answer to this question in part depends upon the measure of productivity which is used.

The second is whether policies which can increase productivity growth are more socially desirable than other policies which are competing for scarce government resources. Policies which increase the growth rate of productivity will also have positive or negative effects on a broad set of macroeconomic variables such as unemployment, gross national product, and the distribution of income. Policies which increase labor productivity at the expense of increased unemployment or decreased employment are unlikely to be viewed as socially beneficial.

A. Policies to Increase the Rate of Growth of Productivity

Whether we believe a given policy increases productivity growth depends critically upon which productivity measure we use. For example, policies aimed at reducing the equilibrium unemployment rate are bound to lower the rate of productivity growth as traditionally measured. The reason is that workers in the unemployment pool are predominately at the bottom of the skill range; hence an increase in their employment induces a negative compositional effect on the aggregate labor productivity index. To illustrate this dilemma, suppose that welfare payments and the minimum wage were lowered relative to market wages so that some lower skilled workers became employed for the first time. Since the average product of labor reflects that ratio of output to *employed* labor, such a policy could result in a decrease in this measure of productivity growth while decreasing unemployment and generating what many people would consider to be a positive effect on work incentives. The two methods that we have adopted to avoid this problem are either to weight the demographic groups using wage rates and/or to analyze productivity changes separately for adults and youths.

If the criterion for successful policy is to increase total productivity growth then only those policies which stimulate technical progress — for example, research and development — are likely to be effective.[22] On the other hand, if either the average or marginal productivity of labor is used, then policies which induce substitution away from labor and towards other inputs will augment productivity growth. Examples are policies that increase the supply of capital and energy. Further, if separate labor productivity measures are used for different demographic or occupational groups, such as youths and adults, then policies may increase productivity growth for one group while decreasing it for the other.

[22] Policies which increase Hicks neutral, technological progress will increase all the measures of technological progress discussed in this paper.

Obviously, the desirability of policies which increase technological growth, induce substitution away from labor as a whole or some subgroup of labor, or increase capital formation, differ. If ultimately we are concerned with the size of output and how it is distributed, labor productivity measures may be relatively poor indicators of these criteria. While total productivity or technological change tells us about the size of income, they tell us little about how income is distributed. Average and marginal productivity of labor tell us about labor's wage, but little about the total output or how other factors fare.

The nonlabor market policies to increase the rate of growth of labor productivity work through substitution effects. Almost all policies which increase the availability of the other major inputs into the production process, for example, capital and energy, are likely to stimulate labor productivity growth. The usual policy options for increasing the capital stock, including investment tax credits, accelerated depreciation, and indexing the tax schedule for inflation effects are well known. What is not known are the "bang-for-the-buck" or the impact multipliers of these policy alternatives. The success of such policies depends heavily on the degree to which new capital embodies technological change. The "technological change" or "knowledge" variable tends to be the major factor in productivity growth, but there is little information on the mechanisms which affect its growth rate. Since these issues are discussed in the other papers being presented at this conference, we will ignore these policies and concentrate on those which relate specifically to the labor market.

B. Labor Market Policies

Labor market policies are not generally a desirable way to increase productivity growth. Except for policies which increase the quality of the work force or offset existing inefficiencies, labor market productivity policies work by reducing the ratio of labor to other inputs. That is, such policies require a decrease in the employment of some or all labor groups, given a fixed technology and the supply of factors. As a result, such problems are inconsistent with other macroeconomic objectives including those concerning unemployment and income distribution.

This negative view is in conflict with the frequently expressed discontent with the workings of the labor market. It is often argued that labor productivity growth rates would increase if the numbers of hours of work were reduced, if labor unions imposed fewer work rules that restricted innovation and if the work ethic could be restored. The problem with these arguments is that they are unsupported by data. Indeed, it is unclear that policies designed to achieve these three objectives would increase productivity growth.

First, repeated attempts have been made in recent years to introduce legislation which would reduce the average workweek by about five hours. Attempts to spread the work by reducing the numbers of hours for straight-time wages under the Fair Labor Standards Act could prove counterproductive; that is, they could decrease rather than increase productivity growth rates.[23] If firms were to reduce the regular workweek, many workers would start to moonlight. Moonlighters' second jobs tend to require fewer skills, a result which is consistent with economic theory. Thus, one impact of "spreading the work" amendments to the Fair Labor Standards Act would be to lower efficiency and productivity as individuals switched some of their hours to secondary jobs.

If workers could not find secondary jobs, or were prevented from doing so by legislation, the effect of a reduced hours law would be a reduction in total labor and hence an increase in labor's marginal product. In an earlier paper,[24] we used our cyclically sensitive, three factor translog production function to calculate the effect of a reduction in hours. We found that a 10 percent drop in the labor aggregate would increase labor's marginal product by 10.5 percent in the short run (i.e., before adjustments in the capital stock take place). Since total hours would fall less than the wage increased, the total wage bill would rise by approximately 10 percent.

In this respect it is also useful to make similar calculations using Berndt and Christensen's (1974) aggregate U.S. manufacturing production function with capital, production (blue collar) workers, and nonproduction (white collar) workers as inputs. While we prefer the youth-adult division of the labor input, such a study sheds some light on the income redistribution effects of a policy to regulate hours.

A reduction in hours for one or both types of labor will have differing effects for two reasons. First, there are virtually twice as many blue collar as white collar workers.[25] Thus, a 10 percent cut in white collar workers' hours is only about half as large a reduction in absolute terms as a comparable reduction in blue collar workers' hours. Second, and more importantly, white collar (highly skilled) workers are more complementary with capital than are blue collar employees.[26] While additional capital increases white collar workers' productivity (since these two factors are complements), it reduces the need for blue collar workers (since capital and blue collar workers are substitutes). Thus decreasing the labor-capital ratio will raise the wage of white collar workers by more than that of blue collar workers.

For example, suppose that the average hours per week were reduced sufficiently so that total hours worked by blue and white collar workers fell by 10 percent. Blue collar labor's marginal product would rise by 9.4 percent while that of white collar workers would rise by 11.5 percent, reflecting the greater complementarity between capital and white collar labor. The wage

[23] The Fair Labor Standards Amendment of 1978, sponsored by John Conyers of Michigan, would have raised the premium rate of pay from time-and-a-half to double time, eliminated compulsory overtime, and gradually reduced the standard workweek from 40 to 35 hours over a four-year period.

[24] Perloff and Wachter (1978).

[25] Berndt and Christensen estimate the cost shares of capital, blue collar and white collar workers as 0.181, 0.534 and 0.786 in 1968.

[26] Berndt and Christensen estimate the Hicks partial elasticities of substitution between white collar labor and capital as 3.72 while the elasticity between blue collar workers and capital is −3.77. The elasticity between the two types of labor is 7.88.

bill of the two groups would be affected differently: the white collar workers' wage bill would rise, while that of the blue collar workers would fall.[27]

If only the total hours of blue collar labor fell by 10 percent while white collar employees continued to work the same hours, the marginal product of blue collar labor would go up by 6.7 percent while that of white collar labor would increase by just 5.1 percent. If, on the other hand, only white collar hours fell by 10 percent (which is a smaller drop in labor due to white collar workers' smaller share), then their marginal product would increase by 6.4 percent, while that of blue collar workers would rise by only 2.8 percent. Of couse all these calculations represent once-and-for-all adjustments.

In our earlier paper, we also used our three factor production function to calculate the effect of such policies on potential output, assuming that capital and energy continued to grow as before. Assuming a once-and-for-all drop of 10 percent in total labor hours, the rate of growth of potential output would be cut in half in the first year.[28] If capital were also reduced by 10 percent in response, the growth rate of potential output could be reduced by over 2 percent. Thus, these policies would have substantial output effects as well as productivity effects.

Second, it is difficult to intelligently discuss whether the work ethic has recently become impaired, since it is an undefined term. A recent review of the literature suggests that the demise of the work ethic has been claimed as far back as the Industrial Revolution.[29] The "shiftless and lazy generation" seems to be one of the constants of the labor market. In any case, we are aware of no serious policy which could offset such a decline even if it has occurred.

Third, it is common to blame unions for low productivity because of featherbedding or other restrictive work rules. While there may be some merit in attributing inefficiencies to unions, there seems to be little evidence that unions have increasingly reduced efficiency. Indeed, some recent studies have even suggested that internal labor markets of firms represent an efficient response to the externalities imposed by specific training, bounded rationality, and other factors.[30] It is not obvious how one could test whether unions are responsible for the development of internal labor markets. A study by Brown and Medoff (1976), for example, suggested that these internal labor market effects offset the inefficiencies created by higher wages: that is, unionization was found to have a substantial positive effect on output per worker. Unfortunately, this study rests on two crucial assumptions which cannot be directly tested. Further, it is difficult to adequately control for ability differences between union and nonunion workers.

While there is some anecdotal evidence that restrictive work rules have become less common, very little is known with certainty. Nonetheless, it may

[27] We are assuming that wages equal the value of the marginal products.

[28] Potential output growth rate would fall from 3.33 percent to 1.66 percent in the first year. By the second year, the growth rate would be almost the same in both cases.

[29] See Bernstein (1980).

[30] See, for example, Wachter and Williamson (1978).

be possible to obtain a once-and-for-all increase in productivity by barring certain union practices. Table 9 shows the percent of workers covered by specific contract clauses of all workers under union contracts which cover 1000 or more workers in 1972 and 1976 and 5000 or more workers in 1970. As the data suggest, relatively few union contracts place restrictions on moonlighting, crew size and weight; but almost seven out of ten contracts restrict work by nonbargaining unit personnel. Further it could be argued that the crew size and weight restrictions are often for safety reasons and may not be inefficient. As the table shows, only restrictions on crew sizes have become more prevalent during the 1970s. However, inefficient restrictions are common in a few industries. For example, many construction workers are covered by contracts which limit the use of prefabricated materials (11.7 percent of all construction workers and 70.1 percent of plumbers), require that union-made materials be used (11.5 percent of all construction workers), or

Table 9
Percent of Workers Covered by Contract Clauses

	All Industries			Manufacturing			Nonmanufacturing		
	1970[1]	1972[2]	1976[3]	1970	1972	1976	1970	1972	1976
Restrictions on Moonlighting	9.23	8.19	9.65	.96	.85	7.36	20.45	17.53	11.97
Crew Size (total)	7.94	12.09	20.75	1.92	4.60	8.57	16.10	21.64	33.14
Crew Size (Safety)	NA	NA	10.88	NA	NA	3.70	NA	NA	18.17
Weight	2.87	2.38	2.04	1.92	1.22	.82	4.16	3.84	3.28
Work by Nonbargaining Unit Personnel:	62.82	67.69	67.74	77.83	79.34	82.31	42.47	53.08	52.93
Labor-Management Committees on Productivity:[4]	NA	NA	19.71	NA	NA	26.56	NA	NA	12.74
Testing Provisions	23.48	28.14	30.22	33.74	29.31	35.90	9.56	26.64	24.44
Advance Notice of Technological Change Required	8.99	18.66	18.16	8.22	23.94	23.07	10.03	11.94	13.17
Wage-Employment Guarantee	12.67	13.21	19.37	10.83	4.12	13.36	15.18	24.80	25.48
Production Standards:[5]	29.97	35.31	29.02	51.77	61.84	56.63	.38	1.53	.96
Measures Applicable in Slack Work Periods: Division of Work	8.89	10.31	8.39	15.44	16.46	14.08	0.0	2.48	2.61
Reduction in Hours	34.80	32.57	28.70	45.80	41.70	40.37	19.89	20.95	16.84
Regulation of Overtime	23.70	8.10	6.58	39.56	13.40	11.59	2.19	1.36	1.48

[1] Union contracts covering 5,000 or more workers. BLS Bulletin 1686, 1970.
[2] Union contracts covering 1,000 or more workers. BLS Bulletin 1784, 1972.
[3] Union contracts covering 1,000 or more workers. BLS Bulletin 2013, 1979.
[4] "A labor-management committee on productivity is a joint committee which meets periodically to discuss in-plant production problems and to work out methods of improving the quantity and quality of production."
[5] "Production standards refer to the expected output of a worker or group of workers, consistent with quality of workmanship, efficiency of operations, and the reasonable working capacities of normal operators."

restrict tools and equipment (11.7 percent of all construction workers and 83.2 percent of painters).[31]

The case studies of make-work practices which are discussed by Slichter, Sumner, and Healy (1960, pp.317–41), suggest such restrictive practices usually occur in markets which are local or whose products are perishable. Thus, preventing such restrictions is more likely to increase productivity in railroads, construction, entertainment, local transportation, and a few other industries which make up a relatively small sector of the economy.

Collective bargaining contracts requirements such as labor-management committees on productivity and on production standards could easily work in favor of or against efficiency. Other provisions such as those covering testing of workers (30.2 percent of all contracts) and advance notice of technological changes (18.2 percent of all contracts) are also ambiguous in their effects on efficiency.[32] Production standards which occur in roughly three out of ten contracts (and almost six out of ten manufacturing contracts) could set targets rather than merely placing lower-bounds on production and hence create inefficiency.

Various union rules which apply during slack work periods affect both productivity and unemployment. Since division of work (8.4 percent), reduction in hours (28.7 percent) and regulation of overtime (6.6 percent) are fairly uncommon, layoffs remain the most common adjustment mechanism.[33] By laying off workers, a firm adds to measured unemployment but prevents a drop in productivity which would occur if it kept all its employees during a downturn.

Only about 11 percent of the contracts which refer to scheduled weekly hours have a shorter than 40-hour workweek (and only 0.3 percent have a shorter than 35-hour week). As a result, union restrictions on workweeks are unlikely to be binding constraints. On the other hand, guaranteed overtime at one-and-one-half or double rates may lead to inefficiency in production.

Finally wage-employment guarantees may actually lead to efficiency as Leontief (1946) argued. By appropriately setting both hours and wages, a union can act as though it were a perfectly discriminating monopolist (i.e., the contract is Pareto efficient and on the contract curve at the edge of the core of the economy). While such clauses are rare (16.7 percent of all industries), they are important in transportation where they affect 86.9 percent of unionized workers (ignoring railroad and airline employees) and services (39.9 percent).

Other work rules may affect both unionized and nonunionized firms' measured productivity. The recent trend towards increased paid vacations has caused hours worked to deviate from hours paid. An inattention to this fact may cause certain measures of labor productivity to fall.

[31] See "Characteristics of Construction Agreements, 1972–73," BLS Bulletin 1819, 1974.

[32] It should be noted, however, that advance notice of technological change has become more common since 1970 (or appears more frequently in contracts covering 1000–5000 workers than in those covering over 5000 workers).

[33] Reduction in hours and regulation of overtime are now relied on less frequently than in the beginning of the decade.

To date, little is known about the effects of taxes and subsidies which affect the labor market. Social Security may induce older workers to retire at an earlier age. Such a policy reduces total output, but may increase or decrease measured productivity of various labor inputs. To the degree that unemployment insurance induces workers to remain unemployed, it may exacerbate the unemployment problem, at the same time that it increases productivity.

C. The Broader Macroeconomic Issues

The second policy issue involves the need to examine the productivity slowdown simultaneously with unemployment, income distribution, and inflation. Since policies may be viewed as competing for scarce government resources, there is often a tradeoff between stimulating productivity growth and the other objectives.

Most labor market policies are aimed at lowering unemployment rates or altering the distribution of income. Few are specifically geared to the secular decline in labor productivity growth rates. Most policies, however, are likely to have an indirect impact on one or more of the labor productivity measures by inducing a substitution effect among the various labor and nonlabor inputs. These policies include a complex set of subsidies and taxes on labor such as welfare programs, employment tax credits, unemployment insurance, and social security. Further, government employment policies such as training programs and jobs programs are likely to have a direct impact on productivity. Finally, the growth of government employment may have had dramatic effects. Unfortunately, little evidence currently exists about the productivity effects of government programs.

Recently, employment tax credits have been offered to stimulate employment. The New Jobs Tax Credit (NJTC) may have had an effect in 1977 and 1978; however, the more recent Targeted Jobs Tax Credit (TJTC) is an extremely small program. Our calculations suggest that in 1977 the NJTC may have induced those firms which knew about it to increase employment by over 3 percent compared to firms which did not know about the credit, while holding sales constant.[34] Since the credit gave a greater proportional subsidy to low-wage (unskilled) workers, it may have had a more adverse productivity effect on youths than adults. It is relatively difficult to calculate the productivity effects, however, since the NJTC was not universally used.[35] Thus, some of the new hires by firms claiming the credit may have been drawn from firms which ignored the credit (possibly because they were unaware of its existence). As a result, the credit may have lowered labor productivity in some sectors while raising it in others.

Most government training and employment programs appear to have been so small as to be largely irrelevant as explanations for trends in produc-

[34] See Perloff and Wachter (1979c).

[35] Approximately 14 percent of all firms claimed the NJTC in the first year, and 28 percent in the second year.

tivity. On the other hand, the expansion of government employment may have been quite important, at least in terms of measured productivity. In most studies, government productivity is set at zero (presumably because government output cannot be measured in the same way as that of other sectors). Thus, if the government draws workers and other factors from other sectors, the productivity levels in those sectors will change. We are unaware of a systematic study which has attempted to measure the effects of such movements.

Although most labor market policies are not designed to increase the growth of productivity, there is some confusion on this point. First, the recent identification of stagflation as a single unified problem, has served to confuse long-run secular trends in productivity and unemployment. As we have argued elsewhere the slowdown in productivity and the increase in unemployment rates are largely distinct.[36] The recent high rates of unemployment in the United States, even when the economy is experiencing high capacity utilization rates, are largely a function of increases in the equilibrium level of unemployment. Demographic changes and government labor market programs alone can explain at least a 1.5 percent increase (from a 4 percent base) in the equilibrium rate since 1955. Estimating the equilibrium unemployment rate by inverting a Phillips curve yields an equilibrium rate of at least 6.3 percent in 1978.[37] Our results, however, indicate that much of the increase in the equilibrium rate occurred prior to the productivity slowdown.

One aspect of the picture is quite favorable, however. As the baby boom cohort ages and the baby bust cohort enters the labor market, the equilibrium unemployment rate should decline while the conventionally measured productivity growth rate should increase.

Our calculations indicate that the equilibrium unemployment rate will decline by approximately 1 percent over the next decade due to demographic factors. Government policy and external events can operate to either offset or further this projected decline in the equilibrium unemployment rate. Slow growth and high inflation can remain as problems even as the demographic factors operate to lower the unemployment rate.

Second, the public debate on "supply-side" economics has occasionally confused the adverse effects on welfare programs and high marginal tax rates effects on potential output with those on productivity. Since most labor market policies affect output and labor in offsetting directions, they have only a small effect on productivity. However, if the policy concern is potential output or the rate of growth of output rather than of the average product of labor, the impact of labor market policies can be quite large. Any policy that affects the number of manhours supplied will also affect potential output. Ending mandatory retirement rules, easing the marginal tax rate on wage income, and increasing the flow of immigrants are a few of the vast number of government actions that could lead to an increase in the number of

[36] See Perloff and Wachter (1980).

[37] See, for example, Perloff and Wachter (1979a).

manhours supplied. It is important to stress, however, that these policies would alter potential output, but would not necessarily have any impact on the rate of growth of labor productivity. On the other hand, increases in output due to increases in manhours will still mean increases in income per capita and to many, this may be as important as income per manhour.

VI. Conclusions

While labor market factors cannot fully explain the productivity slowdown, it is important to control for the composition of the labor market in order to accurately measure productivity and determine the timing of the slowdown. In this paper, we examined several approaches to developing better measures of labor and productivity.

The usual productivity measure of labor, the average product, was shown to be unreasonably sensitive to shifts in the composition of the work force. The now fairly standard adjustment which creates demographically corrected labor and productivity measures is also biased if labor groups are not perfect substitutes.

In this study, we disaggregated labor into youth (unskilled) and adult (skilled) labor groups, instead of the more usual production — nonproduction worker dichotomy. Using estimated aggregate production functions, we were able to reject the hypothesis that the different types of workers are perfect substitutes.[38]

We therefore stress the use of disaggregated labor productivity measures. In particular, we rely on marginal productivity measures which are sensitive to substitution and technological progress effects. The demographically adjusted youth and adult marginal product figures (Table 5) show that youth productivity has lagged behind adults'. Indeed, while youths' average productivity increased relative to earlier periods in the last five years (Table 5), their marginal productivity follows the opposite pattern.

By asking the counter factual question, how would productivity have grown in the absence of cyclical fluctuations, we can examine the effects of those fluctuations on income and productivity. Comparing the potential marginal product figures in Table 6 to the estimated actual numbers in Table 5, one sees that the major cyclical impact on marginal products occurred during the last five years. Indeed, had the economy been at full employment during this period, both youths' and adults' marginal productivity would have averaged over 0.5 percentage point greater annual growth.

It is also worth noting that fixating on labor productivity leads one to form an over-grim picture of the economy. During the last five years, capital and energy's marginal products have grown at historically high rates. As a result, total productivity measures show a much lower productivity slowdown than do labor productivity measures.

[38] Comparable results were obtained by Berndt and Christensen (1974) using production and nonproduction workers.

Finally, while it is difficult to evaluate government *labor market policies* quantitatively, there is little evidence to suggest that they can be used to stop or reverse the slowdown. For given growth rates of technology and supplies of nonlabor inputs, most labor market policies to raise productivity growth rates would require a slowdown in the rate of growth of employment. This approach, however, would be inconsistent with other desirable public policy goals. Indeed, since most labor market policies are oriented toward increasing employment, decreasing unemployment, or redistributing income, they will generally decrease the employment of skilled workers and other inputs relative to unskilled workers, thus exacerbating the productivity slowdown. It must be stressed, however, that there is little quantitative evidence to suggest that these policies generate large negative productivity effects. Labor market policies, to the extent that they have a large impact, probably operate indirectly; on the margin these programs involve the allocation of government budgetary resources that could be used for programs with a direct and positive impact on productivity growth. Of particular importance are programs that would increase the supply of other inputs — especially capital and energy.

Appendix

The three-factor cyclically sensitive translog production function and the associated data are described in Perloff and Wachter (1979a). The four-factor cyclically sensitive translog production function will be described in more detail in a forthcoming paper.

The capital, demographically adjusted labor, and energy series are the same as in Perloff and Wachter (1979a). The new youth and adult labor series were constructed in the following manner. Annual Current Population Survey (CPS) hours data for the 14 standard BLS demographic groups were interpolated to quarterly numbers using the average weekly hours series for males 16+ which is available quarterly. Hours were multiplied by quarterly nonagricultural employment data from *Employment and Earnings* after civilian government employees were removed (using data from the May CPS and unpublished sources). Then the data were aggregated into two groups (workers age 16–24 and 25+), using the annual relative income of year-round, full-time workers (March CPS) as weights within each group.

The income data were used to estimate wage bills for the two groups subject to the constraint that the two wage bills had to sum to the total labor wage bill. The total wage bill is the compensation of employees in the private nonfarm sector from the *Survey of Current Business*.

The cyclically sensitive translog production function is:

$$\ln Q = \beta_0 + \beta_1 + \beta_2 t^2 + \beta_3 t^3 + \beta_4 I_0 + \beta_5 I_1$$

$$I_0 = \sum_i \alpha_i^0 \ln i + \tfrac{1}{2}\Sigma\Sigma\gamma_{ij}^0 \ln i \ln j,$$

$$I_1 = \mathrm{UGAP}\,(\sum_i \alpha_i^1 \ln i + \tfrac{1}{2}\sum_i\sum_j \gamma_{ij}^1 \ln i \ln j),\quad i,j, = Y,A,K,E,$$

where t is a time trend.

See Perloff and Wachter (1979a) for details as to how coefficients are estimated using share equations. The maintained hypothesis is that the production function is homogenous (but not necessarily of degree one).

The estimated coefficients are:

α^0_Y	.013 (0.101)	α^1_Y	0.672 (0.414)
α^0_A	0.706 (0.057)	α^1_A	−0.504 (0.279)
α^0_E	0.395 (0.162)	α^1_K	−1.027 (0.729)
α^0_E	−0.115 (0.169)	α^1_E	0.858 (0.757)
γ^0_{YY}	−0.056 (0.030)	γ^1_{YY}	0.379 (0.115)
γ^0_{YA}	−0.032 (0.009)	γ^1_{YK}	−0.122 (0.042)
γ^0_{YK}	0.032 (0.026)	γ^1_{YK}	−0.127 (0.106)
γ^0_{YE}	0.057 (0.031)	γ^1_{YE}	−0.130 (0.127)
γ^0_{AA}	0.268 (0.036)	γ^1_{AA}	−0.732 (0.165)
γ^0_{AK}	−0.131 (0.026)	γ^1_{AK}	0.467 (0.123)
γ^0_{AE}	−0.105 (0.020)	γ^1_{AE}	0.387 (0.095)
γ^0_{KK}	0.009 (0.044)	γ^1_{KK}	0.070 (0.195)
γ^0_{KE}	0.091 (0.043)	γ^1_{KE}	−0.410 (0.191)
γ^1_{EE}	−0.043 (0.057)	γ^1_{EE}	0.153 (0.245)

R^2 for the system = 0.9216
Weighted mean square error for the system = 1.1303
with 270 Degrees of Freedom.
(Standard Errors are in the parentheses).

This production function is globally convex (evaluated at the data means). It is convex for each quarter (evaluated at the equilibrium values). The following production function was estimated using a first-order autocorrelation correction:

$$\ln Q = \underset{(0.4071)}{4.2029} + \underset{(0.0055)}{0.0284t} + \underset{(0.0005)}{0.0003t^2} - \underset{(0.00001)}{0.00001t^3} + \underset{(0.0855)}{0.3866\, I_o} - \underset{(0.0234)}{0.2178\, I_1}$$

$R^2 = 0.9786$
Degrees of Freedom = 90
$\rho = -0.8584$
(0.0524)

REFERENCES

Berndt, Ernst R. and Lauritis R. Christensen. "Testing for the Existence of a Consistent Aggregate Index of Labor Inputs," *American Economic Review*, June, 1974, pp. 391–404.

—— and Mohammed S. Khaled. "Parametric Productivity Measurement and Choice among Flexible Functional Forms," *Journal of Political Economy*, V. 87, Number 6, December, 1979, pp.1220–1245.

—— and David O. Wood. "Engineering and Econometric Interpretations of Energy-Capital Complementarity," *American Economic Review*, V. 69, Number 3, June, 1979, pp.342–354.

Bernstein, Paul. "The Work Ethic That Never Was," *The Wharton Magazine*, V. 4, Number 3, Spring, 1980, pp.19–25.

Brinner, R. *Technology, Labor and Economic Potential*. Lexington, Mass.: Data Resources, Inc. Study 29, 1978.

Brown, Charles and James Medoff. "Trade Unions of the Production Process," *Journal of Political Economy*, vol. 86, N.3, 1978, pp.355–378.

Clark, Peter K. "Capital Formation and the Recent Productivity Slowdown," *Journal of Finance*, June, 1978, pp.965–975.

Denison, Edward F. *Accounting for Slower Economic Growth: The United States in the 1970s*. Washington, D.C.: The Brookings Institution, 1979.

Easterlin, Richard A. *Population, Labor Force and Long Swings in Economic Growth: The American Experience*. New York: Columbia University Press for the National Bureau of Economic Research, 1968.

Gollop, Frank M. and Dale W. Jorgenson. "The U.S. Productivity Growth by Industry. 1947–1973," in J. W. Kendrick and B. N. Vaccara, ed., *New Developments in Productivity Measurement*. National Bureau of Economic Research, forthcoming, 1980.

Griffin, J. M. and P. R. Gregory. "An Intercountry Translog Model of Energy Substitution Responses," *American Economic Review*, V. 66, Number 5, December, 1976, pp.845–857.

Hamermesh, Daniel S. and James Grant. "Econometric Studies of Labor-Labor Substitution and Their Implications for Policy," *Journal of Human Resources*, Fall, 1979, pp.518–542.

Kendrick, John W. *Postwar Productivity Trends in the United States, 1948–1969*. National Bureau of Economic Research, 1969.

Leontief, W. W. "The Price Theory of the Guaranteed Annual Wage Contract," *Journal of Political Economy*, February, 1946.

Morrison, Catherine J. and Ernst R. Berndt. "Short Run Labour Productivity in a Dynamic Model." Dept. of Economics, The Univ. of British Columbia, June, 1979.

Nordhaus, William D. "The Recent Productivity Slowdown," *Brookings Papers on Economic Activity*, 3:1972, pp.493–545.

Norsworthy, J. R., Michael J. Harper and Kent Kunze. "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, 2:1979, pp.387–421.

Okun, Arthur M. "Upward Mobility in a High Pressure Economy," *Brookings Papers on Economic Activity*, 1:1973, pp.207–261.

Perloff, Jeffrey M. and Michael L. Wachter. "Worksharing, Unemployment, and Economic Growth Rates," in *Work Time and Unemployment*. National Commission for Manpower Policy. Special Report No. 28. October, 1978. pp.87–122.

——. "A Production Function — Nonaccelerating Inflation Approach to Potential Output: Is Measured Potential Output Too High?" *Carnegie — Rochester Conference Series on Public Policy*, V. 10, 1979a, pp.113–163.

——. "Alternative Approaches to Forecasting Potential Output, 1978–1980," *Proceedings of the American Statistical Association*, 1979b, pp.104–113.

—— "The New Jobs Tax Credit: An Evaluation of the 1977–1978 Wage Subsidy Program," *Papers and Proceedings of the American Economics Association*, May, 1979c, pp.173–179.

——. "Demographic Aspects of the Stagflation Problem," Joint Economic Committee *Special Studies on Economic Change*, forthcoming, 1980.

Perry, George L. "Potential Output and Productivity," *Brookings Papers on Economic Activity,* 1:1977, pp.11–60.

Rasche, Robert H. and John A. Tatom. "Potential Output and Its Growth Rate — The Dominance of Higher Energy Costs in the 1970s," in *U.S. Productive Capacity: Estimating the Utilization Gap.* Center for the Study of American Business. Washington University, Working Paper No. 23, December, 1977, pp.67–106.

Slichter, Sumner, James Healy, and E. Robert Livernash. *The Impact of Collective Bargaining on Management.* Washington D.C.: The Brookings Institution, 1960.

Tatom, John A. "The Productivity Problem," *Federal Reserve Bank of St. Louis Review,* V. 61, Number 9, September, 1979, pp.3–16.

Wachter, Michael L. "The Changing Cyclical Responsiveness of Wage Inflation over the Postwar Period," *Brookings Papers on Economic Activity.* 1:1976a, pp.115–159.

——. "The Demographic Impact on Unemployment: Past Experience and the Outlook for the Future," *Demographic Trends and Full Employment,* U.S. National Commission for Manpower Policy, Special Report No. 12, December, 1976b, pp.27–99.

—— and Oliver E. Williamson. "Obligation Markets and the Mechanics of Inflation," *Bell Journal of Economics,* Autumn, 1977, pp.549–571.

Discussion

J.R. Norsworthy*

This paper on demographic shifts and cylical fluctuations in the productivity slowdown is an excellent one in several respects. I will note these points quickly, and, as is customary, turn my attention to matters that could be improved.

The authors begin by pointing out that average labor productivity is inferior to marginal labor productivity for analyzing the productivity slowdown — a point well taken but perhaps belabored. Their general approach is then to estimate a model of the production process that is sensitive to cyclical fluctuations and changes in energy prices separating the "lumpenproletariat" into two "lumpen" — young and adult workers. The authors then use the results of this estimation to analyze productivity growth, real wages and income, and labor market policies. In my opinion, their general method is entirely appropriate, and only this kind of approach could make the conclusions believable.

It seems to me, however that a number of points warrant discussion in that alternative or additional procedures would make the conclusions easier to evaluate and perhaps ultimately to believe.

The results of the production function estimation are not reported nor are the data on which it is based in sufficient detail. Since the entire paper depends upon the estimation, the authors might have devoted one page (in a total of 50) to reporting the estimation technique, parameter estimates and equation properties. The substitution elasticities, or other indications that the demand surfaces for young and adult workers indeed slope downward, are really essential to establish the credibility of the rest of the results. My earlier plaudits really should be conditional on satisfactory estimation results and convexity for the productivity function.

The authors claim to have adjusted for cyclical movement in the economy by incorporating a single variable in the production function — the gap between the current and equilibrium employment rates, UGAP. There are three difficulties with this. First, UGAP is itself subject to changes due to other than business cycle influences. . . . how about demographic change? The "youthful bulge" in the labor market? The rising participation rate of females? Second, a closely related point is that UGAP is codetermined with

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the demand for labor in the aggregate sector for which the authors estimate the production function, and should be estimated jointly with the share equations describing the production function. Third, a single variable describing the disequilibrium in production associated with varying levels of output seems inadequate and indeed the cyclically adjusted data retain some procyclical movements. In particular, the quantity of capital cannot be instantaneously adjusted, and this leads to compensating under- or over-adjustment in other input factors.[1] The disequilibrium adjustment process for a four-factor model such as the authors estimate would be described by nine parameters rather than only three — or perhaps nine *more* parameters. Because the theory and practice in dynamic modeling of the production process are in a state of rapid and multidirectional evolution, it may be better to modify the claims for the present approach rather than to attempt to live up to them. An appropriate claim would be "that first-order effects of labor market disequilibrium in the demand for the input factors have been adjusted for, ignoring the codetermination of labor market disequilibrium and labor demand."

Now it is somewhat inappropriate to refer to "the production function" in the first place, because in fact no translog-based production function has the share equations that the authors estimate. This should not be taken as too harsh a criticism, because the same is true of many of the dynamic multifactor studies including some of mine.[2] Again, the key to the "no such production function" problem is the codetermination of unemployment and the demand for labor in the author's model. Accordingly, even if the authors had reported elasticities of substitution for the estimated model, some question would have remained about their interpretation.[3]

The authors make much of the point that youth and adult labor are not perfect substitutes, based on tests for aggregation. These tests should be described at least generically. (Are they separability tests following the Berndt-Christensen reference?) Further, it is at least arguable that if the youth and adult age groups had been adjusted for other characteristics — education, occupation, industry and (possibly) class of worker (i.e., employed or self-employed) — the aggregation tests would have passed. More precisely, it cannot be concluded that the two groups cannot be aggregated into a single input due to the influence of a particular characteristic, age — presumably operating primarily as a proxy for experience — unless the effects of age alone can be isolated. If the effective quantities of labor input from the two groups are measured without regard to age, and the aggregation test fails, it is at least a

[1] See M.I. Nadiri and S. Rosen, "Interrelated Factor Demand Functions," *American Economic Review*, Sept. 1969, pp. 457–71.

[2] However, substantial improvements are being made now; the work of E.R. Berndt and others provide an outstanding example of theoretically complete approaches. See the sections by Berndt and Morrison, and Denny, Fuss and Waverman in E.R. Berndt and B.C. Field, eds., *Measuring and Modeling Natural Resource and Energy Substitution*, MIT, forthcoming.

[3] For a discussion of this problem see J.R. Norsworthy and Michael J. Harper, "Dynamic Models of Energy Substitution in U.S. Manufacturing," in Berndt and Field, *Measuring and Modeling*.

reasonable presumption that age is the critical factor. However, there is pretty good evidence that the rapid employment growth since the mid-1960s was characterized by more education; that employment grew more rapidly in the nongoods producing industries; and that particular occupations expanded more rapidly.[4] Thus these other characteristics may be responsible wholly or in part for the authors' results.

The discussions of the comparative trends of average and marginal labor productivity, and total (factor) productivity would be clearer if based on effective labor inputs — adjusted for other elements of composition change as noted above. Likewise effective capital and energy inputs should be used in estimating the production function. (They may have been — this information would be helpful in interpreting the results.) In particular, the discussion of the dating of the productivity slowdown would be improved — and probably more convincing — if effective rather than largely undifferentiated factor inputs were its basis. In any event, I think that the slowdown is best thought of as occurring in two phases — as I have argued elsewhere[5] — an early phase which was unevenly distributed among major industry groups, and a post-1973 phase which was far more general. (Clearly the latter phase must also be examined for energy-related effects.) The dating of the earlier phase may well depend on whether one's primary concern is the average product of labor, the marginal product of labor, or total factor productivity. Inflection points in the subject series should be determining, with due regard for the business cycle.

I think the discussion of policies to promote productivity growth is somewhat off the mark in spots. It should be stated clearly for productivity policy that promoting only total factor productivity growth is the only reasonable goal. Any single-factor productivity policy may raise that factor's productivity at the expense of total factor productivity growth and thus total cost, and therefore exacerbate inflation. At any event, much of the recent productivity policy discussion has centered on incentives to increase capital formation, rather than labor market policies.

The historical focus on labor productivity was not really that wide of the mark, however. Labor was after all the scarcest factor, as judged by the relative rates of price increase, a major cost factor (especially in national income statistics!), and the only factor whose welfare was a widespread national concern. Indeed, in the private business sector the average product of labor, real hourly compensation (adjusted by the CPI rather than the implicit price deflator), were strongly and positively correlated during the postwar period. Of course, nothing much was changing in the relative price movement of major input factors. Multifactor productivity (capital and labor only) also moved parallel with labor productivity, its growth slowing by about 1 per-

[4] Peter Chinloy, "Sources of Quality Change in Labor Input," *American Economic Review*, March, 1980.

[5] J.R. Norsworthy, Michael J. Harper and Kent Kunze, "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, 2: 1979, pp 389–421.

cent in 1965–73. But from 1973 to 1978, whereas labor productivity growth (unadjusted) slowed a further 1 percent, but K–L productivity growth slowed only about 0.15 percent per year.[6] So it is indeed time to examine other measures of the efficiency of resource use, and the authors' suggestions in this vein are quite appropriate.

The discussion of labor market policies is encouraging in that appropriate quantitative techniques are brought to bear on the issues. Again, the author's conclusions would be easier to evaluate if the estimated model and its properties were at hand. As regards future work that might be undertaken in the authors' framework, it would be interesting to see what the distributional implications of the model are, as between laborers, rentiers, and sheiks, over the next 10 years for a range of energy prices and output demand.

In summary, the generally quite plausible results are achieved by what seems to me to be an entirely appropriate analytic method. The major problem in execution is the failure to adjust the youth and adult labor segments for other characteristics that may have biased the results. The freedom-of-information spirit of the times suggests also that the estimation results and other model characteristics be reported, perhaps in an obscure appendix

[6] Ibid.

Policy Responses to the Productivity Slowdown

William D. Nordhaus*

Much has been written by economists about the sources of the productivity slowdown; and self-serving policy recommendations by interest groups abound. Strangely, the two are seldom connected. It is as if, upon seeing a neighbor jog his rounds more slowly than usual, we give him our expert advice without finding out why.

But, surely, our advice to our neighbor must depend on the source of his lagging pace. Perhaps his shoes are old and pinch his feet, in which case we would recommend a program of modernizing his jogging equipment. Or, instead, has he grown somewhat fat, in which case a period of dietary austerity is in order? On the other hand, if his strength is depleted, it might be suicidal for him to run faster.

My theme here is similar. The possible reasons for the U.S. productivity slowdown are numerous. How we should respond depends on what has happened. A less fanciful example of the dilemma can be seen in the area of drilling for oil. Figure 1 shows the finding rate for oil over the last 15 years. As can be seen, there was a sharp break in the trend in 1973: whereas finding rates had been falling at about 1 percent per year up to 1974, from 1974 to 1978 they fell at 12 percent per year.

What was the source of the productivity break in oil drilling in 1974? There are two classes of reasons — manmade *obstacles* and natural *depletion.* In the former category we would place the results of the regulatory apparatus set up in 1973 to control oil prices. In the depletion category we might guess that the dramatic upturn in drilling rates since 1973 has led to severe short-run diminishing returns.

Although the oil drilling story is fascinating in itself, I tell it here only to illustrate the more general point. How we should respond to the productivity drop in oil drilling depends crucially on which of the two explanations in the last paragraph we believe. If we think manmade impediments (price controls, high or distorted taxes, confusing regulations) are to blame, then we should work overtime to rationalize or dismantle these obstacles. If, on the other hand, we feel that we have simply been dealt a poor hand by nature (depletion of resources or new ideas, low marginal productivity of capital), then the appropriate response is much less clear. Upon seeing that the yield per well drops sharply, do we want special tax incentives for investment or saving to induce us to drill more wells? Or should we drill less and use the freed resources to develop synthetic fuels or to enjoy solar intensive beach

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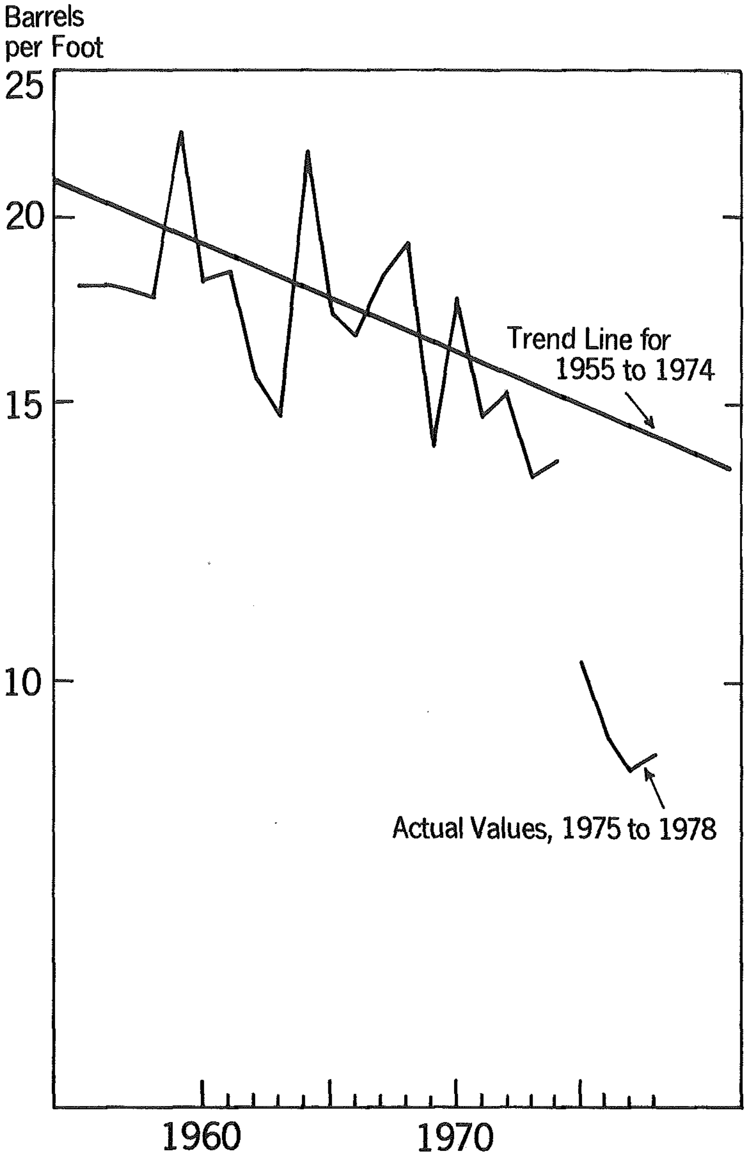
Figure 1
Productivity in Oil Drilling, 1955-78
(Crude oil reserves added per successful oil foot drilled)



Source: U.S. Department of Energy, Historical Review of Domestic Oil and Gas Exploratory Activity, October 1979, DOE/EIA-1096.

Table 1
Measures of Productivity Performance, before and after 1973

	[Annual average growth rate, percent] 1948–73	1973–79
Output per Hour of all persons:		
Total Economy	2.3	0.2
Private Business	2.9	0.6
Nonfarm Private Business	2.4	0.5

SOURCE: *Economic Report of the President, 1980.* Figure for total economy is real GNP divided by total employment.

activities? There is no clear answer. Some old joggers try harder while others fade away.

With these introductory notions, I now turn to a discussion of the productivity puzzle and policy reactions. The next section provides my personal synthesis of existing studies. The following sections then review policy responses.

A. Sources of the Productivity Slowdown

The purpose of the present section is to review the recent discussion of the productivity slowdown. I will use the inaccurate "productivity slowdown" as shorthand for "a slowdown in the growth rate of labor productivity." Has there really been a productivity slowdown? Is it unprecedented in recent economic history? What are the generally accepted reasons given for its occurrence? And how do the reasons given fit into the depletion versus obstacles theory given above?

1. *Has there really been a productivity slowdown?*

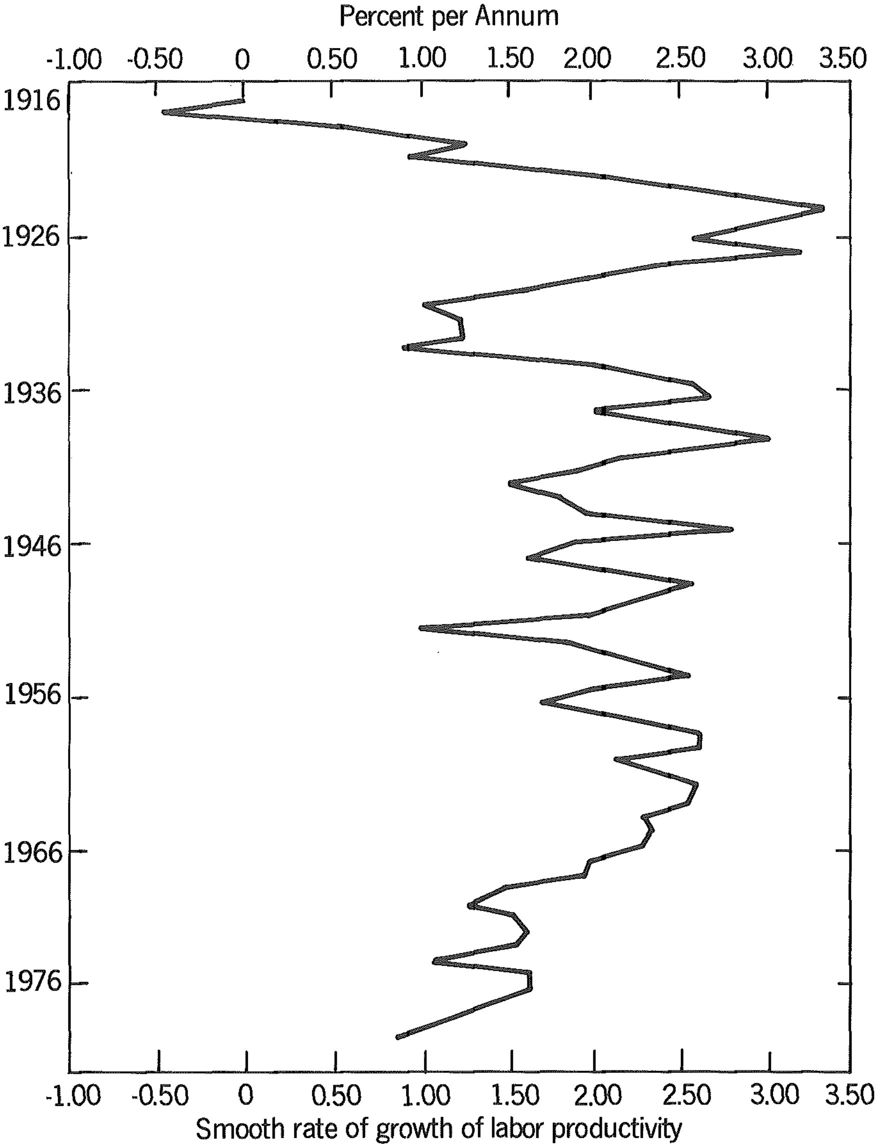
It is by now generally accepted that the productivity growth rate in the United States has significantly slowed down over the course of the 1970s. There is no consensus about the exact timing of the slowdown; productivity growth has clearly slowed since the early 1960s, but whether the decisive year was 1969 or 1973 is subject to dispute. In what follows we will use the year 1973 as the break year because a distinct break shows in the data that year, and many prominent reasons for the slowdown (energy prices being the outstanding example) appeared in 1973.

Using 1973 as a break point, Table 1 gives several measures of aggregate productivity performance in the earlier and later period. The decline in the growth of labor productivity is clear for all concepts used. As a rough rule of thumb, the growth in the private business economy has fallen from around 3 percent per annum to about 0.5 percent per annum after 1973.

It should be noted that the productivity decline is also extremely widespread. Of the 12 major industry groups, only communications and the fi-

Figure 2

Estimated Long-Term Growth of Productivity



Series is output per worker-hour in the private nonfarm business economy. Cyclical influence has been removed as described in footnote 1. For each year the rate is the six-year average ending in year shown on left.

nance, insurance, and real estate group have not suffered a slowdown in the post-1973 period. The productivity slowdown has also been felt in all major industrial countries. Although it is not clear why this fact should make us more convinced that the U.S. slowdown is real, the fact that the slowdown is universal should point us toward widely felt explanations.

At a somewhat deeper level, we might ask whether the productivity slowdown is an illusion. After three days of continuous rain we do not generally dust off plans for building an ark—although after 30 we might. To what extent is the half dozen years of dismal productivity growth sufficient to convince us that, to return to our climatic analogy, we have encountered a technological climate change rather than a long run of storms.

To my knowledge, no one has looked hard at the question of whether the recent productivity slowdown has a precedent. For this reason, I patched together a long time series on labor productivity in the nonfarm U.S. business sector running over the period 1909 to 1979. Using standard techniques I removed the cyclical influence on productivity.[1] I then asked a number of questions about the past behavior of the cyclically corrected series.

First, we can simply inspect the time series on productivity growth. The most revealing series, shown in Figure 2, is the long time series on smoothed, cyclically corrected productivity growth. For this series, I chose a six-year moving trend (corresponding to the six lean years since 1973). The results are quite striking. If we ignore the wiggles, the rate of productivity growth from World War I to the middle 1960s was more or less constant. Starting about 1966, however, a slow but steady downward creep has occurred from an average of 2 to 2½ percent annually to a level of slightly under 1 percent in 1979. Moreover, the smoothed rate of productivity growth in 1979 was lower than any year since 1933, and one would have to go back to 1920 to find a markedly worse year. The only year remotely as poor in the postwar period was 1951. Thus casual evidence indicates that one would have to go very far back — to a period which surely stretches credibility about the data — to find comparable poor experience.

A second way of examining the data is to perform a formal statistical test on the hypothesis that the structure changed after 1973. To do this, we simply take the regression described in footnote 1 below and add a dummy variable to the post-1973 period. This technique gives results that are consistent with the visual impression in Figure 1. When the test is confined to the postwar period (1949 to 1979), the decline in productivity is statistically significant (the dummy shows slower productivity growth by 1.3 percent with a standard error of .63 percent). However, if the entire period is weighed (1912

[1] The cyclical influence was removed as follows: A regression of productivity change on output growth and lagged output growth was run; the coefficients being .316 (±.044) and -.077 (±.044) respectively. A cyclically corrected productivity growth was then constructed by subtracting from measured growth the deviations of output growth from its mean times the estimated coefficients. Note that the sum of the coefficients is about 0.25, indicating that faster growth leads to faster productivity growth in the long run. While this extent of economies of scale is high, it is not entirely out of line with estimates of Denison or Kaldor.

Table 2
Changes in the Rate of Growth of Labor Productivity: Pre–1965 to Post–1972

	J. Kendrick	Norsworthy, Harper, Kunze	Norsworthy, Harper, Kunze	E. Denison	Z. Griliches	P. Clark	P. Clark	L. Thurow	Miscellaneous
Sector	Private Business	Private Business	Private Nonfarm Business	Total Economy	Manufacturing	Private Nonfarm Business	Private Nonfarm, Nonresidential Business	Private Nonfarm Business	Private Business
Output Measure	Gross Dom. Inc.	Gross Dom. Inc.	Gross Dom. Inc.	Net Nat'l. Inc.	Gross Output	Gross Dom. Inc.	Gross Dom. Inc.	Gross Dom. Inc.	
Periods Studied	1948–66 & 1972–78	1948–65 & 1973–78	1948–65 & 1973–78	1953–64 & 1972–76	1959–68 & 1969–77	1948–65 & 1973–76	1948–65 & 1973–78	1948–72 & 1972–78	
Total Decline	–2.40	–2.12	–1.68	–2.64			–1.83		
Cyclical	–0.30			–0.05				–0.40	
Trend						–1.67			
Capital	–0.40	–0.74†	–0.57†	–0.17		–0.4 to† –0.97	–0.54†		
Labor	+0.10	–0.28	–0.18	–0.14		+0.04			
Energy		–0.18 (manufacturing)	–0.18 (manufacturing)	–0.10					–0.6 (Jorgenson–Hudson) –1.3 (Rasche–Tatom) –0.2 (G. Perry)
Regulation	–0.30	–0.09	–0.08	–0.27				–0.20*	
Research	–0.60			–0.10	–0.10 to –0.40				
Sectoral Shifts	–0.50			–0.27				–0.60**	–0.10 (CEA)
Other Factors	–0.30	–0.83	–0.67	–1.54		–0.67 to –1.28	–1.29		

Table 3
"Best Guess" Sources of Productivity Decline*

Total Decline	2.5 percentage points
Cyclical (slower growth in output)	0.3
Trend	2.2
Sources:	
Capital	0.3
Labor	0.1
Energy	0.2
Regulation	0.2
Research & Development	0.1
Sectoral Shifts	0.3
Unexplained	1.0

* The "slowdown" is the difference in the growth rate of productivity per hour worked from the period 1948–65 to the period 1973–79. Output is gross product originating in the private business sector. Note that a positive number indicates a slowdown.

to 1979), the slowdown is smaller (.98 percent) and has a larger standard error (1.0 percent). Thus, while the slowdown may look quite unprecedented for those with short memories, in the longer view, the slowdown is one which we would expect to occur from time to time. Indeed, such slowdowns have occurred twice before in the last 60 years. On the basis of the postwar period, we would expect to draw a hand as bad as that of the last six years once every four decades. Over the entire sample period, we would expect as bad a hand about once a decade.

2. *Why has productivity slowed?*

From now on I will assume that productivity has slowed and turn to the reasons. By now a gaggle of studies is available on the sources of the slowdown, but I will restrict my attention to those that deal with broad aggregates rather than with individual industries. With the assistance of Robert Lurie of Yale University, I have compiled in Table 2 the key results of several of the recent studies.

In the various studies, seven important factors have been identified as possible sources of the productivity slowdown. For the most part, the technique used to estimate the effect of the specific factor on productivity growth is known as "growth accounting." This technique assumes that there is a well-behaved aggregate production function, and that for most factors the contribution of inputs (the marginal product of a factor) is measured by its market return.

We will not attempt to summarize the studies in any detail at this point, but make general comments about the overall findings. In addition, for the private business economy, we make in Table 3 a "best guess" as to the magnitude and the source of the productivity slowdown.

It is generally agreed that the slower rate of growth of the capital stock has contributed significantly to the productivity slowdown. The severe recession after 1973, as well as policies which were less pro-investment than in the earlier periods, led to a significantly slower growth in the utilized capital stock. In addition, a point omitted in most studies, the profit rate on capital (and presumably the marginal productivity of capital) has declined in recent years. This would imply that at a given rate of growth of capital the contribution to output would be smaller. There is a serious problem in most of the estimates in Table 1 of the contribution of the capital stock (see Berndt's paper in this volume). They compound changes in stock with changes in utilization. The latter appears responsible for most of the contribution of capital to lower growth. Assuming the two factors have the same output elasticity is clearly a misspecification. The best guess as to the contribution of the slower growth of the capital stock to the slowdown is 0.3 percent per annum; changes in utilization since 1973 should hardly be attributed to cost of capital or similar variables.

As the productivity concept we are using here is output per hour worked, the contribution of labor is likely to be small. However some demographic shifts have taken place over the postwar period; consequently, the best guess is that labor quality subtracted approximately 0.1 percent annually from productivity growth.

The contribution of energy to the productivity slowdown is extremely controversial, and is discussed elsewhere in this conference. The estimates generally converge on numbers in the range of 0.1 to 0.2 percent per annum, except for models which have a rapid adjustment of the capital stock to change relative prices. Given the implausibility of the latter assumption, we will use 0.2 percent per annum as the best guess for the contribution of changed energy prices to the productivity slowdown.

The influence of regulation is perhaps the most difficult effect to measure. The direct effects — inputs diverted to tasks that do not show up as measured output — are easily measured, and the estimates given in Table 4 reflect these direct effects. The indirect effects — chilling effects of regulation or innovation, entrepreneurship, or choice of techniques — do not appear in the estimates. As I suspect the latter are quite significant, I use the high end of the range in estimating the effects of regulation on productivity.

Two other items which have been explicitly identified and measured with some care are the effects of the lower intensity of research and development, and the role of sectoral shifts. It is estimated that these contribute modestly to the productivity slowdown. One of the important features of Griliches' study is the suggestion that the social rate of return on R & D has declined markedly in the most recent period.

A final factor in the productivity slowdown is the effect of slower economic growth since 1973 upon productivity growth. This factor is sometimes ignored, even though there is considerable evidence of short-run (even long-run) increasing returns to scale. Most studies that directly examine this question find some modest effect of cyclical conditions — ranging up to 0.3 percent for the period 1973 to 1978. It should also be noted that the utilization correction discussed under capital above is really a cyclical correction rather

Table 4
Sources of Productivity Slowdown and Appropriate Policy Responses

Category	Quantitative Significances (percent of slowdown		Policy response
1. Shift in tastes	Capital (due to incentives). Internalize externalities	10%	no response
2. Market failure	Capital (due to tax system).	5%	correct market failure
3. Self-inflicted wounds	Regulation and cycle (due to poor policies).	20%	Improve regulatory and anti-inflation policies
4. Depletion	Energy. R&D. Investment (lower productivity of capital). Sectoral shifts. Cycle (due to slowdown) Residual.	65%	Ambiguous. Probably save smaller fraction of output.

than a capital contribution. In a statistical test performed for this paper (and described in footnote 1) I found that the slower economic growth for the private business sector contributed about 0.3 percent to the slowdown after 1973. I will use 0.3 percent as a reasonable best guess.

Table 3 collects my best guess as to the sources of the productivity slowdown in the private business sector. In this collection, I have used the period up to 1965 and after 1973, because it is so difficult to identify exactly where the break point came historically. For these periods, the productivity slowdown was 2.5 percent. Taking all the identified factors, we can reasonably explain about 1.5 percent of the decline, but the remaining 1.0 percent must at this point be labeled as mystery.

B. Policy Responses: General Principles

Having reviewed briefly current knowledge about the sources of the productivity slowdown, I turn to the question of how we should respond. I first discuss general principles and then turn to specific suggestions.

To begin with, can the literature on economic growth say anything about how policy should respond to the productivity slowdown? Let us start by assuming that economic growth policies had been well-designed in the period before 1973. Figure 3 illustrates the growth equilibrium that might have been experienced in the 1960s. Given the consumption possibility curve—$F(c_1, c_2)$ — and the utility function — $U(c_1, c_2)$—the best outcome is with consumption $(\hat{c}_1, \hat{c}_2)$. Savings in the first period is $(\bar{c} - \hat{c}_1)$ and the economy grows at

Figure 3

Outcome of Choice of Optimal Growth Path Before Productivity Slowdown

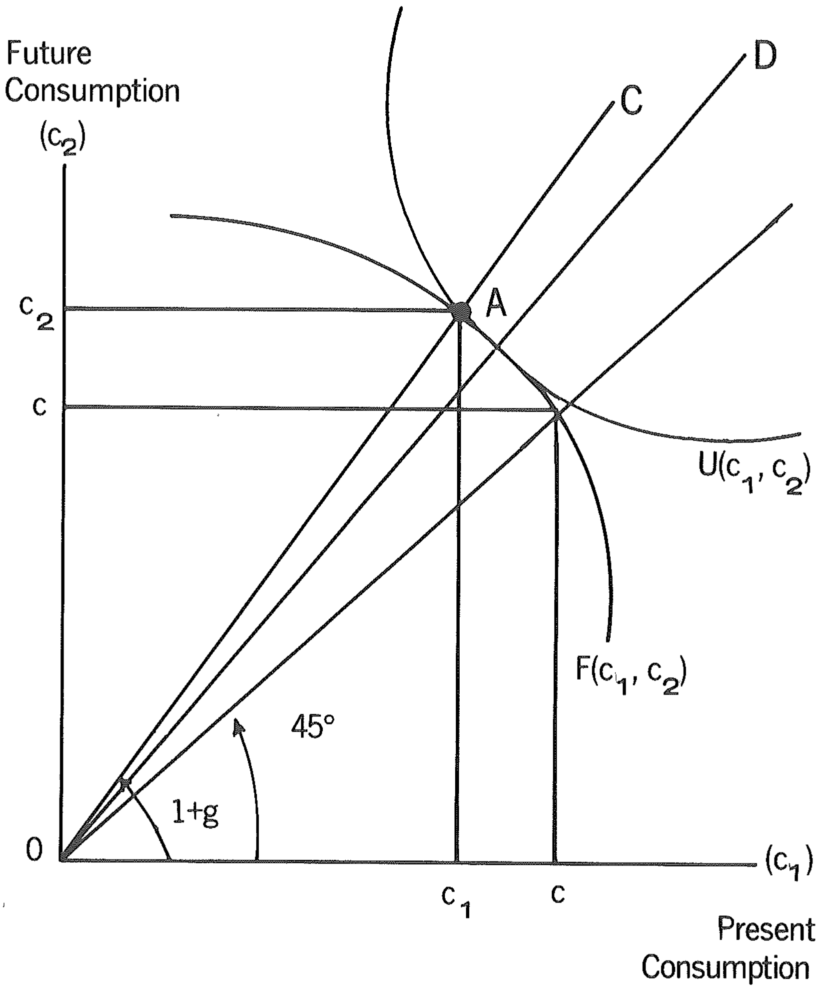
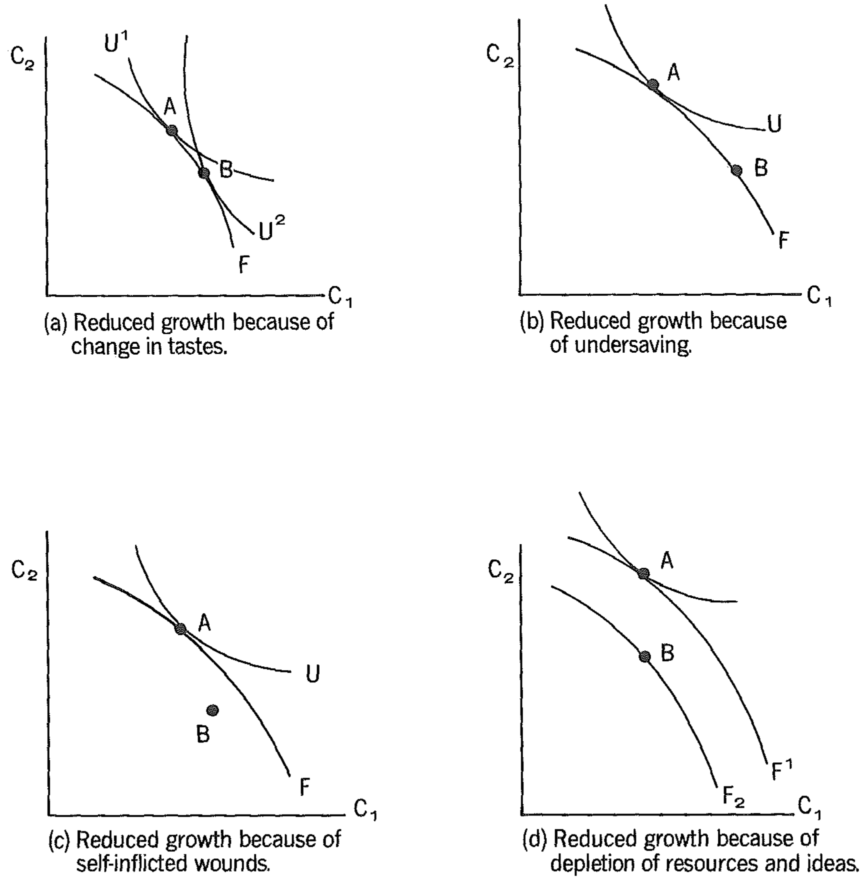


Figure 4

Illustration of four possible reasons for the productivity slowdown. In each panel, point A represents the consumption bundle before, and point B after, the productivity slowdown.



(a) Reduced growth because of change in tastes.

(b) Reduced growth because of undersaving.

(c) Reduced growth because of self-inflicted wounds.

(d) Reduced growth because of depletion of resources and ideas.

rate g on ray from the origin OC.[2]

If we return to examine our economy a few years later—after the productivity slowdown—what do we see? Unfortunately, we don't see the F or U functions in Figure 3. Rather, we simply observe that the economy is growing at a reduced rate along line OD rather than the earlier ray OC.

What are the causes of the reduced growth? In the various panels of Figure 4 we show the important possibilities. We will first attempt to fit the different causes of part A into the analytical mold, then we will discuss the appropriate policy response.

Table 4 divides the "best guess" sources into the four categories, and notes the appropriate policy response. Needless to say, this division is not obvious, but the exact numbers are less important than the general outline.

a. The shift in tastes category would arise in two cases. I interpret the lack of further pro-growth policies during the 1970s and the attempt to internalize externalities as changes in tastes. In both cases, decisions were taken which were tilted toward consumption or away from conventionally measured output. A rough guess would be that one-tenth of the slowdown arises from this source.

b. The second category is market failure. As noted below, there are few documented examples outside of the role of inflation in the tax system, and this is ambiguous. I would guess 5 percent as a total.

c. The third category is self-inflicted wounds. One clear case is poor cyclical management. Excessively expansionary policies before 1973, and poor choice of tools for fighting inflation since 1973, led to a distinctly slower growth rate and thereby slower productivity growth. A second example of poor management is excessively stringent or inefficient regulation. A rough guess is that 20 percent of the slowdown fits here.

d. The balance of the slowdown, totaling 65 percent, can be attributed to depletion. The evidence on the depletion hypothesis is quantitative and circumstantial but, in my view, persuasive. The review of sources of productivity growth above seems unable to find a substantial number of causes of type (a), (b), and (c), so we are probably left with depletion as a residual. The decline in productivity in extractive industries is of course a literal example of depletion. The decline in the return on capital and R&D (without a surge of either) seems to indicate depletion of investment opportunities. There is evidence that economies of scale in electrical generation and many processing industries have been exhausted. We have also largely exhausted the productivity bonus due to sectoral shifts from agriculture to industry. It would also be appropriate to attribute to depletion the cyclical (or economies of scale) effects that are due to these items. Finally, and vaguest of all, I have the impression that great inventions such as those we have witnessed in the past century (telephone, automobile, rayon, airplane, computer, ballpoint pen) are

[2] The discussion of diagrams in the text is based on the standard optimal growth analysis. A thumbnail description of the derivation of the informal presentation is given in the Appendix.

appearing less and less frequently.

We next turn to a detailed discussion of the appropriate policy reactions to each of the different sources of the productivity slowdown.

a. In Figure 4a we consider the possibility that a change in tastes has led to a reduction in the desired growth rate. Such a change would reflect a transition to a lower steady state growth path as the saving rate is reduced. In our formal model of the Appendix, such an outcome might arise because of greater impatience (higher ρ) or a lower tolerance for inequality across generations (higher b). The revulsion against the abuses of an industrial society, the rise of "no growth" philosophies, and social regulation are less easily formalized but obviously important forces, and the impact of regulation attests to their importance; we guessed that 10 percent of the slowdown can be attributed to this source. If it did occur through a legitimate channel, presumably we would accept the outcome and not wish to undo it. That is, if we wish to grow slower because people are persuaded that a no- or slow-growth society is preferable, then it would hardly seem sensible to reverse these policies because they have succeeded.

b. A case with the same observable outcome as case (a) is that, through mistaken policies or market failures, the economy has been undersaving and underinvesting. We guessed that 5 percent arises here. One mechanism by which a market failure could occur is inflation. As a result of the acceleration of inflation, the fraction of tax to replacement cost depreciation has fallen from 100 percent in 1965 to 90 percent in 1979. Similarly, in inflationary periods the taxation of nominal interest payments as ordinary income raises considerably the tax rate on property income. Both of these could lead the economy to save and invest less. If we are convinced that we have fallen into the undersaving trap, the policy response is clear: we must correct the market failures (the tax code or our inflationary ways), tighten our belts, and save and invest more.

Some will find it highly surprising that undersaving and underinvesting through (a) or (b) are given such little weight here. It is useful to note that both theories (a) and (b) have a fatal flaw as explanations of recent behavior. They both have an unambiguous prediction that the marginal product of capital, and therefore the pretax rate of return on investment, should have risen since the days of high productivity growth. The clear evidence is that the rate of profit has fallen. Thus for 1955–69 the pretax rate of profit on corporate capital was 12.9 percent, while for the 1970s it fell to 9.4 percent. Similar data are given in the McCracken report for other industrial countries, where the evidence is even more compelling. More generally, I regard it as one of the major puzzles of economic psychology how those who argue that the United States is undersaving ignore the fact that the profit rate does not corroborate their theories.

c. The third view of the productivity crisis, illustrated in Figure 4c, is that the United States has with increasing frequency taken to shooting itself in the foot. Increasingly stringent social regulation is the most prominent example of policies which inhibit growth, although there appears to be, as well, increasing sensitivity to the counterproductive facets of policies such as payroll taxes, minimum wages, self-imposed embargoes, and trade restrictions. Empirically, we found some evidence that self-inflicted wounds, or obstacles, have led to a minor portion of the productivity slowdown — perhaps 20 percent of the slowdown arises here.

The policy response to self-inflicted wounds is obvious — ban economic handguns — but it may not be politically popular. While all agree that we should pursue the abstraction of more effective regulation, few argue for venting gases from Three Mile Island, or for killing the sacred cows of microeconomic policy (Davis-Bacon, minimum wages, etc.).

d. The final category into which we might put the productivity slowdown, shown in Figure 4d, is that of depletion. Is it not possible that we are riding down the backside of a long-term decline in productivity growth, a Kontradieff cycle? In this case the consumption possibility curve in Figure 4d has shifted inward; for a given level of first period consumption, second period consumption (and growth) is reduced. We guessed that 65 percent of the slowdown was attributable to depletion.

Of all the possible sources of the productivity slowdown, depletion is the one for which a policy response is most difficult to prescribe. Should we jog less or more as we get older? If oil is expensive to find, should we drill fewer or more holes? In Figure 4d, we see more generally that the new optimal consumption choice may have a higher or lower growth rate depending on the shape of the utility function and on the way that the consumption possibility curve shifts.

In some special cases we can make limited statements as to the optimal policy. Take as an example the case formally analyzed in the Appendix — the standard optimal growth model. The productivity slowdown is here best seen as a decline in the rate of labor-augmenting technological progress. In such a circumstance an optimal response is to reduce the equilibrium rate of return on investment (the reduction is proportional to the extent to which higher consumption is less valuable, b). But for a Cobb-Douglas (or substitution inelastic) technology *the eventual optimal savings rate will be below that which held before the productivity slowdown.* The reason why the optimal savings rate is lower after a productivity slowdown is straightforward: the amount of capital needed to equip a growing labor force declines. As an example, assume that the labor force is constant, that labor force quality and output growth both grow at 4 percent annually, that the capital-output ratio is fixed at 2, and that 6 percent of capital depreciates annually. Then 20 percent of output must be set aside for investment — 12 percent for replacement plus 8 percent for growth. If the rate of quality improvement and output growth decline to 2 percent, then the required savings rate is 12 plus 4 or 16 percent. Thus because output is growing more slowly, the need for capital broadening is reduced. If the slowdown is a result of depletion, we can make a strong argument for investing less rather than more.

C. Specific Policy Responses

Having spent most of my time circling the issue, it is time to attack the question of specific policy responses to the productivity slowdown. It is useful to group our approaches into "demand side" and "supply side" approaches. The first two policy tasks (inflation and demand management) refer to the demand side, while the next three (investment, regulation, and energy policy) concern the supply side.

1. *Anti-inflation policy*

The first issue on the demand side concerns the role of anti-inflation policies in productivity policies. We must here separate out inflation per se, which we discuss here, from the indirect effects of inflation on demand management or supply side, which we turn to later. Little serious research can be drawn on to indicate the extent to which inflation is the proximate or ultimate cause of our problem. One clear mechanism, discussed in the Kopcke paper, is that inflation may raise the burden of taxation on capital because depreciation allowances do not rise as fast as economic depreciation. He argues that much of the decline in investment (and therefore of productivity) "can be attributed to rising inflation since the late 1960s."

I find the Kopcke argument unconvincing on two grounds. First, he nowhere actually shows what, in his model, inflation has done to the cost of capital and to productivity. Much more important, however, is that he omits from his argument the fact that inflation is a double-edged sword. It not only cuts the fraction of true depreciation that is deductible, but it also raises interest deductions because of the effect of inflation on nominal interest rates.[3] Examine the ratio of the sum of positive incentive due to interest deductibility and negative incentive due to illiberal depreciation allowance to true profits. This ratio has risen from 0 in 1955 to 12 percent in 1965 to 21 percent in 1979. Hardly a major disincentive. In fact, the recent outpouring of complaints of unfair depreciation rules shows a scandalous lack of attention to the fine print. A perusal of company reports indicates most companies are gaining more from deductibility of interest than they are losing from illiberal depreciation.

A second area in which inflation can lead to slower productivity growth is through resource misallocation. Thus, in regulated utilities the fact that control systems are designed for noninflationary periods means that, recently, marginal costs are well above average historical costs. Similar misallocation arises because of tax distortions, such as the fact that high debt-equity industries (electric utilities) have lower effective tax rates. There are other, but vaguer, misallocations concerning inflation's effects on risk and uncertainty. And, of course, there is the classical cost of inflation — shoe leather.

[3] A more rigorous treatment shows that inflation actually raises tax deductions for high debt equity ratios, long lifetimes, and high inflation rates. For example, with inflation of 10 percent, a constant pretax real interest rate of 5 percent, a lifetime of 10 years, and a 1:2 debt-equity ratio, an increase in inflation decreases the cost of capital (increases the post-tax return on investment).

I am unaware of any studies which would impute large annual costs to these misallocations due to inflation. Indeed, the theorem of little triangles suggests that inflation losses — like monopoly or tariff losses — are unlikely to be more than a few tenths of a percent of output.

On the whole, then, it is hard to see a convincing link from the recent inflation to productivity. If this is the case, this victory over inflation by itself will contribute little to improving our productivity performance.[4]

2. *Demand management policies*

A second area on the demand side which might have a significant effect on productivity is demand management. Here a number of facets of demand management might affect productivity. Four that come to mind are growth, level, and variance of the pressure of demand, as well as composition and possible bias in demand management policies.

a. The overall growth of aggregate demand clearly has a significant impact on productivity growth. Growth in the 1973–79 period was 1.1 percent slower than in 1948–65, and we guessed this might be responsible for 0.3 percentage points of the slowdown. Most of the slowdown in recent years is, however, lower potential output due to lower productivity, so that the remedy for slower productivity growth appears here to be more rapid productivity growth — hardly a useful insight.

Some of the slowdown in output growth, perhaps a third, is due to the anti-inflationary policies after 1973. And more of the same is in sight. To the extent that we can adopt more efficient anti-inflationary policies, such as tax-based incomes policies, we can temporarily grow faster and reap slightly more productivity growth. This bonus seems to me yet another in a powerful list of arguments for more innovative policies to fight inflation.

b. A more subtle question is whether a generally higher level of demand, a perpetual state of tight markets such as exists in Eastern Europe, will lead to more or less rapid total factor productivity growth. People have worked hard to find such an effect, but no convincing evidence has turned up. If a larger market is a spur to invention, so are hard times. Failing such evidence, I don't think we can turn to productivity growth as a reason to run a perpetually overheated economy.

c. One of the most familiar litanies is that productivity has been hurt by stop-go economic policies. Nowhere is there greater confusion than on what "stop-go" means. We must separate out the variance of policies (hitting the brake or accelerator) from the variance of outcomes (changes in the speed of the car). The reason we engage in stop-go policies is to *reduce* the variance of outcomes. Every sensible person would certainly desist from stop-go policies if that would stabilize output and inflation. But many of us feel that a constitutionally imposed balanced budget or a fixed money growth would lead to a more unstable economy.

It would seem obvious, then, that a successful stop-go policy would

[4] This statement does not mean that the productivity slowdown has had no effect on inflation.

create greater predictability and certainty, would lead to lower risk premia on investment, and would improve productivity; an unsuccessful policy would do the reverse. Thus the goals of stabilization policy are coincident with those of productivity policy.

A different question is whether economic policy since the New Economics has been stabilizing or destabilizing of output variables. Its *intent* has surely been to stabilize output, but reviews on its success are mixed. The greater variance of output since 1973, however, has surely been largely due to nonpolicy shocks rather than policy mistakes. And, in any case, the increased variance in output since 1973 cannot explain the deterioration in productivity growth, for the variance is smaller than the interwar or early postwar period.

d. A final set of issues in demand management concerns the composition and possible bias in policies. These are closely related to supply-side issues, but it will be useful to raise them briefly at this point. The major issue in the composition of policies concerns the division of labor between monetary and fiscal policy. It has been a common (and accurate) complaint that monetary policy fights inflation while fiscal policy fights recession. The result has been that "Q" has fallen from 1 in the late 1960s to .65 in 1979, and that the real cost of equity capital (the corrected earnings-price ratio) has risen from 7 percent in 1970 to 12 percent in 1979. At the same time federal government outlays as a share of GNP have risen almost 1 percent. The institutional characteristics which lead to anti-investment and anti-productivity cyclical responses are well-known (the Congress responding to political pressures and cycles while the Federal Reserve System puts a greater weight on a stable currency).

There are hopes that the bias in demand policies might improve. The survival of the fragile Congressional budget process is clearly extremely important to some kind of fiscal discipline. A constitutional limitation of Presidential term to six years would help insulate the other branch from election-year economics.

The movement to floating exchange rates has helped free monetary policy from being hostage to exchange markets, but further reliance on intervention rather than interest rates could allow further pro-growth monetary policy.

Taken together, improved demand management policy appears to be one modest element in improving our productivity performance. Many of the suggestions raised here are worthwhile on their own, and the effect on productivity adds some weight to the argument. But I doubt that more than a few tenths of a percent additional growth can be squeezed out of the feasible set of reforms of demand-side policies.

3. *Investment*

The central policy response to a productivity slowdown is to set in motion policies that change the savings and investment patterns of the nation. Obviously, this is an extremely complex issue and we can only touch on the major issues.

The first issue, discussed at length above, is whether the United States should save more as a result of the productivity slowdown. My tentative conclusion is that if investment and growth policies were well-designed before the slowdown, *the nation should save and invest a smaller fraction of its output after a decline in productivity.* This conclusion is reinforced by the observation that the rate of return on investment has declined in the last decade or so.

Given our conclusion that we should save less, we must look elsewhere to argue that the policy response should be to increase investment incentives. The first place to look is in market failures. That is, we might feel that our economy has been undersaving all along because of inherent biases in our mixed economy. This is a defensible view, but it has nothing to do with the productivity slowdown. Presumably the urgency of the undersaving problem is less today than a decade ago because the optimal savings rate is probably reduced by the slowdown.

A second potential market failure lies in the fact that slow productivity might per se worsen the market failure; thus if low productivity led to higher inflation, this might raise tax rates on genuine capital income. Aside from the questionable impact of inflation (which has no intrinsic connection to productivity growth) we have found no mechanism that would lead from slower productivity growth to a greater discrepancy between optimal and actual investment.

We might, however, want to proceed in a lawyerlike fashion — asking what would make sense in terms of investment policy if we decided that we did want to save and invest more as a result of the productivity slowdown. We would probably first start by asking where it makes most sense to channel investment, then ask how to raise the additional savings. If I had to list investments in the order of social return, it would be the following: oil production and conservation, R & D, foreign direct investment, corporate fixed investment, human capital, consumer durables, public investment, housing, land, art, gold, mandated regulatory investments. Any pro-growth strategy would probably be well off if it consisted of incentives to augment flows into the first five of the above, and to withdraw flows from the last five or six.

Once we confront the problems of rechanneling national output in such a way, it becomes clear that many familiar solutions are not really an answer. Take generalized pro-savings programs such as mandatory pension plans, lower social security benefits, replacing income with consumption taxes, lower taxes on property income or capital gains, or more generally a shift in the mix from tight money/loose fiscal to loose money/tight fiscal. These policies will increase savings and investment in general, but their effects will be generally spread from oil conservation to higher gold prices. Because the fraction of the capital stock that resides in the high-yield investments is relatively low, the average yield on changes in the composition of output from consumption to investment may be small. Thus generalized anticonsumption policies should be pursued only if we are convinced that the freed resources will end up in energy conservation, R&D, or corporate capital rather than in low-yield investments such as gasohol, South African gold mines, the M-X missile, or solar-heated swimming pools.

Because I am skeptical about generalized pro-savings policies as a way of improving our productivity performance, I would instead attempt to retarget flows to investment by selective fiscal policies. The most attractive in my mind are:

1. An energy policy that has a very high reward on incremental production or conservation of oil (more on this later).
2. A program of channeling resources into research and development. The most productive way to do this would be to legislate a general tax credit for R&D, perhaps providing special incentives in those sectors (energy, pollution control, corporate capital) that appear to have the highest yield on research.
3. A program of assisting foreign direct investment, both through selective changes in regulations, a revamped DISC, and pursuit of a multinational code for investment and services.
4. The largest program would be a program of investment incentives for corporate investment. This should certainly consist of correcting structural defects in the current investment incentives system, such as removing the bias of the investment tax credit toward short-lived investments and its extension to structures. The appropriate way to correct inflation's distortions on depreciation would be to move toward allowing depreciation allowances to take a replacement cost basis. Many of the current proposals (the "10-5-3" proposal) are extremely poorly designed to correct the distortions in today's tax code and will further subsidize investments in the real estate and commercial building market — hardly a way to improve productivity. A more radical approach would be to restructure the corporate income tax system, for capital is surely more heavily taxed there than is efficient. Two approaches that would reduce the inefficiencies from heavy company taxation are, first, a program of full integration of corporate and personal taxes and, second, moving toward higher rates of indirect taxation.
5. Finally, I am impressed by the extent to which the nation is depreciating its stock of intellectual resources. The crumbling of the ivory towers due to deferred maintenance, and the declining relative incomes of those in the academy, can hardly be a healthy sign for basic science and technology over the coming decades. Increased support of basic research, and the institutions that nourish research and produce researchers, must surely be central to an increased investment program.

At the same time, we should attempt to correct some of the major problems that arise in the current system that gives a preference to low-yield investments.

1. The most important defect is the enormous tax preference to owner-occupied dwellings, where interest and taxes are deductible but imputed income is not taxed. The recent move toward allowing borrowing for mortgages at the state and local interest rate is, as well, an extremely dangerous trend. A major plank in the platform of those who want to make a more efficient use of our investment resources should be to reduce the incentives for very low-yield investments here.
2. Movement toward an indexed tax system, in which taxes at full rates are levied on real returns, would remove some of the distortion that allows sterile investments in gold, art, and land to become so attractive.
3. Regulatory reform, discussed below, is a major possible source of productive investment. It appears that we are channeling an excessive amount of new investment into some sectors or technologies. Complementarity of mandated with new investment, together with the grandfathering of old capital, is currently a major impediment to productive use of investment resources.

4. *Energy*

The energy sector is one in which structural change over the last 10 years has been so rapid that it has affected overall economic performance. With respect to the productivity problem, three facets must be recognized. First, the energy industries have experienced an extremely sharp decline in productivity growth. Mining experienced a productivity deceleration of 10 percent and utilities of 7 percent over the postwar period. Second, the sharp run-up of energy prices since 1973 led to some substitution of other factors of production for energy, lowering the productivity of these other factors. Finally, the inflationary impact, terms of trade, and real income losses due to the energy crisis contributed to the slower demand growth and concomitant slower productivity growth since 1973.

The major controversy concerning energy's impact on productivity has been generated by the capital-energy complementarity issue. The issue can be quite succintly put by considering two polar cases and realistic data for 1973–77. Start with the normal case, where energy, capital, and labor are combined in a Cobb-Douglas production function with shares of 0.1, 0.2, and 0.7 where labor supply and real interest rates are exogenous. In this world a 25 percent rise in real energy prices will lead to a long-run decline in labor productivity of about 3.2 percent. At the other extreme, let energy and capital be used in fixed proportions and combined with labor in a Cobb-Douglas production function. In such a case, doubling of energy prices leads to a decrease in labor productivity of 3.4 percent. Over a four-year period, with full adaptation of the capital stock, we should find a decline in productivity of 0.80 to 0.87 percent. (In a more complete model, Hudson and Jorgenson estimate that the four-year effect was 0.6 percent annually.) It is hard to see how this discrepancy could generate much controversy.

In fact, this capital-complementarity controversy has been a smokescreen which effectively camouflaged the real issue — the embodied nature of energy use. The error in both models above was to assume that the capital stock and energy use adapted instantaneously to changed relative prices, the so called putty-putty model. In the first model, energy consumption should have fallen 6 percent annually relative to trend, while in the second it should have fallen 2 percent annually. In fact, in the long run most energy conservation takes place through substituting more energy-efficient refrigerators, houses, and cars — a process whose half-life is probably 20 years. From a statistical point of view, the reason time-series putty-putty models keep telling us that energy and capital are substitutes is that, by creating a complementary factor of capital and energy, the speed of reaction of energy demand is effectively slowed down from 6 percent a year to 2 percent a year — to a speed closer to the putty-clay model.

The significance of the putty-clay view is that the effect of energy prices on productivity is spread over many years. In a no-growth economy where capital lives 20 years, the Cobb-Douglas putty-clay model would predict that as a result of the 1973 price shock productivity would show an energy drag of 0.1 to 0.2 percent until 1993. During this entire period, we will be progressively replacing high cost oil with high cost capital and labor. The slower the adjustment, the longer is the period over which the productivity drop is spread.

Turning to the policy aspects, the adjustment speed presents an interesting paradox about efficient energy policies. It is generally agreed that one of the central goals of energy policy is to accelerate the replacement of the energy-inefficient capital stock with fuel-efficient capital. We have for this reason taken extensive steps to subsidize replacement of old oil and gas equipment and regulate the energy performance of autos, houses and appliances. Paradoxically, these policies are *anti-productivity* measures, for they accelerate use of energy-efficient but labor-inefficient technologies. In today's tight world oil markets, the best energy policy is one that will, on the margin, lower potential output. By driving the marginal product of energy beyond the world price, industrial countries can reduce oil prices and improve their terms of trade. Thus while national output may be reduced, national income is increased.

As we look forward to the 1980s, what are the needs for energy policy and how do they relate to productivity policy? My view is that three features of energy policy are necessary to avoid energy's drag on our real incomes.

1. The first and key policy is to assure that energy price signals facing consumers and producers reflect social costs. In my view, social costs of oil consumption are around two times the world price because of the effects of increased consumption on world oil prices, terms of trade, inflation, and macroeconomic policy. All industrial countries should seek a harmonization of oil import or product taxes (not just on gasoline) rising to a level of $30 per barrel. Indeed, such a policy should be the first item on the agenda of every major international policy conclave.

As mentioned above, this policy will hurt rather than help productivity. In extractive industries, marginal products will fall even further than in

Figure 1, and in the rest of the economy will scramble to scrap old oil-inefficient capital. Yet over the long run, the major danger to our economies is that our output increases will be drained away as tribute money; since 1973 one-third of our output increase has been lost to increased value of oil imports.

2. An aggressive energy policy like that proposed above will involve enormous transfers from consumers to oil producers and the government. Careful thought should be given to the recycling of the revenues. Experience in the United States is that at least a fraction of the revenues will be devoted to marginal uses (gasohol being perhaps the most inefficient — indeed, counterproductive — use on record). If the tax revenues are completely wasted, then a first approximation suggests no gain from the tax-based energy policy. Put differently, the main gain from high energy taxes is that the oil expenditures become domestic income rather than foreign income. If the domestic income is not turned to useful purposes, then the potential gain is not realized.

One way in which oil taxes can be efficiently recycled is by lower prices, e.g., through subsidies, tax credits, or lower value-added or social insurance taxes. In these cases some of the inflationary costs of high energy taxes would be removed.

A second route would relate quite directly to productivity. Today, many analysts feel that there will be large "supply side" effects of lower taxes on capital and labor — lower overall taxes would stimulate the supplies of capital and labor and would reduce welfare losses from differential taxation. Thus, one of the possible advantages of heavy energy taxes, together with lower taxes on capital and labor, would be that this fiscal reorganization could actually enhance the efficiency of our tax system overall. More generally, one of the key productivity-raising measures we should keep in mind is to improve our fiscal system — to raise a larger fraction of the necessary government revenues by taxing goods we want to discourage (oil consumption or pollution) and a smaller fraction on those activities that we want to encourage (supply of labor and capital as well as production of useful goods and services).

3. Finally, other points in our productivity discussion complement energy policy. The most important is regulatory reform. A recent study by the Department of Energy concludes that the sum total of our key energy policies (e.g., tax preferences for drilling, Jones Act, natural gas decontrol, incremental pricing, windfall profits tax) is a wash with respect to oil prices and oil imports; yet they clearly cost an enormous amount of effort and expenditure. One of our first tasks should be to dismantle many of these conflicting regulations. A second area is in social regulation. Nowhere do the inefficiencies of our current regulatory structure appear heavier than in energy. We have excellent case studies — such as in new source performance standard (NSPS) for steam electric plants — where it is clear that we have "gold-plated" our regulations. The original NSPS proposed a standard that actually yielded higher population-weighted sulfur emissions than a less cost-

ly standard. In addition, oil imports were projected to be 300,000 barrels a day higher in the original case. It seems clear that by moving toward sulfur taxes, more modest goals, and putting these in a regulatory budget framework, we could save considerable money and make more productive use of our resources.

A second area where other policy reforms could assist energy policy is in R & D. The history of energy R & D from the breeder reactor to the Concorde is that government has been calling the plays from the bench, and calling them badly. We would be well served by a policy which shifts more of the energy R & D funding to the public, and more of the detailed decisions on loops versus vats or underground versus above ground retorting to entrepreneurs. The R&D tax credit suggested above — perhaps higher in energy — could speed the transition to a more sustainable energy system.

5. *Regulation*

Attempts to change the regulatory environment in the United States are high on the list of many who wish to improve productivity performance. To some extent, particularly for the business community, this emphasis arises because much of the regulatory system was an anathema to begin with, and the productivity slowdown is a fine excuse to reverse or abolish programs which were never palatable. Even though the business attack on the regulatory process may be as much ideology as economics, there are, in my view, sound reasons for trying to improve the regulatory process as a part of an attempt to improve the productivity performance in the United States. In what follows I will outline three major areas of reform that might contribute to reviving our lagging productivity.

In discussing the regulatory process, we must distinguish between the older economic regulation (which prescribes pricing or conditions of entry) from the newer social regulation (which is broader and regulates the externalities of pollution, health, or worker safety). We have made considerable progress in the last few years in dismantling the economic regulatory apparatus — witness major legislation on the books for airlines, security markets, railroads, financial markets, and natural gas, as well as prospective loosening of regulatory constraints in trucking, oil, and communications. The first set of policies would be to press further and faster in removing or revising the regulatory constraints in economic regulation. Aside from those in the mill, we should press for further reforms in the area of agriculture (dairy and milk as well as setasides), energy, and local utility rate reform.

The other side of the regulatory story is, unfortunately, much less encouraging. The last 10 years have witnessed an explosion of social regulation. By most measures, we will probably see extremely large mandated costs over the next decade as the regulations recently promulgated begin to bite. Estimates of the 10-year cost of major regulations promulgated in the last four years run in the $300-600 billion range.

The high cost of implementing the new social regulation is not per se a reason to stop or slow these programs. There is disturbing evidence, however, that the social regulatory process is quite inefficient.[5] Robert Crandall's paper touches on some of the important inefficiencies in the process, particularly the bias against new investment. A broad overview of the inefficiencies in the regulatory process suggests that two major areas are in need of reform: inefficient regulatory techniques and the lack of a budget constraint on regulators.

The inefficient regulatory techniques are discussed in the Crandall paper and have been widely criticized by economists. The most significant problem is the use of quantity regulation and engineering standards rather than price regulation or performance standards. In the example of the controls of sulfur emissions, it would be much more efficient to use emission taxes rather than emission limits as a way of reducing emissions. OSHA generally specifies equipment to be used rather than health effects to be reduced. Examples where inefficient regulatory techniques are used are legion in the area of social regulation, yet the movement away from inefficient quantity regulation toward more efficient price regulation has been extremely slow. One of the major regulatory reforms that might significantly lower the costs of attaining our regulatory goals would be to improve the techniques. Some examples are:

— In air and water pollution, substitute emission charges for emission limits.
— In automobile emissions, allow tradeoffs between emissions as a first step and then institute an emission tax on new and old vehicles.
— In the area of worker safety, substitute injury taxes and mandatory insurance policies for specified work practices and engineering requirements.
— Substitute a wellhead tax for price controls on natural gas.
— Substitute performance for specification standards wherever possible.

None of these ideas are new — in fact they are so old they are practically forgotten. Again, to the extent that we would like to use the productivity slowdown as an occasion to retune our economic engine, these old ideas should be part of the overhaul.

In addition to the inefficiency of the regulatory tools in social regulation, there is considerable evidence that the political process which sets the goals or stringency of regulation is defective. More or less independent regulatory agencies implement virtually all regulation in the U.S. economy. While in earlier days this independence might have been necessary to protect the integrity of the political process, the pendulum has swung too far. Regulators are acting in the place of the legislative and executive branch in allocating tens of billions of dollars a year — indeed, the figures given above suggest even more — without the political accountability that we expect in the tax and expenditure system. Put differently, regulators function without

[5] This section draws on many of the ideas in a book under preparation with Robert Litan, *Toward Sensible Regulation.*

an effective budget constraint in making their major decisions. Recent history shows many examples (sulfur scrubbing, aid for the handicapped, ozone standards, oil pricing and entitlements allocation) where regulators allocated many billions of national output without involving the other two branches of government sufficiently in setting the goals, the standards, and the dollars to be allocated.

There are several policy proposals today for restructuring the regulatory process. (A fuller discussion is contained in the Litan-Nordhaus book.) These proposals can be broken into two parts — assuring greater political accountability and imposing a budget constraint. Imposing greater political accountability means that the President and the Congress should have greater say in the detailed decisions, particularly the costs, of major regulatory actions. We have witnessed a very modest increase in Presidential oversight in the last four years, but regulators remain largely autonomous. One proposal to impose greater political control is the idea of a "legislative regulatory agenda." Under this proposal, all major regulations must be approved by being part of an annual agenda that is enacted. By requiring that regulation be included in the agenda, regulators would be prodded to assure that the overall economic impact of their actions was reasonable, that they had weighed appropriate costs and benefits, and that major political actors were generally in accord with these actions.

A more radical proposal is the "regulatory budget." Under this proposal, the legislative agenda would be supplemented by a quantitative cost control system. Each regulatory agency would be given an annual budget for new regulations, and it would be required to keep its total actions within this budget for a given year. Thus the Environmental Protection Agency might be forced to limit the costs of its new regulations to a total of $30 billion in a year; the budget constraint would force the agency to design cost-effective regulations and to exercise restraint in setting its regulatory goals.

These three proposals are among many that are before the Congress today. Clearly many details must be worked out, particularly in the area of social regulation. I am convinced that by pushing forward on each of the three routes of regulatory reform discussed here, many of the chilling effects of regulation on productivity could be alleviated or reversed.

* * *

Having reviewed specific policy responses to the productivity slowdown, one further point remains to be made. Few of the recommendations that are made arise directly from the productivity slowdown. They represent sound economic management. We should do them in 1980, but then we should also have done them in the mid-1960s before the productivity slowdown began. Although the economic climate may change, principles for construction of sound shelters endure.

APPENDIX

In fact, a great deal of implicit theory lies behind the deceptively simple diagram in Figure 3. What I have in mind in order to make this discussion rigorous is something like the following.

Let c(t) be consumption per worker at time t and L(t) the size of the work force. We assume that the labor force is a fixed proportion of the population; therefore, c(t) can also be regarded as an index of per capita consumption. The labor force L is growing exponentially at rate n. Labor-augmenting technical progress is occurring at rate h ; so $L(t)e^{ht}$ is the effective labor force, which is growing at rate $g = n + h$. Gross output per worker is $e^{ht}f(k)$, where k is the ratio of capital stock to effective labor force K/Le^{ht} . Capital depreciates at the exponential rate δ . Finally, let $r(t) = f'[k(t)] - \delta$ be the net instantaneous return on capital and $R(t) = \exp [\int_0^t r(v)dv]$ be the t - period rate of return. Then a unit reduction of per capita consumption at time 0 will yield R(t) exp (−nt) units of per capita consumption at time t. Define "income," $\bar{c}$, as that level of consumption that is indefinitely sustainable, so $\bar{c} - c(0)$ is per capita "savings" at time 0 .

The other half of the story relates to the social valuation of increments of future consumption yielded by current saving. Suppose that society's intertemporal preferences can be described by an additive social welfare function $\int u[c(t)] \exp(-\rho t)\, dt$ where u(c) is the one-period utility of consumption, ρ is the constant pure rate of time preference at which utility is discounted, and the elasticity of marginal utility with respect to consumption is $u''c/u' = -b$.

An optimal consumption path equates the marginal cost and marginal value of saving. In general, this requires that $r(t) = g + \rho - h + b\,c'(t)/c(t)$. In steady state, this reduces to $r = n + \rho + bh$.

Discussion

Robert M. Solow*

The productivity question turns out to be more delicate than you might expect. For a start, the underlying time series is pretty irregular, as a look at Nordhaus's Figure 2 will show. Remember: that time series has been smoothed twice, once by removal of an estimated business-cycle effect and again by a six-year moving average. The extent and timing of the productivity slowdown can not be determined with precision from so ragged a history. Different authors, different data and different methods can, and do, give different results. One of the merits of Nordhaus's paper is that he brings to bear that neglected econometric weapon, common sense, and tries to state clearly what a reasonable person might think is there to be explained and, perhaps, to be made the object of policy. In the course of laying all this out, he raises some basic questions and slaughters some sacred cows. On most of the issues I am in sympathy with Nordhaus, though I do have a few minor differences of opinion and there is one more cow I am tempted to ship to the knacker. Since I am basically comfortable with the paper, I think I will do the unexpected and actually discuss it, more or less sequentially.

First of all, let us return to Figure 2 and the underlying facts. I think it is very useful to take a look at a period longer than a couple of decades, because I am a little doubtful about the use of growth-accounting methods with short-run phenomena. There are two elements in the generation of Figure 2 that might be worth talking about. One is the method by which cyclical effects are removed. If I understand the technique, it has the probably undesirable implication that a sustained increase of 1 percent in the annual growth of output generates a sustained increase of .25 of a percent in the annual growth of productivity. You would expect that coefficients on current and lagged output growth would add to zero; otherwise the regression equation claims that an increase in the rate of growth of the labor force, translated into growth in output, automatically elicits faster growth of productivity. One can understand why an unrestricted regression might have coefficients adding up to a positive number — for instance the reverse causation from productivity growth to output growth. I would feel a little better if the business-cycle correction had been done in a way that enforced neutrality, but it may not matter much for the end result.

My second question about Figure 2 is this. The last observation plotted

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is for 1979. If that is a six-year moving average, it can hardly be a centered six-year moving average. It has to be a trailing moving average. If I am right, then the plot for 1979 is the average of the readings for the years 1974–1979 inclusive. That would more naturally be plotted at New Year's Eve 1977. In other words, one might read Figure 2 as if the graph were shifted three years to the left (or the time axis three years to the right). That is interesting because the graph as it stands is compatible with dating the productivity slowdown from 1962. Translated, that would mean from 1959–60, a dating which would suggest wholly different cause-effect chains from those discussed here. I am not advocating such a view; I mention it because I am dubious about sudden breaks in the productivity trend, and also because it drives home how ill-defined the slowdown is. If productivity had risen a bit faster in 1967–69 or 1971–73, we would probably not be talking about a productivity slowdown in the second half of the 1970s. If you think of Figure 2 as a quality control chart for some industrial process, it would take very little amendment of the figures to keep its right-hand end within the control lines that are supposed to alert the quality-control engineer to a shift in the underlying process.

However that may be, I am, like Nordhaus, willing to accept the existence of a productivity slowdown. Let me now turn to its sources. I have no serious argument with Nordhaus's rough allocation in Table 4. If I had to pick nits, I would query the .20 of a percent allocated to regulation and the same amount allocated to higher energy costs. I presume that the diversion of capital equipment to meet pollution and safety standards is already accounted for in the allocation to capital, though I am not sure. All I mean to say is that the chilling indirect effects of regulation leave me, so to speak, a little cold, only because they are too intangible to evaluate.

The productivity effects of increased energy costs are a matter of controversy. I am inclined to leave that issue to the experts, of whom Nordhaus is one and I am not. My only reason for entering a query is that later on in the paper Nordhaus does a few calculations using a Cobb-Douglas aggregate production function in which energy appears as an input with an elasticity of 0.10. That seems quite high; Berndt's paper quotes a number less than 0.02 for manufacturing (relative to gross output, more like 0.05 relative to value-added), but I do not know what kind of adjustment to make for the rest of the economy. No matter; I am sure the energy issue will be debated and I have no fixed opinion.

The other aspect of Table 4 that seems worth a word is the small allocation, .10 of a percentage point of deceleration, to labor. The productivity slowdown is not a labor problem; that is also the message of the Perloff-Wachter paper, and I agree with it. Apparently the negative age-sex effects are fully offset by favorable education effects. I have occasionally wondered about all this. Presumably wage differentials related to age and sex reflect a mixture of discrimination and a return to experience and training. If it were all discrimination, age and sex would be irrelevant to productivity, more or less by definition, except for minor adjustment costs like doors on locker rooms and company time spent coming on strong. If stratifying employment by age and sex is supposed mainly to capture experience and training differences, then it would seem preferable to measure those differences directly. I presume it can not be done, or else it would be done. So I am left with a nagging wish to know if those age-sex effects on productivity, on unemployment rates, on the Phillips curve, are for real.

For later reference, note that Nordhaus attributes only .10 of a point of the slowdown to a shortfall of Research and Development, though he later on expresses the nostalgic feeling that they don't make inventions like they used to. Evidently Professor Nordhaus is not adequately in awe of the achievement represented by the transistorized earphone radio, Astroturf, or the slam dunk. Opinions differ.

In his broad division of the sources of productivity slowdown, Nordhaus gives 65 percent of the weight to what he calls "depletion." I have no major difference of opinion here, although I do think that he interprets "depletion" rather broadly. Of the examples he gives, the decline in productivity in the extractive industries probably owes a lot to mine safety regulation, especially in coal mines (which sounds to me like productivity well lost), the decline in the return on corporate capital, if it is indeed noncyclical, need not represent depletion of investment opportunities unless there is some reason for diminishing returns to have come on with a rush in the 1970s, and the decline in the return on R&D spending is hardly a solid enough finding to deserve an explanation.

I have a general point to make here. I know he doesn't believe it, but the way Nordhaus has organized his thoughts suggests that the correct policy response to the productivity slowdown somehow involves finding out what caused it and then undoing the cause, unless it represents a change in tastes. But that need not be so. There is nothing irrational in discovering that factor X was the cause and responding by pushing harder on factor Y; if higher energy costs have reduced the rate of productivity growth, we might rationally conclude that we can no longer afford inefficient regulatory policy.

I do think it is very important to absorb Nordhaus's conclusion that some sources of productivity slowdown are optimally met by saving and investing a smaller fraction of output. He is right about that, and the opposite reflex is one of the sacred cows he leaves by the wayside. I am not sure — and neither is he, I imagine — that it is generally correct to model all depletion phenomena as a fall in the exogenous rate of labor-augmenting technical progress. But there are other stories in which it remains true that the saving-investment share ought optimally to fall as the growth rate tapers off. There may well be opposite cases too; the important thing is to realize that the optimal policy response does not always preserve the growth rate.

The second sacred cow dispatched by Nordhaus is the undersaving argument. I think he is right in what he says, and so I will not dwell on this point. There is a much older question, which has nothing to do with the productivity slowdown but does relate to growth-and-investment policy generally: how to make sense of the apparent willingness of people to save at interest rates considerably lower than the pre-tax rate of return on corporate capital. But that would take us away from the main issue.

The third cliché Nordhaus attacks is the one that blames the productivity slowdown, like everything else from the high divorce rate to the failure of Red Sox pitching, on the recent inflation, and concludes that, if only we could stop the inflation, productivity would revive and Mike Torrez would be able to get the side out. Nordhaus doesn't believe it, and neither do I.

Now I come to the sacred cow that Nordhaus leaves standing; I don't exactly want to knock it over, but I do want to suggest some healthy skepticism. I have in mind the focus on R&D spending.

To begin with, academic people should be wary of promoting research spending as a cure-all for productivity problems. It sounds too much like the Machinery and Allied Products Institute proclaiming that it is our patriotic duty to have an investment boom. It may be so, but I would rather hear it from a less interested source. Of course, if we are sure of our ground, then we should not be inhibited from speaking the truth just because it is good for us personally. How strong is the evidence?

I pointed out earlier that Nordhaus attributes only .10 of a percentage point of the 2 plus percentage point slowdown to diminished R&D. That is in Denison's ballpark, but considerably less than John Kendrick's estimate. However, my own dictum comes into play here: R&D could be the cure for what ails you even if it didn't cause the disease. (In a recent paper, by the way, Zvi Griliches remarks: ". . . it is unlikely that the recent productivity slowdown can be blamed primarily on the R&D slowdown. If anything, causality may run in the other direction." Griliches imputes about 0.14 percentage points of the productivity slowdown to lagging R&D, close to Nordhaus's figure.)

Griliches and Kendrick, and no doubt others, proceed by calculating a "stock" of R&D, a cumulation of real current expenditures less some sort of depreciation of old knowledge. They then treat this stock as a factor of production in the ordinary growth-accounting framework. Griliches gives it an output-elasticity of 0.06; Kendrick appears to use a larger estimate, say 0.10 or 0.12. It is a reasonable approach and I do not know of a better one. But it is hardly self-evident that productively useful knowledge behaves like a stock, is added to by R&D spending with some specifiable lag after the money is spent, and has a marginal product like a conventional input. It may well be so, but I am not comfortable making promises based on that model. I am especially worried by proposals like Nordhaus's blanket 70 percent subsidy on energy research and 30 percent subsidy on development. It is true that he puts the social value of new energy sources very high, and he may be right; but one does fear that a blanket 70 percent subsidy would buy some mighty gold-plated research with a mighty low payoff, performed in some mighty plush offices.

Many, indeed most, of Nordhaus's proposals strike me as excellent ideas. A lot of them would be excellent ideas even if there had been no productivity slowdown — for example, moving to more effective, less conventional, anti-inflation policies so that the whole burden does not fall on tight money, or shifting incentives so that land, gold, and art become less attractive assets. It would be nice if we were pushed into doing these desirable things just as a way of coping with the productivity problem, even if there is no direct causal connection.

On the productivity slowdown itself, I continue to counsel agnosticism about causes and effects. At a conference sponsored by my favorite Federal Reserve Bank, it is only right that I should tell you about a wonderful *graffito* that I saw the other day in the Boston financial district, not far from the Boston Fed. Someone had spray-painted across a large sheet of plywood covering a window: "I don't know. I just don't know."

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