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 ρ(ρ= .1i, 1 = O, ..., 9):

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

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

$g_2 = N_2^{-1}(X^tR^tRy/\sigma^2 + N_1g_1)$,

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.):

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

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.

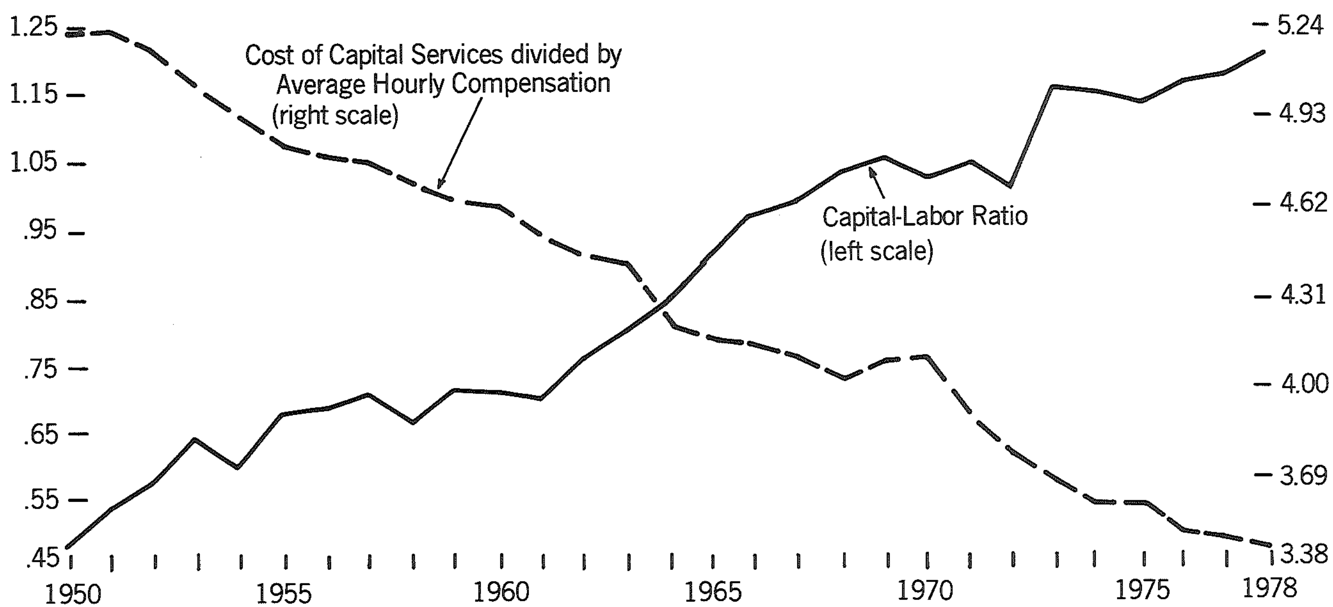
According to the estimates shown in expression (6) the pace of technical progress has fallen throughout the postwar period for nonfarm, nonresidential business. The rapid accumulation of capital offset the modest decline in the growth of technical change in the 1960s, but in the 1970s slower capital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

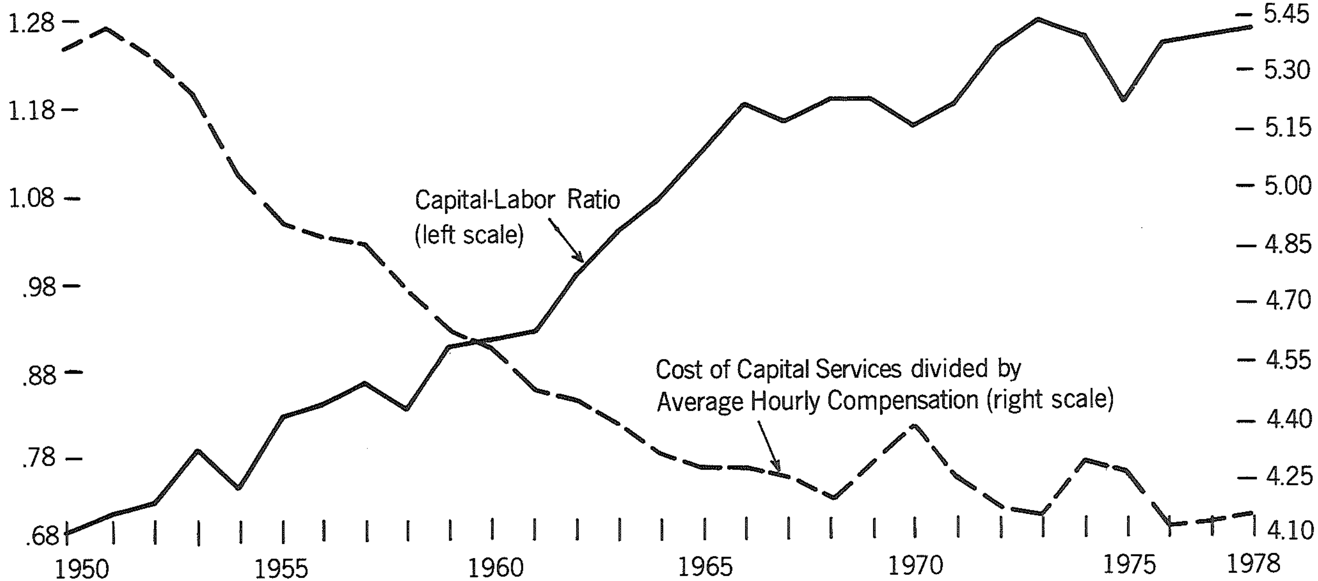
For these reasons perhaps more than half of the productivity slump can be addressed by traditional macroeconomic policies that stimulate investment spending.

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.

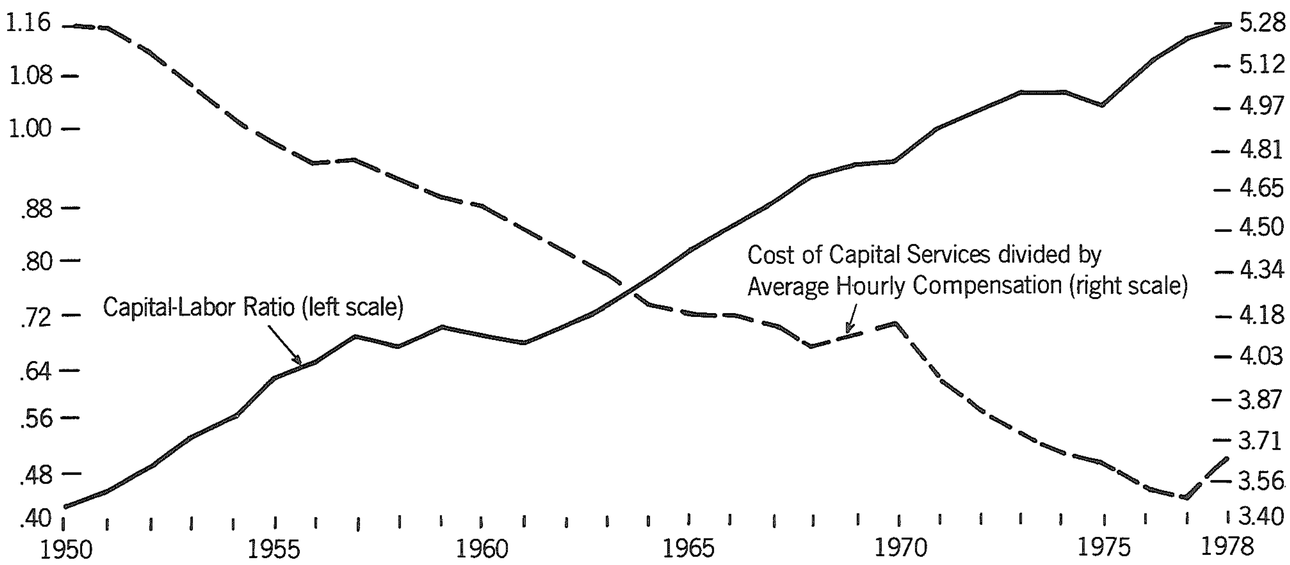
Manufacturing Business

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.

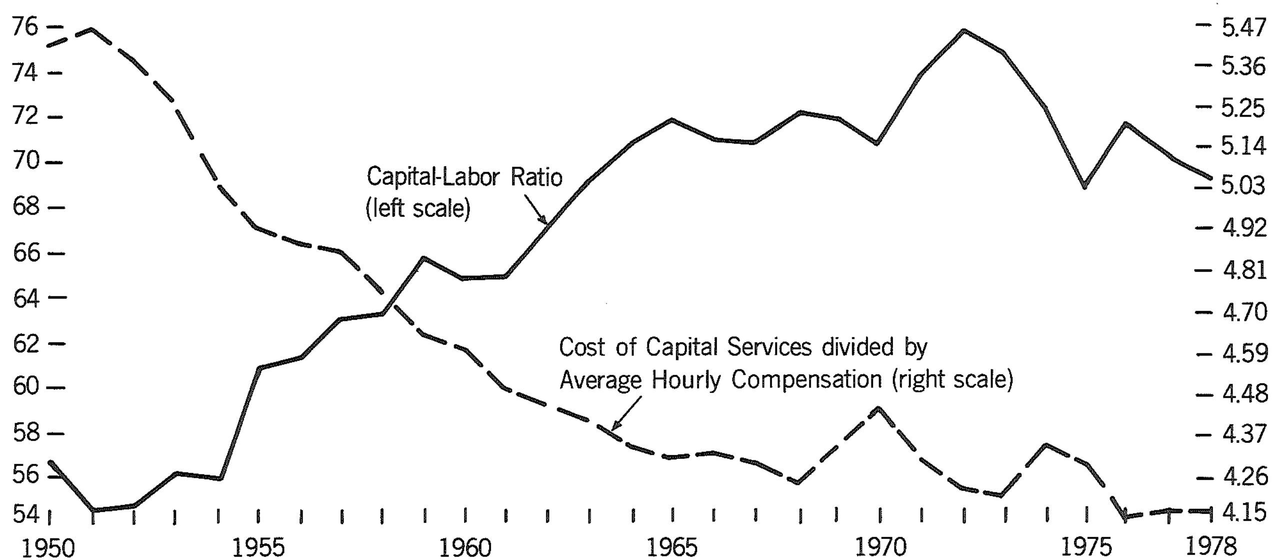
As shown in charts 3 and 4, the capital-labor ratios for manufacturing firms generally increased from 1950 to 1978, rising especially rapidly until the late 1960s. Throughout the postwar period, the average annual growth of the stock of equipment exceeded hours by a relatively constant 2.6 percentage

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-

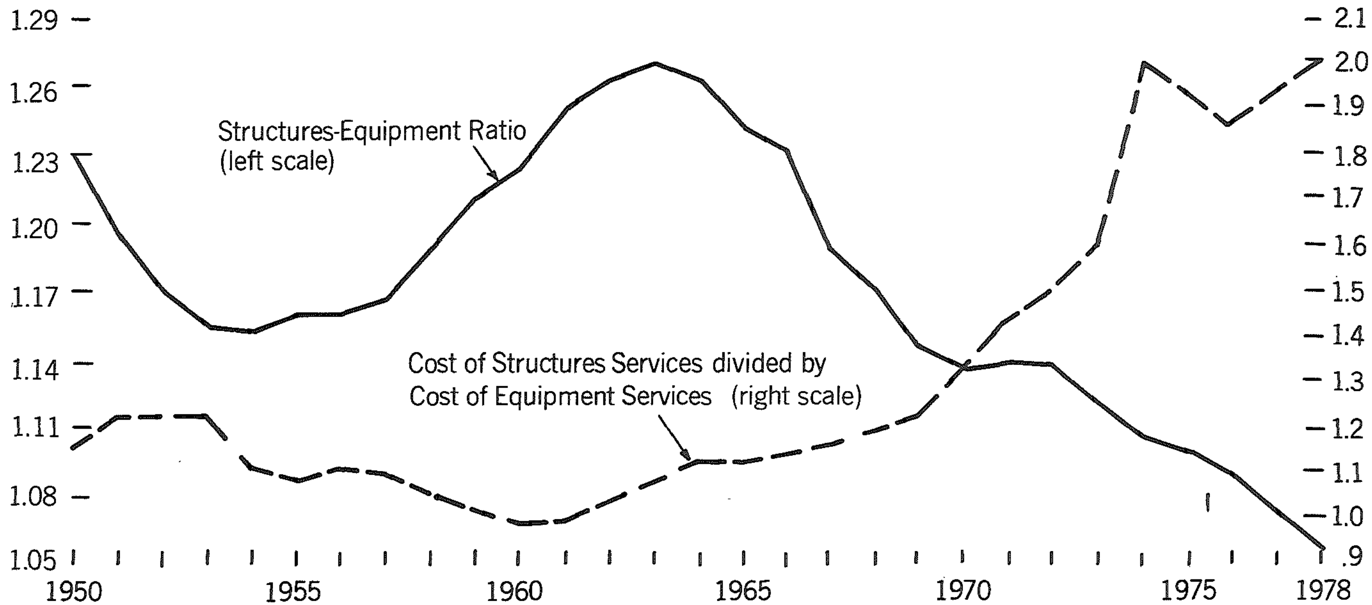
1970s. Therefore, today's debt yields do not assuage the high tax burden on business, contrary to William Nordhaus's observation that "the ratio of the sum of positive incentive due to interest deductibility and negative incentive due to illiberal depreciation allowance to true profits" has risen since 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 r tes 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

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

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

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

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

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

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.

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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.