WILLIAM D. NORDHAUS*
*Yale University*

# *The Recent Productivity Slowdown*

DURING THE FIRST HALF OF THE TWENTIETH CENTURY, the growth of output per manhour (hereafter called "labor productivity") was accelerating. According to Kendrick, labor productivity grew at an annual rate of 1.7 percent over the 1899–1929 period, and then at 2.4 percent over the 1929–57 period.[1] The acceleration of the early part of the century, however, was apparently reversed some time in the postwar period, as the following table shows:[2]

| *Period* | *Annual growth rate of output per manhour* |
|---|---|
| 1948–55 | 3.11% |
| 1955–65 | 2.51 |
| 1965–71 | 1.88 |

Many explanations have been offered for the slowing trend in labor productivity. Some economists cite a shift in the composition of output to-

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1. See John W. Kendrick, *Productivity Trends in the United States* (Princeton University Press for the National Bureau of Economic Research, 1961), Table 4, p. 72. A similar result is found in Edward F. Denison, *The Sources of Economic Growth in the United States and the Alternatives before Us*, Supplementary Paper 13 (Committee for Economic Development, 1962), p. 266.

2. Source: Table 1 below. Here and in all subsequent tables, rates of growth of variables are given as first differences of logarithms (for example, the rate of growth of $X$ between 1948 and 1955 is $[\{\log(X_{55}) - \log(X_{48})\}/7]$).

ward low productivity industries,[3] others the changing composition of the labor force.[4] Still others argue that there has been no slowdown at all.[5] Whatever their fundamental explanations, everyone agrees that the cycle plays a part. The present study attempts to sort out the facts and determine what is behind the disappointing performance of labor productivity.

This paper is concerned with growth in *measured* productivity, which in turn depends on output measures that are not completely adequate from a statistical or conceptual point of view. In addition, the input measures are very primitive. But most important, movements in gross national product cannot be equated with movements in economic welfare. The slippage between the two concepts is too great to allow the equation of the growth in potential GNP with the growth in economic well-being. On the other hand, the available evidence indicates that productivity growth is perhaps the most powerful cause of the secular rise in the growth of per capita economic welfare.[6]

## Aggregate Movements in Labor Productivity

Before examining the behavior of labor productivity in individual industries I first define the concept of normal output and consider the question of aggregate movements in labor productivity.

### NORMAL OUTPUT

Because cyclical movements in output influence productivity, a cyclical correction based on the level of capacity utilization should be introduced.

3. See Victor R. Fuchs, *The Service Economy* (Columbia University Press for the National Bureau of Economic Research, 1968); William J. Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *American Economic Review*, Vol. 57 (June 1967), pp. 415–26.

4. See George L. Perry, "Labor Force Structure, Potential Output, and Productivity," *Brookings Papers on Economic Activity* (3:1971), p. 559.

5. See, for example, "Prepared Statement of Edward F. Denison," in *Improving National Productivity*, Hearings before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, 92 Cong. 2 sess. (1972), p. 119; also see Denison's lengthy comment on Perry, "Labor Force Structure," *Brookings Papers on Economic Activity* (3:1971), pp. 566–73.

6. For a detailed analysis of the connection between GNP and a measure of economic welfare, see William D. Nordhaus and James Tobin, "Is Growth Obsolete?" in *Economic Growth*, Fiftieth Anniversary Colloquium 5 (Columbia University Press for the National Bureau of Economic Research, 1972).

To estimate aggregate and industrial utilization this study uses the notion of "normal output," the level that GNP would attain if the unemployment rate were at its normal level, defined as its postwar average of 4.7 percent (using the conventional labor force definition). The concept is identical to potential output, except that the unemployment rate target is taken to be the average historical rate rather than an estimate of the minimal noninflationary rate. From an empirical point of view, the only operational difference between normal output and potential output comes in the projections of potential output like those in the final section. From a theoretical point of view, certain gains accrue from using the normal output concept, especially in defining capacity utilization for an industry.

Estimates of aggregate normal output used here employ the usual technique of adding back a cyclical correction to observed GNP. (The exact equation for predicting normal output is given in Appendix B.) The only substantive issue concerns the residuals in the estimated relationship between actual GNP and the unemployment rate. I have chosen to include the residuals (in effect making normal GNP equal to actual GNP plus the estimated cyclical correction), because any changes in the underlying growth rate of output, such as the acceleration in the late 1960s due to the more rapid growth of the labor force, should also appear in the estimated growth of normal output. The danger from inclusion of residuals in the growth of normal output is the possibility of bias in the estimate of the cyclical productivity coefficient. Although a complete examination of the properties of the procedure has not been made, it appears that its use here will yield an accurate estimate of the movement of normal output if fluctuations in the rate of growth of output are due largely to changes in inputs or persistent changes in the rate of growth of labor productivity; on the other hand, insofar as the errors are due to erratic and transient changes in productivity, the assumption will bias toward unity the estimates of the cyclical coefficients.[7]

7. It was possible to determine the magnitude of the possible bias by substituting a series on *smoothed* normal output for the unsmoothed series. The smoothed series was a scaled-down version of the official potential output series, one that shows roughly constant year-to-year growth. The same regressions were run as reported below in Tables 1 and 2.

The secular rates of productivity growth were virtually identical. The cyclical coefficients differed systematically according to the predictions indicated in the text. For the aggregate relation the sum of the cyclical coefficients ($\delta_{0i}$) was 0.90 rather than 1.063. For the disaggregated coefficients ($\delta_{1i}$) the difference was in the same direction, but amounted only to 0.088 on average. If the entire difference between the two estimates were bias, the difference for year-to-year residuals (such as those in Table 5) would be at most 0.3 per-

AGGREGATE PRODUCTIVITY

In making an estimate of the growth of aggregate productivity for comparative purposes, I use the same form of estimation applied to individual industries in the next section. In particular, I assume that normal labor requirements per unit of normal output are independent of the size of normal output and decline exponentially over time. In addition, I assume that the percentage deviation of actual labor inputs from normal labor requirements is proportional to the percentage deviation of actual from normal output. This set of assumptions leads to the following equation used for estimation of the aggregate productivity relation:

$$e - xn = \delta_{00} + \delta_{10}(x - xn) + \delta_{20}t + v_0, \tag{1}$$

where

$e$ = log of manhours
$x$ = log of real GNP
$xn$ = log of normal real GNP
$t$ = a linear time trend
$v_0$ = an error term.[8]

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centage point. For the subperiod productivity growth estimates (such as those presented in Tables 4, 10, 13, 16, and 17) the estimates from the two methods differ by an order of magnitude of 0.05 percentage point.

What then are the probable effects of use of the unsmoothed normal output series? In the first place, the true coefficients lie somewhere between the estimates using the unsmoothed and smoothed normal output series. The truth lies closer to the former or the latter in proportion as year-to-year movements in normal output were caused by inputs or by erratic changes in productivity, respectively. Second, the possible bias of the cyclical coefficients stemming from using the unsmoothed series is systematically upward, with the order of magnitude being around 0.1. Third, the effect on the estimated and projected rate of productivity growth is slightly pessimistic since terminal years were years of low utilization. Quantitatively, the downward bias in the estimate of productivity growth for the period 1965–71 might be as high as 0.05 percent. This would not alter substantially the result presented below.

8. The derivation of the aggregate production relation relies on developments in the next section but the essentials will be given here. Let $e$, $x$, and $xn$ be geometric indices of the log of employment, output, and normal output; $xn$ is defined as the prediction from the following equation:

$$x = \kappa_0 + \kappa_1(U - U_{norm}) + \kappa_2 t + v_0, \tag{i}$$

where $U$ is the actual unemployment rate, $U_{norm}$ the normal rate. Rewritten, (i) becomes

$$xn = x - \hat{\kappa}_1(U - U_{norm}). \tag{ii}$$

Now, constructing geometric indices, $e$, $x$, and $xn$ using weights $\theta_i$,

$$e = \Sigma e_i\theta_i, \qquad x = \Sigma x_i\theta_i, \qquad xn = \Sigma xn_i\theta_i. \tag{iii}$$

**Table 1. Regression Estimates for Aggregative Productivity Equation, 1948–1971[a]**

| *Independent variables* | *Coefficient* | *Standard error* | *t-statistic* |
|---|---|---|---|
| Constant | −8.687 | ... | ... |
| Time | −0.02567 | 0.000385 | 66.7 |
| Log (GNP/normal GNP) | 0.796 | 0.095 | 8.38 |
| Log (GNP/normal GNP)$_{-1}$ | 0.267 | 0.097 | 2.76 |
| $\bar{R}^2 = 0.996$ | *Standard error of estimate* = *0.0130* | *Durbin-Watson statistic* = *0.74* | |

Sources: Derived from equation (1) discussed in the text. See Appendix B for sources of the basic data, which are on an annual basis.
a. The dependent variable is log (manhours/normal GNP). Normal GNP is the level that would be attained if the unemployment rate were at its normal level, defined as its postwar average of 4.7 percent. The residuals are shown in Table 9.

The data for this specification are simply the aggregates of the individual industry data, and they therefore share their sins and virtues.

The results for the aggregate equation are shown in summary form in Table 1. Residuals are shown under the heading "aggregate" in Table 9. The most important feature of the estimate is that, according to this simple specification, labor productivity did indeed fall below its trend value beginning in 1969. The shortfall is not particularly alarming; it lies, in fact, within the prediction range of two standard errors of estimate. Starting in 1966 and in every year until 1971, the growth in labor productivity was less than the trend rate. In 1971 labor productivity grew at a rate slightly above the postwar average.

In order to check the results for the annual equation shown in Table 1, I also estimated equation (1) using constructed quarterly data for the period 1949:1 to 1972:2.[9] No important differences appeared between the quarterly and annual results. The coefficients on the utilization rate were slightly

From (iii) and (7) in the next section,

(iv) $$\Sigma e_i\theta_i - \Sigma xn_i\theta_i = \Sigma\delta_{0i}\theta + \Sigma\delta_{1i}(x_i - xn_i)\theta_i + \Sigma\delta_{2i}t\theta_i + \Sigma\epsilon_i\theta_i,$$

or

(v) $$e - xn = \delta_0' + \delta_1'(x - xn) + \delta_2't + \epsilon',$$

where the $\delta_i$ are suitably averaged aggregate parameters, assuming the $\delta_{1i}$ and $(x_i - xn_i)$ are uncorrelated. Equation (v) differs from equation (1) in the text in that the aggregate variables in (1) are logarithms of arithmetic indices, whereas the aggregates in equation (v) are logarithms of geometric indices.

9. Because quarterly data on employment by establishment are not available for the period, they had to be constructed. The quarterly interpolation of the annual data was made using labor force survey data on average hours worked and total employment. The quarterly data were constrained to average to the annual manhour data used in the annual aggregate and industry equation.

better determined for the quarterly equation, but the sum remained close to unity. The annual residuals were virtually identical in the two equations, as were the sums of squared *annual* residuals. There was no decrease in the residual for 1972 apparent in the quarterly residuals, as of the second quarter. In short, the annual estimates shown in Table 1 are confirmed by the quarterly data.

## Measurement of Labor Productivity by Industry Groups: The Model

In assessing recent trends in labor productivity, the most important question is whether the recent slowdown is associated with (a) changes in the composition of output; (b) sharp declines in labor productivity growth in a few isolated sectors; or (c) a decline in productivity growth broadly based in virtually all sectors. The first step is to outline a technique for measuring labor productivity in the major industries to help determine which of these possibilities is correct.

### CYCLICAL CORRECTION

The problem of correcting for the normal cyclical movements of productivity has no easy solution. Clear evidence exists that short-run increasing returns arise from short-run movements in output. While in aggregate studies, cyclical changes are customarily corrected by using a proxy such as the aggregate unemployment rate, this procedure is not adequate for industrial productivity.[10] GNP forthcoming at a 4 percent unemployment rate may well be a reasonable measure of potential output in a labor-constrained economy; but no similar constraint binds a single industry, which can bid away labor and materials from other industries until it runs into excessive costs or physical limitations on output.

By and large, most studies of disaggregated productivity movements have been unable to purge the cyclical elements from the estimates of trend productivity. The procedure used here introduces the concept of "normal industrial demand," defined as that level of industrial demand that would be forthcoming if aggregate demand were at its normal level. Specifically, ac-

10. The first use of this technique was by Arthur M. Okun. See his "Potential GNP: Its Measurement and Significance," reprinted in his *The Political Economy of Prosperity* (Brookings Institution, 1970), pp. 132–45.

tual demand is assumed to be determined by aggregate output, the utilization rate of aggregate output, and relative prices. Normal demand is then the prediction of that relation when aggregate demand is at its normal level.

### THE MODEL

Seven specific assumptions for each industry underlie the analysis:[11]

First, the demand for each sector is a function of its price relative to the general price level, the unemployment rate relative to the normal unemployment rate, and the level of normal aggregate output:

$$(2) \qquad x_i = \alpha_{0i} + \alpha_{1i}(p_i - \bar{p}) + \alpha_{2i}(U - U_{norm}) + \alpha_{3i}\overline{xn} + v_{1i},$$

where

$x_i$ = log of gross product originating by industry in 1958 prices
$p_i$ = log of deflator for $x_i$
$U$ = the actual unemployment rate
$U_{norm}$ = the normal unemployment rate
$\overline{xn}$ = log of normal aggregate GNP in 1958 prices
$\bar{p}$ = log of a geometric index of prices using 1958 output weights.

The conventions followed are that uppercase letters are in natural units and lowercase letters are in natural logarithms.

Second, estimates are then made of normal demand for a given industry from equation (2) on the basis of what demand would have been if aggregate output had been at its normal level, that is, if $U = U_{norm}$. This implies the following definition of $xn_i$, (the log of) normal demand:

$$(3) \qquad xn_i = \alpha_{0i} + \alpha_{1i}(p_i - \bar{p}) + \alpha_{3i}\overline{xn}.$$

Note that the residuals are excluded from the definition of normal output. Further, given the identity

$$\overline{XN} = \sum_{i=1}^{12} XN_i,$$

there is one redundant equation. Industry 10 (finance, insurance, and real estate) was considered the residual sector because of its treatment in the construction of the industrial accounts (see pp. 506–07).

11. Exact definitions of data are given in Appendix B. The twelve industries are agriculture; mining; contract construction; nondurable manufacturing; durable manufacturing; transportation; communication; public utilities; trade; finance, insurance, and real estate (FIRE); services; and government.

The third stage in the argument concerns the growth of capacity and "normal output." Firms are assumed to calculate the path of demand according to the methods outlined in the first and second steps, that is, to be aware of the nature of demand for their output. Such awareness involves knowledge that sales have a cyclical component, that relative price affects demand, and that the economy is growing. In making long-run decisions, however, firms are assumed to keep their eye on normal sales, or sales cyclically corrected. They do not, in this view, expect a current recession to last indefinitely. They then construct capacity so that "normal output" coincides with "normal demand." Normal output ($QN_i$) is assumed to follow a Cobb-Douglas production function:

$$qn_i = \beta_{0i} + \beta_{1i}en_i + \beta_{2i}k_i + \beta_{3i}t + v_{2i}, \tag{4}$$

where

$qn_i$ = log of normal output
$en_i$ = log of normal labor input
$k_i$ = log of net capital stock
$t$ = time;

$\beta_{3i}$ is interpreted as the secular rate of growth of total factor productivity. By the assumption that normal output adjusts instantaneously to normal demand, it follows from (4) that

$$xn_i = \beta_{0i} + \beta_{1i}en_i + \beta_{2i}k_i + \beta_{3i}t + v_{2i}. \tag{4a}$$

Fourth, I estimate below the full model suggested by (4). Given the problems of obtaining reasonably accurate and complete data on capital, I have made the assumption that normal capital-labor ratios ($K_i/EN_i$) grow at a constant exponential rate $\beta_{4i}$, and that there are constant returns to scale, so that $\beta_{1i} + \beta_{2i} = 1$. These imply that

$$en_i = xn_i - \beta_{0i} - (\beta_{3i} + \beta_{4i}\beta_{2i})t - v_{2i}. \tag{5}$$

Fifth, for normal labor inputs, manhours are assumed to adjust to short-run demand according to the following relationship:

$$e_i - en_i = \delta_{1i}(x_i - xn_i) + v_{3i}, \tag{6}$$

where $e_i$ is short-run labor inputs or employment, and $\delta_{1i}$ is the short-run cyclical productivity coefficient for industry $i$.

Sixth, solving (5) and (6) yields

$$e_i - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + \epsilon_i, \tag{7}$$

where

$$\delta_{0i} = -\beta_{0i} \qquad \delta_{2i} = -\beta_{3i} - \beta_{4i}\beta_{2i} \qquad \epsilon_i = -\nu_{2i} + \nu_{3i}.$$

The assumptions represented in equation (7) permit estimation, by industry, of (a) the short-run productivity coefficient, and (b) the secular rate of growth of labor productivity. It is important to note that the growth of labor productivity has two components: the secular rate of growth of total factor productivity ($\beta_{3i}$) and the contribution of capital deepening ($\beta_{4i}\beta_{2i}$).

Seventh, for the price equation required for projections, price is assumed to be a markup over normal unit labor costs, plus a trend:

$$p_i - w_i - en_i + xn_i = \gamma_{0i} + \gamma_{1i}t + \nu_{4i}, \tag{8}$$

where $w_i$ is the log of the wage rate.

## Productivity Estimates by Industry

The following sections present the basic results of the analysis for twelve industries. The regressions for equation (7) are shown in Table 2.[12]

### CYCLICAL PRODUCTIVITY

First, the phenomenon of short-run increasing returns shows up fairly consistently across the board. The estimates of $\delta_{1i}$ in equation (7)—the coefficient on capacity utilization—generally lie between zero and one, indi-

12. Here, as elsewhere, the results sometimes indicate significant autocorrelation of residuals, generally when there has been considerable deceleration or acceleration in the secular growth of labor productivity. Table 2 indicates that the assumption of a constant rate of growth is incorrect for mining, construction, transportation, public utilities, FIRE, and services, which have the most serious problems with autocorrelation of errors.

To determine the impact of this misspecification, the basic equations were also run with correction of first-order autocorrelation. For the most part the results were unchanged. No drastic changes appeared in the cyclical coefficients, although the standard errors were generally smaller. Only three of the $\delta_{2i}$ coefficients changed by more than 5 percent. Construction rose to 0.0118, transportation fell to 0.0311, and FIRE fell to 0.0150. For the $\delta_{2i}$, the standard errors are generally 50 percent to 150 percent larger where the correction for autocorrelation is made. It seems unlikely that any major changes in the results below would be occasioned by such changes.

**Table 2. Coefficients for Labor Productivity Equations, 1948–71**

| *Industry* ($i$) | *Constant* ($\delta_{0i}$) | *Cyclical productivity* ($\delta_{1i}$) | *Decline in manhour requirements, 1948–71* ($\delta_{2i}$) | *Standard error of estimate* | *Durbin-Watson statistic* | $R^2$ |
|---|---|---|---|---|---|---|
| Agriculture | 9.48 | 0.476 | −0.0533 | 0.0132 | 1.28 | 0.999 |
| | | (0.136) | (0.00039) | | | |
| Mining | 7.82 | 1.080 | −0.0375 | 0.0317 | 0.47 | 0.988 |
| | | (0.136) | (0.00094) | | | |
| Construction | 8.83 | 1.480 | −0.0090 | 0.0800 | 0.23 | 0.608 |
| | | (0.374) | (0.0024) | | | |
| Nondurable manufacturing | 8.55 | 0.923 | −0.0314 | 0.0130 | 1.05 | 0.997 |
| | | (0.0749) | (0.00039) | | | |
| Durable manufacturing | 8.49 | 0.830 | −0.0251 | 0.0242 | 1.06 | 0.986 |
| | | (0.058) | (0.00072) | | | |
| Transportation | 8.53 | 0.575 | −0.0332 | 0.0337 | 0.85 | 0.982 |
| | | (0.145) | (0.0010) | | | |
| Communication | 8.27 | 1.242 | −0.0565 | 0.0374 | 0.54 | 0.992 |
| | | (0.351) | (0.0011) | | | |
| Public utilities | 7.79 | 0.413 | −0.0547 | 0.0320 | 0.52 | 0.994 |
| | | (0.149) | (0.00094) | | | |
| Trade | 8.80 | 0.433 | −0.0273 | 0.0160 | 1.42 | 0.994 |
| | | (0.150) | (0.00047) | | | |
| FIRE[a] | 7.47 | 0.717 | −0.0167 | 0.0331 | 0.46 | 0.935 |
| | | (0.270) | (0.00098) | | | |
| Services | 9.09 | 0.548 | −0.0095 | 0.0187 | 0.82 | 0.938 |
| | | (0.123) | (0.00055) | | | |
| Government | 9.05 | 0.974 | 0.0014 | 0.0076 | 1.32 | 0.980 |
| | | (0.0309) | (0.00023) | | | |

Source: Derived from equation (7) discussed in the text. See Appendix B for sources of the basic data. Numbers in parentheses are standard errors.

a. In this and other tables, FIRE covers finance, insurance, and real estate.

cating that a 1 percent rise in output leads to a less than proportional rise in manhours. Three industries—mining, construction, and communication—are exceptions to this rule.

Six of the twelve industries show significant increasing returns: agriculture, durable manufacturing, transportation, public utilities, trade, and services. The remainder display no significant departure from constant returns; no industry has significant decreasing returns.[13]

Is there any pattern in these results? Short-run increasing returns are

13. The precise definition of these is: for increasing returns—(a) $\hat{\delta}_{1i} - 2\hat{\sigma}(\hat{\delta}_{1i}) < 1$; for decreasing returns—(b) $\hat{\delta}_{1i} - 2\hat{\sigma}(\hat{\delta}_{1i}) > 1$; and for no significant departure—neither (a) nor (b). Here $\hat{\delta}_{1i}$ are the estimated coefficients and $\hat{\sigma}(\hat{\delta}_{1i})$ are the estimated standard errors of the coefficients.

often attributed to the presence of considerable overhead labor as well as to inflexibility in hiring and firing workers in the short run. Is the cyclical responsiveness of productivity then associated with the extent of overhead labor? Unfortunately, no measure reports reliably the extent to which a worker is not "overhead." One measure is the fraction of workers classified as production or nonsupervisory workers,[14] another the ratio of total employees to total employment.[15] The relation between the fraction of overhead workers (as measured in these two ways) and an industry's cyclical response is shown in Table 3. The regressions reported at the bottom of Table 3 suggest that the extent of cyclical response does not depend in a predictable way on the proportion of nonoverhead workers.[16]

It is useful to compare the estimates of cyclical productivity for individual industries with the aggregate equation. The coefficient on the aggregate productivity estimate is a composite of a fixed term and a composition term. From note 8, $\delta_{10}(x - xn) = \sum \delta_{1i}(x_i - xn_i)\theta_i$. Let $ZN_i$ be the normal share of industry $i$ ($ZN_i = XN_i/XN$ or $zn_i = xn_i - xn$). Thus $x_i - xn_i = x_i - zn_i - x + x - xn = (x_i - zn_i - x) + (x - xn)$. The first term $(x_i - zn_i - x)$ is the deviation of the log of the share of the $i$th industry from its normal share, whereas the second term $(x - xn)$ is simply the log of the deviation of actual from normal aggregate output. Thus the composite cyclical coefficient ($\delta_{10}$) can be divided into two terms, first, the "composition" effect, and second, the "weighted average" disaggregated effect:

$$\delta_{10}(x - xn) = \underbrace{\sum \delta_{1i}(x_i - zn_i - x)\theta_i}_{\text{composition term}} + \underbrace{[\sum \delta_{1i}\theta_i](x - xn)}_{\text{weighted average term}}.$$

14. For the exact definition of a production worker, see Appendix B.

15. This second measure assumes that employees are relatively less a fixed factor than self-employed workers. Given the discrepancies in definitions of production or nonsupervisory workers, it seems useful to try this second concept. For the exact definition, see Appendix B.

16. One suspicious result is the significant increasing returns for agriculture. The specification is probably at fault here. The formulation assumes that firms choose labor inputs in response to an output target, where output is determined by an exogenous level of sales. In this scheme, the firm's errors in estimating productivity will not bias the estimates. Whereas such a framework is reasonable in the industrial sector, where firms are price setters, this procedure is clearly inappropriate for agriculture. It seems much more likely that shifts in supply factors (weather, corn-hog cycles, and so on) are at work than shifts in demand factors. If this is the case, relatively large shifts in output will occur with little corresponding movement in employment, giving a downward bias to the cyclical coefficient, $\delta_{1i}$.

**Table 3. Cyclical Productivity, and Proportions of Production Workers and Employees, 1964**

| *Industry* | *Cyclical productivity* ($\delta_{1i}$) | *Production workers as proportion of total employees, 1964*[a] | *Employees as proportion of total employment, 1964*[b] |
|---|---|---|---|
| Construction | 1.48 | 0.85 | 0.80 |
| Communication | 1.24 | n.a. | 0.99 |
| Mining | 1.08 | 0.78 | 0.95 |
| Nondurable manufacturing | 0.92 | 0.75 | 0.97 |
| Durable manufacturing | 0.83 | 0.73 | 0.97 |
| FIRE | 0.72 | 0.81 | 0.88 |
| Transportation | 0.58 | n.a. | 0.93 |
| Services | 0.55 | 0.92 | 0.83 |
| Agriculture | 0.48 | n.a. | 0.36 |
| Trade | 0.43 | 0.89 | 0.84 |
| Public utilities | 0.41 | n.a. | 0.98 |

Sources: Column 1 is from Table 2 above; column 2 is from *Manpower Report of the President, 1972*, p. 216. For employees as a fraction of total employment, see Appendix B.

The regressions are $\underset{}{\delta_1} = 0.317 + \underset{(0.634)}{0.549}$ (production workers as fraction of total employees) $R^2 = 0.077$

$\delta_1 = 2.24 - \underset{(2.07)}{1.68}$ (employees as fraction of total employment) $R^2 = 0.118$

a. Ratio of production or nonsupervisory workers to total employees.

b. Ratio of (a) employees in the specific industry to (b) employees plus self-employed plus unpaid family workers in that industry.

n.a. Not available.

Following are the weighted average terms (calculated using 1958 output weights) and the composition terms determined residually:[17]

| | |
|---|---|
| Aggregate ($\delta_{10}$) | 0.903 |
| Weighted average term | 0.747 |
| Composition term | 0.156 |

As can be seen, the aggregate estimate shows less cyclical sensitivity than the weighted sum of the disaggregated estimates because of the composition

17. This table is derived from the composition and weighted average terms of the composite cyclical productivity equation discussed in the text. See Appendix B for sources of the basic data. The aggregate coefficient ($\delta_{10}$) is different from the sum shown in Table 1. For purposes of comparison with the disaggregated equations, the aggregate equation was run with the lagged term omitted, giving 0.903 rather than the 1.063 shown in Table 1.

This calculation misses the effect of differential productivity levels on the cyclical coefficient. The weighted average term uses output weights ($\theta_i$ in the notation of note 8) for all series. This implicitly assumes productivity levels are the same in all industries, so that any differences in productivity levels are included in the residual composition term.

term. The composition term is positive because industries in which *demand* is cyclically sensitive also show productivity that is cyclically insensitive. Ranked in order of their short-run income elasticity, the industries most sensitive to demand are durable goods manufacturing, transportation, and mining, and they are third, fifth, and seventh, respectively, in cyclical productivity insensitivity. Services, trade, and public utilities are practically at the bottom of the list in both productivity sensitivity and demand insensitivity.

### SECULAR PRODUCTIVITY

The general trend of productivity advance for each industry is also shown in Table 2. The coefficients $\delta_{2i}$ represent the estimated annual rate of decline in manhour requirements per unit of normal output over the period 1948–71. The estimates accord with those of other studies.

### RECENT EXPERIENCE

Are individual industries experiencing the same slowdown in productivity that is apparent in the aggregate? Table 4 shows the actual and cyclically corrected rates of growth of labor productivity for three subperiods of the years 1948–71. The last column shows the estimate from Table 2. These data reveal a significant deceleration in five industries (mining, construction, durable manufacturing, public utilities, and FIRE); significant acceleration in two industries (transportation and services), and no significant pattern in five industries (agriculture, nondurable manufacturing, communication, trade, and government). As it turns out, the cyclical correction does not change the pattern of results significantly. The only serious changes are for construction, where the decline in labor productivity looks even worse before correcting for the cycle; for durable manufacturing, where the deceleration is attenuated by the cyclical correction; and for services, where more acceleration is apparent.

Finally, the residuals from each industrial equation are given in Table 5; residuals that lie more than one standard error away from the predictions are marked with asterisks.

The combined results in Tables 4 and 5 make clear that growth in labor productivity has been deteriorating in four industries. The most notable is construction, where productivity has actually been falling since 1965. FIRE

**Table 4. Actual and Cyclically Corrected Growth of Output per Manhour, Subperiods 1948–71**

| | *1948–55* | | *1955–65* | | *1965–71* | | *1948–71* |
|---|---|---|---|---|---|---|---|
| *Industry* | *Actual* | *Cyclically corrected* | *Actual* | *Cyclically corrected* | *Actual* | *Cyclically corrected* | *Estimate from equation (7)* |
| Agriculture | 5.03 | 5.20 | 5.33 | 5.29 | 5.20 | 5.20 | 5.33 |
| Mining | 4.93 | 4.88 | 3.38 | 3.33 | 2.53 | 2.57 | 3.75 |
| Construction | 4.70 | 4.71 | −0.01 | −0.05 | −0.87 | −0.18 | 0.90 |
| Nondurable manufacturing | 3.21 | 3.29 | 3.16 | 3.15 | 3.60 | 3.66 | 3.14 |
| Durable manufacturing | 3.18 | 3.11 | 2.59 | 2.39 | 1.93 | 2.33 | 2.51 |
| Transportation | 2.01 | 2.07 | 3.58 | 3.06 | 3.14 | 3.02 | 3.32 |
| Communication | 5.13 | 5.00 | 6.24 | 5.05 | 4.28 | 4.21 | 5.65 |
| Public utilities | 7.19 | 7.00 | 5.20 | 5.35 | 4.27 | 4.32 | 5.47 |
| Trade | 2.91 | 3.05 | 2.64 | 2.62 | 2.23 | 2.54 | 2.73 |
| FIRE | 1.64 | 1.79 | 2.31 | 1.01 | −0.39 | −0.28 | 1.67 |
| Services | 0.47 | 1.30 | 0.79 | 0.51 | 1.34 | 1.74 | 0.95 |
| Government | −0.18 | −0.18 | −0.05 | −0.23 | −0.18 | −0.20 | −0.14 |
| Aggregate | 3.11 | ... | 2.51 | ... | 1.88 | ... | 2.57 |

Sources: The "actual" estimates are calculated directly from the data (see Appendix B). The cyclically corrected rates use the predicted rate of growth of productivity in Table 2, minus the average annual rate of change of the residual from each industrial equation. The last column is from Table 2.

also has a very pronounced deterioration, and mining and public utilities evidence a slightly less pronounced pattern. How seriously should we take these results? I think that those for construction and FIRE, which are the most pronounced, should be used with great caution. The deflation procedures used for construction are known to be seriously defective in that they rely heavily on input cost data. Given the method of deflation, and especially the putative improvement in deflators recently, the change in the estimated rate of productivity increase, from 4.7 percent in the 1948–55 period to −0.2 percent in the 1965–71 period, poses a puzzle. Perhaps a change in the composition of output in construction is responsible for the shift, or perhaps it is an oddity due to the effects of double deflation. I know of no corroborating evidence of such a dramatic slowdown.

As for the FIRE industry, there are three reasons to question the validity of the results. First, simply from a technical point of view, FIRE is the residual industry, so the estimate of capacity utilization includes the cumu-

**Table 5. Residuals from Labor Productivity Equations, by Industry, 1964–71[a]**

Percent

| *Industry* | *1964* | *1965* | *1966* | *1967* | *1968* | *1969* | *1970* | *1971* |
|---|---|---|---|---|---|---|---|---|
| Agriculture | 1.17 | 0.98 | 0.07 | −3.07[b] | −0.02 | 0.59 | 0.02 | 1.78[b] |
| Mining | −2.12 | 0.97 | −2.26 | −2.69 | −1.31 | 2.14 | 3.82[b] | 8.04[b] |
| Construction | −3.84 | −0.62 | 3.32 | 4.17 | 3.18 | 7.32 | 8.51[b] | 10.19[b] |
| Nondurable manufacturing | −1.10 | −0.34 | 0.40 | 2.17[b] | 0.64 | 0.15 | −0.39 | −3.44[b] |
| Durable manufacturing | −2.83[b] | −3.61[b] | −0.62 | 1.26 | −0.07 | 1.03 | 1.69 | −2.50[b] |
| Transportation | 0.11 | −1.79 | −3.53[b] | −2.04 | −1.96 | −1.56 | −0.04 | 0.04 |
| Communication | −4.07[b] | −3.65 | −1.40 | −2.40 | −2.33 | 0.71 | 5.33[b] | 5.01[b] |
| Public utilities | −3.76[b] | −2.54 | −2.36 | −1.51 | −0.14 | 3.69[b] | 6.73[b] | 4.37[b] |
| Trade | −1.21 | −0.56 | −1.46 | −1.01 | −1.66[b] | 0.62 | 1.58 | 0.60 |
| FIRE | −2.76 | −4.82[b] | −4.47[b] | −5.56[b] | −3.18 | 3.43[b] | 5.89[b] | 6.87[b] |
| Services | 2.91[b] | 1.68 | 0.72 | −1.16 | −2.16[b] | −1.29 | −1.42 | −3.07[b] |
| Government | −1.39[b] | −1.11[b] | 1.51[b] | 0.91[b] | −0.22 | −0.87[b] | −0.39 | −0.75 |

Sources: Same as Table 2.

a. The interpretation of residuals is the percentage excess of the logarithm of actual manhours over that of estimated manhours, $e_i(t) - \hat{e}_i(t)$. Thus a positive residual in recent years indicates that productivity growth has slowed.

b. Observation is more than one standard error away from predictions.

lative errors of other industries. In fact, the normal output series for FIRE is not as absurd as it might be, but it does wobble more than is plausible. Second, FIRE is conceptually odd, in that it includes a very heavy share of imputed returns to owner-occupants and to financial institutions. The important point here is that the entire return from owner-occupied dwellings is imputed to capital and none at all to the labor service component. As any homeowner knows, this assumption is exasperatingly contrary to fact. Finally, FIRE is something of a residual category in the construction of the industry accounts. When the residual in the estimate of aggregate real output using the industrial approach is too widely different from the aggregate real output estimate using the product approach, some undetermined fraction of the residual is buried in the FIRE sector by adjusting the deflator and therefore the estimate of the real output in that sector.

For mining and public utilities, the causes of the recent deterioration cannot be laid to the quality of the output data. Conceivably, new legislation on safety may have hurt measured labor productivity in mining, while tougher environmental standards may have had a similar effect for public utilities.

The recent trend in services is encouraging if these figures can be taken seriously. Given the method of deflation, however, I am inclined to question that any real acceleration has occurred.[18] Since only a quarter of output can be considered properly measured, the productivity movements in services are implausibly large.

## Further Determinants of Productivity

The model outlined above uses highly simplified production relations. No attempt was made to introduce capital or materials, lags or breaks in trend, or demographic variables. Do any of these constitute gross omissions that compromise the conclusions of the model?

### LAGGED RESPONSE TO OUTPUT

The model assumes that manhours respond immediately to short-run changes in output. Since some analysts have found a long lag in response in certain cases, it appeared useful to test the proposition by adding a lagged term for capacity utilization. In all cases the unlagged term dominated the lagged term. In most cases the unlagged term was insignificant. For three industries—agriculture, mining, and communication—the lagged term was marginally significant. For agriculture and communication the sum of the cyclical coefficients was well above the estimate shown in Table 2, while the others generally showed a small rise, ranging from −0.01 for government to +0.14 for trade. Given the marginal contribution of the lagged term, all equations were run without it.

18. In a recent article, Martin L. Marimont gives a breakdown of the methods of estimating gross product originating in the service industries, showing that 31 percent is deflated by output price, 36 percent by the earnings index, and the balance by a mixture of the two. See his "Measuring Real Output for Industries Providing Services: OBE Concepts and Methods," in Victor R. Fuchs (ed.), *Production and Productivity in the Service Industries*, Studies in Income and Wealth, Vol. 34 (Columbia University Press for the National Bureau of Economic Research, 1969), Tables 1 and 4. One of the more amusing details brought out by Marimont is the index for current-dollar output in the burial industry: This is the "number of corpses other than paupers needing burial times the average current price of cemetery lots" (p. 33). The output concept is then corpses. What's good for the death rate is good for GNP.

**Table 6. Evidence on Break in Productivity Trend after 1965**

| Industry | Differential productivity growth after 1965: Coefficient | Standard error | t-statistic |
|---|---|---|---|
| Agriculture | 0.00012 | 0.00092 | 0.1 |
| Mining | 0.00710 | 0.00200 | 3.6 |
| Construction | 0.02000 | 0.00420 | 4.8 |
| Nondurable manufacturing | −0.00110 | 0.00100 | −1.1 |
| Durable manufacturing | 0.00025 | 0.00180 | 0.1 |
| Transportation | −0.00550 | 0.00250 | −2.2 |
| Communication | 0.00380 | 0.00250 | 1.5 |
| Public utilities | 0.00760 | 0.00170 | 4.6 |
| Trade | −0.00020 | 0.00110 | −0.2 |
| FIRE | 0.00380 | 0.00220 | 1.7 |
| Services | −0.00450 | 0.00083 | −5.4 |
| Government | −0.00032 | 0.00058 | −0.6 |
| Average (weighted by 1958 normal output) | 0.00124 | 0.00158 | ... |

Sources: Derived from the following equation: $e_i - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + \delta_{3i}t$ *dum* 66, where *dum* 66 = 0 up to 1965, and 1 after 1965, and the symbols are as identified in note 8. See Appendix B for sources of the basic data.

## A BREAK IN PRODUCTIVITY TREND?

The aggregate results presented above indicate that the residuals generally reached a minimum around 1965. Further, the residuals of the individual equations form a similar pattern in several cases.[19] It therefore seemed worthwhile to investigate the possibility of a slowdown directly by introducing into the basic equation another term, which allowed for a different rate of productivity growth after 1965.

Table 6 shows the coefficients on the additional variable. The weighted average is very close to zero, indicating that a weighted average of individual productivity growth did not decline significantly.[20]

19. There are two ways of dating the turn in 1965. For the aggregate, the residuals peak in 1965–66, then decline (see Table 9). Of the twelve industries reported individually in Table 5, nine show some kind of inflection in the sixties—one in 1963 and two each in the years 1964–67. The natural breaking point comes in 1965.

20. The same kind of question was investigated using a quadratic time term over the entire period. Judging from the standard errors, this was sometimes a superior specification. The conclusions in the text were maintained.

DEMOGRAPHIC COMPOSITION OF THE LABOR FORCE

The dramatic change in the composition of the labor force in recent years has appeared to some analysts to be the root of the recent productivity slowdown. The reasoning behind this view was stated by Perry:

> In the weighted employment total, an employee whose productivity (as measured by his wage) is only half the average productivity of all workers gets only half weight.
>
> Since the composition of the work force has been shifting continually toward relatively more women and young workers, individuals who have relatively low wage weights, the growth rate of weighted employment is lower than that of officially measured employment throughout the postwar period. But while the *difference* between the growth rate of the two measures averaged about 0.2 percentage point until 1965, it became 0.5 percentage point during the 1965–70 period. This change makes it especially important to use the weighted employment variable in analyzing the trend of productivity and potential output in recent years.[21]

The assumption that relative average productivities of various groups of workers are proportional to relative earnings is a hallowed tradition in productivity studies. It rests on the proposition that in a competitive equilibrium relative values of marginal products of inputs are proportional to the relative prices of the inputs.

In the context of relative average productivities, arguments can be made on both sides of this proposition. Supporting it is the traditional body of economic theory. But two factors cast serious doubt on it. First, if, as many economists have argued, discrimination has acted in favor of prime-age males (in the sense that relative wages are not proportional to relative marginal physical productivities), movement of females into traditionally male industries will not lead to the deterioration in productivity predicted by the demographic composition hypothesis.

Second, and perhaps more important, a large part of the increase in employment of females has taken place in industries where output is not measured with any precision. Thus about three-fourths of female workers are employed in services, trade, FIRE, and government—all of which suffer from serious conceptual problems in the measurement of output.

The test proposed here does not develop a complete measure of "wage-weighted employment" because of data limitations. There are, however,

21. Perry, "Labor Force Structure," p. 537.

data for the proportion of total employees who are female for all industries, for periods beginning variously from 1948 to 1964.[22]

The following technique was used to test the demographic composition hypothesis. The hypothesis holds that wage-weighted manhours, $e_i^*$, is the correct variable for the basic productivity equation, (7) above:

$$e_i^* - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + u_i^*, \tag{7D}$$

where $u_i^*$ is the error term.

Assuming that (7*D*) is the correct model, it can be rewritten as:

$$e_i^* - e_i + e_i - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + u_i^*$$

or

$$e_i - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + (e_i - e_i^*) + u_i^*.$$

The easiest way to test this is to include $(e_i - e_i^*)$ as an additional independent variable:

$$e_i - xn_i = \delta_{0i} + \delta_{1i}(x_i - xn_i) + \delta_{2i}t + \delta_{3i}(e_i - e_i^*) + u_i^*. \tag{9}$$

If the coefficient on $(e_i - e_i^*)$ turns out to be zero, the demographic composition hypothesis is rejected, while if it is unity the hypothesis is supported.

The results for the test of the demographic composition hypothesis are shown in Table 7. In general, the addition of the demographic term does not significantly improve the explanation. In no industry are the data able to distinguish between the unitary coefficient (signifying that demographic composition matters) and a coefficient of zero (composition does not matter).[23] In a few industries the demographic term is significant, but only

22. Perry's procedure was more complicated than the one used here, since he corrected for age as well as sex composition (*ibid.*, p. 564). The data indicate that for the 1960s most of the power is obtained by the change in sex composition. The following are the average annual changes in the ratios of teenagers and females to total employment over recent periods:

| | *1955–65* | *1965–71* |
|---|---|---|
| Teenagers to total | 0.0010 | 0.0014 |
| Females to total | 0.0033 | 0.0049 |

23. It is difficult to construct an aggregate test of the hypothesis. One approach is to compare the results through a likelihood-ratio test, by comparing the two hypotheses: the first, $H_1$, that $\delta_{3i}$ is zero and that demographic composition has no effect, and the second, $H_2$, that $\delta_{3i}$ is one. The likelihood ratio for industry $i$, $\lambda_i$, gives the ratio of the likelihood function valued for $H_1$ to the likelihood function valued for $H_2$ under the standard normality assumptions. The product of the likelihood ratios ($\lambda = \lambda_1 \times \lambda_2 \cdots \lambda_{12}$) gives the likelihood ratio for the entire sample, 1.07. Although no completely appropriate test exists, the critical ratios for a standard two-tailed 5 percent region for 92 degrees of freedom are 0.37 and 2.7. From the data analyzed above it is impossible to reject or accept either hypothesis.

**Table 7. Results for Test of Demographic Composition of the Labor Force as Reason for Slowdown in Productivity, Selected Sample Periods, 1948–71**

| *Industry* | *Coefficient* $\delta_{3i}$ | *Sample period* | *Degrees of freedom* |
|---|---|---|---|
| Agriculture | −0.149 (0.708) | 1948–71 | 20 |
| Mining | −2.46 (12.33) | 1960–71 | 8 |
| Construction | −7.76 (40.35) | 1964–71 | 4 |
| Nondurable manufacturing | 1.70 (5.56) | 1959–71 | 9 |
| Durable manufacturing | 8.02 (1.27) | 1959–71 | 9 |
| Transportation | −6.48 (2.46) | 1964–71 | 4 |
| Communication | 22.04 (14.76) | 1964–71 | 4 |
| Public utilities | 8.98 (10.92) | 1964–71 | 4 |
| Trade | 8.81 (2.56) | 1960–71 | 8 |
| FIRE | 10.10 (2.04) | 1960–71 | 8 |
| Services | 0.180 (1.03) | 1958–71 | 10 |
| Government | 6.35 (1.43) | 1964–71 | 4 |

Sources: Equation (9) discussed in the text. See Appendix B for sources of the basic data. The numbers in parentheses are standard errors.

at the cost of lying well outside of the a priori range of zero to one. In transportation, for example, the coefficient is significantly negative, while for government, trade, FIRE, and durable manufacturing, it is significantly greater than unity. Only in agriculture do the data begin to distinguish between the two hypotheses; here the coefficient is almost significantly different from unity.

One other questionable result comes out of the disaggregation. Three of the four industries in which the demographic effect shows up (trade, FIRE, and government) are those in which the output measures are seriously defective. These industries account for half of female employment. It is especially puzzling that measured productivity per person-hour has slowed down in government when output is measured in person-hours.

Thus in *no* individual industry can the demographic composition hypothesis be distinguished from its competitor. The demographic correction term [log $(E/E^*)$] *is* significant in some industries—durable manufacturing, transportation, trade, FIRE, and government. But in each of these cases the coefficient is implausibly large, indicating some spurious correlation.

Because the data used here cannot distinguish between the hypotheses, neither can be summarily rejected. However, the demographic variable does not move sufficiently in the sample periods to be a significant factor in any single industry. Perhaps the favorable results for the aggregate productivity equations discovered by Perry arise from spurious correlation rather than from the different productivities of different age-sex groups that he hypothesized.

### CHANGING CYCLICAL RESPONSE

A further rationale for the recent productivity slowdown is the responsiveness of employment to cyclical conditions. According to this argument, the recession after 1969 was unusual because it came after such a long period of prosperity; businessmen perhaps expected that it would be very brief and therefore hoarded their labor more than they had in earlier recessions. Employment thus would decline less than it had in earlier recessions and productivity would rise less rapidly.

A couple of approaches were used to test this view. First I took the simplistic tack of allowing cyclical conditions to react differently before and after 1964. There was no general pattern except general insignificance. Next I constructed a variable that reflected the recent labor market slackness; the specific variable was the average unemployment rate over the last three years. A test was run to see if the cyclical coefficient responded positively to labor market slackness; only in services was there any indication that it did. It does not appear plausible that changes in cyclical response can account for the recent productivity slowdown.

### CAPITAL INPUTS

The estimates of productivity presented here apply to the average product of labor. Other inputs, particularly capital, are also important in productivity movements. As shown in the development of the model above, capital inputs enter through the coefficient on time. Average productivity growth in equation (7) is $\delta_{1i} = \beta_{3i} + \beta_{4i}\beta_{2i}$, that is, the rate of total factor productivity growth plus the product of the growth rate of capital-labor ratios and the elasticity of normal output with respect to capital inputs. Inadequate data on capital generally prevent separating the influence of capital and labor services, and all productivity estimates are hampered by this possible specification error. A more complete framework for productivity accounting might well change some of the conclusions of this paper.

Little can be done to correct this shortcoming, given the lack of adequate data on capital services. I have, however, attempted to see whether the introduction of capital into the production relations would alter the results. The experiments were confined to three sectors, agriculture, manufacturing, and private nonfarm nonmanufacturing, for which the U.S. Office of Business Economics made a careful study of capital stocks (see Appendix B).

Introducing capital involves the basic production relations in equation (4a). Since the short-run productivity term and the effect of capital cannot be simultaneously estimated, the assumption is that the short-run productivity coefficient in equation (7) is unity (that is, $\delta_{1i} = 1$).

From (4a) and (6),

$$xn_i = \beta_{0i} + \beta_{1i}(e_i - x_i + xn_i - v_{3i}) + \beta_{2i}k_i + \beta_{3i}t + v_{2i}$$

or

$$(7K) \qquad e_i = \frac{(1 - \beta_{1i})}{\beta_{1i}}xn_i - \frac{\beta_{0i}}{\beta_{1i}} + x_i - \frac{\beta_{2i}}{\beta_{1i}}k_i - \frac{\beta_{3i}}{\beta_{1i}}t - \frac{\beta_{2i}}{\beta_{1i}} + v_{3i}.$$

Again assuming constant returns, the final equation is

$$(7KC) \qquad e_i - x_i = \left(\frac{1 - \beta_{1i}}{\beta_{1i}}\right)(xn_i - k_i) - \frac{\beta_{3i}}{\beta_{1i}}t - \frac{\beta_{0i}}{\beta_{1i}} + \left(v_{3i} - \frac{v_{2i}}{\beta_{1i}}\right).$$

Table 8 gives the estimates of equations (7*K*) and (7*KC*).

The results for capital are very discouraging. In all equations the capital term has the wrong sign, although it is significant only for manufacturing. There is obviously good reason for the wrong sign. Some capital deepening occurred in the late 1960s as a result of the investment boom, yet productivity per manhour turned down, if anything. Plainly, recent movements in labor productivity are not explicable in terms of the omission of capital. The implications of these results for use of empirical aggregate production functions are matters for further reflection.[24]

24. The possibility that the omission of capital, land, and other inputs could be biasing the results can be independently checked from Denison's estimates. In his comments on Perry cited in note 5, Denison implicitly estimates the annual growth of total input per manhour (see his Table 1, line 3 plus line 7 minus line 4, *Brookings Papers o*

**Table 8. Results for Test of Capital Equations as Explanation of Slowdown in Productivity**

| *Industry* | *Coefficients* $\gamma_0$ | $\gamma_1$ | $\gamma_2$ | $\gamma_3$ | *Standard error of estimate* | *Durbin-Watson statistic* |
|---|---|---|---|---|---|---|
| | | | Equation (*7KC*) | | | |
| Farm | 9.46 | −0.0474 | −0.0537 | ... | 0.0175 | 2.31 |
| | | (0.065) | (0.00064) | | | |
| Manufacturing | 8.61 | −0.206 | −0.0250 | ... | 0.0179 | 0.92 |
| | | (0.100) | (0.0013) | | | |
| Other private | 8.568 | −0.142 | −0.0240 | ... | 0.0127 | 1.17 |
| | | (0.118) | (0.00048) | | | |
| | | | Equation (*7K*) | | | |
| Farm | 10.97 | −0.568 | −0.0476 | 0.0791 | 0.0177 | 2.27 |
| | | (0.749) | (0.00876) | (0.0802) | | |
| Manufacturing | 11.18 | −0.707 | −0.00512 | 0.186 | 0.0166 | 1.17 |
| | | (0.257) | (0.00956) | (0.0929) | | |
| Other private | 11.10 | −0.495 | −0.00589 | 0.0372 | 0.0117 | 1.29 |
| | | (0.200) | (0.0086) | (0.120) | | |

Sources: Derived from equation (*7KC*) and equation (*7K*), discussed in the text. See Appendix B for sources of the basic data. The numbers in parentheses are standard errors.

## The Recent Slowdown

The result of all the tests of the competing hypotheses about the recent productivity slowdown is that the *basic disaggregated model*—the sectoral model of productivity introduced in equations (2) to (8)—cannot be significantly improved upon by any of these devices; hence that model will serve as the sole basis for subsequent discussion.

### PRODUCTIVITY PERFORMANCE IN THE DISAGGREGATED MODEL

The first and most important test will be to determine the predicted employment requirements in the basic disaggregated model to see whether these indicate a significant slowdown in the aggregate growth of labor productivity. This test employs a simulation of the employment requirements generated by the estimates from equations (2) to (8). For this simulation,

*Economic Activity*, 3:1971, p. 569). This figure is 1.28 percent for 1948–55, 0.81 percent for 1955–65, and 0.94 percent for 1965–69. Denison's corrections (not all of which are, in my mind, acceptable) would predict a slowdown of about 0.34 percent in the growth of productivity, whereas the actual was 0.90 percent.

normal aggregate output, sectoral outputs, and sectoral prices are taken as exogenous. The demand equations then generate normal outputs for each industry from equation (3), while the manhour requirements are generated by the manhour demand equations (7). The aggregate manhour requirements are then the sum of the individual predictions.

The results of this simulation are shown in Table 9 alongside the anal-

**Table 9. Predictions of Manhour Requirements and Errors in the Predictions, Aggregate and Disaggregated Models, 1948–71**

| *Year* | *Manhours*[a] *(billions)* | *Percentage error in productivity index*[b] *Aggregate* | *Disaggregated* |
|---|---|---|---|
| 1948 | 2.551 | 2.870 | 0.811 |
| 1949 | 2.465 | 0.378 | −0.392 |
| 1950 | 2.551 | 0.504 | −1.924 |
| 1951 | 2.709 | 0.799 | 0.037 |
| 1952 | 2.749 | 0.489 | 1.249 |
| 1953 | 2.771 | −0.617 | 0.702 |
| 1954 | 2.689 | −1.150 | 0.051 |
| 1955 | 2.736 | −1.590 | −1.457 |
| 1956 | 2.772 | −0.387 | 0.258 |
| 1957 | 2.745 | −0.450 | 0.574 |
| 1958 | 2.653 | −1.418 | −0.201 |
| 1959 | 2.738 | 0.787 | 0.074 |
| 1960 | 2.761 | 0.551 | 0.942 |
| 1961 | 2.748 | 0.244 | 0.588 |
| 1962 | 2.822 | 0.654 | 0.385 |
| 1963 | 2.834 | −0.597 | −0.111 |
| 1964 | 2.911 | −0.990 | −0.836 |
| 1965 | 3.007 | −1.283 | −0.893 |
| 1966 | 3.124 | −1.288 | −0.491 |
| 1967 | 3.149 | −1.070 | −0.178 |
| 1968 | 3.213 | −0.809 | −0.745 |
| 1969 | 3.288 | 1.193 | 0.451 |
| 1970 | 3.246 | 2.107 | 1.009 |
| 1971 | 3.225 | 1.916 | −0.167 |
| Root mean-square error | ... | 1.207 | 0.783 |

Sources: The aggregate model is the aggregate equation (1). The disaggregated model is estimated in equations (7) above, using the actual output and estimated normal output for each industry, as well as historical unemployment, price, and aggregate normal output (see Appendix B). The manhour prediction for the disaggregated model then simply adds up the predicted manhour requirements for each industry to arrive at the total.

a. Actual number of manhours (weekly rate).

b. Percentage error in the predictions of the aggregate model and the disaggregated model [100 (actual − predicted)/predicted].

**Table 10. Sources of Growth in Labor Productivity, Subperiods 1948–71**
Percentage points

| *Source* | *1948–55* | *1955–65* | *1965–71* | *Changes, 1948–55 to 1965–71* |
|---|---|---|---|---|
| Aggregate productivity growth | | | | |
| Cyclically corrected | 3.20 | 2.54 | 2.03 | −1.17 |
| Constant industrial productivity growth, cyclically corrected | 3.13 | 2.53 | 2.23 | −0.90 |
| Source of effect on aggregate productivity growth | | | | |
| Changing industrial productivity growth | 0.07 | 0.01 | −0.20 | −0.27 |
| Changing composition of output relative to 1955–65 | 0.60 | 0.00 | −0.30 | −0.90 |

Source: Table 9.

ogous predictions from the aggregate productivity equation (1). Disaggregation has clearly yielded a significant gain, reducing the root mean error by 35 percent and lowering the standard error to 0.8 percent, which is quite respectable in comparison with other studies.

Of greater interest is the fate of the recent slowdown. The second column of Table 9 shows the performance of the aggregate productivity equation in explaining the recent productivity slowdown. It shows an inflection point after 1965, as an underestimate of productivity of 1.3 percent turns into an overestimate of 2 percent by 1970–71. The performance of the disaggregated equations, which reflect the effects of compositional shift, is recorded in the third column; it reveals virtually no unexplained slowdown after 1965, with the errors of 1965 and 1971 differing by only 0.7 percent.

These calculations support a preliminary judgment about the sources of the recent deceleration in labor productivity. Table 10 shows the contribution of changing composition of output and of unexplained rates of productivity growth in individual industries. The actual growth of productivity per manhour (cyclically corrected) slowed by 1.17 percentage points from 1948–55 to 1965–71. Of these 1.17 points, 0.90 is predicted simply by the changing composition of output and 0.27 is due to unexplained productivity deceleration in individual industries.[25]

25. Productivity also caused concern in 1956–57. Unlike the recent experience, that slowdown was greater for the disaggregated model than for the aggregate equation (see Table 9). The 1956–57 slowdown shows up very broadly across almost all industries, with particularly large movements in durable manufacturing and transportation.

**Table 11. Predicted and Actual Output Shares, by Industry, Subperiods 1948–80**

Percent

| Industry | 1948–55 Predicted | 1948–55 Actual | 1956–65 Predicted | 1956–65 Actual | 1966–71 Predicted | 1966–71 Actual | 1972–80 Predicted |
|---|---|---|---|---|---|---|---|
| Agriculture | 5.5 | 5.5 | 4.5 | 4.6 | 3.6 | 3.6 | 3.1 |
| Mining | 3.1 | 3.0 | 2.6 | 2.7 | 2.4 | 2.3 | 2.1 |
| Construction | 4.8 | 4.6 | 4.1 | 4.4 | 3.6 | 3.4 | 3.1 |
| Nondurable manufacturing | 12.4 | 12.3 | 12.1 | 12.3 | 12.6 | 12.5 | 12.4 |
| Durable manufacturing | 17.8 | 17.6 | 16.9 | 17.2 | 18.7 | 18.2 | 18.2 |
| Transportation | 5.5 | 5.5 | 4.7 | 4.7 | 4.7 | 4.7 | 4.3 |
| Communication | 1.6 | 1.6 | 2.1 | 2.1 | 2.8 | 2.8 | 3.6 |
| Public utilities | 1.9 | 1.8 | 2.4 | 2.5 | 2.9 | 2.8 | 3.4 |
| Trade | 16.5 | 16.4 | 16.7 | 16.9 | 17.2 | 17.3 | 17.5 |
| FIRE | 10.6 | 11.6 | 14.8 | 13.2 | 12.4 | 13.3 | 13.9 |
| Services | 9.3 | 9.1 | 9.2 | 9.5 | 9.4 | 9.4 | 9.5 |
| Government | 11.0 | 11.0 | 10.0 | 10.1 | 9.7 | 9.6 | 8.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Sources: Actual figures are raw shares of each industry without cyclical correction (see Appendix B). The predictions are made according to the simulation procedure described in the text (pp. 515–16), and exclude cyclical movements. Figures may not add to totals because of rounding.

MOVEMENTS IN OUTPUT AND EMPLOYMENT SHARES

The actual and estimated movements in output shares in each of the twelve sectors are shown in Table 11. For the historical period 1948–71, the shares predicted from the demand equations when output is at its normal level (with prices and outputs endogenous) are shown as "predicted," while the historical shares are shown as "actual." The only appreciable error is for FIRE, the troublesome residual industry. The last column of Table 11 shows the projected shares for the 1972–80 period, which imply no dramatic or discontinuous shifts. The only faintly noticeable movements are that real government output is projected to fall slightly faster than its most recent rate and that the manufacturing share is predicted to reverse the increase observed from the second to the third subperiod.[26]

26. The possibility that using fixed (1958) weights biases the estimate of productivity growth should be considered. It is a well-known phenomenon in economic growth that—because of the negative correlation of output growth and price changes—using early prices overstates growth and productivity, and conversely. The presence of this effect can be checked only in a limited way because it is possible to disaggregate only

**Table 12. Manhour Shares, by Industry, Actual for Selected Years, 1948–71, Predicted, 1980**

Percent

| *Industry* | *1948* | *1955* | *1965* | *1971* | *1980* |
|---|---|---|---|---|---|
| Agriculture | 17.9 | 12.4 | 7.5 | 5.3 | 3.2 |
| Mining | 1.5 | 1.3 | 0.9 | 0.8 | 0.6 |
| Construction | 4.1 | 5.2 | 4.9 | 4.6 | 4.6 |
| Nondurable manufacturing | 11.4 | 10.8 | 10.3 | 10.2 | 9.0 |
| Durable manufacturing | 12.8 | 14.8 | 15.1 | 14.5 | 14.5 |
| Transportation | 5.6 | 4.4 | 3.8 | 3.6 | 2.9 |
| Communication | 1.3 | 1.2 | 1.2 | 1.3 | 1.3 |
| Public utilities | 0.8 | 0.9 | 0.9 | 0.8 | 0.8 |
| Trade | 18.6 | 18.6 | 18.9 | 18.8 | 18.2 |
| FIRE | 2.8 | 3.6 | 4.3 | 4.3 | 4.6 |
| Services | 12.4 | 12.6 | 15.8 | 16.5 | 19.1 |
| Government | 10.9 | 14.0 | 16.4 | 19.1 | 21.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Sources: Figures for 1948, 1955, 1965, and 1971 are actual shares of each industry in total manhours, cyclically corrected (see Appendix B). Figures for 1980 are those predicted by the simulations described in the text. Figures may not add to totals due to rounding.

The movement of the relative shares in total manhours is shown in Table 12. Comparison of the two tables underlines the differential movement of output shares and manhour shares as a result of differing rates of productivity growth among industries.

### FURTHER DISSECTION OF THE CHANGING RATE OF PRODUCTIVITY GROWTH

The results presented so far indicate that shifts in the composition of output have accounted for a sizable part of the recent slowdown in labor productivity. But *why* and *how*?

Consider how changes in composition among industries affect the aggregate growth of productivity. Even if every industry has its own constant rate of trend productivity growth, as assumed in the model above, the aggregate growth of productivity is not merely an average with constant weights of the sectoral productivity growth rates. First, any systematic

twelve broad industry groups. With 1969 rather than 1958 prices, the growth of labor productivity in the period 1948–58 was 0.12 percent less than that reported above. The corresponding effect appeared for the 1958–70 period, but the magnitude was only 0.025 percent. It does not appear likely that problems of index numbers lie behind the slowdown in productivity.

tendency for industries with especially high rates of productivity growth to have rising shares of output over time increases their weights and adds to aggregate productivity growth. Second, a systematic shift of employment shares from industries with low productivity levels to ones with high productivity levels raises the growth of aggregate productivity above the weighted average of the sectors. Conversely, movements of output shares toward sectors with low productivity growth rates or of employment shares toward sectors of low productivity levels will depress the aggregate growth of productivity.

As equation (A-2) in Appendix A demonstrates, the growth of aggregate productivity can be decomposed into several parts to reflect these compositional impacts. The first term (a predicted fixed-weight rate term) shows the predicted rate of aggregate productivity growth if relative shares of output were constant and if levels of productivity were identical in all industries.

The second term (change in the predicted fixed-weight rate term) shows the impact of changes in the shares of output among sectors, still ignoring differences in levels of productivity among them.

The third and fourth terms show the effects of changing employment shares among industries with different levels of productivity. They measure the extent to which employment has tended to shift toward or away from industries with above-average productivity levels. This effect is broken into two terms: the fixed-productivity-weight term ("fixed-weight level term"), measuring the pure level effect if relative productivity levels among industries had remained constant at their 1958 values; and the "actual-weight level term," showing the effect of the interaction of changing employment shares and changing relative productivity levels.

Table 13 decomposes the growth of productivity into the four terms discussed above for the three subperiods of the postwar period.[27] The sum of the four terms gives the predicted rate of aggregate productivity change. This dissection of productivity change indicates that the slowdown in productivity growth can be traced almost exclusively to the level factor, or the effect on aggregate productivity of shifts in employment shares among industries with different levels of productivity. In the early postwar period of 1948–55, the level terms added 0.75 percentage point to aggregate produc-

27. Both the first and second terms above used the predicted rather than the actual rate of productivity growth in the various industries; as shown in Appendix A, this introduces a fifth term of "unexplained change," which is fortunately small and hence will be ignored in the calculations below.

**Table 13. Decomposition of Predicted Rate of Labor Productivity Growth, and Actual Rate of Growth, Cyclically Corrected, Subperiods 1948–71**

| *Component or aggregate* | *1948–55* | *1955–65* | *1965–71* |
|---|---|---|---|
| Predicted rate terms | | | |
| 1. Fixed-weight (1958 weights) | 2.34 | 2.34 | 2.34 |
| 2. Change in fixed-weight term | 0.01 | 0.02 | 0.05 |
| Level terms | | | |
| 3. Fixed-weight (1958 weights) | 0.55 | 0.19 | −0.04 |
| 4. Actual-weight | 0.20 | −0.03 | −0.14 |
| 5. Predicted rate of aggregate productivity growth, cyclically corrected | 3.10 | 2.52 | 2.21 |
| 6. Actual rate of aggregate productivity growth, cyclically corrected from equation (1) | 3.20 | 2.54 | 2.03 |

Sources: Derived from equation (A-2) discussed in Appendix A, and basic data cited in Appendix B. The derivation of the components is as follows:
*Lines 1 and 2*—The predicted rate is given by summing $-\delta_{2i}Z_i(t)$ for the twelve industries where $Z_i(t)$ is the output share of the industry and the $-\delta_{2i}$ are the productivity growth rates from Table 2. Line 1 uses the values of the $Z_i$ for 1958, while line 2 is the value for a given year minus the value for 1958.
*Lines 3 and 4*—The level terms are $\Sigma\dot{S}_i[(A_i/A_0)^0 - 1]$ for line 3 and $\Sigma\dot{S}_i(t)[(A_i/A_0) - (A_i/A_0)^0]$ for line 4, where $S_i$ = share of predicted manhours of industry $i$, $A_i$ = productivity per manhour in industry $i$, and the superscript zeros evaluate the ratios for the base year, 1958. See Appendix A.
*Line 5*—Sum of lines 1 to 4.
*Line 6*—Actual rate of change in aggregate productivity corrected for the cycle using the cyclical correction estimated in equation (1).

tivity growth, signifying a marked shift of employment toward industries of especially high productivity; in the most recent period, 1965–71, the level effects dragged down aggregate productivity growth by 0.18 percentage point. Comparing the two periods, the change in the level terms accounts for almost 1 full percentage point slowdown in the growth of aggregate productivity. Roughly two-thirds of that swing is accounted for by the fixed-weight level term, reflecting the differences in productivity levels.

It is striking that the rate effect seems to be negligible, recording a very small shift in the shares of output toward industries with high rates of productivity growth.

In combination the separate effects yield the predictions of aggregate productivity growth shown in line 5 of the table, which correspond reasonably closely to the cyclically corrected estimate of the actual rate of productivity shown in line 6. The prediction shown in line 5 reflects a slowdown of aggregate labor productivity growth of almost a full percentage point in the postwar period, only slightly less than the actual slowdown.[28]

28. The discrepancy of 0.01 to 0.03 percentage point between the predicted rates of aggregate productivity growth on line 2 of Table 10 and on line 5 of Table 13 probably reflects the omission of second-order terms and some rounding.

CONTRIBUTION OF INDIVIDUAL INDUSTRIES TO THE LEVEL EFFECT

It is possible to focus the analysis further by examining the contribution of each individual industry to the level terms, which were found above to be the main elements in the productivity slowdown. Each of the level terms can be decomposed into the twelve components—each representing the effect of the change in the employment share of a specific industry on aggregate productivity. Thus the fixed-weight level term for agriculture reflects the effect of the falling employment share of agriculture, taking the productivity of agriculture relative to the aggregate at the level of 1958. The actual-weight level term for agriculture then represents the difference in the effect of employment shifts which in turn reflects the fact that agriculture's relative productivity actually differed from the 1958 value.

Productivity relatives among industries, recorded in Table 14, reveal considerable dispersion, with productivity in agriculture, services, and government falling decidedly below the mean, while that in mining, communication, public utilities, and FIRE considerably exceeds it. Given the sizable differences in productivity, it is not implausible for the level effects to be quite large.

Table 15 indicates how the twelve industries contribute to the total level effect; it thus decomposes lines 3 and 4 of Table 13.

**Table 14. Productivity Relatives, by Industry, Selected Years, 1948–80[a]**

| *Industry* | *1948* | *1955* | *1965* | *1971* | *1980*[b] |
|---|---|---|---|---|---|
| Agriculture | 0.35 | 0.41 | 0.55 | 0.66 | 0.88 |
| Mining | 2.19 | 2.29 | 2.58 | 2.83 | 3.27 |
| Construction | 1.06 | 0.91 | 0.77 | 0.73 | 0.64 |
| Nondurable manufacturing | 1.12 | 1.12 | 1.19 | 1.25 | 1.38 |
| Durable manufacturing | 1.27 | 1.22 | 1.21 | 1.23 | 1.27 |
| Transportation | 1.12 | 1.14 | 1.23 | 1.30 | 1.46 |
| Communication | 1.16 | 1.38 | 1.88 | 2.25 | 3.17 |
| Public utilities | 1.89 | 2.23 | 2.99 | 3.53 | 4.89 |
| Trade | 0.91 | 0.88 | 0.90 | 0.93 | 0.98 |
| FIRE | 3.81 | 3.45 | 3.16 | 3.06 | 2.94 |
| Services | 0.81 | 0.70 | 0.59 | 0.56 | 0.50 |
| Government | 0.94 | 0.75 | 0.57 | 0.51 | 0.40 |
| Aggregate | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Source: Derived from manhour and gross product data described in Appendix B.

a. The table shows manhour productivity (cyclically corrected) in a given industry relative to the aggregate productivity per manhour.

b. Predicted from the simulation described in the text.

The industries making the most important contribution to the level effect are agriculture, durable manufacturing, FIRE, services, and government. For all of the postwar period, the shift out of agriculture (with its below-average level of productivity) has provided a considerable boost to the growth of aggregate productivity, contributing on average about one-

**Table 15. Contribution of Level Effects to the Decline in Labor Productivity, by Industry, Subperiods 1948–71**[a]

Percentage points

| *Type of effect and industry* | *1948–55* | *1955–65* | *1965–71* | *Changes, 1948–55 to 1965–71* |
|---|---|---|---|---|
| *Fixed-weight effect* | | | | |
| Total, all industries | 0.55 | 0.19 | −0.04 | −0.59 |
| Agriculture | 0.44 | 0.27 | 0.20 | −0.24 |
| Mining | −0.04 | −0.05 | −0.03 | −0.01 |
| Construction | −0.02 | * | * | 0.02 |
| Nondurable manufacturing | −0.01 | * | * | 0.01 |
| Durable manufacturing | 0.06 | * | −0.02 | −0.08 |
| Transportation | −0.02 | −0.01 | * | 0.02 |
| Communication | * | * | * | * |
| Public utilities | 0.02 | * | −0.01 | −0.03 |
| Trade | * | * | * | * |
| FIRE | 0.29 | 0.16 | * | −0.29 |
| Services | −0.01 | −0.11 | −0.04 | −0.03 |
| Government | −0.14 | −0.07 | −0.14 | * |
| *Actual-weight effect* | | | | |
| Total, all industries | 0.20 | −0.03 | −0.14 | −0.34 |
| Agriculture | 0.06 | −0.01 | −0.05 | −0.11 |
| Mining | * | * | * | * |
| Construction | 0.02 | * | * | −0.02 |
| Nondurable manufacturing | * | * | * | * |
| Durable manufacturing | * | * | * | * |
| Transportation | * | * | * | * |
| Communication | * | * | * | * |
| Public utilities | * | * | * | * |
| Trade | * | * | * | * |
| FIRE | 0.04 | * | * | −0.04 |
| Services | * | * | * | * |
| Government | 0.08 | * | −0.07 | −0.15 |

Sources: The fixed-weight effect for industry $i$ is defined from equation (A-2) in Appendix A as $\dot{S}_i[(A_i/A_0)^0 - 1]$, while the actual-weight effect is $\dot{S}_i[(A_i/A_0)^0 - (A_i/A_0)]$. $\dot{S}_i$ = change in the share of total manhours in industry $i$, and the superscript zero refers to the value for the base year (1958). See Appendix B for the sources of the basic data. The figures may not add to totals because of rounding.

a. The values shown are the contributions of individual industries to the total level effect.

* Less than 0.005 percentage point.

quarter percentage point a year to it. On the other hand, the employment shifts toward both services and government (also low-productivity industries) have been a drag, each slowing the productivity growth rate by about 0.1 percentage point.

What industries have contributed most to the *decline* in the level effect of 0.93 percentage point? Clearly agriculture and FIRE are the most important, contributing −0.35 and −0.33, respectively. Government and durable manufacturing are also important, contributing −0.15 and −0.08, respectively. The decline in the contribution of agriculture reflects the fact that employment in agriculture has fallen from 18 percent of manhours in 1948 to only 5 percent currently, so that a given proportional decline in its employment now has a much smaller effect on aggregate manhours. Moreover, because agriculture's productivity relative is rising, although still far below unity (Table 14), the actual-weight effect is positive before 1958 and negative thereafter. In the case of government, the share of manhours has been rising (Table 12) while the productivity relative has kept falling (Table 14), resulting in an adverse shift in the actual-weight effect. For durable manufacturing (an industry of above-average productivity level), the employment share rose early in the postwar period, but has recently dipped.

Perhaps the only puzzling results are those for services and for FIRE. How is it possible that services were so small a drag over the entire period and virtually no drag for 1965–71? The reason was the sudden strengthening in productivity in the service sector after 1965 and the associated slowdown in its share of manhours (Tables 4 and 12).

And how could FIRE have contributed so much in early years and so little in recent years? The problem is mainly one of measurement. The FIRE industry consists mainly of real estate, including owner-occupied dwellings. It is extraordinarily capital intensive. Labor's share of income (employee compensation as a percentage of gross product originating) was 22 percent for FIRE in 1969 as against 61 percent for all industries. Moreover, of the total output in FIRE, about 41 percent is currently imputation on owner-occupied dwellings, for which there is no return to labor.[29] Obviously, movement of output in the FIRE industry, in particular its real estate portion, can have a significant effect on output without any corresponding effect on employment. Thus the stability of the manhour share of FIRE from 1965 to 1971 (see Table 12) led to a large deceleration in aggregate

29. Thus while the entire economy showed an average productivity per full-time equivalent employee of $14,700 in 1971, the figure for real estate was $164,700!

labor productivity. This result implicates the tight monetary policy of the second half of the sixties in the productivity slowdown, but leaves the extent of its contribution an intriguing question.[30]

## THE GROWTH OF POTENTIAL OUTPUT IN THE 1970S

What growth in potential output can the United States expect during the next decade? As we have seen, the growth in aggregate labor productivity has indeed been slowing, but the analysis here points to the changing composition of output as the cause. Because the model can generate future changes in the composition of output, the growth of potential can be estimated from the combination of the demand relations and the productivity and price relations. These projections differ from others only in projecting output at normal unemployment (4.7 percent of the civilian labor force) rather than at 4.0 percent.[31]

The simulation assumed that the trend productivity estimates for each industry shown in Table 2 would hold for the period 1972–80. An intuitive check of the plausibility of this assumption can be made by examining Table 4, which suggests that the assumption may be slightly optimistic.

30. In retrospect, FIRE may have been a poor choice for a residual industry, given its contribution to the productivity slowdown. As a test, FIRE was included in the demand equations in the same way as other industries. The simulation of the disaggregated model in Table 9 was rerun with this altered specification. The result was to raise the residual for the disaggregated model by 0.00046 for 1948, by −0.00004 for 1965, by 0.00054 in 1965, and by 0.00189 in 1971. The coefficients of the productivity equation for FIRE changed very little. There do not appear to be any serious problems stemming from the choice of FIRE as a residual industry.

31. An estimate of potential output using the "official" unemployment rate of 4.0 percent is relatively easy to make. According to the estimates of labor force participation in Appendix A, the potential labor force participation rate rises by 0.68 percentage point and the unemployment rate falls by 0.7 percentage point, so potential employment rises by 0.68 + 0.75, or 1.43 percent. If the normal unemployment rate falls from 4.7 percent to 4.0 percent, no permanent gain in productivity would accrue, according to the model used here. Potential output would therefore be 1.43 percent higher at 4.0 percent unemployment than at 4.7 percent. This is the assumption that is made in Table 17. If the normal unemployment rate were to stay at 4.7 percent, cyclical productivity gains of about 0.5 percent (or about $4 billion) would be added to the estimate in Table 17. The assumption that the normal unemployment rate *falls* to 4.0 percent accounts for most of the difference between the *level* of my estimate of conventional potential output for 1972 ($818.7 billion) and the official estimate ($825.0 billion). There is, however, no substantial effect on the rate of growth of potential from using the different unemployment targets.

**Table 16. Rates of Productivity Growth per Manhour, Cyclically Corrected, Subperiods 1948–80**

Percent

| *Period* | *Predicted from model* | *Actual* |
|---|---|---|
| 1948–55 | 3.13 | 3.20 |
| 1955–65 | 2.53 | 2.54 |
| 1965–71 | 2.23 | 2.03 |
| 1971–76 | 2.16 | ... |
| 1976–80 | 2.07 | ... |

Sources: The prediction is normal output per manhour predicted from the estimated equations according to the procedures described in the text. Actual figures are from Table 13.

Judging from the simulation of the basic model shown in Table 9, however, the errors flowing from the assumption of constant productivity growth seem roughly to cancel out by 1971. Projecting these industry trends to 1980 yields the predicted productivity relatives shown in Table 14. The output and manhour shares predicted by the demand, price, and productivity equations are recorded above in Tables 11 and 12.

Table 16 shows the predicted rate of growth of productivity per manhour. The simulation projects a continuation of the slowing trend in output per manhour that was observed over most of the postwar period, although the rate of deceleration is predicted to decline slightly. The prediction for the period from 1971 to 1980 is an average annual rate of growth of productivity per manhour of about 2.1 percent, substantially below the average of about 2.6 percent for the period 1948–71 but only slightly below the 2.2 percent rate of 1965–71. The reason for the further decline is simply the continually shrinking significance of the movement of employment out of agriculture, and the shift into services and government (see Table 12).

The estimates of potential output, of its growth, and of labor productivity are presented in Table 17. The most dramatic figure appears for the rate of growth of potential. The model used here projects a growth of 3.4 percent annually over the 1970s, considerably slower than in the last few years. This figure contrasts with Perry's optimistic estimate of 4.3 percent and with the official estimate of the current growth of potential of 4.3 percent.[32]

The major difference between Perry's projection and the projection in Table 17 lies in predicted productivity growth. Differences in predicted input growth are small. Perry estimated that potential manhours (unweighted)

32. Perry, "Labor Force Structure," p. 560. The "official" estimate is given in *Business Conditions Digest*, several recent issues.

**Table 17. Projection of Potential Output, 1972–80**

| Description of economy | Potential output (billions of 1958 dollars) 1972 | 1976 | 1980 |
|---|---|---|---|
| At 4 percent unemployment | 818.7 | 939.9 | 1,073.5 |
| At 4.7 percent unemployment | 807.1 | 925.9 | 1,058.4 |

| Source of growth of potential output | Average annual rate of growth (percent) 1972–76 | 1976–80 |
|---|---|---|
| Total growth in potential output | 3.49 | 3.40 |
| Source | | |
| Employment | 1.57 | 1.55 |
| Average hours | −0.24 | −0.22 |
| Aggregate productivity | 2.16 | 2.07 |

Source: Derived by author on the basis of simulations described in the text.

would grow at 1.44 percent over the period 1970–80, while I project a growth rate of 1.33 percent over 1971–80. On the other hand, Perry estimated a 2.86 percent average of productivity growth for 1970–80, whereas the present estimate is 2.1 percent for 1971–80.[33]

What causes this large discrepancy in predictions? It revolves essentially around whether the last five- or six-year period is seen as the exception or the norm. Perry argues that the recent productivity deceleration was due in part to changes in the composition of the labor force, and that as the labor force stabilizes the growth of productivity will rise toward its postwar average. The findings here suggest that it is the composition of output that is behind the slowdown: As the movement toward low-productivity sectors continues, we should expect a further productivity deceleration.[34]

33. Perry's figures reported here differ from those in his Table 2, *ibid.*, and the section "Projected Potential Output," pp. 559–60. The figures shown in Perry's article are 1.33 percent growth for weighted manhours and 2.97 percent for weighted productivity. Perry has kindly provided me with an estimate of growth of *unweighted* manhours, which is the figure shown in the text. The estimate of productivity is 4.30 − 1.44 = 2.86.

34. It is useful to get a rough idea of the statistical confidence one can place in the projections. The variance of the midsample estimate of potential output is equal to the sum of the variances of productivity level, labor force participation, and hours (plus covariance terms that will be ignored). The variance of the 1980 prediction is then the variance of the midsample estimate times a factor (around 1.5 in the actual calculations) that accounts for the fact that the 1980 level is way out from the sample mean.

The variances of productivity level (for a given demand pattern), labor force participation rate, and hours—all taken as a percent of the mean—are 0.6, 1.7, and 0.7 percent, respectively. If uncertainty about demand adds another 1.0 percent to the variance, the total variance of the 1980 prediction is then 4.0 × 1.5 = 6.0 percent. Thus the standard

In 1948–55, the economy was deriving a considerable bonus in its productivity growth from employment shifts among industries with different productivity levels. If output shares remained constant, the long-run growth in labor productivity would be 2.34 percent (see Table 13), but in this period, agriculture and FIRE were contributing approximately an additional 0.8 percentage point through level effects (see Table 15). These bonuses did not persist, and by the 1965–71 period, the level effects were actually lowering the aggregate growth rate by almost 0.2 percent. Unless dramatic new trends in the composition of output or in the underlying growth in labor productivity develop in the next decade, a further deterioration in labor productivity will develop as the level effects continue to decline.

## SUMMARY OF FINDINGS

A careful examination of the postwar experience reveals a slowdown in productivity growth in recent years over and above that which could be explained by cyclical conditions alone. For the entire economy, the average annual rate of productivity growth cyclically corrected fell from 3.20 percent in 1948–55 to 2.54 percent in 1955–65, and then to 2.03 percent in 1965–71. Disaggregating to twelve broad industry groups serves to explain most of the deceleration simply in terms of change in the composition of demand and unchanging rates of productivity growth in individual industries. More precisely, the estimated aggregated productivity growth with unchanging individual industrial productivity growth was 3.13 percent, 2.53 percent, and 2.23 percent, respectively, for the three periods.

A further dissection of the cause of the slowdown indicates that it was due mainly to differences in productivity levels among industries, rather than to different rates of growth of productivity among industries. In this regard, the contributions of agriculture and FIRE were especially important, while durable manufacturing and government also retarded growth. Projections of future patterns of demand indicate that the productivity growth rate for the 1970s should proceed at a rate slightly lower than predicted for the last few years. Specifically, if demand follows historical pat-

error of prediction of the 1972–80 growth rate is on the order of 0.3 percentage point. Note that this estimate accounts for the autocorrelation in the residuals of the estimated equation. If the usual statistical criteria were applied, the range from 2.9 to 4.1 percent would be a 95 percent confidence interval for the prediction of the 1972–80 growth rate.

terns and if productivity changes in individual industries remain at their postwar averages, the rate of productivity growth per manhour should be about 2.1 percent annually, as compared with 2.6 percent annually for the entire 1948–71 period.

# APPENDIX A

# *Supplementary Equations*

## The Decomposition of Aggregate Productivity

THE DECOMPOSITION of aggregate productivity is discussed on pages 519–21. To separate the cases, the basic relations can be employed again. If $A_i$ is cyclically corrected output per manhour in industry $i$ and $A_0$ is the aggregate, then (suppressing time subscripts),

$$A_0 = X_0/E_0 = \sum\left(\frac{X_i}{E_i}\right)\left(\frac{E_i}{E_0}\right) = \sum A_i S_i,$$

where $X$ = gross national product, $E$ = manhours, and $S_i = E_i/E_0$ is the $i$th industry's share of total manhours. Taking time derivatives (denoted by dots above variables),

$$\dot{A}_0 = \sum \dot{A}_i S_i + \sum A_i \dot{S}_i$$

or

$$\frac{\dot{A}_0}{A_0} = \sum \frac{\dot{A}_i}{A_i}\frac{A_i}{A_0} S_i + \sum \frac{A_i}{A_0}\dot{S}_i;$$

or, again letting lowercase letters indicate logarithms,

$$\dot{a}_0 = \sum \dot{a}_i \frac{A_i}{A_0} S_i + \sum \frac{A_i}{A_0}\dot{S}_i. \tag{A-1}$$

It is slightly more convenient to transform the first part of equation (A-1) into output terms. Let $Z_i = X_i/X_0$ be the $i$th industry's share of total output. Equation (A-1) can then be rewritten as

$$\dot{a}_0 = \sum \dot{a}_i Z_i + \sum \frac{A_i}{A_0}\dot{S}_i.$$

Next, break the second term (called here the level term) into three parts:

$$\text{Level term} = \sum \frac{A_i}{A_0}\dot{S}_i = \sum \dot{S}_i\left[\frac{A_i}{A_0} - \left(\frac{A_i}{A_0}\right)^0 + \left(\frac{A_i}{A_0}\right)^0 - 1 + 1\right],$$

where $(A_i/A_0)^0$ is the productivity relative in the base year (1958). Because $\sum \dot{S}_i$ is identically zero, this can be rewritten:

$$\text{Level term} = \sum \dot{S}_i\left[\left(\frac{A_i}{A_0}\right)^0 - 1\right] + \sum \dot{S}_i\left[\left(\frac{A_i}{A_0}\right)^0 - \frac{A_i}{A_0}\right].$$

Finally, let $\hat{a}_i$ be the estimated value for $-\delta_{2i}$ shown in Table 2 and let $Z_i^0$ be the base year (1958) share of $X_i$. The final decomposition of aggregate productivity then is

$$\text{(A-2)} \quad \dot{a}_0 = \underbrace{\sum \hat{a}_i Z_i^0}_{\substack{\text{predicted fixed-}\\ \text{weight rate term}}} + \underbrace{\sum \hat{a}_i[Z_i(t) - Z_i^0]}_{\substack{\text{change in predicted}\\ \text{fixed-weight rate term}}}$$

$$+ \sum \dot{S}_i\Bigg[\underbrace{\left(\frac{A_i}{A_0}\right)^0 - 1}_{\substack{\text{fixed-weight}\\ \text{level term}}}\Bigg] + \sum \dot{S}_i\Bigg[\underbrace{\left(\frac{A_i}{A_0}\right) - \left(\frac{A_i}{A_0}\right)^0}_{\substack{\text{actual-weight}\\ \text{level term}}}\Bigg]$$

$$+ \underbrace{\sum (\dot{a}_i - \hat{a}_i)[Z_i(t) - Z_i^0]}_{\substack{\text{unexplained change in}\\ \text{fixed-weight rate term}}}.$$

The first four terms constitute the decomposition shown in Table 13.

### Projection of Potential Output

The projection of potential output relies on the model outlined in equations (2) to (8). The only extraneous estimates needed are the estimates for hours by industry and for total potential employment.

The following equation establishes hours:

$$h_i = a_{0i} + a_{1i}(x_i - xn_i) + a_{2i}t + \epsilon_i,$$

where $h_i$ = log hours, $x_i$ = log of gross product originating by industry, and $xn_i$ = log of normal output in industry $i$. Since $x_i = xn_i$ for the simulation, hours can be projected independently of output.

For total employment the procedure is a bit more complicated. The noninstitutional population over 16 years old is exogenous. This is taken from projections made by the U.S. Bureau of the Census for 1980 and uses log-linear interpolation (data are from the *Manpower Report of the President, 1972*, pp. 157, 252, and 253).

The next step uses the following participation rate equation:

$$PR_t = \underset{}{0.674} - \underset{(0.122)}{0.352\, U_t} - \underset{(0.132)}{0.413\, U_{t-1}} - \underset{(0.113)}{0.207\, U_{t-2}} + \underset{(0.00176)}{0.000228t},$$

Standard error of the estimate = 0.00514; Durbin-Watson statistic = 1.20; annual data, 1950–71.
The numbers in parentheses are $t$-statistics.

where $PR_t$ is the labor force participation rate (establishment concept), and $U_t$ is the unemployment rate (again, establishment concept).

The normal labor force participation rate, $PR_{norm}$, is the estimated rate when the unemployment rate is at the normal rate. Finally, aggregate normal employment, $E_{norm}$, is then

$$E_{norm} = Pop\ 16 \times PR_{norm} \times (1 - 0.044).$$

The actual and predicted labor force participation rates (in percent) are as follows:

| | *Actual* | *Predicted* |
|---|---|---|
| 1950 | 62.0 | 62.4 |
| 1960 | 62.5 | 62.3 |
| 1970 | 64.6 | 64.1 |
| 1980 | . . . | 63.6 |

# APPENDIX B

## *Data Sources*

*Total employment (ET)*: This series is derived from the U.S. Office of Business Economics (OBE) estimates of total workers, published in the national income accounts tables in July issues of the *Survey of Current Business* (referred to as NIA tables below). For each industry except agriculture, total employment equals the total number of part-time and full-time employees as well as the self-employed. No adjustment is made for hours of work. Total employment for each industry is derived as follows: *ET* equals "persons engaged in production" (NIA Table 6.6) plus "full time and part time employees" (NIA Table 6.3) minus "full time equivalent employees" (NIA Table 6.4).

The only modification is that for agriculture the labor force survey estimate of unpaid family workers is added to the employment estimate, adding approximately 15 percent to the estimate for total agricultural employment. For the nonfarm sector, the number of unpaid family workers was both small (0.7 percent of total nonagricultural employment) and almost constant; therefore nonfarm unpaid family workers were omitted.

There are some serious conceptual differences between the OBE establishment series and the U.S. Bureau of Labor Statistics (BLS) household concept of employment estimates.[1] The OBE series is the only acceptable one for this study for two reasons: First, some care is taken to match the employment data with the output concept; and, second, data referring to total number of employees and hours (rather than number of workers over 16 years) is appropriate for productivity estimates.

*Production or nonsupervisory workers.* The concept of production workers is of some importance for the discussion of productivity. The *BLS Handbook of Methods* gives the following definitions of production or nonsupervisory workers:

1. See the discussion in Gloria P. Green, "Comparing Employment Estimates from Household and Payroll Surveys," *Monthly Labor Review*, Vol. 92 (December 1969), pp. 9–14.

In manufacturing . . ., production workers [are] those employees, up through the level of working foremen, who are engaged directly in the manufacture of the product of the establishment. . . . [This excludes] persons in executive and managerial positions, and persons engaged in activities such as accounting, sales, advertising, routine office work, professional and technical functions, and force account construction. Production workers in mining are defined in a similar manner. . . .

In the transportation, communication, and public utility industries, in retail and wholesale trade, in finance, insurance, and real estate, and in most of the service industries . . . nonsupervisory workers include most employees except those in top executive and managerial positions.

In contract construction, the term construction workers covers workers, up through the level of working foremen, who are engaged directly on the construction project. . . .[2]

It is clear from this description that the definition of overhead workers is not consistent across sectors; in particular, the definitions for mining and manufacturing are much more restrictive than those for the other sectors.

*Hours per worker* ($H$): While the employment data are quite satisfactory, the hours data are more troublesome. Again, the primary reliance has been on establishment data. For six industries (mining, construction, durable and nondurable manufacturing, trade, and FIRE[3]), there are continuous time series for average weekly hours of production or nonsupervisory workers. I have followed other analysts in assuming that the hours of nonproduction workers parallel those of production workers.[4]

Nonproduction workers accounted for a fraction of all workers that ranged from 8 percent in trade to 17 percent in nondurable manufacturing and FIRE in 1947, and from 11 percent in trade to 28 percent in durable manufacturing in 1971. Hence, the omission of hours of nonproduction workers is unlikely to be a serious problem. Nonetheless, the upward trend in the fraction of nonproduction workers may lead to some structural changes, and the available evidence indicates that in the last decade the workweek for nonproduction workers has not experienced the decline noted in the average workweek (see Bureau of Labor Statistics, *Handbook of Labor Statistics, 1971*, Table 76).

2. U.S. Bureau of Labor Statistics, *BLS Handbook of Methods for Surveys and Studies*, Bulletin 1711 (1971), p. 19.

3. FIRE is composed of the finance, insurance, and real estate industries.

4. *Ibid.*, p. 215. The exception is manufacturing, for which a series for hours of nonproduction workers has been patched together. Given the fragmentary nature of the evidence on nonproduction workers, however, I have used only the series for production workers.

For five industries—transportation, communication, public utilities, services, and government—the published data are available only since 1964. For services and government for years prior to 1964, I have used the series constructed by Kendrick.[5] Values for omitted years were linearly interpolated, and spliced to the published series at 1964. For transportation, communication, and public utilities, I relied on the crude technique of using a fixed-weight index of hours for the industrial sector (mining and manufacturing) as a substitute up to 1964. Although this probably is not a good estimate for these industries, they are sufficiently small so that the aggregate prediction is little affected. For agriculture I have used the implicit estimates for the BLS productivity studies (*Handbook of Labor Statistics, 1971*, Table 82). This series is conceptually defective, since it is on a labor force rather than an establishment basis.

*Manhours* ($E$): Manhours are the product of total employment and hours per worker, each measured at a weekly rate.

*Gross product* ($X$): Gross product by industry is from NIA Table 1.21, with historical data from the *Survey of Current Business*, Vol. 47 (April 1967). Aggregate gross national product (GNP) equals the sum of the industry totals plus the discrepancy.

*Deflators for gross product* ($P$): Same sources as $X$.

A few words are in order about the output and price series. (The basic discussion is contained in U.S. Office of Business Economics, "GNP by Major Industries: Concepts and Methods," April 1966; processed; also see John W. Kendrick, ed., *The Industrial Composition of Income and Product*, Studies in Income and Wealth, Vol. 32, Columbia University Press for the National Bureau of Economic Research, 1968.) The gross product series is an attempt to develop complete measures of industrial origin of GNP. The series starts on the income side of the account, with real output derived by deflation. The ideal technique of deflation is the method known as "double deflation," or deflation of both gross outputs and inputs, but in fact double deflation is used only for farms, manufacturing, gas and electric utilities, and railroads. In the other cases, the deflator was for gross output.

In principle, the deflation procedure in the industrial account is at least partially independent of the deflation in the product account. It is slightly encouraging, therefore, to see that the published statistical discrepancy is not too large.

5. John W. Kendrick, "Postwar Productivity Trends in the United States, 1948–1969" (April 1971; processed), Table A-9.

*Total unemployment rate, establishment basis* ($U$): The unemployment rate in the present study uses a slightly different definition from the conventional labor force definition. The *establishment* labor force is defined as total employment plus the estimated number of unemployed from the labor force survey. This concept is used mainly for convenience in projection, but also because it includes the armed forces.

*Normal unemployment rate* ($U_{norm}$): The normal unemployment rate is simply the average of the establishment concept of the unemployment rate, 4.4 percent, which corresponds to about 4.7 percent on the conventional unemployment measure.

*Normal GNP* ($XN$): The following output equation is used to generate normal output:

$$\log(GNP) = $$
$$\underset{}{6.1565} + \underset{(0.00042)}{0.03676t} - \underset{(0.302)}{2.930}(U_t - U_{norm}) + \underset{(0.306)}{0.1645}(U_{t-1} - U_{norm}).$$

Standard error of estimate = 0.0141; Durbin-Watson statistic = 1.19; annual data, 1948–71.
The numbers in parentheses are standard errors.

The unemployment rate is the establishment concept discussed above. Normal output simply corrects GNP by the estimated cyclical effects:

$$\log(XN) = \log(GNP) + 2.930(U_t - U_{norm}) - 0.1645(U_{t-1} - U_{norm}).$$

According to this concept, output was 3.3 percent below normal in 1971.

*Capacity utilization* ($X_i/XN_i$): The approach employed here to measure the pressure of demand in given industries uses the "normal output" concept.[6]

*Wage-weighted employment.* The test of importance of demographic factors was seriously hampered by insufficient data. The basic data for this test were the fractions of female employees in an industry. Data sources for these series were as follows:

For agriculture, services, and the aggregate, *Manpower Report of the President, 1971,* Tables A-1, A-2, and A-11.

For all other industries, *Handbook of Labor Statistics, 1971,* Tables 38 and 43.

6. For a comparison of this with other approaches, see Frank de Leeuw, "The Concept of Capacity," *Journal of the American Statistical Association,* Vol. 57 (December 1962), pp. 826–40, and *Measures of Productive Capacity,* Hearings before the Subcommittee on Economic Statistics of the Joint Economic Committee, 87 Cong. 2 sess. (1962).

The test of the hypothesis proceeds as follows: It is assumed that workers of industry $i$ have productivity per person-hour of $A_i$. It is further assumed that productivities are in proportion to gross hourly earnings.

The actual change is to use "male-equivalent" employment, $ET^*$, where this is defined as $ET^* = ET_{male} + 0.56\ ET_{female}$. The weight of 0.56 assigned to female employment is that for total money earnings for year-round full-time workers for 1969, from U.S. Bureau of the Census, *Current Population Reports*, "Income in 1969 of Families and Persons in the United States," Series P-60, No. 75 (1970), Table 52.

*Capital* ($K$): The concept of capital uses the net capital stock from U.S. Office of Business Economics, "Fixed Nonresidential Business Capital in the United States, 1925–1970" (November 1971; processed; reproduced by National Technical Information Service). The exact concept is net stocks of privately owned equipment and structures, in 1958 dollars, using straight-line depreciation, with 85 percent of the service lives given by the U.S. Treasury Department's *Bulletin "F"* (revised, 1942), constant cost 1 version, as described in *Fixed Nonresidential Capital.*

# *Comments and Discussion*

**Barry Bosworth:** The notion that output mix is an important determinant of aggregate productivity growth is certainly not novel, but the conclusion of this paper that a large and accelerating shift has occurred toward industries with low productivity levels is striking. Nordhaus develops some convincing evidence that, because of these shifts, the overall trend rate of productivity growth in the U.S. economy may be slowing. It is also interesting that the dominant effect is the shift between industries with high and low levels of productivity rather than between industries with high and low rates of productivity growth.

A related issue is the effort made to explain why productivity slowed down so drastically in 1969 and 1970 and to determine whether that was some abnormality or a normal cyclical occurrence. On the surface, this study seems to be quite successful in explaining those years, since the errors of Nordhaus' disaggregated model were not larger than they had been in some previous periods. But this conclusion is in part the result of very large standard errors even in the basic disaggregated equations. An error of 1 percent in predicting productivity is a serious mistake; it corresponds to an error of approximately 1 percentage point on the unemployment rate.

A few aspects of the methodology in this paper trouble me. The procedure used for the cyclical correction seems unnecessarily crude in view of the existing empirical literature on labor demand functions. Several statistical biases arise through the use of the unemployment rate to adjust actual output, and thereby estimate normal output, in an equation explaining a basic determinant of the unemployment rate. For example, in a year like 1969, when the growth in productivity was lower than anticipated, the unemployment rate was by definition lower than anticipated. The cyclical correction using that unemployment rate then understates normal output and hence the output gap. The result is a prediction that productivity growth will not be much depressed, which conflicts with the low rate of growth that is observed. In a formal sense, the error term in these equations is strongly and directly correlated with an independent variable. As a result, the equations are likely to underestimate the cyclical effects on productivity. In my judgment, the errors in the relationship between actual output and unemployment should not have been included in the definition of normal aggregate output (much as Nordhaus omitted them in estimating the normal output of individual industries). Apparently, Nordhaus included the residuals to reflect variations in factors such as labor force growth, but these could have been treated directly in the equation.

If the primary interest is on the trend term, the problem of estimating the cyclical component of productivity may be of small moment. But a poor cyclical estimate may impede the attempt to identify the influence of other factors, such as capital stock and the demographic mix of the labor force; and it can seriously cloud analysis of the sharp falloff in productivity growth in 1969 and 1970. It is difficult to reconcile the results for the recent period with those of other investigators—Eckstein and Wilson, Fair, and the Wharton and Fed-MIT-Penn models. For example, the labor demand equations of the last two models substantially underestimate employment and thus overestimate productivity in 1969 and 1970.

I doubt the wisdom of applying the statistical model to agriculture and government. Productivity growth in government is zero by definition: Output is measured by labor input. In fact, because of some mix effect from a change in the distribution among different types of government employment, the measured growth in government productivity is not precisely zero; but as Nordhaus' results show, it is neither sizable nor meaningful. I prefer to focus on the behavior of productivity in the private nonfarm sector. The overall shift effects reported in this paper are far less important in private nonfarm productivity than in GNP productivity. I find the slowdown in the growth of private nonfarm productivity in 1969 and 1970 puzzling; those years dominated the results of the period from 1965 to 1970. Nordhaus' own results suggest something abnormal in those two years: Most of the ten private nonfarm industries have positive residuals in his Table 5, indicating that actual productivity was lower than predicted. When aggregated, these residuals do not produce a sizable overestimate of productivity because a substantial and heavily weighted negative residual for services helps to balance out the calculation. But the determination of productivity in the service sector is extremely hazardous.

In general, severe weaknesses inherent in industry data on output and manhours urge caution in viewing Nordhaus' results. I am not comfortable with the explanation in this paper that finance, insurance, and real estate account for an important and prolonged slowdown in private nonfarm productivity, and yet that tricky sector is the key to the verdict when agriculture and government are excluded.

**Robert Solow:** The main result of Nordhaus' paper is that the recent slowdown in the rate of change of productivity is primarily a consequence of changes in the composition of output toward industries with low levels of productivity. Relatively speaking, a deceleration of the shift from agriculture to the rest of the economy has the same effect as a shift toward industries with low levels of productivity. The increase in aggregate productivity that has been the result of the shift out of agriculture must diminish because so little agricultural employment remains to move out.

The second point in the paper is that the shift to sectors of low productivity is likely to continue until 1980, so that productivity growth may slow a bit more. Hence, potential output will not grow as fast over the next ten years as it did during the past ten, or even during the past five.

One important feature of the findings is that little or no permanent productivity gain is to be had from a higher utilization rate, and hence no significant productivity windfall is to be picked up in the current recovery. The main question that I want to discuss is how to connect Nordhaus' results with George Perry's contrasting prediction of a high rate of growth of potential output over the next decade. In addition to cyclical and unexplained factors, Perry attributes the recent slowdown in productivity to shifts in the demographic composition of employment toward women and the young, who themselves have low levels of productivity—at least as measured by wage rates. Perry expects a stop in that kind of shift in the demographic composition of the labor force and, along with it, in the lower rate of growth of productivity. So he concludes that a higher rate of productivity increase will resume.

These two stories are obviously incompatible in the sense that one predicts a deceleration of potential output and the other does not. The connection between the two is that the industries with low productivity, such as services and government, are precisely those industries that employ most of the women when the share of women in total employment increases. Perry implies that when the demographic composition of employment stabilizes, the shift to low-productivity employment will stop. In contrast with Perry's demographic view of the world, Nordhaus stresses the shift in industrial composition. He sees service and government jobs as low-productivity jobs, quite apart from the demographic peculiarity that women get absorbed into them. So long as the industrial shift continues, so will the slowdown. Nordhaus implies that even if adult men move into services and government they will have low-productivity jobs, while Perry presumes that as adult men move into these industries, they will bring with them the higher productivity that goes along with their age-sex characteristics. In part, the outcome depends on techniques of measurement. If, in fact, more high-wage adult men take jobs in the government and service industries, will that show up as an increase in productivity or will it merely be deflated out as a more rapid wage increase?

Perhaps the relationship between levels of productivity among industries and their age-sex employment mix explains Nordhaus' failure to confirm the role of changing demography at the industry level. Or perhaps the data are so deficient that nothing can be proved in the time series within industries.

On a more technical issue, I am puzzled by Nordhaus' estimates of the relationship between productivity and utilization. In the aggregate productivity equation described in Table 1, the sum of the two regression coefficients (current and lagged) on the logarithm of the utilization rate for GNP add up to slightly more than one. If the sum of those coefficients were exactly one, then productivity would be independent of the unemployment rate in the long run. Moreover, we reach that long run after only a one-year temporary catchup. If the unemployment rate falls from one constant level to another, productivity would get an extra push for one year, but then it would come back to its previous path. If the point estimate of 1.06 were taken seriously (which it should not be in terms of the standard errors), a decline in the unemployment rate below "normal" would be expected to reduce productivity a bit in the long run. Other researchers have generally found a permanent—or at least much more enduring—addition to productivity from lower unemployment. Nordhaus himself gets that result for most of the individual industries that show cyclical productivity coefficients of less than unity in Table 2. These results imply a permanent one-time gain in productivity in response to an increase in the utilization rate.

Finally, I am just a bit uncomfortable that the paper does not describe the projected movement of relative prices among industries during the coming decade. The projections of output and employment shares among industries depend on wage behavior exogenous to the model and the resulting price behavior. It would be a help if one could evaluate the plausibility of those projections and the sensitivity of the aggregate productivity prediction to them.

**Beatrice N. Vaccara:** I found the paper interesting because it attempts to do many of the same things that we are now pursuing in the Bureau of Economic Analysis in attempts to measure the effects of industrial shifts on the aggregate level of productivity growth. We are using sixty-five industries, and would like to disaggregate even further if such detail were available. Our work makes me skeptical of the meaning of industrial shifts observed when the economy is split into only twelve sectors. We find more differences between component industries in nondurable manufacturing than among many of the twelve sectors Nordhaus studies. Because we disaggregate more finely and because our methods are entirely different, it is very difficult to track down the reasons for the differences between our conclusions and those of this paper.

Our findings would confirm Nordhaus' view that the rate of productivity growth slowed markedly in 1965–71 as compared with 1948–55. But we believe the slowdown can be seen in most of the individual industries, not just in the mix. In fact, in some cases the aggregate for the sectors tends to disguise the slowdown. The aggregate of nondurable manufacturing, for example, shows very little slowdown, but that is primarily due to shifts of the mix within the sector. Among the individual nondurable manufacturing industries, only 20 percent of the output in 1970 was accounted for by industries that did not experience a slowdown. Our averages and profiles for each of the broader sectors are similar to Nordhaus' except for services, where we get a quite different result: We do not find a recent speedup in productivity there.

Our results have not been corrected for cyclical influences because, in our judgment, we have not developed a satisfactory procedure to do so. We have calculated what productivity growth would have been if the employment mix had been held constant for the sixty-five industries. We find that the change in the mix accounts for about 45 percent of the slowdown in productivity growth for the economy as a whole, and about 35 percent of the slowdown in the private economy. The difference between 45 and 35 percent reveals that the shift to government is an important element of the change in the mix. Our studies suggest that, compared with constancy of employment shares, it is primarily shifts in the mix toward industries with slower *rates* of productivity growth that retard aggregate productivity rather than shifts toward industries with lower *levels*. This is the reverse of Nordhaus' finding that level effects predominate, but the difference may reflect, in part, his focus on mix shifts relative to constant output (rather than employment) shares.

I want to discuss what Nordhaus calls the graveyard—the FIRE sector of the economy (finance, insurance, real estate). The current-dollar estimate of product originating in the FIRE area is not unusual or particularly poor. The deflator for that area is essentially a residual, a fact that impairs the measurement of real product. But the error resulting from the residual procedure is probably no more than one-half of one percent, and it should not trend upward or downward over time; therefore, it cannot significantly alter the estimated rate of growth of output or productivity. Nor does imputed rent account for a slowdown. Even when FIRE excludes imputed rent, a marked slowdown remains in the rate of productivity growth—indeed, an actual decline in productivity appears: In the period 1948–55 the rate of productivity growth for FIRE excluding imputed rent was $-0.10$; for the period 1965–71 it was $-1.52$.

Nordhaus also suspects that the productivity slowdown observed in construction may stem from defects in the deflator. If anything, the defects of deflation disguise the slowdown. The method of pricing residential construction was changed in 1964, and since then construction output is probably understated to a lesser extent than previously.

## General Discussion

Saul Hymans commented on the difficulty of estimating the influence of capital on labor productivity. Nordhaus found a negative sign on the capital variable, which implies—totally unreasonably—that increases in capital reduce productivity. Hymans suggested that, in line with the experience with the Michigan model, lagging investment might remove the paradox. In that model, it takes almost a year for new capital to start benefiting labor productivity; for a couple of quarters it tends to reduce productivity, perhaps because of a learning phenomenon or set-up and installation costs.

Hymans also felt that Nordhaus' test of the Perry demographic variable was a bit unfair statistically. If Perry is correct, weighted employment should be the dependent variable in the relationship of employment to output. Testing its role as an independent variable can produce biased estimates because, if Perry is right, weighted employment is necessarily correlated with the error term.

William Fellner explored further the connection between industrial composition and the demography of employment. If the supply of relatively low-wage workers stops increasing in relation to that of higher-wage workers, will the shift of employment toward lower-wage industries continue? Will the wage rates of women and teenagers rise relative to those of men as a result of shifts in relative labor supplies? If so, will there be a corresponding change in relative productivities so that any rise in the wage rates of women and teenagers will be matched by increased productivity? Fellner suggested that one set of answers to these questions would justify the Perry projection of high productivity growth and another would point to the Nordhaus verdict of a slowdown. In this connection, Perry reported that Edward Denison had not found much variation in the relative wages of various demographic groups over long periods of time, despite significant variations in relative supply.

A number of participants raised questions about the small (and, in the aggregate case, transitory) cyclical impact on productivity that Nordhaus found. In response, Nordhaus agreed that he believed his equations tended to understate the amount of cyclical correction and the duration of the cyclical effect in the aggregate. On the other hand, Nordhaus emphasized, his cyclical productivity relationship still left room for a very substantial Okun's law coefficient, since labor force participation and the length of the workweek could be strongly responsive to changes in unemployment. Moreover, Nordhaus defended his procedure as a lesser evil than the alternative assumption that normal output grew uniformly at an exponential rate. Such an assumption would produce biases in the other direction by attributing to cyclical fluctuations output changes that resulted from variations in the growth of the labor force or in the trend of productivity itself.

R. A. Gordon was troubled by the discussion of cyclical effects. He pointed out that the 1961–69 expansion was so much longer than previous postwar cycles that cyclical relationships had to be basically different. R. J. Gordon felt that the impact on productivity of changing utilization rates is not really a cyclical phenomenon but a rate-of-growth phenomenon; productivity grows fastest early in an expansion when output grows rapidly. Lawrence Klein suggested that the treatment of the government sector could and should be refined by the profession so that it could discard the unrealistic assumption of zero productivity growth. In those areas where specific outputs can be defined and government productivity can be measured, there is evidence that government is not a sector of low productivity growth. Klein added that the compulsory draft into the armed services during the 1965–71 period could have dragged down productivity figures as they are now constructed. In fact, many fairly productive people were put into the army at the low wages of a draftee and these wages were taken as a measure of their productivity. The introduction of a volunteer army should correct some of this distortion in the data.

Arthur Okun noted the more optimistic view held by Edward Denison and other observers that the recent productivity slowdown may be—at least for nonfarm business—entirely an unusually pronounced cyclical reaction with little long-term significance. The productivity optimists believe that labor demand in recent years may have been bolstered by the longevity of the previous expansion that R. A. Gordon had mentioned, particularly by employers' prolonged experience with tight labor markets in the middle and late 1960s. The optimists see the productivity slowdown primarily as a 1969–70 phenomenon rather than one starting in 1965. Joseph Pechman wondered whether the 1972 rebound in productivity might support the productivity optimists. Nordhaus reported that the 1972 performance could not be appraised yet in terms of his disaggregated model, but his aggregate model showed no unusual rebound for the first half of the year.

Franco Modigliani explored the welfare implications of the productivity slowdown that Nordhaus foresaw. He argued that differences in productivity among industries had to result from basic differences in the factors employed in those industries: differential abilities in the work force, differential amounts of investment in physical or in human capital, or different degrees of monopoly power. If shifts in the pattern of demand pushed output and employment in the direction of industries that have lower productivity levels because they require either less physical capital or less human capital, the result would be recorded as a slowdown in productivity growth, but it would not necessarily mean that society would be worse off. Offsetting the slower growth in output per manhour would be a reduced requirement for investment. So far as Modigliani could see, the only types of slowdown in productivity due to shifts in the mix that really meant the nation would be worse off would be those that resulted because the workers had less ability or because they had less opportunity to use their ability.