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The Productivity Paradox: Evidence from Indirect Indicators of Service Sector Productivity Growth

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1. Introduction

Difficulties in measuring the output of service sectors have been well documented in many studies. This has lead to corresponding difficulties in creating a reliable index of productivity in service industries. On the other hand, input measures are quite adequate in service sectors, as in other industries within the economy. Labor, capital, and material inputs are easily identifiable and measurable in services, and are, in principle, no different than in other industries. The basic problem, then, is how to measure productivity in an industry in which output is difficult to measure but inputs are easily measured.

Most recent attempts to obtain a better measure of productivity in service industries have aimed at improving the output measures. For example, in the banking industry, the number of checks processed or cleared per hour has been proposed as an output indicator; for the airline industry, passenger-miles; for legal services, the number of wills prepared or the number of real estate closings per year; and for the health industry, the number of procedures performed per year (see, for example, Bresnehan, Milgrom, and Paul, 1992; Dean and Kunze, 1992; Fixler and Zieschang, 1992; Gordon, 1992; and Murray, 1992). In almost all cases, the use of these direct indices of service output results in higher measured productivity growth than those based on conventional national accounting data.

There are problems in these approaches due to the fact that most services produce a composite output. Such approaches usually capture only one or several aspects of the output and often the least important parts of the industry's activity. In the banking industry, for example, the most important activity in terms of revenue and manpower is the loan department and for this it is very difficult to arrive at a suitable index -- number of loan applications received, number of loans approved, dollar amount of loans approved, the interest rate charged and other fees generated, the default rate, and so on? In law firms, the chief revenue source are the complex legal cases taken on and the most suitable measure is, perhaps, hours billed -- a value added measure.

An alternative approach used in this study is to consider several indirect indicators of productivity growth in the service sector by examining changes in the input mix. The trick is to avoid using service output measures or price deflators in designing such indices. It should be noted at the outset that the indirect measures relate to the *growth rate* of productivity rather than to its level. Moreover, the indices developed provide circumstantial evidence rather than direct evidence on productivity movements.

Two approaches are used here. The first is based on changes in direct input-output coefficients. I utilize changes in the inter-industry coefficients and the capital-labor and materials-labor ratios as indices of productivity growth. Technological progress (total factor productivity or TFP growth) in goods-producing industries has historically been associated with not only a rising level of output per unit of input but also with a change in input proportions -- in particular, an increasing capital-labor and materials-labor ratio. Goods-producing sectors with low productivity growth, on the other hand, have typically been characterized by a relatively stable ratio of capital to labor as well as materials used per labor hour.

The second approach considers changes in the occupational composition of employment within service sectors. The justification is similar. In sectors with rapidly changing technology, we would expect to find substantial changes in the occupational make-up of the industry. Conversely, in sectors with stagnant technology, we would expect little change in employment composition.

A number of indices of occupational change are used here: (i) the change in the overall occupational composition of employment within an industry; (ii) the ratio of scientific and technical manpower to total industry employment; (iii) the proportion of knowledge workers in total employment; (iv) the proportion of professionals and technical labor in total employment; and (v) the proportion of managerial and administrative labor in total employment. A related indicator is changes in the average cognitive skill level of the workforce in an industry. Skill levels can be measured by the average level of educational attainment or Dictionary of Occupational Title (DOT) direct skill measures.

For the analysis of coefficient changes, I rely on U.S. input-output data for years 1958, 1967, 1977, and 1987. The analysis of changes in occupational composition will be based on data from the U.S. decennial Census of Population for 1960, 1970, 1980, and 1990.

The remainder of the paper is organized as follows. The next section (Section 2) develops the accounting framework. Section 3 describes the data sources and methods. Section 4 presents descriptive statistics and Section 5 the regression results. Concluding remarks are made in the last section.

2. Accounting Framework

Define:[1]

U = an input or "use" commodity-by-industry flow matrix, where u_{ij} shows the total amount of commodity i consumed by industry j.

V = an output or "make" industry-by-commodity flow matrix, where v_{ij} shows the total output of commodity j produced by industry i.[2]

$x = V^T\mathbf{1}$ = (column) vector, showing the gross output of each commodity,

where a superscript T refers to the transpose of the indicated matrix, and

$\mathbf{1}$ = vector with unit entries.

Also, let:

$y = (V^T - U)\mathbf{1}$ = (column) vector of final demand by commodity.

e = (row) vector, showing total employment by industry.

k = (row) vector, showing total capital stock by industry.

To derive the corresponding technical coefficients, I will make use of the commodity technology model, where it is assumed that each commodity is produced by the same technology, irrespective of the industry of production. In this case, industries are considered independent combinations of outputs j, each with their separate input coefficients (a_{ij}). As shown in ten Raa et. al. (1984), the commodity technology requirements (coefficient) matrix is given by:

$A = U[V^T]^{-1}$ = matrix of interindustry technical coefficients,

where V is restricted to a square matrix (that is, there are as many industries as commodities).[3] Row vectors of labor and capital stock coefficients can be derived in analogous fashion:

$\ell = e[V^T]^{-1}$ = (row) vector of labor coefficients

and

$\kappa = k[V^T]^{-1}$ = (row) vector of capital coefficients.

In addition, let us define

n = total employment (a scalar) in the economy.

c = total capital stock (a scalar) in the economy.

w = the annual wage rate (a scalar), assumed constant across industries.

r = the rate of profit on the capital stock (a scalar), also assumed constant across industries.[4]

p = (row) vector of commodity prices, given by the Leontief equation:

$p = (w \ell + r \kappa)(I - A)^{-1}$

In the I-O framework, sectoral output is measured by gross commodity output x (alternately called gross domestic output or GDO), while the inputs consist of employment, fixed capital, and materials (intermediate inputs). The rate of TFP (total factor productivity) growth for sector j is defined as:

(1) $$\pi_j \equiv -(\sum_i p_i da_{ij} + wd\,\ell_j + rd\,\kappa_j)/p_j$$

where π is the corresponding row vector and "d" refers to the differential. This measure is a continuous version of a measure of sectoral technical change proposed by Leontief (1953). Since for any variable z, dz = z·d log z, where log is the natural logarithm, sectoral TFP growth is also given by

(2) $$\pi_j = -\sum_i \alpha_{ij}(d \log a_{ij}) - \alpha_{Lj}(d \log \ell_j) - \alpha_{Kj}(d \log \kappa_j)$$

where $\alpha_{ij} = p_i a_{ij}/p_j$, $\alpha_{Lj} = w\,\ell_j/p_j$, and $\alpha_{Kj} = r\,\kappa_j/p_j$. These three terms give the current value shares of the respective inputs in the total value of output. Since productivity growth rates are measured over discrete time periods rather than instantaneously, the average value share of α_{ij}, α_{Lj}, and α_{Kj} over the sample period is used to measure π (the so-called Tornqvist-Divisia index).[5]

Let us also define aggregate TFP growth, ρ, as

(3) $$\rho \equiv [pdy - wdn - rdc]/py.$$

This measure is directly analogous to equation (1), the index of sectoral TFP, except that intermediate inputs are netted out. Indeed, with further manipulation, ρ can be rewritten in the more usual form as the growth in output less the growth of labor and capital, each weighted by their respective value shares:

(4) $\rho \equiv \sum_i ß_i(d \log y_i) - \alpha_L(d \log n) - \alpha_K(d \log c)$,

where α_L = wn/py, the wage share in total income; α_K = rc/py, the capital share in total income; and $ß_j = p_j y_j/py$, showing the share of final output j in the total value of final output.

3. Data Sources and Methods

Our basic data source consists of U.S. input-output dollar flow tables, which were originally obtained from the Bureau of Economic Analysis on the 87-sector level for years 1958 and 1967 in single-table format, and on the 85-sector level for years 1967, 1977, and 1987 in the dual use-make table format. The single-table format relies on the so-called BEA transfer method. In this method, the transaction matrix is constructed on an industry by industry basis. A secondary product produced by industry i which is primary to industry j is recorded as a purchase made by industry j from industry i. The actual sales of the secondary product produced in i are then "transferred" to the sales row of industry j.[6] The 1967, 1977, and 1987 data are available in separate make and use tables.[7] There were several adjustments required to make the four tables compatible, which are described in detail in Wolff (1997).[8]

All matrices are deflated to 1972 dollars using sectoral price deflators. Productivity growth rates for 1958-67 are calculated using the single-table basic framework (and making use of the 1967 single table data). Productivity growth rates for 1967-77 and 1977-87 are calculated using the use-make framework (and relying on the 1967 dual table data). Because of alignment difficulties between the various input-output years (several industries are collapsed in the 1987 table, in particular), productivity growth estimates are available for only 68 industries.

The 85 industries are divided into two groups, goods and services. The goods industries include: agriculture (1-4)[9], mining (5-10), construction (11-12), manufacturing (13-64), transportation (65), communications (66-67), and utilities (68). Services include: trade (69), finance, insurance, and real estate (70-71), government services (78, 79, and 82), and all other services (72-77 and 84). It should be stressed that I include communications, transportation, and utilities in the goods sector because for the purposes here they have relatively easily measured output and are more like the other goods industries than services from this standpoint.

Employment data for 267 occupations and 64 industries are obtained from the decennial Census of Population for years 1960, 1970, 1980, and 1990. Since occupation and industry classifications have changed substantially with each census, I used Commerce Department compatibility tables for 1960-70 and 1970-80 to produced consistent matrices for the four years. Fortunately, there were only very minor changes in classification between 1980 and 1990 (see Wolff, 1996a, for more details on the construction of these matrices).

The measure of cognitive skill is based on the fourth (1977) edition of the DOT. For some 12,000 job titles, it provides a variety of alternative measures of job-skill requirements based upon data collected between 1966 and 1974.[10] I use the index of cognitive skill Substantive Complexity (SC), which is a composite measure of skills derived from a factor analytic test of DOT variables by Roos and Treiman (Miller et. al., 1980: Appendix F). The results provided strong support for the existence of such a factor: it was highly correlated with General Educational Development, Specific Vocational Preparation (training time requirements), Data (synthesizing, coordinating, analyzing), and three worker aptitudes - Intelligence (general learning and reasoning ability), Verbal and Numerical. This measure is developed for each of the 267 occupations (see, Wolff, 1996a, for more details).

Another measure of cognitive skills, which is derived from the 1970 Census of Population data, is Median Years of Schooling-1970 (EDUC-1970). Median years of schooling is computed for each occupation in 1970 on the basis of actual schooling attainment reported by respondents in the 1970 Census of Population. If the actual skill requirements of each occupation remain constant over time, then EDUC-1970 serves as an indicator of the changes in the educational requirements of the workplace.

Average industry skill scores are computed as a weighted average of the skill scores of each occupation, with the occupational employment mix of the industry as weights. Computations are performed for 1960, 1970, 1980, and 1990 on the basis of the occupation by industry employment matrices.

Another dimension of occupational skills is based on the number of "knowledge producers" in an industry. The basic data are again from the U.S. Decennial Censuses of 1960, 1970 1980, and 1990. In the classification schema, professional and technical workers have generally been classified as knowledge workers, depending on whether they are producers or users of knowledge. The line is somewhat arbitrary at points, and judgment calls have been made. Management personnel have been taken to perform both data and knowledge tasks, since they produce new information for administrative decisions and also use and transmit this information (see, Wolff, 1996b, for more details).

4. Descriptive Statistics

A. Time Patterns of Productivity Growth

Before presenting the regression analysis, it is helpful to see what the conventionally measured productivity growth figures are for the various sectors of the economy. As shown in Panel 1 of Table 1, the annual rate of labor productivity growth for the entire economy fell from 1.8 percent per year in 1958-67 to 0.9 percent per year in 1967-77 and then to 0.7 percent per year in 1977-87.

In the goods industries, there was generally a slowdown in labor productivity growth between the 1958-67 and 1967-77 periods and then a modest recovery in the 1977-87 period. This was true for agriculture, mining, construction, durable manufacturing, transportation, and communications. The two exceptions are nondurable manufacturing, whose productivity growth rate increased from 2.9 to 3.4 percent per year between the first two periods and then declined to 2.7 percent in the third; and utilities, where productivity growth remained very high, at over 5 percent per year, in the first two periods and then fell to virtually zero in the third. Altogether, average annual labor productivity growth in the goods-producing industries (including communications, transportation, and utilities), was strong in the 1958-67 period, averaging 2.5 percent per year, declined to 1.7 percent per year in the 1967-77 period, and then recovered slightly to 1.9 percent per year in the 1977-87 period.

The pattern is very different for the service industries. Labor productivity in wholesale and retail trade grew strongly, by 2.0 percent per year, in the 1958-67 period, actually turned negative in the 1967-77 period, and then increased at a respectable pace in 1977-87, at 1.5 percent per year. In both finance, insurance, and real estate (FIRE, for short) and in general services, labor productivity growth fell off between 1958-67 and 1967-77 and the fell off even more sharply and turned negative in the 1977-87 period. For the government sector, labor productivity remained virtually constant between 1958 and 1987. Overall, labor productivity growth in services fell from 1.2 percent per year in 1958-67 to 0.46 percent per year in 1967-77 and then fell again, to 0.35 percent per year in 1977-87. As a result, the gap in annual labor productivity growth between the goods sectors and the service sectors widened, from 1.25 percentage points in 1958-67 to 1.50 percentage points in 1977-87.

Panel 2 shows the corresponding results for TFP growth,. TFP growth for the total economy was very strong in the 1958-67 period, averaging 1.5 percent per year, and then fell sharply to 0.3 percent per year in 1967-77 and, unlike labor productivity growth, showed no recovery in the 1977-87 period. In the goods sector as a whole, TFP growth averaged 2.1 percent per year in 1958-67, fell sharply to 0.6 percent per year in 1967-77, and then rebounded to 1.0 percent per year in 1977-87. In contrast, in services, TFP growth fell from an average annual rate of 0.9 percent in 1958-67 to 0.16 percent in 1967-77 and 0.19 percent in the 1977-87 period.

Time patterns of results on TFP growth for the individual goods-producing sectors are, in general, quite similar to the overall pattern for this group. All goods sectors show a fall-off in TFP growth between the 1958-67 and 1967-77 periods and all except mining, nondurable manufacturing, communications, and utilities show a recovery in the 1977-87 period. All four service sectors show a decline in TFP growth between the 1958-67 and 1967-77 periods, in all cases turning from positive to negative TFP growth, and all with the exception of trade show a further decline in the 1977-87 period.

By both measures, productivity growth appears to be much lower in services than in goods industries. Moreover, the disparity has generally widened over time, from the early 1960s to the 1980s. Indeed, in the 1958-67 period, both labor productivity and TFP growth in the service industries were quite "respectable", averaging in the neighborhood of one percent per annum. However, by the 1977-87 period, productivity growth in services was virtually zero. Many economists have contended that the apparent poor performance of the service industries in the later years is due to increasing problems in the measurement of output in these sectors over time, not due to actual changes in productivity. I now construct some related measures of technological activity to analyze this question.

B. Measures of Technological Activity.

Several measures of technological activity are developed that do not directly rely on sectoral output measures. The first is the growth in the ratio of capital to labor, shown in the top panel of Table 2. If labor productivity growth is, in reality, higher in goods industries than services, part of this might be accounted for by a higher rate of increase in the former's capital-labor ratio. Some support is provided for this argument. Over the entire 1958-87 period, the rate of capital-labor growth was higher in goods industries than services -- 2.4 versus 1.5 percentage points per year. However, capital-labor growth was higher in services than goods industries in the 1958-67 period and the two were close in the 1977-87 period. Moreover, capital-labor growth was higher in trade and in FIRE than in manufacturing.

A similar argument applies to the ratio of total intermediate inputs to labor.[11] Over the entire 1958-87 period, the rate of growth in this ratio was greater in the goods sector than in the service sector, but the difference was not great (2.3 versus 1.8 percent per year). Moreover, this ratio grew much faster in services than the goods-producing sector in the 1977-87 period. Another "anomaly" is that the rate of increase in the ratio of total intermediate inputs to labor over the 1958-87 period was about the same in trade and general services as in manufacturing.

Table 3 shows two indicators of investment activity of the major sectors of the economy. The first of these is investment in office, computing, and accounting equipment (OCA) per FTEE. In the 1977-87 period, the one where purchases of OCA were by far the greatest, FIRE led the way, at $1,068 (in 1987 dollars) per FTEE, followed by mining ($523), utilities ($464), durables manufacturing ($266), and communications ($226). As a whole, the service sector has been investing more intensively in computer equipment than the goods sector, but this was largely due to the very heavy investments made by FIRE. The trade and general service sectors were actually below average in terms of OCA investment per FTEE.

The second indicator is total investment in equipment, machinery, and instruments (including OCA) per FTEE. It should at once be noticed that total equipment investment was more than ten times greater than OCA investment, even in the 1977-87 period, which probably explains why computerization by itself has not had much effect on overall productivity growth. The goods industries invested much more heavily than the service sector in equipment per FTEE -- about double overall. The leading sectors were all goods producers -- utilities, communication, and mining.

Another indicator of the rate of technological activity is the degree to which the interindustry coefficient structure shifts over time. For this, I employ an index of similarity. First define:

$$s^t_j = a^t_{ij} / \sum_i a^t_{ij},$$

which shows the input (in constant dollars) from industry i to industry j as a share of the total sum of interindustry inputs (all in constant dollars) into sector j. Then, the standard similarity index for industry j for two time periods t1 and t2 is given by:

$$(5) \quad SI^{12} = \frac{\sum_i s^{t1}_j \cdot s^{t2}_j}{[\sum_i (s^{t1}_j)^2 \cdot \sum_i (s^{t2}_j)^2]^{1/2}}$$

The index SI is the cosine between the two vectors s^{t1} and s^{t2} and varies from 0 -- the two vectors are orthogonal -- to 1 -- the two vectors are identical.[12] The index of dissimilarity, DI, is defined as:

$$(6) \quad DI^{12} = 1 - SI^{12}$$

where a greater value of the index DI indicates more dissimilarity between the two vectors.

Results for DI are shown in Table 4. The communications sector was by far the most dynamic in terms of shifting its input structure over the period 1958 to 1987 (a DI value of 0.54), and particularly for the period 1977-87. The second most dynamic sector was general services (0.26), followed by durables manufacturing (0.20), utilities (0.18), and transportation (0.15). However, overall, goods industries experienced more change in their interindustry coefficient structure than services, particularly in the 1977-87 period.

In Panel 2, I present measures of the dissimilarity index DI for changes in occupational structure over each decade. There are a number of interesting results worth commenting upon. First, the degree of occupational change was greater in the 1980s (DI equals 0.095) than in the 1960s (0.056) and much greater in these two periods than in the 1970s (0.019). These results confirm anecdotal evidence about the substantial degree of industrial restructuring during the 1980s.

Second, though the degree of occupational change was greater in the goods sector than the service sector, the difference was relatively small (0.199 versus 0.161 over the period 1960-90). The three sectors that experienced the greatest occupational restructuring over the three decades were communications (0.262), utilities (0.231), and general services (0.231). Occupational change was particularly low in agriculture (0.025), construction (0.075), and transportation (0.089).

Tables 5 and 6 show various indices of "brain-power" by industry. The first of these, shown in Table 5, is the ratio of knowledge workers to total industry employment. The service industries as a group were more intensive in their use of knowledge workers than the goods sector but the leading sector was communications (21.8 percent in the 1980s), followed by the government sector (16.1 percent), general services (15.6 percent), and FIRE (15.4 percent). The increase in the share of knowledge workers in total employment between 1960 and 1990 was about the same for services as for the goods industries.

The ratio of scientists, computer analysts, engineers, and technicians tot total employment was much greater in the goods-producing sector than in services (5.2 versus 2.4 percent in 1990) and the ratio grew faster in the goods sector than in services over the three decades. In contrast, the total number of professional and technical workers as a share of total employment was more than twice as great in services as in goods industries in 1990 and grew faster in services than goods-producing industries between 1960 and 1990. The share of managers and administrators in total employment was greater in services but it grew faster in the goods sector.

As shown in Table 6, cognitive skill levels (SC) were, on average, higher in the service sector than the goods sector. In 1990, employees in FIRE had the highest average SC score (5.36), followed by general services (4.91), communications (4.86), and the government sector (4.68). The growth in mean SC was about the same in services as in the goods industries between 1960 and 1990. The pattern is very similar for the Med.Educ-70 (Median Education-1970) score. The average Med.Educ-70 score was higher in services than the goods sector and was led by general services (13.4 in 1990), followed by FIRE (13.2), communications (13.0), and government (12.9). The percentage change in this score over the three decades was also about the same in the goods and service sectors.

5. Regression Analysis.

I now turn to regression analysis to sort out the influences of these various technological indicators on measured productivity growth among industries. There are three questions of interest. First, which, if any, of these factors is found to have a significant effect on measured productivity growth? Second, is the goodness of fit better among goods-producing industries alone in comparison to all industries, including services? Third, do the regression results differ substantially between goods-producing and service industries, and, if so, does this difference throw any light on measurement problems in service output?

The dependent variable in the regressions is the rate of TFP growth. The independent variables include the technological indicators described above, such as scientific and technical manpower as a proportion of total industry employment, the ratio of OCA investment to FTEE, the ratio of total equipment investment to FTEE, the occupational change index, and both the level and change in average industry skill scores. I include two other technological variables. The first of these is RDGDP, which shows the amount of R&D expenditure in constant dollars per constant dollar of GDP in sector j. The data are obtained from National Science Foundation (various years). The second is an index of direct technological spillovers from supplying to purchasing sector, given by:

$$TFPIND_{jt} \equiv \sum_i a^o_{ijt} \cdot \pi_{it},$$

which is a measure of sector j's indirect knowledge gain from technological change in its supplying sectors. The matrix A^o is identical to the A matrix except that the diagonal is set to zero to prevent double-counting of TFP growth. It is assumed that the information gained from supplier i's TFP is proportional to its importance in sector j's input structure. In Wolff (1997), this variable was found to be highly significant.

The basic estimating equation is:

$$\text{(7)} \quad TFPGRT_j = b_0 + b_1\, RDGDP_j + b_2\, TFPIND_j + b_3\, TECHACT_j + \varepsilon_j$$

where $TECHACT_j$ is one of the other indices of technological activity in the industry and ε_j is a stochastic error term. It is assumed that the ε_{jt} are independently distributed but may not be identically distributed. The regression results reported in Tables 7, 8, and 9 below use the White procedure for a heteroscedasticity-consistent covariance matrix. The constant b_0 is usually interpreted as the pure rate of technological progress.

The sample is a pooled cross-section time-series data set consisting of 68 industries and 3 time periods (1958-67, 1967-77, and 1977-87). From Griliches (1980), the coefficient of RDGDP is interpreted as the rate of return of R&D, under the assumption that the (average) rate of return to R&D is equalized across sectors. Time dummies for the periods 1967-77 and 1977-87 are introduced to allow for period-specific effects on productivity growth not attributable to R&D or the other technological indicators. A dummy variable identifying the 10 service industries is also included to partially control for measurement problems in service sector output. The regressions are also run separately among the 58 goods-producing industries and on the 10 service industries.

The first set of regression results, for all industries, is shown in Table 7. In specification (1), which includes only RDGDP, TFPIND, and a service dummy variable (SERVDUM) as independent variables, both RDGDP and TFPIND have positive coefficients and are significant, at the five and one percent level, respectively. The coefficient of SERVDUM is negative, as expected, but not significant here. The goodness of fit, as measured by the adjusted-R^2 ($\bar{R}^2$), is only 0.076. When dummy variables are added in for the two time periods (DUM6777 and DUM7787), neither is statistically significant and the $\bar{R}^2$ statistic declines (results not shown).

In specifications (2)-(4), OCAFTEE (investment in OCA, in 1987 dollars, per FTEE) and DIOCCUP (the dissimilarity index based on changes in the occupational composition of employment within the industry) are included as independent variables along with RDGDP and TFPIND. Both variables have negative coefficients. However, OCAFTEE is not statistically significant, whereas DIOCCUP is significant at the 10 percent level when included by itself but not significant when included with OCAFTEE. The two other technology variables -- DIACOEFF (the dissimilarity index based on total interindustry coefficients) and EQUIPFTE (investment in equipment, machinery, and instruments, in 1987 dollars per FTEE), -- are both very insignificant. However, the coefficients of these two variables are both negative.

In Table 8, I add in various measures of the degree of "brainpower" within industry. Four of the indices of the presence of such workers -- KNOWLAVG (the share of knowledge workers in total industry employment, averaged over the period), PROFAVG (the share of professional and technical workers), SCAVG (the average substantive complexity or cognitive skill score of the industry, averaged over the period), and MEDUCAVG (the average median education-1970) -- all have insignificant coefficients (see specifications 5 to 9). In two cases, the coefficients are actually negative (though still highly insignificant). The change in skill levels of these four variables (as well as the annual growth rate of skills, which is not shown) all have insignificant coefficients. These coefficients, however, are generally positive. The major exception is ADMINAVG (the share of managerial and administrative workers), which has a positive coefficient and is significant at the five percent level. However, the change in the share of managerial and administrative workers has a negative coefficient, though it is insignificant. The evidence seems to suggest that, with the exception of managerial workers, the presence of high cognitive skill workers is not particularly beneficial to the productivity growth of an industry.[13]

Another interesting result is that the coefficient of TFPIND remains highly significant even with the inclusion of these skill variables and its coefficient value remains virtually unchanged. On the other hand, RDGDP becomes less significant and its coefficient value falls somewhat. The reason for this is that there is a positive correlation between the level of R&D expenditures of an industry and the industry's average skill level (correlation coefficients of 0.34 between RDGDP and KNOWLAVG, 0.37 between RDGDP and PROFAVG, and 0.34 between RDGDP and MEDUCAVG), reflecting the scientists and engineers employed in R&D activity. However, the correlation between RDGDP and ADMINAVG is slightly negative (-0.09). It is also of interest that the adjusted-R^2 statistic falls somewhat with the addition of these skill variables, with the exception of ADMINAVG and ADMINCHG.

Table 9 shows the regression results when the sample is restricted to goods-producing industries only and to service industries only. When the sample is restricted to goods industries only, the coefficient estimates and significance levels of the two major technological variables -- RDGDP and TFPIND -- remain virtually unchanged, as shown in specification (10). However, none of the other technological variables is significant, including OCAFTEE, DIOCCUP, DIACOEFF, and EQUIPFTE, though they all still generally have negative coefficients (see specifications 11 and 12, for example). It is also of interest that when DIOCCUP is added to the regression, RDGDP remains significant, though at the 10 percent level (result not shown) but when any of the skill measures are added, with the exception of ADMINAVG, RDGDP becomes insignificant. The reason is that for goods industries only, the correlation between RDGDP and the various skill measures are quite strong (a value of 0.54 between RDGDP and PROFAVG and 0.51 between RDGDP and MEDUCAVG, for example).

None of the brainpower variables is even remotely significant, with the exception again of ADMINAVG (see specifications 11 and 12). However, the coefficients of the level and change forms of these skill variables are all positive. In the case of administrative variables, the coefficient of ADMINAVG is positive and significant at the 10 percent level, while the coefficient of ADMINCHG is very insignificant. Also, of interest that the goodness of fit of the various regression forms has not improved when the sample is restricted to goods-producing industries.

The regression results for the service industries alone, using conventionally measured TFP growth, are very different than those for the goods industries. As shown in specifications (13-15) of Table 9, the coefficient of TFPIND is now negative and generally significant at the ten percent level. The coefficients of both OCAFTEE and DIOCCUP are negative and significant at the one or five percent level in every case.[14] The adjusted-R^2 statistic is much higher for the service industry regressions than the goods industry regressions -- in the range of 0.20 - 0.26 compared to 0.07 - 0.09.

Of the skill variables, only PROFAVG and ADMINAVG are significant. PROFAVG is significant at the five percent level and has a negative coefficient. All the other skill level variables, such as MEDUCAVG, have negative coefficients but are not significant. The coefficient of ADMINAVG is positive and significant at the five percent level.

6. Conclusion and Interpretation of Results

The regression results from the sample which includes all industries has provided some rather startling findings. First, computerization, as reflected in the variable OCAFTEE, has not produced a positive impact on productivity growth. If anything, its coefficient estimates have generally been negative (though not significant). Second, major restructuring of technology, as reflected primarily in DIOCCUP (the change in occupational composition), seems to have a retardant effect on productivity growth. The two sets of results might reflect the high adjustment costs associated with the introduction of new technology. Third, brainpower, as reflected in the various measures of both the level of and the change in worker skill, does not appear to have a strong positive effect on productivity growth. If anything, the coefficients of the skill level variables are negative more often than positive. Fourth, the presences of administrators and mangers (though not necessarily their growth over time) has a positive effect on productivity growth (perhaps, administrators are good for something after all!). However, overall, the results clearly support the view that brainpower -- whether human or artificial -- has not greatly boosted measured productivity growth in the U.S. economy.

The major issue still to resolve is whether the poorer productivity performance of services is due to output measurement problems or to the fact that productivity in services has very different determinants than productivity in goods industries. The regression results between the goods-only and the service-only industries are definitely different. Productivity in services seems to suffer much more than in goods industries from computerization and technological restructuring (as reflected in OCAFTEE and DIOCCUP, respectively) and from the presence of high skilled workers.

Yet, when we considered the aggregate performance of services in terms of both labor productivity and TFP growth, services were performing reasonably well in the 1958-67 period. Moreover, both services and goods industries suffered major declines in productivity growth in the 1967-77 period. The major difference is that while productivity growth recovered in goods industries in the 1977-87 period, it failed to do so in services. The major change in service industries in this latter period is its high rate of computerization and its greater degree of employment restructuring.

The extreme difference in regression results between the goods-producing and the service industries does, I believe, provide strong circumstantial evidence of mismeasurement of service output. It does seem that brainpower - whether human or artificial -- is associated with a more heterogeneous output (or a greater variety of output), making output harder to measure. In other words, it may be that the quality of service output is becoming harder to measure because of increasing heterogeneity.

The high degree of computerization found in finance, for example, has been responsible for the creation of a bewildering array of new financial products. The same appears to characterize the insurance industry and business services. Moreover, professional workers, such as lawyers, are often involved in the production of customized services, making their output very difficult to measure. The fact that both the computerization variable (OCAFTEE) and the share of professional workers in total employment (PROFAVG) both have significant negative coefficients in regressions across service industries but not across goods industries is consistent with this argument. Moreover, the increasing value of these two variables, particularly OCAFTEE, in services over time may explain why the downward bias in measuring service output has likewise risen over time.

A similar case can be made for the degree of employment restructuring (DIOCCUP). Rapid changes in employment mix in services, such as finance and business services, may also be associated with greater heterogeneity of products and increasing difficulties in measuring output. Likewise, the purchase of inputs which are themselves undergoing rapid technical change (TFPIND) may also lead to a new set of services being provided by the industries which purchase such inputs. These two arguments would be consistent with the findings of significant negative coefficients for DIOCCUP and TFPIND in service industry regressions but not in goods-producing industry regressions. Likewise, the fact that the degree of employment restructuring increased substantially between the 1970s and 1980s would create increasing difficulties in measuring service output.

A simple experiment provides additional support to this argument. If one were to use the coefficients derived from goods-producing industry only regressions to predict TFP growth in service industries (based on their actual values for the independent variables), one would find that the predicted values of service industry TFP growth are almost universally greater than their actual measures. Moreover, the error (the difference between predicted and actual TFP growth) generally increases over time, between the 1958-67 and 1977-87 periods.

These results, however, should not be interpreted to mean that service sector productivity, even if correctly measured, will be as high as productivity growth in goods-producing industries. As we have argued elsewhere (bee Baumol, Blackman, and Wolff, 1989, Chapter 6), it is likely that services which are basically labor activities, such as haircutting and teaching, are inherently limited (that is, stagnant) in the degree to which they can increase the amount of output produced per hour of labor input. However, it still appears that for many of these service industries, the official national income and product account measures have understated the actual increase in their productivity.

Footnotes

* I would like to express my gratitude to the C.V. Starr Center for Applied Economics at New York University and the Alfred P. Sloan Foundation which provided financial support for this work.

[1] The time subscript is dropped for notational convenience.

[2] In the traditional one-matrix input-output framework, the V matrix is implicitly treated as a diagonal matrix.

[3] An alternative formulation is possible through the industry technology model, where it is assumed that each industry has the same input requirements per dollar of output for each commodity which it produces and that the market shares for each commodity are fixed among industries. As documented in ten Raa et. al (1984) and ten Raa and Wolff (1991), the industry technology model is unfortunately characterized by several serious analytical difficulties, so that I use only the commodity technology model here.

[4] It is implicitly assumed that the government sector receives a shadow rate of return r on its capital stock.

[5] In input-output data, there are many cells with zero values, so that the logarithm transformation would not be applicable. As a result, equation (1) is used in this paper to compute sectoral TFP growth.

[6] See, for example, U.S. Industry Economics Division (1974), for a discussion of methodology and for a listing for the sectors. This method creates artificial transactions. A formula for the transfer based input-output coefficient is given by Kop Jansen and ten Raa (1990) who also show that the method distorts the material and financial balance equations of input-output analysis. As a result, the method can distort the measurement of productivity growth in both supplying and purchasing industries j. Moreover, it can also affect the measurement of linkages between sectors.

[7] A description of the 1967 tables can be found in U.S. Interindustry Economics Division (1974); of the 1977 tables in U.S. Interindustry Economics Division (1984), and of the 1987 tables in Lawson and Teske (1994). The 1967 data were not published as separate make and use tables, but the raw data for them are available on computer tape, which Paula Young of BEA graciously supplied to us.

[8] Also see Wolff (1997) for details on data sources and methods.

[9] Sector numbers refer to the standard BEA 85-sector classification scheme. See, for example, U.S. Interindustry Economics Division (1984) for details.

[10] For a discussion of some of the limitations of these data, see Miller et. al. (1980) and Spenner (1983).

[11] It should be noted that this index is partially "contaminated" by the use of price deflators for service sector inputs.

[12] This index is also partially "contaminated" by the implicit use of sectoral price deflators for inputs from the service industries.

[13] The remaining brainpower indicator -- the share of scientists, computer analysts, engineers, and technicians in total industry employment -- is also insignificant for both the level and change form.

[14] RDGDP is not included because by construction its value is zero for service industries. It should also be noted that the coefficient of TFPIND is positive and insignificant when OCAFTEE is omitted.

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Table 1
Labor and Total Factor Productivity (TFP) Growth By Major Sector, 1958-87[a]

(Average annual growth in percentage points)

	1958-67	1967-77	1977-87	1958-87
	1. Labor Productivity Growth			
A. Goods Industries				
Agriculture, forestry, and fisheries	2.91	-0.13	3.06	1.91
Mining	5.61	-1.04	0.06	1.41
Construction	0.64	-3.27	-1.27	-1.37
Manufacturing, Durables	3.02	2.47	2.87	2.78
Manufacturing, Nondurables	2.89	3.40	2.68	2.99
Transportation	3.15	1.21	1.44	1.89
Communication	5.48	4.69	4.83	4.98
Electric, gas, and sanitary services	5.44	5.32	-0.10	3.49
B. Service Industries				
Wholesale and retail trade	1.97	-0.23	1.47	1.04
Finance, insurance, and real estate	1.87	0.42	-0.77	0.46
General Services	0.99	0.72	-0.46	0.40
Government and government enterprises	0.25	0.08	0.19	0.17
Aggregated Sectors				
Total Goods	2.45	1.74	1.85	2.00
Total Services	1.20	0.46	0.35	0.65
Total Economy (GDP)	1.79	0.91	0.69	1.11
	2. Total Factor Productivity Growth			
A. Goods Industries				
Agriculture, forestry, and fisheries	-1.26	-2.23	3.38	0.00
Mining	2.13	-0.13	-3.07	-0.44
Construction	0.52	-4.23	-0.40	-1.43
Manufacturing, Durables	2.74	1.46	1.96	2.03
Manufacturing, Nondurables	2.42	2.06	1.76	2.07
Transportation	3.49	1.08	1.86	2.10
Communication	2.98	2.54	2.54	2.68
Electric, gas, and sanitary services	3.61	3.55	-0.29	2.25
B. Service Industries				
Wholesale and retail trade	0.99	-1.35	0.15	-0.11
Finance, insurance, and real estate	0.16	-0.50	-2.11	-0.85
General Services	0.11	-0.15	-0.72	-0.26
Government and government enterprises	0.25	-0.43	-0.17	-0.13
Aggregated Sectors				
Total Goods	2.14	0.62	1.04	1.24
Total Services	0.88	0.16	0.19	0.39
Total Economy (GDP)	1.49	0.28	0.34	0.68

a. See equation (1) for the definition of sectoral TFP growth and equation (3) for the definition of overall TFP growth.

Table 2
Growth Rates of the Capital-Labor and Interindustry Inputs-Labor Ratios
By Major Sector, 1958-87[a]
(Average annual growth in percentage points)

	1958-67	1967-77	1977-87	1958-87
	1. Capital / Labor Ratio			
A. Goods Industries				
Agriculture, forestry, and fisheries	5.51	11.98	-2.33	5.04
Mining	1.12	1.80	7.55	3.57
Construction	7.26	0.95	-2.36	1.77
Manufacturing, Durables	0.53	2.34	2.94	1.99
Manufacturing, Nondurables	2.26	2.47	1.90	2.21
Transportation	-0.48	1.45	-1.99	-0.33
Communication	4.85	4.63	3.10	4.17
Electric, gas, and sanitary services	1.93	5.44	-3.39	1.31
B. Service Industries				
Wholesale and retail trade	4.28	2.55	3.28	3.34
Finance, insurance, and real estate	3.64	5.12	3.91	4.25
General Services	4.86	0.37	0.72	1.88
Government and government enterprises	1.10	0.31	0.62	0.66
Aggregated Sectors				
Total Goods	2.49	3.30	1.30	2.36
Total Services	2.66	0.84	1.12	1.50
Total Economy	2.38	1.76	0.85	1.64
	2. Interindustry Inputs / Labor Ratio			
A. Goods Industries				
Agriculture, forestry, and fisheries	4.95	9.51	-0.34	4.70
Mining	2.06	4.31	3.91	3.47
Construction	4.13	-0.34	1.67	1.74
Manufacturing, Durables	3.02	0.93	2.15	2.00
Manufacturing, Nondurables	2.96	1.37	0.85	1.68
Transportation	2.98	3.60	1.85	2.80
Communication	5.73	3.58	10.73	6.71
Electric, gas, and sanitary services	4.10	1.64	-2.75	0.89
B. Service Industries				
Wholesale and retail trade	1.94	1.00	2.79	1.91
Finance, insurance, and real estate	0.86	-0.10	1.38	0.71
General Services	2.89	-1.15	3.41	1.68
Government and government enterprises	1.21	-0.32	3.70	1.54
Aggregated Sectors				
Total Goods	3.70	1.88	1.39	2.28
Total Services	1.90	-0.06	3.53	1.78

a. Capital is based on gross capital stock, labor on employment, and interindustry inputs are in constant (1972) dollars.

Table 3
Investment in Office, Computing, and Accounting Equipment (OCA)
And Total Machinery, Equipment, and Instruments per FTEE, 1958-87[a]
(1987$, Period Averages)

	1958-67	1967-77	1977-87	1958-87
	1. Investment in OCA / FTEE			
A. Goods Industries				
Agriculture, forestry, and fisheries	0.1	0.9	5.0	2.1
Mining	14.9	24.3	522.5	245.8
Construction	4.2	3.5	10.8	6.7
Manufacturing, Durables	17.7	30.9	265.5	116.9
Manufacturing, Nondurables	12.0	19.4	120.1	54.2
Transportation	20.0	17.7	117.3	57.4
Communication	22.6	25.6	226.2	109.4
Electric, gas, and sanitary services	21.5	16.6	464.1	208.4
B. Service Industries				
Wholesale and retail trade	9.3	16.3	171.5	85.5
Finance, insurance, and real estate	73.4	186.5	1,067.6	587.2
General Services	15.7	15.8	155.6	93.3
Government and government enterprises	NA	NA	NA	NA
Aggregated Sectors				
Total Goods	13.1	20.2	170.6	76.4
Total Services (except government)	20.1	39.1	279.6	155.0
Total Economy (except government)	16.0	29.2	231.8	115.6
	2. Investment in Machinery & Equipment / FTEE			
A. Goods Industries				
Agriculture, forestry, and fisheries	3,816	6,875	5,134	5,143
Mining	7,416	11,769	14,401	11,600
Construction	2,290	2,540	1,504	2,027
Manufacturing, Durables	1,841	2,580	3,089	2,540
Manufacturing, Nondurables	2,258	3,291	3,825	3,145
Transportation	4,931	7,058	6,117	6,013
Communication	9,140	14,314	18,253	14,429
Electric, gas, and sanitary services	11,658	18,970	21,309	17,872
B. Service Industries				
Wholesale and retail trade	957	1,349	1,934	1,512
Finance, insurance, and real estate	2,796	4,691	8,766	6,202
General Services	1,682	2,056	1,991	1,928
Government and government enterprises	NA	NA	NA	NA
Aggregated Sectors				
Total Goods	3,060	4,509	4,880	4,191
Total Services (except government)	1,433	2,054	2,834	2,292
Total Economy (except government)	1,995	3,340	3,732	2,613

a. Source for Investment Data: Bureau Of Economic Analysis, Department of Commerce, Diskette of Detailed Investment by Industry. Source for FTEE: Bureau of Economic Analysis, National Income and Product Accounts,diskettes.

Table 4
Dissimilarity Indices (DI) of Interindustry Technical Coefficients
And the Distribution of Occupational Employment, 1958-87

	1958-67	1967-77	1977-87	1958-87
1. Dissimilarity Index (DI) for Interindustry Coefficients[a]				
A. Goods Industries				
Agriculture, forestry, and fisheries	0.001	0.018	0.023	0.003
Mining	0.050	0.045	0.066	0.070
Construction	0.013	0.033	0.020	0.055
Manufacturing, Durables	0.010	0.040	0.103	0.204
Manufacturing, Nondurables	0.012	0.021	0.014	0.041
Transportation	0.077	0.037	0.030	0.147
Communication	0.039	0.073	0.416	0.544
Electric, gas, and sanitary services	0.005	0.139	0.081	0.183
B. Service Industries				
Wholesale and retail trade	0.009	0.035	0.072	0.130
Finance, insurance, and real estate	0.023	0.041	0.028	0.074
General Services	0.023	0.157	0.046	0.264
Government and government enterprises	0.068	0.046	0.021	0.112
Total Goods	0.014	0.030	0.039	0.084
Total Services	0.017	0.020	0.020	0.068

	1960-70	1970-80	1980-90	1960-90
2. Dissimilarity Index (DI) for Employment				
A. Goods Industries				
Agriculture, forestry, and fisheries	0.001	0.001	0.017	0.025
Mining	0.025	0.020	0.045	0.152
Construction	0.025	0.005	0.053	0.075
Manufacturing, Durables	0.039	0.014	0.096	0.147
Manufacturing, Nondurables	0.050	0.023	0.088	0.126
Transportation	0.024	0.014	0.048	0.089
Communication	0.061	0.043	0.128	0.262
Electric, gas, and sanitary services	0.169	0.053	0.105	0.231
B. Service Industries				
Wholesale and retail trade	0.019	0.029	0.078	0.162
Finance, insurance, and real estate	0.117	0.033	0.080	0.139
General Services	0.091	0.029	0.047	0.231
Government and government enterprises	0.054	0.042	0.045	0.106
Total Goods	0.061	0.014	0.110	0.199
Total Services	0.056	0.026	0.077	0.161
All Industries	0.056	0.019	0.095	0.162

a. Interindustry inputs are in constant (1972) dollars.

Table 5
Knowledge Workers and Related Workers as a Share of Industry Employment
By Major Sector in the U.S., 1960-90

(figures are in percent)

	1960	1970	1980	1990	Change 1960-90
1. Knowledge Workers / Total Employment					
A. Goods Industries					
Agriculture, forestry, and fisheries	0.9	2.3	3.4	3.6	2.7
Mining	7.6	10.5	12.6	14.8	7.3
Construction	7.2	7.7	7.6	10.1	2.9
Manufacturing, Durables	7.5	10.2	10.5	12.3	4.9
Manufacturing, Nondurables	6.4	8.1	8.9	11.1	4.8
Transportation	4.9	5.1	5.6	6.2	1.3
Communication	11.1	13.4	17.4	21.8	10.7
Electric, gas, and sanitary services	8.4	9.3	11.3	14.5	6.1
B. Service Industries					
Wholesale and retail trade	7.9	7.0	9.3	10.7	2.8
Finance, insurance, and real estate	10.6	10.6	12.1	15.4	4.8
General Services	11.1	12.5	13.7	15.6	4.5
Government and government enterprises	11.8	13.9	15.5	16.1	4.3
Aggregated Sectors					
Total Goods	6.1	8.3	9.0	10.9	4.7
Total Services	9.9	10.5	12.2	14.0	4.2
All Industries	8.0	9.6	11.0	12.9	4.9
2. Scientists, Computer Analysts, Engineers, & Technicians / Total Employment					
Total Goods	3.4	5.0	5.3	5.2	1.7
Total Services	1.3	2.0	2.5	2.4	1.1
All Industries	2.3	3.3	3.6	3.3	1.0
3. Professional and Technical Workers / Total Employment					
Total Goods	5.8	8.4	9.2	9.7	3.8
Total Services	16.0	20.2	21.6	22.0	6.1
All Industries	11.0	15.1	16.8	17.8	6.8
4. Managers and Administrators / Total Employment					
Total Goods	5.1	5.9	6.9	9.0	3.9
Total Services	12.5	10.6	12.6	13.9	1.5
All Industries	8.8	8.5	10.4	12.2	3.4

Table 6
Average Skill Scores By Major Sector in the U.S., 1960-90

	1960	1970	1980	1990	% Change 1960-90
	1. SC (Substantive Complexity)				
A. Goods Industries					
Agriculture, forestry, and fisheries	3.67	3.62	3.59	3.69	0.7
Mining	3.52	3.90	4.05	4.21	19.7
Construction	3.90	4.13	4.19	4.24	8.8
Manufacturing, Durables	3.50	3.75	3.79	3.92	12.0
Manufacturing, Nondurables	3.01	3.30	3.46	3.65	20.9
Transportation	3.17	3.32	3.38	3.27	3.0
Communication	4.13	4.39	4.62	4.86	17.9
Electric, gas, and sanitary services	3.78	3.97	4.17	4.49	18.8
B. Service Industries					
Wholesale and retail trade	3.85	3.82	3.94	4.02	4.2
Finance, insurance, and real estate	4.83	5.09	5.17	5.36	11.1
General Services	4.27	4.66	4.80	4.91	15.0
Government and government enterprises	4.22	4.38	4.54	4.68	10.9
Aggregated Sectors					
Total Goods	3.46	3.68	3.78	3.90	12.7
Total Services	4.15	4.37	4.52	4.64	11.8
All Industries	3.81	4.07	4.23	4.37	14.9
	2. Med.Educ-70 (Median Education-1970)				
A. Goods Industries					
Agriculture, forestry, and fisheries	10.19	10.34	10.49	10.65	4.5
Mining	11.42	11.69	11.89	12.04	5.4
Construction	11.17	11.38	11.43	11.46	2.6
Manufacturing, Durables	11.81	12.00	12.05	12.07	2.2
Manufacturing, Nondurables	11.44	11.65	11.76	11.86	3.7
Transportation	11.56	11.71	11.76	11.63	0.6
Communication	12.66	12.80	12.92	12.96	2.4
Electric, gas, and sanitary services	11.92	12.02	12.19	12.42	4.2
B. Service Industries					
Wholesale and retail trade	12.10	12.09	12.13	12.07	-0.2
Finance, insurance, and real estate	12.73	13.00	13.07	13.15	3.3
General Services	12.68	13.23	13.36	13.42	5.8
Government and government enterprises	12.71	12.79	12.90	12.94	1.8
Aggregated Sectors					
Total Goods	11.40	11.69	11.78	11.81	3.5
Total Services	12.46	12.76	12.87	12.91	3.6
All Industries	11.94	12.30	12.45	12.51	4.8

Table 7
Regressions of Technological Variables
On Industry TFP Growth (TFPGRT): All Industries[a]

Independent Variables	Specification (1)	(2)	(3)	(4)
Constant	0.0002 (1.44)	0.0029 (1.58)	0.0051** (2.17)	0.0048* (1.95)
RDGDP	0.072** (1.99)	0.073** (1.97)	0.068* (1.81)	0.069* (1.82)
TFPIND	0.924*** (2.77)	0.896** (2.45)	0.960*** (2.82)	0.966*** (2.61)
OCAFTEE		-0.052 (0.79)		-0.027 (0.38)
DIOCCUP			-0.042* (1.71)	-0.035 (1.21)
SERVDUM	-0.0052 (1.23)	-0.0082* (1.75)	-0.0057 (1.37)	-0.0086* (1.85)
R^2	0.089	0.122	0.113	0.138
$\bar{R}^2$	0.076	0.104	0.095	0.116
Std Err σ	0.0147	0.0144	0.0146	0.0143
Sample Size	204	198	204	198

a. Estimated coefficients are shown below the respective independent variables and the absolute value of the t-statistic is shown in parentheses. The White procedure for a heteroscedasticity-consistent covariance matrix is used in the estimation.

* Significant at the .10 level (two-tailed test).
** Significant at the .05 level (two-tailed test).
*** Significant at the .01 level (two-tailed test).

Key:

TFPGRT: Annual rate of growth of total factor productivity.

RDGDP: Ratio of R&D expenditure in constant dollars to GDP in constant dollar

TFPIND: A weighted sum of the annual rates of TFP growth of supplying industries, where the weights are given by the interindustry input coefficients.

SERVDUM: Dummy variable for the 10 service industries.

OCAFTEE: Investment in OCA, in 1987 dollars, per FTEE

DIOCCUP: Dissimilarity Index based on 267 occupations by decade.

KNOWLAVG: The ratio of knowledge workers to total employment, period average

KNOWLCHG: The change in the ratio of knowledge workers to total employment over the period.

PROFAVG: The ratio of professional and technical workers to total employment, period average

PROFCHG: The change in the ratio of professional and technical workers to total employment over the period.

ADMINAVG: The ratio of administrative and managerial workers to total employment, period average

ADMINCHG: The change in the ratio of administrative and managerial workers to total employment over the period.

SCAVG: Average SC (substantive complexity) score by industry, period average

SCCHG: The change in average SC (substantive complexity) score by industry over the period

MEDUCAVG: Average Med.Educ-1970 score by industry, period average

MEDUCCHG: The change in average Med.Educ-1970 score by industry over the period

Table 8

Regressions of Technological and Skill Variables
On Industry TFP Growth (TFPGRT): All Industries[a]

Independent Variables	Specification (5)	(6)	(7)	(8)	(9)
Constant	0.0045*	0.0054**	0.0001	0.0055	-0.0059
	(1.71)	(2.12)	(0.06)	(0.70)	(0.26)
RDGDP	0.067*	0.069*	0.065*	0.061	0.054
	(1.76)	(1.73)	(1.83)	(1.48)	(1.23)
TFPIND	1.036***	0.904**	1.170***	0.845**	0.897**
	(2.76)	(2.47)	(3.19)	(2.28)	(2.39)
DIOCCUP	-0.044*	-0.041*	-0.054**	-0.044**	-0.043*
	(1.68)	(1.66)	(2.52)	(2.05)	(1.92)
Average Skill	0.0095	-0.0046	0.0906**	-0.0003	0.0009
	(0.47)	(0.30)	(2.20)	(0.15)	(0.40)
Change in Skill	-0.0321	0.0261	-0.0334	0.0091	0.0098
	(0.42)	(0.41)	(0.52)	(1.40)	(1.13)
SERVDUM	-0.0059	-0.0056	-0.0105**	-0.0059	-0.0069
	(1.23)	(1.26)	(2.08)	(1.22)	(1.40)
R^2	0.116	0.115	0.142	0.122	0.120
$\bar{R}^2$	0.089	0.088	0.115	0.095	0.093
Std Err σ	0.0146	0.0146	0.0144	0.0146	0.0146
Sample Size	204	204	204	204	204
Skill Measures	KNOWLAVG KNOWLCHG	PROFAVG PROFCHG	ADMINAVG ADMINCHG	SCAVG SCCHG	MEDUCAVG MEDUCCHG

a. See footnotes to Table 7 for key.

* Significant at the .10 level (two-tailed test).
** Significant at the .05 level (two-tailed test).
*** Significant at the .01 level (two-tailed test).

Table 9

Regressions of Industry Technological and Skill Variables
On Labor Productivity Growth: Goods and Service Industries Separately[a]

Independent Variables	Goods Industries Only (10)	(11)	(12)	Service Industries Only (13)	(14)	(15)
Constant	0.0024 (1.41)	0.0024 (0.92)	-0.0010 (0.31)	0.0237*** (3.97)	-0.0082 (0.68)	0.1090 (1.61)
RDGDP	0.072** (1.99)	0.037 (1.05)	0.063* (1.77)			
TFPIND	0.928*** (2.64)	1.071*** 2.80)	1.145*** (2.97)	-3.759* (1.86)	-0.396 (0.19)	-4.102* (1.91)
OCAFTEE				-0.375*** (5.22)	-0.272** (2.75)	0.325*** (5.42)
DIOCCUP		-0.032 (1.03)	-0.038 (1.28)	-0.220** (2.43)	-0.189** (2.68)	-0.209*** (3.48)
Average Skill		0.0226 (1.25)	0.0860* (1.86)	-0.0426** (2.21)	0.1753** (2.15)	-0.0074 (1.43)
Change in Skill		0.0003 (0.01)	-0.0070 (0.10)	0.1819 (1.01)	-0.1330 (1.16)	0.0197 (1.15)
R^2	0.081	0.105	0.118	0.424	0.394	0.381
$\bar{R}^2$	0.072	0.078	0.092	0.264	0.225	0.209
Std Err σ	0.0130	0.0129	0.0129	0.0195	0.0200	0.0202
Sample Size	174	174	174	24	24	24
Skill Measures		PROFAVG PROFCHG	ADMINAVG ADMINCHG	PROFAVG PROFCHG	ADMINAVG ADMINCHG	MEDUCAVG MEDUCCHG

a. See footnotes to Table 7 for key.
* Significant at the .10 level (two-tailed test).
** Significant at the .05 level (two-tailed test).
*** Significant at the .01 level (two-tailed test).