Measures of technical change and structural change in services in the U.S.:
Was there a resurgence of productivity growth in services?

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Traditional measures of productivity growth show very low gains made by most service industries since 1980 in the United States. However, other indices of "technological activity," such as computerization, show that these service industries have actually been more technologically active than goods producing industries over this period. Services have invested much more heavily in computerization than goods-producing industries (about double since 1980). The educational attainment of the work force and other skill indices are greater in services than goods producers over this period. Moreover, the degree of change in the occupational composition of employment has been almost as great among service industries as in goods industries since 1970.

In my 1991 paper, I called attention to this inconsistency in the case of the insurance industry. This paper will investigate different indicators of technological activity among service industries and compare these with comparable measures for goods producers. Moreover, the paper will try to shed some light on this apparent paradox. The paper will also pay particular attention to the post-1980 period, which has seen a tremendous growth in the use of computers in production and which Freeman (1987) and others have termed a new "techno-economic paradigm," based on computer-driven information technology. In particular, I will consider whether the introduction of information technology (IT) has led to a productivity revival in services as anectodal evidence seems to suggest.

The paper is divided into six parts. The first part of the paper will summarize the underlying "cost disease" model of the service sector. The second part will present basic data on productivity growth for service and goods sectors. The next two parts of the paper will include descriptive statistics on various indicators of technological activity in service and goods industries over the 1950-2003 period in the United States. The indicators in Section 3 include: (1) the skill level of the workforce and (2) the change in the occupational composition of employment. Those in Section 4 include: (3) investment in total equipment per worker; and (4) investment in office, computing, and accounting (OCA) equipment per worker. The basic data sources for the paper are employment data for 267 occupations and 64 industries which are obtained from the Census of Population for years 1950, 1960, 1970, 1980, 1990, and 2000; and National Income and Product Accounts and corresponding wealth and employment data. The level of industry detail is 45 sectors. Section 5 will include regression results on the relation between standard measures of productivity growth and these other indicators of technological activity. Concluding remarks (Section 6) will be made in the final section of the paper.

1. **Background**

The cost-disease model, originally developed by Baumol (1967) and later expanded by Baumol, Blackman, and Wolff (1989), provides the framework for the empirical analysis. Before entering the substance of the discussion, let us first discuss several definitional issues. Generally, a service is defined as an economic activity which yields a product that is not a physical object. Transmission of a telephone call, the litigation of an attorney, and the teaching of a course all have their market prices and are valued by consumers. Each purchaser of such a service may have a good deal to show for the expenditure, but it is not incorporated in a tangible product.

Intangibility of product, however, is probably the *only* attribute common to all services. In particular, there is one way in which they differ from one another that is crucial from the point of view of my analysis, and that is their differences in amenability to standardization. Some services like data processing and telecommunications are impersonal and electronic and, as shown in Table 1, have very high productivity growth. They are generally susceptible to standardization and "commodization." This group includes telecommunications (for example, telephoning), utilities (for example, electricity generation), and transportation (for example, airlines and trucking). As a result, this type of service is capable of achieving high productivity growth. I call this first group "standardized services."

The second group is less amenable to standardization and, indeed, is characterized by customized output. As a result, these are services for which productivity change is very difficult to achieve. Such productivity stagnancy may be virtually endemic to the product (for example, a half-hour string quartet). Or, such a service may be so unstandardized that it is incompatible with mass production methods (for example, medical diagnosis or investigating a legal problem). Or, it may result from the fact that acceptable product quality requires some specifiable minimum labor input (for example, attention by a skilled physician or a teacher). Besides amusements and entertainment, legal services, medical services and education, this group would include professional services, repair services, and government services. I call this second group "traditional" or "customized services."

In reality there are gradations between the extreme cases of the standardized and customized services. I call this intermediate group "hybrid services." This includes wholesale and retail trade, restaurants, and financial services. In the case of retail trade, there are both types of services provided. In high-end clothing stores, fitting and altering of garments is a customized service, while in discount stores such as Walmarts there is little individualized service and the output of the sector is very much a standardized product. Insofar as the retail sector has undergone "Walmartization," we might expect this sector to be drifting over toward the standardized category. The Internet and e-commerce are also creating similar tendencies. As a result, we might expect that productivity growth will pick up in the trade sector (the results in Table 1 actually indicate this trend). A similar dichotomy exists between high-end restaurants, with customized food preparation, and fast-food chains like MacDonald's, which specialize in commodized food preparations. There are also two types of financial services. On the one hand, check processing and many financial transactions done on ATM machines in retail banking are now almost completely automated, while, on the other hand, loan decisions and investment banking still require a considerable amount of personal discretion. Depending on which part of the business starts to predominate, both restaurants and financial services may show upward or downward trends in productivity growth.

It is also of note that with regard to the traditional services, many are undergoing the process of standardization. Automobile repair services have recently adopted computerized diagnostic equipment to help locate car problems. There is now a major development of computer software for medical diagnoses. In the case of legal services, software has been developed to create standardized wills and house contracts. It will be interesting to see whether these changes have led to enhanced productivity growth in these sectors as well.

2. **Productivity Growth in the U.S, 1950-2003**

We begin by looking at trends in productivity growth by major sector of the economy. As shown in Table 1, on the basis of U.S. Bureau of Economic Analysis data on output, labor input, and capital stock, conventionally measured total factor productivity (TFP) growth in the whole economy dipped slightly between the 1950s and 1960s, from 1.4 to 1.0 percent per annum, plummeted in the 1970s to 0.4 percent per year, and then recovered to 1.1 percent per year and then 0.9 percent per year in the 1980s and 1990s, respectively (see the Data Appendix for data sources and methods and information on measuring TFP). Over the entire half century, overall TFP growth averaged 0.95 percent per year. The years 1995-2003 are also shown since this period was heralded as the era of the 'new economy.' However, in terms of conventional TFP growth, it was unremarkable, with an average annual TFP growth of 1.18 percent, slightly above its long-term trend.[1] TFP growth in the goods sector as a whole was higher than that of services over the five decades – 1.42 percent per year compared to 0.84 percent per year.

Of the four goods sectors, TFP growth was by far strongest in manufacturing. It was also fairly steady over time. TFP growth was about average in the agricultural sector over the five decades and did show a great deal of variation over time. On the other hand, overall TFP growth over the half century was actually negative in mining and construction. There is some evidence of a major surge in productivity growth in both agriculture and manufacturing the 1995-2003 period, though the opposite is the case for mining and construction.

TFP growth in the three standardized services has been quite robust over the entire 50 years, from 1950 to 2000. Indeed, utilities recorded the highest TFP growth over the half century of any of the sectors listed in the table and communications ranked second (communications was first in terms of labor productivity growth and utilities ranked second). Except for the 1970s for transportation, TFP growth has been relatively steady over time for the three sectors. There is also no noticeable jump in TFP growth in the 1995-2003 period (though there was a big increase for utilities in terms of labor productivity growth).

TFP growth in the customized service industries (Panel D) was virtually zero -- indeed, negative, for several service industries --over the half century from 1950 to 2000. TFP growth averaged -0.7 percent per year in business services and -1.1 percent per year in health and education. TFP growth did fluctuate over time in the four customized service sectors but there is not noticeable trend – either upward or downward – over time. Moreover, there is no indication that TFP growth picked up after 1995 – in fact, just the opposite except for health and education.

The intermediate case – the hybrid services – is quite interesting (see Panel C). TFP growth in the trade sector averaged 0.9 percent per year over the 50 years – just about average overall –but was virtually zero in finance, insurance, and real estate (FIRE). However, TFP growth in the trade sector, as predicted, shows a steep upward trajectory after 1980, which continues in the 1995-2003 period. TFP growth in FIRE also shows a large jump in the 1990s and again in the 1995-2003 period.

3. **Skills and Occupational Changes**

[1] Results for the entire economy and individual sectors are quite similar for labor productivity growth as well (unless otherwise noted below).

I begin the consideration of alternative indices of technological activity with skill change. I use the fourth (1977) edition of the Dictionary of Occupational Titles (DOT) for my skill measures. 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. This probably provides the best source of detailed measures of skill requirements covering the period 1950 to 2000. Various measures of workplace skills are developed from this source for each of 267 occupations (see Wolff, 1996, for more details). In this application, I use one of the measures, Substantive Complexity (SC). This is a composite measure of skills derived from a factor analytic test of DOT variables. It was found to be 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.

Table 2 shows the average SC scores by major sector over the period from 1950 to 2090 (the periodization is based on data availability). Cognitive skill levels (SC) are, on average, higher in the service sector than the goods sector. In 2000, the average SC score was 4.8 in services, compared to 4.1 in the goods sector. In this year, employees in FIRE and business services were tied for the highest average SC score (5.61), followed by communications (5.29), health and education (5.07), and the government sector (4.98). On the other hand, the growth in mean SC over the half century was slightly higher in goods industries (0.74 points) than in services (0.67 points). Still, the biggest increase in SC levels occurred in business services (1.91 points) and the second highest was in communications (1.37 points).

A second measure of worker skill is the mean years of schooling of employees within an industry (see Table 3). These are derived directly from decennial Census of Population data for years 1950, 1960, 1970, 1980, 1990, and 2000. The pattern is very similar for the mean education of the workforce as for cognitive skills. Average schooling is higher in services than the goods sector. In 2000 the difference is more than a full year of schooling. In 2000, the ranking was led by business services (14.4 years), followed by health and education (14.3 years), government (14.2 years), FIRE (14.2 years), and communications (14.2 years). The change in mean education over the five decades, as with the change in SC, was larger in the goods sector (3.5 years) than in the service sector (3.0 years).

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 1950, 1960, 1970

1980, 1990, and 2000. 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. 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 Baumol, Blackman, and Wolff, 1989, Chapter 7, for details on the classification system).

Table 4 shows the ratio of knowledge workers to total employment by major sector of the economy. In 2000 the service industries as a group are somewhat more intensive in their use of knowledge workers than the goods sector (14.6 versus 14.4 percent), and the leading sector in 2000 was communications (28.9 percent), followed by business services (27.9 percent), FIRE (21.1 percent), and the government sector (18.7 percent). However, once again, the increase in the share of knowledge workers in total employment between 1950 and 2000 was greater (in this case much greater) for goods industries (10.2 percentage points) than services (4.2 percentage points).

Another indicator of technological change within an industry is the degree to which the occupational structure shifts over time. For this, I employ an index of similarity. First define:

M = occupation-by-industry employment coefficient matrix, where m_{ij} shows the employment of occupation i in industry j as a share of total employment in industry j.

The employment data, as indicated above, are for 267 occupations and 64 industries and are obtained from the decennial Census of Population for years 1950, 1960, 1970, 1980, 1990, and 2000. The similarity index for industry j between two time periods 1 and 2 is given by:

$$(1) \quad SI^{12} = \frac{\Sigma_i \, m^1_{ij} m^2_{ij}}{[\Sigma_i (m^1_{ij})^2 \;\; \Sigma_i (m^2_{ij})^2]^{1/2}}$$

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. The index of occupational dissimilarity, DI, is defined as:

$$(2) \quad DI^{12} = 1 - SI^{12}$$

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

Results for DI are shown in Table 5. The DI index for the total economy, after rising slightly from 0.050 in the 1950-1960 period to 0.056 in the 1960-1970 decade, dropped to 0.019 in the 1970s, then surged to 0.095 in the 1980s, but fell to 0.055 in the 1990s. However, for most individual industries, the most rapid degree of occupational change occurred during the 1990s. In fact, the unweighted average of DI was by far the highest in the 1990s than in the other decades. These results confirm anecdotal evidence about the substantial degree of industrial restructuring during the 1990s.

However, by and large, the degree of occupational restructuring was very similar, on average, in the goods industries as in the service industries. The four sectors that experienced the greatest occupational restructuring over the five decades are business services (0.170); accommodations, recreation, and personal services (0.140); mining (0.125), and manufacturing (0.110).

4. **Equipment and Computer Investment**

I next consider the investment activity of goods and service industries. As shown in Table 6, average annual investment in equipment, machinery, and instruments (including OCA)[2] per person engaged in production (PEP) was higher among the goods sectors than among services – 26 percent higher in 2000. The two leading sectors in the 1990s are both services – communications ($33,500 per PEP) and utilities ($28,900 per PEP) -- followed by mining ($21,000 per PEP) and FIRE ($12,900 per PEP). However, the growth in equipment investment per PEP between the 1950s and the 1990s periods was higher in services (a ratio of 4.7) than in the goods sector (a ratio of 3.5.

The next indicator is average annual investment in office, computing, and accounting equipment (OCA) per PEP.[3] As shown in Table 7, overall investment in OCA per PEP grew by a factor of 38 between the 1950s and the 1990s periods, from $8 (in 2000 dollars) per PEP to $289. Its growth was about double in services (a factor of 43) than in the goods sector (a factor of 23). By the 1990s, the computer (OCA) intensity of services was about double that of the goods sector ($327 versus $168 per PEP). The most OCA-intensive sector in the 1990s was by far FIRE, at

[2] In the 1990s, the figures also include software.
[3] As noted above, software is included in equipment in the 1990s. However, since it is not included in previous periods, I exclude software from OCA.

\$2,007 per employee, followed by communications (\$1,557 per employee) and utilities (\$598 per employee.

5. Regression Analysis

A. Modeling Framework

I begin with a standard neoclassical production function f_j for sector j:

$$(3) \qquad X_j = Z_j f_j(KC_j, KO_j, LAB_j, INT_j, RD_j)$$

where X_j is the (gross) output of sector j, KC_j is the input of IT-related capital, KO_j is the input of other capital goods, LAB_j is the total labor input, INT_j are total intermediate inputs, RD_j is the stock of research and development (R&D) capital, and Z_j is a (Hicks-neutral) total factor productivity (TFP) index that shifts the production function of sector j over time.[4] For convenience, I have suppressed the time subscript. Moreover, capacity utilization and adjustment costs are ignored. It then follows that

$$(4) \qquad d \ln X_j = d \ln Z_j + \varepsilon_{Cj}\, d \ln KC_j + \varepsilon_{Oj}\, d \ln KO_j + \varepsilon_{Lj}\, d \ln LAB_j + \varepsilon_{Nj}\, d \ln INT_j + \varepsilon_{Rj}\, d \ln RD_j$$

where ε represents the output elasticity of each input and $d \ln Z_j$ is the rate of Hicks-neutral TFP growth. If we now impose the assumption of competitive input markets and constant returns to scale, it follows that an input's factor share (α_j) will equal its output elasticity. Let us now employ the standard measure of TFP growth π_j for sector j:

$$(5) \qquad \pi_j \equiv d \ln X_j/dt - \alpha_{Cj}\, d \ln KC_j/dt - \alpha_{Oj}\, d \ln KO_j/dt - \alpha_{Lj}\, d \ln LAB_j/dt - \alpha_{Nj}\, d \ln INT_j/dt$$

It then follows that:

$$(6) \qquad \pi_j = d \ln Z_j/dt + \alpha_{Rj}\, d \ln RD_j/dt$$

[4] This is a modified form of the production function used by Stiroh (2002).

In particular, in the standard neoclassical model, there is no special place reserved for IT capital in terms of its effect on TFP growth.

As Stiroh (2002) argues, there are several reasons why we might expect the standard necoclassical model to fail in the case of the introduction of a radically new technology that might be captured by IT investment. These include the presence of productivity spillovers from IT, problems of omitted variables, the presence of embodied technological change, measurement error in variables, and reverse causality. If for one of these reasons, the output elasticity of IT ε_{Cj} exceeds its measured input share α_{Cj} , say by u_{Cj}, then

$$(7) \qquad \pi_j = d \ln Z_j/dt + \alpha_{Rj}\, d \ln RD_j/dt + u_{Cj}\, d \ln KC_j/dt$$

In other words, conventionally measured TFP growth π_j will be positively correlated with the growth in ICT capital.

A similar argument applies to labor productivity growth, LP, defined as:

$$(8) \qquad LP_j \equiv d \ln X_j/dt - d \ln LAB_j/dt$$

If we again impose the assumption of competitive input markets and constant returns to scale, it follows that:

$$(9) \qquad LP_j = d \ln Z_j/dt + \alpha_{Cj}\, d \ln kc_j/dt + \alpha_{Oj}\, d \ln ko_j/dt + \alpha_{Nj}\, d \ln int_j/dt + \alpha_{Rj}\, d \ln RD_j/dt$$

where lower case symbols indicate the amount of the input per worker.[5] If for the reasons cited above there is a special productivity "kick" from IT investment, then the estimated coefficient of kc_j/dt should exceeds its factor input share.

Though productivity growth and changes in input composition are algebraically related, there are several reasons why they may deviate. First, there are costs of adjustments associated with radical restructuring of technology, so that there may be a considerable time lag between the two

[5] Technically, we impose the assumption of constant returns to scale of the traditional factors of production, so that: $\alpha_{Cj} + \alpha_{Oj} + \alpha_{Nj} + \alpha_{Lj} = 1$.

(see David, 1991, for example). Second, while new technology is generally used to lower costs and hence increase measured output per unit of input, new technology might be used for other purposes such as product differentiation or differential pricing. Third, in the case of services in particular, output measurement problems might prevent us from correctly assessing industry productivity growth. This problem could, of course, be partly a consequence of product differentiation and price discrimination.

I next include the change in average worker skills in the production function. There are two possible approaches. Let the effective or quality-adjusted labor input in sector j be given by $Q_j = LAB_j S_j$, where S measures average worker skills in sector j. Then (4.1) can be rewritten as:

$$(10) \qquad X_j = Z_j f^*_j(KC_j, KO_j, Q_j, INT_j, RD_j)$$

Again assuming competitive input markets and constant returns to scale (to the traditional factors of production) and still using (8) to define labor productivity growth, we obtain:

$$(11) \qquad LP_j = d \ln Z_j/dt + \alpha_{Cj} \, d \ln kc_j/dt + \alpha_{Oj} \, d \ln ko_j/dt + \alpha_{Nj} \, d \ln int_j/dt + \alpha_{Lj} \, d \ln S_j/dt + \alpha_{Rj} \, d \ln RD_j/dt$$

In this formulation, the rate of labor productivity growth should increase directly with the *rate of growth* of average worker quality or skills.

The second approach derives from the standard human capital earnings function. From Mincer (1974),

$$\text{Ln } w = a_o + a_1 S$$

where w is the wage, S is the worker's level of skills (or schooling), and a_0 and a_1 are constants. It follows that

$$(d\text{Ln } w)/dt = a_1(dS/dt)$$

By definition, the wage share in sector j is $\alpha_{Lj} = w_j LAB_j/X_j$. Under the assumptions of competitive input markets and constant returns to scale, $\alpha_{Lj} = \varepsilon_{Lj}$, a constant. Therefore, $X_j/LAB_j = w_j/\varepsilon_{Lj}$. In this case, effective labor input E is given by the equation: Ln Q = S + ln LAB. It follows from (8) that

$$(12) \qquad LP_j = d \ln Z_j/dt + \alpha_{Cj}\, d \ln kc_j/dt + \alpha_{Oj}\, d \ln ko_j/dt + \alpha_{Nj}\, d \ln int_j/dt + \alpha_{Lj}\, dS_j/dt + \alpha_{Rj}\, d \ln RD_j/dt$$

In other words, the rate of labor productivity growth should be proportional to the *change in the level* of average worker quality or skills over the period.

B. Regression Analysis.

In the first regression, the dependent variable is the rate of industry TFP growth. The independent variables R&D expenditures as a percent of net sales and the growth in the stock of OCA capital. The statistical technique is based on pooled cross-section time-series regressions on industries and for the decades that correspond with the decennial Census data. The basic sample consists of 45 industries and 3 time periods (1960-70, 1970-80, 1980-90, and 1990-2000).[6] The estimating equation:

$$(13) \qquad TFPGRTH_j = \beta_0 + \beta_1\, RDSALES_j + \beta_2\, OCAGRTH_j + v_j$$

where $TFPGRTH_j$ is the rate of TFP growth in sector j, $RDSALES_j$ is the ratio of R&D expenditures to net sales in sector j, OCAGRTH is the rate of growth of the stock of OCA capital, v_j is a stochastic error term, and the time subscript has been suppressed for notational convenience. It is assumed that the v_{jt} are independently distributed but may not be identically distributed. The regression results reported below use the White procedure for a heteroscedasticity-consistent covariance matrix.

From (6) it follows that the constant β_0 is the pure rate of (Hicks-neutral) technological progress. From Griliches (1980) and Mansfield (1980), the coefficient of RDSALES is interpreted

[6] The 1950-60 period can not be included in the regression analysis because the R&D series begins fully only in 1958. Moreover, because of a major change in industrial classification in 1997 with the adoption of the North American Industrial Classification System (NAICS) in the U.S., the 1990-2000 sample consists of only 33 industries.

as the rate of return of R&D, under the assumption that the (average) rate of return to R&D is equalized across sectors.[7] Time dummies for the periods 1960-70, 1970-80, and 1980-90 are introduced to allow for period-specific effects on productivity growth not attributable to R&D or OCA investment.

The particular focus of the paper is to compare the productivity performance of the three groups of service industries. As a result, three service dummy variables are introduced to identify the standardized, hybrid, and customized service industries. Because I am also interested in the effects of the 'new economy' on these service sectors, three sets of interactive variables are also included: (1) interactions between the service dummy variables and the growth in OCA; (2) interactions between the service dummy variables and time period dummy variables for 1980-2000; and (3) interactions between the service dummy variables and both the growth in OCA and time period dummy variables for 1980-2000. Similar interactions effects are also included for the change in SC and the change in mean education.

The first set of regression results is shown in Table 8. The constant term ranges from 0.015 to 0.019. These estimates are comparable to previous estimates of the Hick-neutral rate of technological change (see Griliches, 1979, for example). The coefficient of the ratio of R&D expenditures to net sales is significant at the five percent level. The estimated rate of return to R&D ranges from 0.15 to 0.16. These estimates are about average compared to previous work on the subject (see Mohnen, 1992, for example, for a review of previous studies).[8]

The coefficient of the growth of OCA is negative but not statistically significant. The same result holds for two alternative measures of IT, the growth in the stock of computers and the stock of OCA plus communications equipment (OCACM). As noted above, these specifications really

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[7] The proof is that RDSALES = dR/X. From (2) and (4) it follows that:

$$\pi = \varepsilon_R\,(dR/R) = \varepsilon_R\,(dR/X)(X/R) = (\varepsilon_R X/R)(dR/X)$$

Therefore,

$$\beta_1 = (\varepsilon_R X/R) = (dX/X)(X/R)/(dR/R) = dX/dR.$$

The term dX/dR is the marginal productivity of R&D capital, which is equivalent tot he rate of return to R&D.

[8] The coefficient of the number of full-time equivalent scientists and engineers engaged in R&D per employee is also significant in every case, typically at the five percent level. In the tables, I present results using R&D expenditures because it is more conventional.

measure the excess returns to computer investment over and above that to capital in general, since TFP growth already controls for the growth of total capital stock per worker.

The coefficient of the dummy variable for the standardized service industries is positive but not significant, indicating that its productivity performance is on a par with the traditional goods industries. In the first specification, the coefficient of the dummy variable for hybrid services is negative and significant at the five percent level, and the coefficient of the dummy variable for customized services is negative and significant at the one percent level. As expected, the absolute value of the coefficient for customized services is greater than that for hybrid services (-0.020 compared to -0.016).

I next add interaction terms between the service dummy variables and OCA growth (specification 2). The interaction terms between both standardized and hybrid services and OCA growth are virtually zero but that between customized services and OCA growth is negative though not significant. The results suggest that in the case of customized services, OCA growth actually lowers productivity growth, perhaps because of costs of adjustment. With the interaction effect included, the coefficients of both standardized services and the hybrid services remain virtually unchanged but that of customized services becomes less negative and insignificant. The results suggest that customized services have lower productivity growth than other sectors due, in part, to the deleterious effects of OCA investment on their output performance.

The addition of a second interactive effect between the three types of services and the 1980-2000 period (specification 3) reveals that these three coefficients are all negative, though not statistically significant. These results suggest that if anything the two decades of the 'new economy' have had a negative, not positive, effect on the performance of the service industries. With these new interaction terms included, the coefficients of the three service dummy variables and those of the three interaction effects between the service dummies and OCA growth become more positive.[9]

Table 9 shows the regression results for labor productivity growth as the dependent variable and both the change in cognitive skills (SC) and the change in mean education as independent variables. I also include R&D intensity and the growth of total capital per worker. As in the first set of regressions, the coefficient of R&D intensity is positive, ranges from 0.16 to 0.18, and is here

[9] A third set of interaction terms between the three service dummy variables, OCA growth, and the 1980-2000 time period all prove insignificant (results not shown).

significant at the ten percent level. The coefficient of the growth in total capital per worker is significant at the one percent level and its value ranges form 0.30 to 0.33 -- approximately equal to the share of capital income in total income. On the other hand, the coefficients of the change in SC and the change in mean education are statistically insignificant and, indeed, negative in two of the four cases shown here.[10] The coefficients and significance levels of the three service dummy variables in the first two specifications are almost identical to those in the corresponding TFP growth regression (specification 1 of Table 8).

I next introduce interaction terms between the three service dummy variables and the change in SC (or mean education). The interaction effects are positive in five of the six cases, suggesting that upgrading skills or education in services is associated with enhanced productivity performance relative to goods industries but the coefficients are all insignificant (specifications 3 and 4). The coefficients of the three service dummy variables remain by and large unaffected by the inclusion of these interaction terms.[11]

6. **Conclusion**

From the standpoint of productivity performance, it is necessary to distinguish between the three types of service industries. Standardized services like transportation, communications, and utilities behave very much like goods industries in terms of productivity performance. Indeed, in the regression analysis it is not possible to distinguish between their TFP or labor productivity growth rate and that of goods industries after controlling for R&D intensity and other factors. Customized (traditional) services have had much lower productivity growth than goods industries – indeed, virtually zero in the postwar period -- and this result shows up in the econometric analysis as well. The hybrid services are a mix of the first two types. Their productivity performance is lower than that of goods industries and standardized services but higher than that of the customized services. This result shows up both in the historical data as well as in the econometric analysis.

Despite the glowing reports about the 'new economy' and the benefits of computerization, there is no evidence of a productivity resurgence in the customized service industries. In fact, the

[10] Results are similar for the rate of growth of SC and mean education (results not shown here).

[11] Regressions were also estimated with interaction terms between the three service dummy variables and a dummy variable for the 1980-2000 period and with interactions between the three service dummy variables, the change in mean SC (or mean education), and a dummy variable for the 1980-2000 period, but none of these interaction terms is found to be statistically significant.

econometric results suggest that computerization might actually have been deleterious to productivity growth in the customized service sector. The same is true for the standardized services though their productivity growth has historically been very high. On the other hand, the hybrid service industries do show evidence of some enhancement in productivity performance in the 1980s and 1990s, in the case of the trade sector, and in the 1990s, in the case of finance and insurance. This evidence comes from the historical trend data. However, the econometric evidence does not seem to support this result. Indeed, if anything, the econometric results suggest that the two decades of the 'new economy' have had a negative, not positive, effect on the performance of all three service sectors.

Despite the low productivity performance of the customized service sector and, at least until recently, the hybrid service sector, other indicators of technological activity do suggest that these two sectors have not been technological inert. These two sectors scored higher than the goods sector in almost every decade in terms of the average level of cognitive skills, the mean schooling level, and the share of knowledge workers. Cognitive skill levels did increase somewhat faster in the goods sector, though this was not uniform across decades. On the other hand, mean schooling rose noticeably more in the goods sector than the two service sectors in each of the five decades. The share of knowledge workers in the goods sector grew considerably faster than in these two service sectors in the 1950s, 1960s, 1990s, and over the full 50 years, though it expanded more slowly in the 1970s and at about the same rate in the 1980s. The DI index of occupational change was greater for the goods sector than for these services in the 1950s, the 1980s, and the 1990s, and over the five decades, though it was smaller in the 1970s and about the same in the 1960s.

Annual equipment investment per worker was much higher in the goods and standardized service sector than in the customized and hybrid service sector in each of the ten-year periods between 1950 and 2000, while investment in OCA per worker was much higher in the two service sectors (particularly in finance, insurance, and real estate) over the full 50 years and particularly in the 1980s and the 1990s.

The upshot of the paper is that so-called stagnant services, as portrayed in the standard cost-disease model, are *not* technologically inert. Though these industries show up with low productivity growth (zero in the case of the customized service sector), they are very active and have undergone major change over time by other technological indices. Indeed, by some of the indices (mean skills, mean schooling, share of knowledge workers, and investment in OCA) these sectors are more technologically active than goods producers. The production function for these services does not remain fixed over time.

The distinguishing features of service industries in the post-1980 period are both its high rate of computerization and its high degree of employment restructuring. It is likely that both are associated with a more heterogeneous output. 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. Likewise, the fact that the degree of employment restructuring increased substantially between the 1980s and 1990s might be associated with an increasing variety of service products. It is possible that the more heterogeneous output has made service output harder to measure over time, and thus the low productivity growth of services after 1980 is a measurement problem.

There are two other possible explanations. The first of these might reflect the high adjustment costs associated with the introduction of new technology. The paradigmatic shift from electromechanical automation to information technologies (IT) might require major changes in the organizational structure of companies before the new technology can be realized in the form of measured productivity gains (see, David, 1991, for greater elaboration of this argument). Some confirmation of this hypothesis is provided by Bresnahan, Brynjolfsson and Hitt (2002), for example, who find that computerization has a positive effect on firm-level productivity only as long as there are concomitant changes in firm organization. According to this line of argument, productivity growth of the so-called stagnant services should increase to more normal levels in the future as the IT revolution is realized.

The second explanation is that service providers are now able to use this new technology to expand profits in other ways besides augmenting productivity. In particular, services may be employing IT for product differentiation rather than productivity enhancement. For example, they can now customize their products for a larger array of potential clients. Computers allow for greater diversification of products, which, in turn, also allows for greater price discrimination (e.g., airline pricing systems) and the ability to extract a large portion of consumer surplus. Greater product diversity might increase firm profits, though not necessarily its productivity. Some evidence on the production differentiation effects of computers is provided by Chakraborty and Kazarosian (1999) for the U.S. trucking industry (for example, speed of delivery versus average load). If this is the case, then the low productivity growth measured for the stagnant services might persist into the indefinite future.

References

Baumol, William J. (1967), "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *American Economic Review*, Vol. 57, June, pp. 415-26.

Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff (1989*), Productivity and American Leadership: The Long View*, Cambridge, MA: MIT Press.

Bresnahan, Timothy, Brynjolfsson, Eric, and Lorin Hitt (2002), "Information Technology, Workplace Organization, and the demand for Skilled Labor: Firm-Level Evidence, *Quarterly Journal of Economics,* Vol. 117, No. 1, pp. 339-376.

Chakraborty, Atreya, and Mark Kazarosian (1999), "Product Differentiation and the Use of Information Technology: Evidence from the Trucking Industry," NBER Working Paper 7222, July.

David, Paul A. (1991), "Computer and Dynamo: The Modern Productivity Paradox in a Not-Too-Distant Mirror," in *Technology and Productivity: The Challenge for Economic Policy*, OECD, pp. 315-348.

Freeman, Christopher (1987), "Information Technology and the Change in Techno-Economic Paradigm," in Christopher Freeman and Luc Soete, eds., *Technical Change and Full Employment*, (Oxford: Basil Blackwell).

Griliches, Zvi (1979), "Issues in Assessing the Contribution of Research and Development to Productivity Growth," *Bell Journal of Economics*, 10 (1), Spring, pp. 92-116.

Griliches, Zvi (1980), "R&D and the Productivity Slowdown," *American Economic Review*, Vol. 70, No. 2, May, pp. 343-347.

Mansfield, Edwin (1980), "Basic Research and Productivity Increase in Manufacturing," *American Economic Review*, 70 (5), December, pp. 863-873.

Mincer, Jacob (1974), *Schooling, Experience, and Earnings*, (New York: National Bureau of Economic Research).

Mohnen, Pierre (1992),*The Relationship between R&D and Productivity Growth in Canada and Other Major Industrialized Countries*, (Ottawa, Canada: Canada Communications Group).

Stiroh, Keven J. (2002), "Are ICT Spillovers Driving the New Economy?" *Review of Income and Wealth*, Vol. 48, No. 1, March, pp. 33-58.

Wolff, Edward N. (1991), "Productivity Growth, Capital Intensity, and Skill Levels In the U.S. Insurance Industry, 1948-86," *Geneva Papers on Risk and Insurance*, Vol. 16, No. 59, April, pp. 173-90.

Wolff, Edward N. (1996), "Technology and the Demand for Skills", *OECD Science, Technology and Industry Review*, 18, pp. 96-123.

Data Appendix

1. NIPA employee compensation: Figures are from the National Income and Product Accounts (NIPA), available on the Internet [http://www.bea.gov/bea/dn2/home/annual_industry.htm]. Employee compensation includes wages and salaries and employee benefits.

2. NIPA employment data: Figures are from the National Income and Product Accounts (NIPA), available on the Internet [http://www.bea.gov/bea/dn2/home/annual_industry.htm]. Persons engaged in production (PEP) equals the number of full-time and part-time employees plus the number of self-employed persons. Unpaid family workers are not included.

3. Capital stock figures are based on chain-type quantity indexes for net stock of fixed capital in 2000$, year-end estimates. Source: U.S. Bureau of Economic Analysis, CD-ROM, "Fixed Reproducible Tangible Wealth of the United States, 1925-97" and the Internet [http://www.bea.gov/bea/dn/home/fixedassets.htm].

4. Research and development expenditures performed by industry include company, federal, and other sources of funds. Company-financed R&D performed outside the company is excluded. Industry series on R&D and full-time equivalent scientists and engineers engaged in R&D per full-time equivalent employee run from 1957 to 1997. Source: National Science Foundation, Internet. For technical details, see National Science Foundation, *Research and Development in Industry*, (Arlington, VA: National Science Foundation), NSF96-304, 1996; and the Internet [http://www.nsf.gov/sbe/srs/nsf01305/htmstart.htm].

5. Total factor productivity growth (TFPGRTH) for sector j is defined as:

$$TFPGRTH_j \equiv \pi_j = Y^*_j - \alpha_j L^*_j - (1 - \alpha_j)K^*_j,$$

where Y^*_j is the annual rate of output growth, L^*_j is the annual growth in labor input, and K^*_j is the annual growth in capital input in sector j, and α_j is the average share of employee compensation in GDP over the period in sector j (the Tornqvist-Divisia index). I measure the labor input using Persons Engaged in Production (PEP) and the capital input by the fixed non-residential net capital stock (1992 dollars).

Table 1. Total Factor Productivity (TFP) and Labor Productivity (LP) Growth by Major Sector, 1950-2003
(Average annual growth in percentage points)

Sector or Industry	Total Factor Productivity Growth 1950-60	1960-70	1970-80	1980-90	1990-00	1950-00	1995-03	Labor Productivity Growth 1950-60	1960-70	1970-80	1980-90	1990-00	1950-00	1995-03
A. Goods Industries														
Agriculture, forestry, and Fisheries	0.41	-0.59	-1.62	3.76	2.44	0.88	5.68	4.06	3.82	0.54	3.35	1.97	2.75	9.57
Mining	0.42	2.19	-3.51	-1.32	0.70	-0.30	-2.87	5.42	4.92	-4.46	2.20	2.27	2.07	-1.56
Construction	3.99	-2.40	-3.86	0.90	-2.07	-0.69	-2.58	4.67	-1.50	-3.51	-0.06	-1.03	-0.29	-1.53
Manufacturing	1.35	1.63	1.44	3.90	2.62	2.19	3.82	2.11	2.52	2.34	4.57	3.44	3.00	5.09
B. Standardized Services														
Transportation	1.20	2.99	0.24	2.30	2.38	1.82	1.87	1.37	2.96	0.19	1.70	2.13	1.67	2.32
Communications	2.76	2.50	2.63	1.78	2.68	2.47	2.16	5.51	4.63	5.12	4.02	4.46	4.75	4.42
Electric, gas, & sanitation	4.39	2.86	2.07	1.91	1.44	2.53	2.48	6.84	4.45	2.97	2.54	2.74	3.91	7.48
C. Hybrid Services														
Wholesale and retail trade and food services	0.82	0.68	-0.84	1.31	2.60	0.91	3.58	1.51	2.29	0.03	2.33	3.41	1.92	4.72
Finance, insurance, and real Estate	1.06	-0.52	-0.06	-2.19	1.12	-0.12	1.06	1.94	1.32	-0.03	0.16	2.33	1.14	1.77
D. Customized Services														
Accommodations, recreation, and personal services	0.34	1.19	0.49	0.52	-1.03	0.30	-0.75	2.08	2.91	1.35	0.49	-1.12	1.14	-0.31
Business services	-0.93	-1.93	0.90	-0.10	-1.32	-0.68	-3.04	-0.19	0.17	2.04	-0.79	-1.52	-0.06	-4.85
Health, education, non-profits	-0.61	0.11	-1.63	-1.60	-1.71	-1.09	0.31	1.11	0.96	-1.87	-0.98	-1.50	-0.46	1.02
Government and government Enterprises	-0.19	0.14	0.04	-0.17	-0.10	-0.06	-0.11	-0.06	0.21	0.17	0.03	0.30	0.13	0.15
Total goods	2.00	0.91	-0.20	2.72	1.65	1.42	2.36	3.35	2.08	0.77	3.15	2.07	2.28	3.35
Total services	1.05	1.19	0.66	0.62	0.70	0.84	0.95	1.63	1.67	0.60	0.74	0.96	1.12	1.33
Total economy	1.37	1.03	0.35	1.13	0.88	0.95	1.18	2.36	1.80	0.63	1.40	1.24	1.48	1.78

Note: The TFP estimates are based on Persons Employed in Production (PEP) and Net Capital Stock; and Labor Productivity on PEP.
See the Data Appendix for sources and methods and Appendix Table 1 for a detailed sector listing.

Table 2. Cognitive Skill (Substantive Complexity) Scores by Year and Sector, 1950-2000

Sector or Industry	1950	1960	1970	1980	1990	2000	Change, 1950-2000
A. Goods Industries							
Agriculture, forestry, and fisheries	3.68	3.67	3.62	3.59	3.68	2.80	-0.89
Mining	3.19	3.52	3.90	4.05	4.15	4.10	0.92
Construction	3.45	3.90	4.13	4.19	4.23	4.22	0.77
Manufacturing	3.17	3.29	3.57	3.67	3.84	4.21	1.04
B. Standardized Services							
Transportation	3.16	3.17	3.32	3.38	3.26	3.55	0.40
Communications	3.92	4.13	4.39	4.62	4.85	5.29	1.37
Electric, gas, and sanitary services	3.93	3.78	3.97	4.17	4.48	4.92	0.99
C. Hybrid Services							
Wholesale and retail trade and food services	3.98	3.85	3.82	3.94	4.05	4.15	0.17
Finance, insurance, and real estate	4.43	4.83	5.09	5.17	5.32	5.61	1.17
D. Customized Services							
Accommodations, recreation, and personal services	3.33	3.19	3.63	3.92	4.02	4.45	1.12
Business services	3.70	3.71	4.57	5.22	5.37	5.61	1.91
Health, education, and non-profits	5.56	5.14	5.05	4.97	5.02	5.07	-0.49
Government and government enterprises	4.26	4.22	4.38	4.54	4.70	4.98	0.71
Total goods	3.36	3.45	3.68	3.77	3.92	4.09	0.74
Total services	4.09	4.06	4.30	4.45	4.56	4.77	0.67
Total economy	3.75	3.81	4.07	4.23	4.38	4.61	0.87

Note: Figures for major sectors are weighted averages of individual industries within each major sector. See the Data Appendix for sources and methods and Appendix Table 1 for detailed sector listing.

Table 3. Mean Years of Education by Year and Sector, 1950-2000

Sector or Industry	1950	1960	1970	1980	1990	2000	Change, 1950-2000
A. Goods Industries							
Agriculture, forestry, and fisheries	7.67	8.43	9.69	11.21	11.69	11.73	4.05
Mining	8.59	10.03	10.96	12.18	12.75	12.63	4.05
Construction	9.19	9.86	10.64	11.78	12.30	12.00	2.80
Manufacturing	9.58	10.43	11.05	11.96	12.62	12.88	3.30
B. Standardized Services							
Transportation	9.38	10.18	10.92	11.96	12.59	12.84	3.46
Communications	11.16	11.69	12.28	12.94	13.70	14.16	3.00
Electric, gas, and sanitary services	10.27	11.11	11.26	12.30	13.06	13.57	3.30
C. Hybrid Services							
Wholesale and retail trade and food services	10.36	10.96	11.49	12.36	12.71	12.87	2.52
Finance, insurance, and real estate	11.42	12.13	12.64	13.27	13.77	14.17	2.75
D. Customized Services							
Accommodations, recreation, and personal services	9.10	9.93	10.92	12.04	12.60	13.16	4.05
Business services	11.99	12.21	12.46	13.24	13.56	14.35	2.36
Health, education, and non-profits	13.19	13.20	12.95	13.56	14.02	14.30	1.10
Government and government enterprises	11.21	11.78	12.27	13.10	13.65	14.23	3.02
Total goods	9.03	9.98	10.83	11.86	12.45	12.55	3.52
Total services	10.62	11.34	11.93	12.81	13.28	13.65	3.03
Total economy	9.91	10.81	11.55	12.51	13.07	13.41	3.50

Note: Figures for major sectors are weighted averages of individual industries within each major sector. See the Data Appendix for sources and methods and Appendix Table 1 for detailed sector listing.

Table 4. Knowledge Workers as a Percent of Total Employment by Year and Sector, 1950-2000							
Sector or Industry	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**Change, 1950-2000**
A. Goods Industries							
Agriculture, forestry, and fisheries	**0.5**	**0.9**	**2.3**	**3.4**	**3.6**	**9.4**	**8.9**
Mining	**4.5**	**7.6**	**10.5**	**12.6**	**14.8**	**13.4**	**8.9**
Construction	**4.9**	**7.2**	**7.7**	**7.6**	**10.1**	**8.5**	**3.6**
Manufacturing	**5.9**	**7.0**	**9.3**	**9.8**	**11.9**	**17.8**	**12.0**
B. Standardized Services							
Transportation	**4.2**	**4.9**	**5.1**	**5.6**	**6.2**	**8.2**	**4.0**
Communications	**9.1**	**11.1**	**13.4**	**17.4**	**21.8**	**28.9**	**19.8**
Electric, gas, and sanitary services	**9.1**	**8.4**	**9.3**	**11.3**	**14.5**	**18.6**	**9.5**
C. Hybrid Services							
Wholesale and retail trade and food services	**10.6**	**7.9**	**7.0**	**9.3**	**10.7**	**5.7**	**-5.0**
Finance, insurance, and real estate	**9.2**	**10.6**	**10.6**	**12.1**	**15.4**	**21.1**	**11.9**
D. Customized Services							
Accommodations, recreation, and personal services	**7.9**	**7.5**	**9.0**	**11.7**	**12.9**	**10.8**	**2.9**
Business services	**10.6**	**21.3**	**27.4**	**33.7**	**37.0**	**27.9**	**17.3**
Health, education, and non-profits	**15.9**	**9.0**	**9.8**	**9.6**	**10.5**	**16.0**	**0.1**
Government and government enterprises	**12.4**	**11.8**	**13.9**	**15.5**	**16.1**	**18.7**	**6.3**
Total goods	**4.2**	**6.0**	**8.4**	**8.9**	**10.8**	**14.4**	**10.2**
Total services	**10.5**	**9.5**	**10.2**	**11.9**	**13.8**	**14.6**	**4.2**
Total economy	**7.5**	**8.0**	**9.6**	**11.0**	**12.9**	**14.6**	**7.1**

Note: Figures for major sectors are weighted averages of individual industries within each major sector. See the Data Appendix for sources and methods and Appendix Table 1 for detailed sector listing.

Table 5. Dissimilarity Index (DI) of the Distribution of Occupational Employment by Major Sector, 1950-2000

Sector or Industry	1950-60	1960-70	1970-80	1980-90	1990-00	Average 1950-2000
<u>A. Goods Industries</u>	-					
Agriculture, forestry, and fisheries	0.000	0.001	0.001	0.017	0.198	0.044
Mining	0.230	0.200	0.031	0.061	0.103	0.125
Construction	0.040	0.025	0.005	0.056	0.032	0.032
Manufacturing	0.175	0.061	0.041	0.090	0.181	0.110
<u>B. Standardized Services</u>						
Transportation	0.031	0.024	0.014	0.070	0.091	0.046
Communications	0.071	0.087	0.038	0.135	0.124	0.091
Electric, gas, and sanitary services	0.080	0.169	0.053	0.127	0.089	0.104
<u>C. Hybrid Services</u>						
Wholesale and retail trade and food services	0.242	0.025	0.022	0.090	0.064	0.089
Finance, insurance, and real estate	0.151	0.117	0.022	0.082	0.153	0.105
<u>D. Customized Services</u>						
Accommodations, recreation, and personal services	0.239	0.079	0.043	0.099	0.241	0.140
Business services	0.387	0.033	0.064	0.169	0.199	0.170
Health, education, and non-profits	0.326	0.014	0.007	0.008	0.059	0.083
Government and government enterprises	0.050	0.054	0.042	0.050	0.180	0.075
Total goods	0.172	0.078	0.036	0.082	0.168	0.107
Total services	0.201	0.068	0.034	0.094	0.145	0.108
Total economy	0.183	0.074	0.035	0.087	0.160	0.108
Total economy (weighted average)[a]	0.050	0.056	0.019	0.095	0.057	0.055

Note: Figures are the unweighted average of individual industries within each major sector. See the Data Appendix for sources and methods and Appendix Table 1 for a detailed sector listing.

a. Figure based on the change in the overall occupational distribution over the period.

Table 6. Annual Investment in Equipment, Machinery, and Instruments per Persons Engaged in Production (PEP), 1950-2000
(2000$, Period Averages)

Sector or Industry	1950-60	1960-70	1970-80	1980-90	1990-00	Ratio 1990-00 to 1950-60
A. Goods Industries						
Agriculture, forestry, and fisheries	2,065	3,352	6,908	4,668	6,516	3.16
Mining	3,914	7,285	10,745	14,214	20,971	5.36
Construction	1,614	1,847	1,957	1,059	2,513	1.56
Manufacturing	1,658	2,183	2,973	3,564	7,175	4.33
B. Standardized Services						
Transportation	3,565	5,250	6,894	6,031	9,691	2.72
Communications	4,266	8,265	12,889	18,549	33,463	7.84
Electric, gas, and sanitary services	10,208	11,825	20,643	27,268	28,929	2.83
C. Hybrid Services						
Wholesale and retail trade and food services	606	879	1,217	1,582	2,453	4.05
Finance, insurance, and real estate	2,473	2,778	3,980	6,856	12,871	5.20
D. Customized Services						
Accommodations, recreation, and personal services	751	1,303	2,247	2,092	1,449	1.93
Business services	631	982	1,553	867	4,813	7.63
Health, education, and non-profits	600	556	599	750	2,401	4.00
Government and government enterprises	– –	– –	– –	– –	– –	– –
Total goods	1,812	2,436	3,472	3,495	6,246	3.45
Total services (except government)	1,057	1,368	1,922	2,281	4,971	4.70
Total economy (except government)	1,372	1,758	2,429	2,623	5,279	3.85

Note: data on equipment investment are not available for the government sector. In 1990-2000, figures also include software. See the Data Appendix for sources and methods and Appendix Table 1 for a detailed sector listing.

Table 7. Annual Investment in Office, Computing, and Accounting Equipment (OCA) per Persons Engaged in Production (PEP), 1950-2000
(2000$, Period Averages)

Sector or Industry	1950-60	1960-70	1970-80	1980-90	1990-00	Ratio 1990-00 to 1950-60
A. Goods Industries						
Agriculture, forestry, and fisheries	0.0	0.1	0.6	1.5	29.7	1295.9
Mining	4.5	9.0	16.7	123.1	507.5	113.2
Construction	2.1	2.2	1.8	2.4	55.0	25.8
Manufacturing	11.1	11.1	18.1	66.0	224.8	20.2
B. Standardized Services						
Transportation	13.7	11.4	9.3	22.8	268.9	19.6
Communications	15.4	13.7	16.0	89.4	1,556.5	101.3
Electric, gas, and sanitary services	14.8	13.1	17.1	196.9	598.1	40.5
C. Hybrid Services						
Wholesale and retail trade and food services	4.4	6.4	13.3	87.7	205.2	46.8
Finance, insurance, and real estate	43.9	51.0	106.3	379.4	2,007.2	45.8
D. Customized Services						
Accommodations, recreation, and personal services	3.2	2.5	4.4	40.1	68.5	21.7
Business services	9.4	6.8	9.4	70.9	465.3	49.7
Health, education, and non-profits	13.1	14.8	7.6	25.8	91.1	6.9
Government and government enterprises	– –	– –	– –	– –	– –	– –
Total goods	7.3	8.1	13.3	48.0	168.0	22.9
Total services (except government)	7.7	8.6	15.3	76.9	327.3	42.7
Total economy (except government)	7.5	8.4	14.7	68.8	288.8	38.3

Note: data on investment in OCA are not available for the government sector. OCA excludes software. See the Data Appendix for sources and methods and Appendix Table 1 for detailed sector listing.

Table 8. Pooled Cross-Industry Regressions of Industry TFP Growth on R&D Intensity OCA Growth, and Service Dummy Variables, 1960-2000

Independent Variables	Specification (1)		(2)		(3)	
Constant	0.017	*	0.015	*	0.019	**
	(2.53)		(2.26)		(2.69)	
Ratio of R&D Expenditures to Sales	0.147	#	0.157	#	0.162	*
	(1.81)		(1.93)		(1.99)	
Annual Growth In OCA	-0.025		-0.014		-0.022	
	(0.93)		(0.45)		(0.69)	
Dummy Variable for Standardized Services	0.004		0.001		0.007	
	(0.55)		(0.15)		(0.70)	
Dummy Variable for Hybrid Services	-0.016	*	-0.016	*	-0.011	
	(2.41)		(1.47)		(0.89)	
Dummy Variable for Customized Services	-0.020	**	-0.013		-0.008	
	(3.56)		(1.60)		(1.00)	
Interaction effect between OCA Growth and Standardized Services Dummy			0.033		0.078	
			(0.49)		(1.00)	
Interaction effect between OCA Growth and Hybrid Services Dummy			0.004		0.028	
			(0.05)		(0.31)	
Interaction effect between OCA Growth and Customized Services Dummy			-0.098		-0.057	
			(1.43)		(0.75)	
Interaction effect between 1980-2000 Time Period Dummy and Standardized Services Dummy					-0.021	
					(1.30)	
Interaction effect between 1980-2000 Time Period Dummy and Hybrid Services Dummy					-0.018	
					(1.32)	
Interaction effect between 1980-2000 Time Period Dummy and Customized Services Dummy					-0.017	
					(1.33)	
R^2	0.173		0.187		0.209	
Adjusted R^2	0.131		0.129		0.135	
Standard Error	0.0257		0.0257		0.0256	
Sample Size	164		164		164	

Note: The sample consists of pooled cross-section time-series data, with observations on 44 industries in 1960-70, 1970-80, and 1980-90, and 32 industries in 1990-2000 (public administration, is excluded because of a lack of data on OCA). Time period dummies are also included for 1960-70, 1970-80, and 1980-90.
The estimation uses the White procedure for a heteroschedasticity-consistent covariance matrix. The absolute value of the t-statistic is in parentheses below the coefficient. See the Data Appendix for sources and methods
Significance levels: # - 10% level; * - 5% level; ** - 1% level.

Table 9. Cross-Industry Regressions of Industry Labor Productivity Growth
On R&D Intensity, Capital Growth, Skill Change, and Service Dummies, 1960-2000

Independent Variables	Specification (1)		(2)		(3)		(4)	
Constant	0.021	**	0.019	**	0.018	**	0.021	**
	(3.58)		(3.17)		(2.92)		(3.43)	
Ratio of R&D Expenditures to Sales	0.164	#	0.182	#	0.174	#	0.178	#
	(1.73)		(1.86)		(1.84)		(1.86)	
Growth in Total Capital Per Worker	0.328	**	0.308	**	0.301	**	0.326	**
	(3.24)		(3.08)		(2.99)		(3.20)	
Change in Substantive Complexity (SC): DELSC	-0.007				0.001			
	(0.95)				(0.11)			
Change in Mean Education: DELEDUC			0.002				-0.003	
			(0.29)				(0.48)	
Dummy Variable for Standardized Services	0.002		0.003		-0.006		-0.014	
	(0.34)		(0.35)		(0.64)		(0.83)	
Dummy Variable for Hybrid Services	-0.016	*	-0.015	*	-0.014	*	-0.019	#
	(2.41)		(2.21)		(2.11)		(1.67)	
Dummy Variable for Customized Services	-0.019	**	-0.019	**	-0.020	**	-0.028	**
	(3.27)		(3.22)		(3.13)		(2.99)	
Interaction effect between DELSC (or DELEDUC) and Standardized Services Dummy					0.050		0.028	
					(1.42)		(1.07)	
Interaction effect between DELSC (or DELEDUC) and Hybrid Services Dummy					-0.011		0.006	
					(0.69)		(0.33)	
Interaction effect between DELSC (or DELEDUC) and Customized Services Dummy					0.007		0.017	
					(0.40)		(1.29)	
R^2	0.224		0.220		0.233		0.233	
Adjusted R^2	0.179		0.175		0.173		0.172	
Standard Error	0.0251		0.0252		0.0252		0.0252	
Sample Size	164		164		164		164	

Note: The sample consists of pooled cross-section time-series data, with observations on 44 industries in 1960-70, 1970-80, and 1980-90, and 32 industries in 1990-2000 (public administration, is excluded because of a lack of data on OCA). Time period dummies are also included for 1960-70, 1970-80, and 1980-90.
The estimation uses the White procedure for a heteroschedasticity-consistent covariance matrix. The absolute value of the t-statistic is in parentheses below the coefficient. See the Data Appendix for sources and methods

Significance levels: # - 10% level; * - 5% level; ** - 1% level.

Appendix Table 1. 45-Sector Industry Classification

Industry Number	1987 SIC Codes
1. Agriculture, forestry, and fishing	01-09
2. Metal mining	10
3. Coal mining	11,12
4. Oil and gas extraction	13
5. Mining of nonmetallic minerals, except fuels	14
6. Construction	15-17
7. Food and kindred products	20
8. Tobacco products	21
9. Textile mill products	22
10. Apparel and other textile products	23
11. Lumber and wood products	24
12. Furniture and fixtures	25
13. Paper and allied products	26
14. Printing and publishing	27
15. Chemicals and allied products	28
16. Petroleum and coal products	29
17. Rubber and miscellaneous plastic products	30
18. Leather and leather products	31
19. Stone, clay, and glass products	32
20. Primary metal products	33
21. Fabricated metal products, including ordnance	34
22. Industrial machinery and equipment, exc. electrical	35
23. Electric and electronic equipment	36
24. Motor vehicles and equipment	371
25. Other transportation equipment	37 [exc. 371]
26. Instruments and related products	38
27. Miscellaneous manufactures	39
28. Transportation	40-42,44-47
29. Telephone and telegraph	481,482,484,489
30. Radio and TV broadcasting	483
31. Electric, gas, and sanitary services	49
32. Wholesale trade	50-51
33. Retail trade	52-59
34. Banking; credit and investment companies	60-62,67
35. Insurance	63-64
36. Real estate	65-66
37. Hotels, motels, and lodging places	70
38. Personal services	72
39. Business and repair services except auto	73,76
40. Auto services and repair	75
41. Amusement and recreation services	78-79
42. Health services, including hospitals	80
43. Educational services	82
44. Legal and other professional services and non-profit organizations	81,83,84,86,87,89
45. Public Administration	--