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Investing in Information Technology: Productivity Payoffs for U.S. Industries

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Although firms have invested billions of dollars in information technology to boost their productivity, many analysts continue to question whether these investments do in fact lead to productivity gains. An industry-level analysis of productivity performance provides robust evidence of a link, showing that the industries experiencing the largest productivity acceleration in the late 1990s were the producers and most intensive users of information technology.

The U.S. economy enjoyed a remarkable upsurge in the late 1990s as unemployment declined, inflation remained in check, and perhaps most important, labor productivity growth accelerated to rates not consistently seen since the 1960s. Annual labor productivity growth for the U.S. nonfarm business sector averaged 2.8 percent over the 1995-2000 period, double its average annual rate of growth for 1973-95 and just short of its 2.9 average for 1959-73. During the same period, U.S. firms made massive investments in information technology (IT), defined here to include computer hardware, computer software, and telecommunications equipment. By year-end 1999, the value of the net stock of IT capital equipment approached $900 billion.

The economy's strong performance has spurred considerable interest in the link between the U.S. productivity revival and the IT revolution. Almost all analysts agree that progress in the *production* of IT, exemplified by the continuous decline of quality-adjusted IT prices, has contributed directly to aggregate, or economy-wide, productivity gains. Some debate remains, however, about the productivity benefits from the *use* of IT. A large body of microeconomic studies and several recent papers using aggregate data conclude that IT investment and use—activities that economists refer to as "capital deepening"—have contributed to labor productivity gains. Some skeptics argue, however, that the surge in aggregate productivity owes little to IT use and can instead be traced largely to IT production and cyclical factors.[1]

This edition of *Current Issues* moves beyond the aggregate data to examine the recent productivity performance of the individual sectors and industries that make up the U.S. economy. The article investigates how productivity growth in different industries has varied over time and how the observed variation relates to IT capital accumulation. Two empirical questions are at issue: First, are U.S. productivity gains confined to a few industries or shared by many? Second, are industry productivity gains linked to the use of IT?

Analysis of the industry-level data reveals that a broad productivity resurgence took place after 1995, with all principal sectors and a majority of industries posting productivity gains. The analysis also shows that the industries experiencing the largest productivity acceleration in the late 1990s were the producers and most intensive users of IT—a finding that provides direct evidence of information technology's role in the U.S. productivity revival.

Productivity, IT, and the Economy

The questions addressed in this article have important implications for the economy. Consider first the question whether productivity gains have occurred in many industries or are concentrated in just a few. If productivity increases have been widespread, then the productivity revival is likely to be more enduring. In contrast, if the increases have been concentrated in a single sector, then the revival may be vulnerable to a slowdown in that one

sector. Moreover, if productivity increases have occurred in many industries, the resulting income and economic gains would likely be distributed across industries; if, however, productivity increases have been more localized, the economic gains could be skewed toward a few industries.

Investigating the distribution of productivity gains is also useful in evaluating the claim that the relatively narrow group of industries that produce IT equipment accounts for much of the aggregate improvement in productivity. The strong productivity performance of these industries is clear and can be seen both in the official productivity statistics and in the ability of these firms to manufacture ever more powerful IT equipment at lower and lower prices. If these firms alone have enjoyed productivity gains, however, one might conclude that the IT revolution is somewhat disappointing.

This leads to the second question addressed in this analysis: Is there empirical evidence of a link between IT use—rather than production—and productivity gains? Over the last few decades, firms have invested heavily in IT in the hope of improving profits and productivity. Potential gains from IT could be realized through a number of channels. Improved information flows within firms contribute to more efficient organizations; better inventory management helps to prevent factory downtime and increases product availability to consumers; low-priced IT systems—for example, automated payrolls or account management systems—reduce the reliance on high-skilled labor.[2]

Several recent studies have concluded that both IT production and IT use are driving the aggregate U.S. productivity revival.[3] If IT use really leads to productivity gains, one would expect to see a link between IT investment and productivity gains across industries. Such a link would allow individual industries and the economy as a whole to produce more output and implies a real economic benefit from the IT revolution.

Some analysts have argued, however, that these gains are not likely to be large. In this view, information technology may primarily be used to reallocate market share between competing firms (for example, when a traditional bookstore loses business to an on-line bookseller), replicate existing activities (when a retailer offers both Internet and catalogue shopping), or increase on-the-job consumption (when workers play video games or day-trade). Moreover, the substantial training and support costs that often accompany IT investment may limit output gains. Indeed, if all of these forces are large enough, one might not see any link between IT investment and productivity gains.[4]

Since actual productivity has in fact accelerated in recent years, the view that IT use has brought no real gains is buttressed by the fact that productivity is procyclical. That is, productivity tends to move with overall economic activity because of changes in resource utilization, productivity shocks, increasing returns, or reallocation effects. Consequently, part of the U.S. productivity resurgence likely reflects particularly strong output growth during the late 1990s. Disagreement exists, however, about how much of the recent productivity surge reflects improvements in the underlying trend and how much is attributable to cyclical forces.[5]

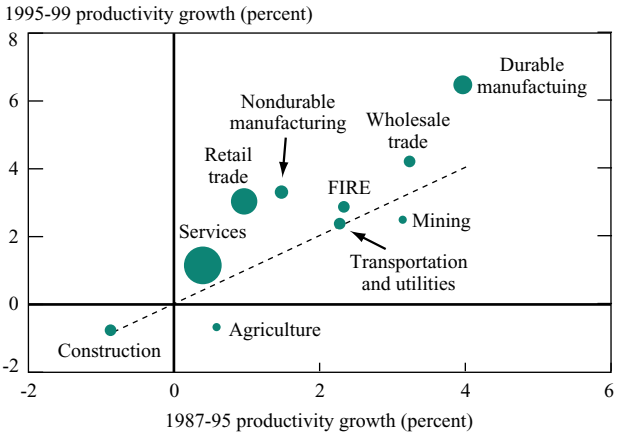
Is the Productivity Revival Widespread?

A useful way to assess the breadth of the U.S. productivity revival is to examine the productivity performance of the sectors and industries that make up the U.S. private economy. Using 1987-99 data on real gross output and full-time-equivalent workers from the Bureau of Economic Analysis (BEA), one can construct a measure of labor productivity—real gross output per full-time-equivalent worker—for ten broad sectors and their sixty-one constituent industries. The breakdown by sectors and industries follows the BEA classifications, with the exception that manufacturing is decomposed into a durable and a nondurable component.[6]

Casual examination of the aggregate productivity growth series suggests that a breakpoint occurred in 1995, so productivity growth for the earlier period (1987-95) can be compared with productivity growth for the later period (1995-99).[7] Chart 1 plots average annual productivity growth in the 1995-99 period against that in 1987-95 for the ten broad sectors that compose the private economy. Any sectors above the

Chart 1

Productivity Accelerated in Eight of Ten Broad Sectors



Sources: Bureau of Economic Analysis; author's calculations.

Notes: All estimates represent average annual growth rates of real gross output per full-time-equivalent worker. The diagonal line indicates no change in productivity growth. Sectors above the line show productivity growth acceleration; those below it show productivity growth deceleration. Sectors are weighted by their 1995 share of private employment.

diagonal line show an *acceleration* of productivity growth, while sectors below the line show a *deceleration* of productivity growth. Since these sectors vary considerably in terms of size, the chart represents each with a plot point proportional to its 1995 share of private employment.

The chart shows a broad productivity revival across virtually all of the private U.S. economy. Eight of the ten major sectors experienced accelerating productivity growth after 1995.[8] As one would expect, the durable manufacturing sector, which produces IT hardware and equipment, achieved especially impressive productivity gains after 1995, but many other sectors also showed sizable gains. In particular, relatively large sectors such as retail trade, services, nondurable manufacturing, and finance, insurance, and real estate (FIRE) showed faster productivity growth in the late 1990s. The two sectors that experienced a deceleration, agriculture and mining, are relatively small, accounting for just 2.9 percent of private output in 1999.

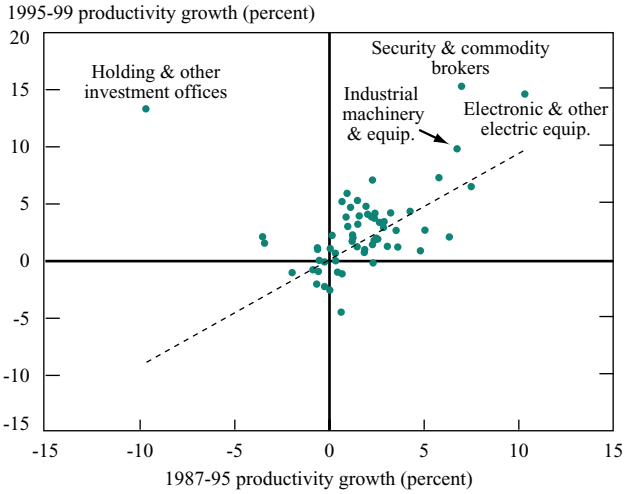
The change in the average productivity growth rates from the earlier to the later period differs considerably across sectors, ranging from -1.25 percentage points in agriculture to 2.50 percentage points in durable goods manufacturing. This finding suggests that looking only at aggregate data may obscure important differences within the economy.

The data on productivity growth in individual industries yield findings similar to the sectoral productivity results. Chart 2 plots average annual productivity growth rates for the sixty-one industries in the BEA classification for the same periods as in Chart 1. Again, productivity gains appear widespread, with thirty-eight of the sixty-one industries showing faster productivity growth in the 1995-99 period than in the 1987-95 period. For the sixty-one industries, the mean increase in productivity growth was 1.09 percentage points; the median acceleration was 0.60.[9]

Two IT-producing industries—industrial machinery and equipment, which includes the manufacture of computer hardware, and electronic and other electric equipment, which includes the production of semiconductors and telecommunications equipment—showed exceptional gains. These gains are largely attributable to the rapid technological advances that are driving the IT revolution. In addition, two finance-related industries—security and commodity brokers and holding and other investment offices—experienced a sharp acceleration in productivity growth. The large gains recorded for these industries may be an artifact of how the BEA measures output, and therefore productivity, in these industries.[10]

Note that, for several reasons, the data in Charts 1 and 2 have not been adjusted for cyclical effects. First,

Chart 2
Productivity Accelerated in a Majority of Industries



Sources: Bureau of Economic Analysis; author's calculations.

Notes: All estimates represent average annual growth rates of real gross output per full-time-equivalent worker. The diagonal line indicates no change in productivity growth. Industries above the line show productivity growth acceleration; those below it show productivity growth deceleration.

it is quite difficult to differentiate trend from cycle without observing a full business cycle. Second, each industry is likely to have different cyclical properties, so any attempt to control for these effects could introduce considerable noise from an imperfect adjustment procedure. Third, the recent productivity revival appears somewhat different from its predecessors, so it may be inappropriate to apply adjustments based on historical relationships to the current period. For example, most of the postwar productivity revivals have occurred as the economy exited recession, while the current period of rising productivity growth began very deep into the economic expansion.[11]

Overall, the results presented thus far point to a broad productivity revival in the late 1990s that encompassed most industries and sectors in the private economy. While the analysis does not establish whether the productivity gains should be attributed to cyclical forces or to the changes in the underlying trend, it demonstrates that the recent productivity revival is not limited to a few industries that produce IT or other durable goods.

Is the Productivity Revival Linked to IT?

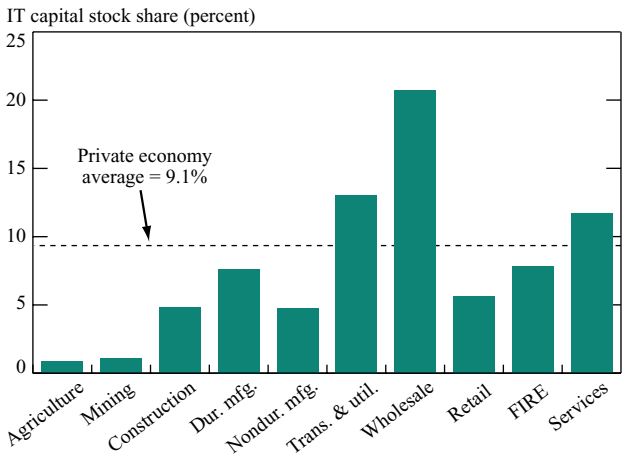
The second question addressed in this analysis is whether the broad productivity revival is linked to the massive investment in IT. From 1996 to 2000, U.S. firms spent nearly $2 trillion on IT hardware and software in pursuit of increased efficiency, higher productivity, and stronger profits. The potential benefits from IT investment vary enormously, however, across sectors

and industries. For example, IT may be a very valuable tool in a financial firm, but it is likely to have fewer applications on a farm. Thus, a natural first step in seeking a link between productivity gains and IT is to assess the intensity of IT use in different parts of the economy.

Chart 3 plots IT intensity, measured as the current dollar share of IT capital in total reproducible, nonresidential assets, for each of the ten major sectors in 1999.[12] As with the sectoral productivity data, considerable variation is evident in IT intensity across sectors. In wholesale trade, 20.7 percent of the value of the capital stock was in IT assets in 1999, while agriculture had only a 0.9 percent share. Other IT-intensive sectors were the transportation and public utilities sector, which includes communications industries (13.0 percent); services (11.7 percent); FIRE (7.8 percent); and durable manufacturing (7.6 percent).

Even more pronounced differences in IT use emerged across industries. Chart 4 plots the distribution of IT capital shares in 1999.[13] The average capital share was 8.9 percent and the median was 4.8 percent, with a range from 0.4 percent (farms) to 38.6 percent (telephone and telegraph). Other industries with a significant share of their capital stock in IT assets include radio and television (34.0 percent), transportation services (30.1 percent), business services (29.7 percent), nondepository institutions (27.8 percent), legal services (23.5 percent), motion pictures (22.9 percent), and wholesale trade (20.7 percent). These industries with IT capital shares above 20 percent attest to the rapid accumulation of IT in industries where this technology has many useful applications.

Chart 3
Sectors Varied Markedly in Intensity of IT Use in 1999



Sources: Herman (2000); author's calculations.

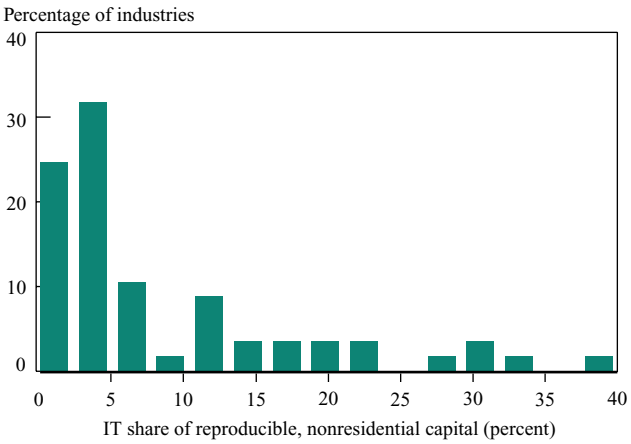
Note: The IT capital stock share is defined as the 1999 current-dollar IT capital stock as a percentage of the reproducible, nonresidential capital stock.

One can take advantage of this wide variation in IT intensity to assess the impact of IT use on productivity. If IT accumulation does indeed contribute to productivity, one would expect the most intensive users to show the largest productivity gains. In contrast, if the U.S. productivity revival is not an IT phenomenon, industry-level productivity gains would likely be independent of IT accumulation.

Before the analysis proceeds, however, two important issues must be considered. First, how should IT intensity be defined? A useful definition is the one introduced above, namely, the share of IT capital stock in the reproducible capital stock, because it captures the investment resources allocated toward these high-tech assets. Second, how can one control for potential reverse causality? Although a link between IT and productivity growth could reflect the fact that IT contributes to productivity, the causality could also run the other way, because industries with strong productivity growth might make large investments in IT. One way to resolve this problem is to compare IT intensity with subsequent productivity growth—for example, by comparing IT intensity in 1995 with productivity growth in 1995-99. While this is not a perfect control if firms have serially correlated productivity shocks or make investment decisions today in anticipation of future productivity shocks, it does lessen the endogeneity concern.[14]

To test for a link between productivity and IT production and use, one can compare the change in average productivity growth from 1987-95 to 1995-99 for three sets of industries: industries that produce IT, industries that use IT intensively, and other industries (see table). As mentioned earlier, fundamental technological progress has enabled the IT-producing industries—industrial machinery and equipment and electronic and

Chart 4
Industry IT Capital Shares Ranged Widely in 1999



Sources: Herman (2000); author's calculations.

other electric equipment—to achieve very strong productivity gains, so it makes sense to isolate these industries. IT-intensive industries are then defined as other industries with an IT capital stock share above the 1995 median of 3.8 percent; the third category consists of all remaining industries.

The two IT-producing industries show a mean productivity acceleration of 3.7 percentage points, while the twenty-six IT-intensive industries show a mean productivity acceleration of 2.0 percentage points. In sharp contrast, productivity gains for the other twenty-nine industries averaged only 0.4 percentage point. When the industries are weighted by their relative size to better represent the economic impact of each industry, the results are similar.[15] The IT-producing industries show a gain of 3.7 percentage points, the IT-intensive industries a gain of 1.4 percentage points, and the other industries a gain of only 0.1 percentage point. These results suggest an important link between IT use and productivity gains.

Two caveats, however, are in order. First, one can argue that cyclical factors are imperfectly controlled for in this type of analysis. Since some of the recent productivity acceleration is undoubtedly a result of strong output growth, there is some merit to this claim. Given the wide variation in productivity that appears to be linked with lagged IT intensity, however, IT use likely plays an important role. Second, IT intensity in this analysis is defined by investment in computer hardware, computer software, and telecommunications equipment. Yet there is much more to the IT revolution. Semiconductors, for example, are now routinely embedded in many other types of goods, from numerically controlled machine tools to coffee makers. In addition, the data on IT use do not specifically account for complementary innovations such as the organizational restructuring or skill changes that often accompany IT investment. Thus, to the extent that other factors are correlated with IT investment, the IT capital share should be thought of as an indicator for all of the changes that accompany the IT revolution rather than the precise impact of IT capital alone.

IT Producers and Users Show Largest Productivity Gains

	Number of Industries	Average Annual Productivity Growth (Percent) 1987-95	1995-99	Change
Unweighted averages				
IT-producing industries	2	8.53	12.22	3.69
IT-intensive industries	26	1.18	3.16	1.99
Other industries	29	1.87	2.30	0.43
Weighted averages				
IT-producing industries	2	8.24	11.90	3.66
IT-intensive industries	26	1.24	2.61	1.37
Other industries	29	0.98	1.11	0.13

Source: Author's calculations.

Notes: Unweighted values for each group of industries are calculated as the mean of the industries' annual productivity growth rates for each period. Weighted estimates use the share of private employment to weight the productivity growth rates of each industry. The IT-producing industries are industrial machinery and equipment and electronic and other electric equipment. IT-intensive industries have a 1995 IT capital share above the 1995 median. Four industries are excluded because detailed capital stock data are not available.

Conclusion

The sharp acceleration of U.S. labor productivity growth and steady accumulation of computing and communication power have led many to believe that IT is a driving force behind the U.S. productivity revival. By underscoring the wide variation in both IT intensity and productivity growth across U.S. industries and by showing a link between the two, this industry-level analysis supports that view.

The analysis also suggests that the U.S. productivity revival is a real phenomenon, not just a cyclical one. Given the large differences in productivity gains between IT-intensive and other industries in the late 1990s, cyclical forces would have to be highly concentrated in precisely those industries that are most IT-intensive to qualify as the whole story. While information technology cannot explain everything about the U.S. productivity revival, the robust link between IT intensity and productivity gains suggests that there is an important economic relationship.

Notes

1. The micro studies are surveyed by Brynjolfsson and Hitt (2000). Aggregate studies that report an impact from IT use include BLS (2000), CEA (2001), Jorgenson (2001), Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Whelan (2000). IT skeptics include Gordon (1999, 2000) and Kiley (1999, 2000).

2. See Brynjolfsson and Hitt (2000) for several case study examples of IT benefits.

3. See BLS (2000), CEA (2001), Jorgenson (2001), Jorgenson and Stiroh (2000), and Oliner and Sichel (2000).

4. See Baily and Gordon (1988), Kiley (1999, 2000), and Gordon (1999, 2000) for details.

5. See CEA (2001) and Gordon (2000) for alternative estimates.

6. The data are all from the BEA's gross product originating database, described by Lum and Moyer (2000). The industries are at roughly the two-digit level as defined by the Standard Industrial Classification (SIC) system.

7. More formal econometric work in Stiroh (2001) points to a break in the aggregate productivity series in third-quarter 1995.

8. CEA (2001), Nordhaus (2000), and Stiroh (2001) also find a broad productivity revival using value-added data.

9. Econometric tests in Stiroh (2001) show that these productivity gains are statistically significant.

10. See Lum, Moyer, and Yuskavage (2000) for details on how output is measured in these industries.

11. Basu, Fernald, and Shapiro (2000) conclude that the recent productivity acceleration stems from faster technological change, not from transitory factors like factor utilization and factor accumulation.

12. These data are based on the BEA's Tangible Wealth Survey, reported in Herman (2000).

13. The distribution in Chart 4 shows the fraction of industries with IT capital shares in a given range. Note that detailed capital data are not available for four industries—social services, membership organizations, other services, and private households—so the analysis of industry IT is limited to fifty-seven industries.

14. One could also implement other timing conventions or instrumental variable techniques, as in Stiroh (2001).

15. These estimates are taken from a weighted least squares regression with dummy variables for the different means and accelerations across the three types of industries, with employment as weights.

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