Is IT Driving the U.S. Productivity Revival?

Kevin J. Stiroh*
Federal Reserve Bank of New York

The U.S. economy enjoyed a remarkable resurgence in the late 1990s. Unemployment steadily declined, inflation remained in check, and perhaps most important, labour productivity growth accelerated to rates not consistently seen since the 1960s.[1] Annual labour productivity growth for the U.S. nonfarm business sector, for example, averaged 2.5 per cent for 1995 to 1999, compared to only 1.4 per cent for 1973-95. Over the same period, U.S. firms spent massive resources on information technology (IT, defined here to include computer hardware, computer software, and telecommunications equipment), with nearly $1.2 trillion in business investment from 1996 to 1999.

Not surprisingly, there has been considerable interest in the potential linkages between the strong acceleration of U.S. labour productivity growth and the IT revolution. This research is now moving toward a consensus that both the production and the use of IT have made important contributions to the U.S. productivity revival in the late 1990s.[2] Not everyone is convinced, however, and some commentators attribute a relatively minor impact to the use of IT.[3]

This article summarizes new evidence in the IT/productivity debate that moves beneath aggregate data and examines the recent productivity performance of the industries that either produce IT, use IT, or have remained relatively isolated from the IT revolution. By examining variation in industry productivity growth over time and by exploring the connection with IT capital accumulation, one can better understand the role of IT in the U.S. productivity revival. In particular, this article reviews two specific empirical questions about recent productivity gains. First, is the U.S. productivity revival widespread in the sense that many industries are showing gains? Second, are these industry productivity gains linked to the use of IT? The answer to both questions appears to be yes.

IT and the U.S. Productivity Revival

The section reviews the two empirical questions mentioned above. First, is the U.S. productivity revival widespread or is it concentrated in relatively few industries? This question is important since it directly reflects the strength and stability of the recent productivity revival. If all

gains were concentrated in a single industry, for example, a relatively narrow slowdown could unhinge the entire productivity revival. Moreover, some have claimed that most of the U.S. productivity revival can be traced to the industries that actually produce IT, implying relatively little gains from the rest of the economy that uses IT. Finally, the breadth of the productivity revival has implications for the distribution of income and economic gains.

Second, can these industry productivity gains be linked to the use of IT? By quantifying the productivity gains associated with IT use, this sheds light on the returns to the massive IT investment by U.S. firms. For example, if IT mostly reallocates market share between firms, this could lead to no industry gains and no net benefit for society. On the other hand, if IT investment and use contributes to economy-wide productivity through traditional capital deepening channels or production spillovers, this enlarges the production possibility frontier for society as a whole and implies a real contribution from IT.

Is the Productivity Revival Widespread?

I first consider the breadth of the U.S. productivity revival, which is typically assumed to have begun in 1995. Casual examination of the time series data suggests this is a reasonable reading of the U.S. experience, and more formal econometric tests for an unknown break point in the aggregate productivity series suggest something structural did change around 1995, although the evidence is not overwhelming. Since industry-level productivity data are available only at an annual frequency, I use the business sector break-date and follow earlier studies by identifying year-end 1995 as the beginning of the productivity revival in the U.S.

Table 1 presents summary statistics for productivity growth for 1995-99 compared to the earlier period 1987-95.[4] I begin with the productivity acceleration for the business sector by comparing the average productivity growth rate for 1995-99 to 1987-95; this acceleration is about 1.4 percentage points using a value-added output concept and 1.2 percentage points using a gross output concept. These estimates are close to the official BLS productivity numbers for the nonfarm business sector, so a conclusion based on BEA data is comparable and not an artifact of this data.

Table 1 then breaks down the economy into 10 broad sectors, where I follow the BEA's sectoral breakdown of the economy except that manufacturing is split into distinct durable and nondurable sectors, and reports productivity gains for each sector. Productivity acceleration varies considerably across sectors, ranging from -1.25 percentage point in agriculture to 2.50 percentage points in durable goods manufacturing when 1995-99 is compared to 1987-95.

These sectoral estimates point to a broad productivity revival across most sectors of the U.S. economy. While it is clear that the durable goods sector, which produces much of IT hardware, showed particularly large gains in the late 1990s, it is also clear that it is not the only sector to show improvement. Eight of the ten sectors show productivity growth increases, and relatively large sectors like wholesale trade, retail trade, and services all show sizable gains. The only sectors that show a productivity deceleration, agriculture and mining, are very small.

Finally, Table 1 provides summary statistics for gross output productivity growth for 61 detailed industries that comprise these 10 sectors. Again, the data suggest a relatively broad productivity revival — the mean and median increase for 1995-99 vs. 1987-95 were 1.09 per-

centage points and 0.60 percentage point, respectively — and nearly two-thirds of individual industries reported productivity gains. Thus, the productivity revival appears relatively broad-based in the sense that the majority of the U.S. economy shows an acceleration in productivity in the late 1990s.

It is also illustrative to examine the industry-level data more directly. Figure 1 plots the average annual productivity growth rate for 1995-99 against the annual rate for 1987-95 for each of the 61 detailed industries. Points above the line indicate accelerating productivity growth, while those below it show decelerating productivity growth. The majority of industries — 38 out of 61 industries — show a productivity acceleration in the late 1990s, which again suggests a broad productivity revival. Econometric tests reveal a meaningful acceleration of productivity growth for the typical industry that is not driven by a few outliers.[5]

It is important to note that I have not attempted to cyclically adjust these data; all data are actual data as reported by BEA. This reflects the notion that the recent period is somewhat different from earlier periods of rising productivity growth. Most of the post-war episodes of productivity acceleration have occurred after economic slowdowns, while the recent revival occurred in the midst of a long economic expansion. If productivity is typically procyclical due to variable utilization and resource reallocation effects, one would expect these forces to have largely worked their way out during the nine-year expansion. Yet, productivity growth is still accelerating, suggesting different driving forces. Basu, Fernald, and Shapiro (2000), for example, conclude that the recent productivity acceleration stems from faster technological change, and not from transitory factors like factor utilization and factor accumulation.

Table 1:
The Productivity Revival is Widespread across U.S. Sectors

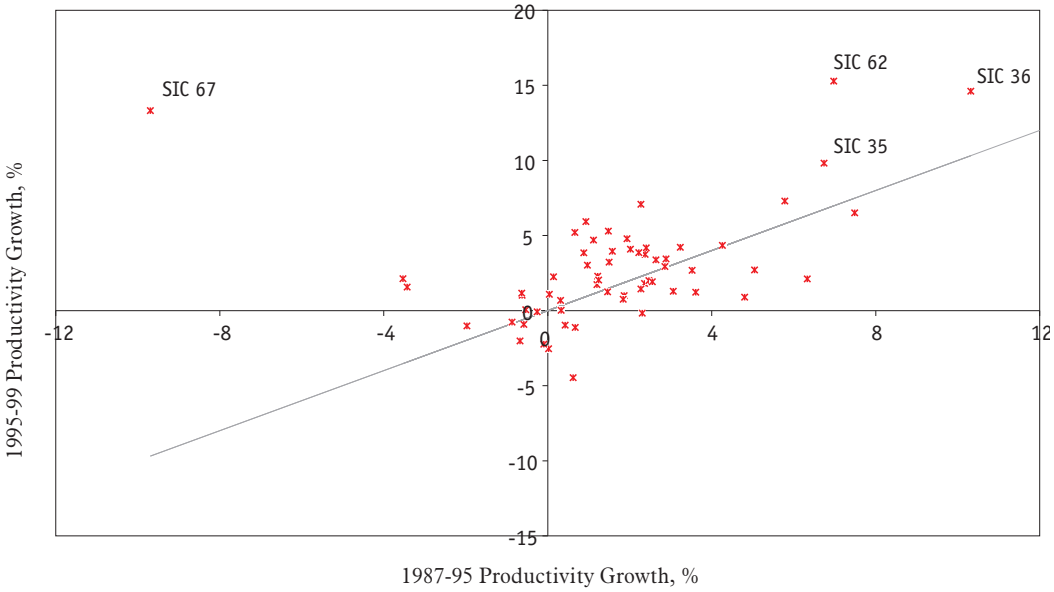
	1987-95	1995-99	Change
Aggregate Measures			
Private industries (Value-Added)	0.98	2.34	1.36
Private industries (Gross Output)	1.23	2.38	1.15
Sector Measures			
Agriculture, forestry, and fishing	0.58	-0.67	-1.25
Mining	3.14	2.50	-0.64
Construction	-0.87	-0.76	0.11
Durable goods manufacturing	3.97	6.47	2.50
Nondurable goods manufacturing	1.48	3.31	1.84
Transportation and public utilities	2.27	2.38	0.11
Wholesale trade	3.23	4.22	0.98
Retail trade	0.97	3.03	2.06
Finance, insurance, and real estate	2.33	2.88	0.54
Services	0.39	1.24	0.85
Industry Measures			
Mean - 61 Industries	1.68	2.77	1.09
Median - 61 Industries	1.50	2.10	0.60

Notes:

Productivity estimates for private industries use either real value-added or real gross output per full-time equivalent employees (FTE), and excludes the statistical discrepancy. Productivity for sectors and industry summary statistics are based on real gross output per FTE. All estimates are average annual growth rates, in percentage points. Industry means and medians are for period averages across industries.

With this caveat in mind, the industry-level data show a productivity revival that is broad-based, and not limited to a few industries that produce IT.[6] A variety of tests show significant acceleration in productivity growth for the typical industry during the late 1990s. While the question of whether these gains should be attributed to cyclical forces or the changes in the underlying trend is not addressed here, the recent productivity revival is clearly not limited to just a few industries.

Figure 1:
Most U.S. Industries Show Productivity Gains in the Late 1990s



Notes: All estimates are average annual growth in real gross output per FTE. The line is a 45 degree line — those industries above the line show productivity growth acceleration, while those below it show productivity deceleration.

Is the Productivity Revival Linked to IT?

One way to examine the impact of IT use on productivity is to examine the productivity performance of the most intensive users of IT relative to other industries. If IT accumulation contributes to faster productivity gains, then the industries that use IT most intensively should show a larger productivity acceleration. Alternatively, if the U.S. productivity revival largely reflects cyclical forces and strong aggregate demand, productivity gains would likely be independent of IT use and all industries would show comparable gains.

An important issue in this type of analysis is how to measure IT intensity, and my preferred measure is the share of IT capital services in total capital services. This indicator identifies those industries that expend a considerable portion of their tangible investment resources on IT and are reallocating their resources toward high-tech assets. Econometric results suggest that IT intensive industries experienced productivity growth about one percentage point per year faster than other industries, suggesting that IT use matters for productivity. Interestingly, non IT intensive industries show essentially no acceleration in productivity growth, while industries that invested heavily in IT in the early 1990s and increased the IT share of capital show significant productivity gains. One could argue that causality is only imperfectly controlled for in this type of analysis, but it appears that IT capital is an important part of the productivity revival across U.S. industries.

A more sophisticated econometric model that controls for other forms of input accumulation and the timing of input growth still shows a strong link between variation in IT intensity and productivity acceleration. This supports the conclusion that industries that made the largest

commitment to IT in the early 1990s experienced the largest productivity gains later on; this indicates IT capital differs substantially from other forms of purchased inputs. Of the major input classes, for example, only IT capital deepening is a consistently associated with future productivity gains. Moreover, the longer the period of lagged IT capital accumulation, the larger the productivity acceleration in the subsequent period.

One potential explanation for the timing of these productivity gains is that some lag is needed to successfully implement IT and reap the productivity payoff. This is consistent with the firm-level evidence in Brynjolfsson and Hitt (2000b) and Kiley (2000) that emphasize adjustment costs, learning lags, and delays in complementary innovations. An alternative interpretation that downplays the direct impact of IT is that firms may simply be investing in IT in anticipation of future productivity gains. This interpretation, however, implies that firms utilize information about expected future gains only with respect to the IT investment decision and not other types of inputs.

A final way to examine the productive impact of IT is to estimate industry-level production functions that explicitly account for the heterogeneity of capital inputs. Despite well-known econometric problems, e.g., simultaneity and omitted variables, this approach has a long history in economics in general, and in the IT literature in particular.[7] Production function estimates using this industry-level data are largely reasonable and suggest an important role for IT capital as a source of productivity. This is again consistent with the earlier results that found IT intensive industries experienced relatively large productivity gains and that IT investment leads productivity growth.

Taken together, these results provide strong evidence that IT capital is quite productive and complements the aggregate studies that attribute an important role for IT capital in the U.S. productivity revival. If IT investment does in fact yield productivity gains with some lag, this suggests continued productivity gains for the U.S. economy since IT investment was quite strong in recent years.

Conclusions

The U.S. economy experienced a sharp acceleration of labour productivity growth in recent years and many analysts have pointed to IT related forces as an important part of the story. The results reviewed in this article strengthen that view by showing a strong link between IT capital accumulation and productivity growth across U.S. industries. Industries that made the largest IT investments in the early 1990s show larger productivity gains in the late 1990s and production function estimates show a relatively large elasticity of IT capital. While IT is not responsible for the entire productivity revival in the United States these results indicate that IT capital accumulation is important for business output and productivity gains.

The evidence that links IT to productivity also provides support for the idea that the U.S. productivity revival is a real phenomenon and not only a cyclical one. Given the substantial differences in productivity growth between IT intensive and other industries, cyclical forces would have to be highly concentrated in precisely those industries that are most IT intensive for this to be the whole story. The strong and robust correlation between IT intensity and productivity acceleration, however, implies that there is a deeper relationship between IT investment and productivity growth.

Notes

* This article summarizes the research paper "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?," Federal Reserve Bank of New York Staff Report, #95. Stiroh is a Senior Economist at the Federal Reserve Bank of New York. Phone: (212) 720-6633; email: kevin.stiroh @ny.frb.org, and the paper is available at http://www.ny.frb.org/rmaghome/staff_rp/2001/2001.html. The views expressed in this paper are the author's only and do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System.

1 This article focuses on labour productivity, defined as output per hour worked.

2 See, for example, Bureau of Labour Statistics (2000a, 2000b), Council of Economic Advisors (2001), Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Whelan (2000a). In addition, many "new economy" proponents have argued that the combination of information technology, globalization, and deregulation is driving the U.S. economy.

3 See, for example, Gordon (1999, 2000) and Kiley (1996, 2000).

4 The data is all from the U.S. Bureau of Economic Analysis (BEA) GPO database described by Lum and Moyer (2000). These period endpoints are chosen since comprehensive data for all industries begins in 1987 and 1995 is a reasonable starting point for the U.S. productivity revival, as discussed above.

5 Four industries stand out. Two of these are high-tech producing industries (industrial machinery and equipment (SIC #35), and electric and other electronic equipment (SIC #36)) and two are finance-related (security and commodity brokers (SIC #62), and holding and other investment offices (SIC #67)). The high-tech industries show exceptional gains due to the fundamental technological advances in the production of IT, while the exceptional finance-related gains may be an artifact of how output, and therefore productivity, are measured in those industries.

6 Looking at value-added productivity, Nordhaus (2001) also concludes that the U.S. productivity revival is not narrowly focused in a few sectors that produce IT.

7 Brynjolffson and Yang (1996) and Brynjolfsson and Hitt (2000a) survey this IT related literature.

References

Basu, Susanto, John G. Fernald, Matthew D. Shapiro (2000) "Productivity Growth in the 1990s: Technology, Utilization, or Adjustment?" Manuscript prepared for the Carnegie-Rochester Conference, November 7.

Bureau of Labor Statistics (2000a) "Multifactor Productivity Trends, 1998." USDL 00-267. September 21.

—— (2000b) "Productivity and Costs, Third Quarter 2000," USDL 00-319. November 2.

Brynjolfsson, Erik and Lorin Hitt (2000a) "Beyond Computation: Information Technology, Organizational Transformation and Business Practices," *Journal of Economic Perspectives*, Vol. 14, No. 4, Fall, pp. 23-48.

—— (2000b) "Estimating the Contribution of Computers to Productivity Growth," Manuscript, February.

Brynjolfsson, Erik and Shinkyu Yang (1996) "Information Technology and Productivity: A Review of the Literature," *Advances in Computers*, February, Vol. 43, pp. 179-214.

Council of Economic Advisors (2001) "Annual Report of the Council of Economic Advisors," in the Economic Report of the President, January.

Gordon, Robert J (1999) "Has the 'New Economy' Rendered the Productivity Slowdown Obsolete?" Manuscript, Northwestern University, June 12.

—— (2000) "Does the 'New Economy' Measure Up to the Great Inventions of the Past?" *Journal of Economic Perspectives*, 14(4), Fall, pp. 49-74.

Jorgenson, Dale W. and Stiroh, Kevin J. (2000) "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, 1, pp. 125-211.

Kiley, Michael T. (1996) "Computers and Growth with Costs of Adjustment: Will the Future Look Like the Past?" Federal Reserve Board, Finance and Economics Discussion Series Paper, 1996-36, July.

—— (2000) "Computers and Growth with Frictions: Aggregate and Disaggregate Evidence," Federal Reserve Board, Mimeo, October.

Lum, Sherlene K.S. and Brian C. Moyer (2000) "Gross Product by Industry 1997-99," *Survey of Current Business*, December, pp. 24-35.

Nordhaus, William D. (2001) "Productivity Growth and the New Economy," NBER Working Paper Number 8096, January.

Oliner, Stephen D. and Daniel E. Sichel (2000) "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives*, Vol. 14, No. 4, Fall, pp. 3-22.

Whelan, Karl (2000a) "Computers, Obsolescence, and Productivity," Federal Reserve Board, Finance and Economics Discussion Series, 2000-06, January.