Has there been a structural improvement in US productivity?

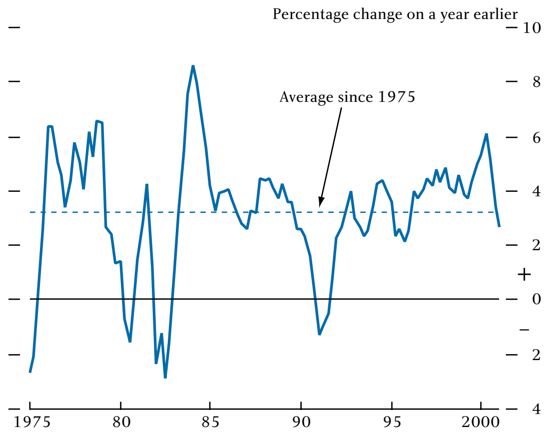
By Stuart Berry of the Bank's International Economic Analysis Division and David England of the Bank's Monetary Assessment and Strategy Division.

Annual labour productivity growth in the United States has averaged 2.8% a year since 1996, compared with an average rate of 1.6% during the preceding 25 years. This marked increase in productivity growth has been a key component of what many commentators have suggested is a 'new economy'. Given the US slowdown since the second half of 2000, a key question is the extent to which these gains reflect structural improvements, rather than cyclical factors. The evidence so far points towards a large role for structural improvements in productivity. If these gains prove to be more cyclical, however, this would have important implications for corporate performance, financial markets and, ultimately, output and inflation.

Recent developments

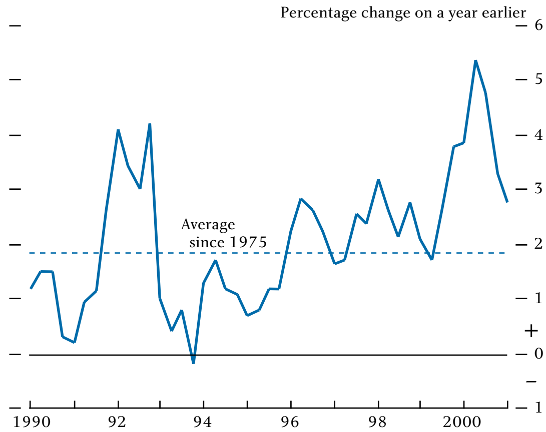
During the past five years, US GDP has grown at an average annual rate of 4.3%, significantly faster than over the preceding 20 years (see Chart 1). At the same time, inflation has remained subdued, suggesting that the supply capacity of the US economy has increased during this period. That has partly reflected strong growth in employment; unemployment has fallen to its lowest level since 1970. But rising levels of labour utilisation so far into a period of expansion are often associated with declining rates of labour productivity growth. In contrast, the past five years have seen a marked pick-up of US labour productivity growth (see Chart 2) so that labour productivity(1) rose in 2000 as a whole by 4.3%, its highest year-on-year growth rate since 1983. Productivity growth has eased somewhat, as GDP growth has slowed in recent quarters and was flat in 2001 Q1. A key issue for the US outlook is the extent to which there has been a structural improvement in US productivity performance.

Chart 1
US GDP growth



Source: Bureau of Economic Analysis.

Chart 2
US labour productivity



Source: Bureau of Labour Statistics.

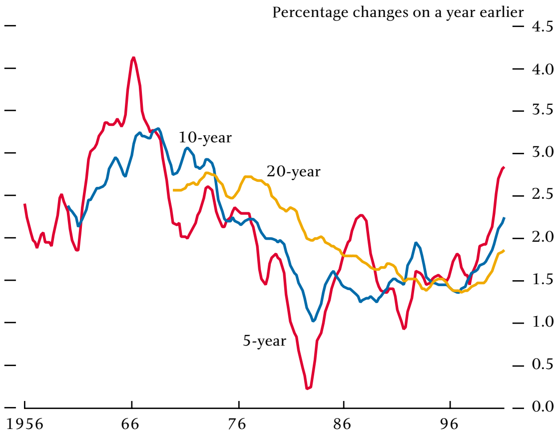
US labour productivity in a historical context

It is useful to start by examining US productivity growth over a longer period. One way of illustrating the recent improvement in productivity growth is to look at historical rolling moving averages of the growth rate over 5, 10 and 20-year windows since 1950. Until recently, these longer-term average growth rates were not unusually strong by historical standards. But the past two years show a different picture. For the 5-year and 10-year measures, the rolling trend of US labour

(1) Measured in terms of hourly non-farm business sector output.

productivity growth is now at its highest rate since the 1970s (see Chart 3).

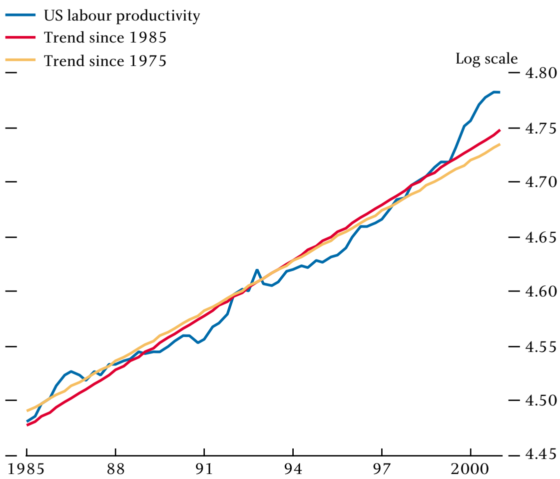
Chart 3
Rolling trend of US productivity growth



Source: Bureau of Labour Statistics.

Another way of illustrating the change in the behaviour of US productivity is to examine its level relative to some estimate of the trend. There are various ways of doing this: one simple method is to estimate a time trend, though this measure will be sensitive to the length of estimation period. Chart 4 shows that in recent years, US productivity has risen well above its recent trend, if that trend is measured since 1975 or since 1985.(1)

Chart 4
US labour productivity(a)



Source: Bureau of Labour Statistics.

(a) Measured as non-farm private business output per hour worked.

A decomposition of US labour productivity growth

An analysis of labour productivity alone would not identify the influence on labour productivity of capital intensity, ie the amount of capital available to workers. One way of assessing the contribution of capital to labour productivity is to use total factor productivity analysis, otherwise known as growth accounting. By assuming that output is a function of a combination of labour and capital inputs, it is possible to decompose output growth into three components:

- growth in labour inputs (measured by employment in hours);
- growth in the total capital stock; and
- a residual.

The residual reflects those increases in output that cannot be attributed to increases in inputs. Movements in the residual can arise from a variety of sources, some of which are temporary, such as cyclical changes in factor utilisation, and others which are permanent, such as technological advances that permit more efficient production techniques. The residual is usually referred to as total factor productivity (TFP), although some factors included within this component, such as cyclical factor utilisation, are distinct from the theoretical concept of TFP, which would generally include only the permanent factors and would therefore have different implications for the economy.

The key assumption used in the growth accounting approach to the decomposition of GDP growth is that factors of production are paid their marginal product. There are also some important measurement issues, particularly those associated with the accurate measurement of the productive capital stock. A number of academics have questioned the robustness of standard measures of these variables for the purposes of growth accounting, and have developed more sophisticated techniques for calculating these series. The results of these studies are reported in the next section.

Explaining the pick-up in labour productivity growth

A number of key pieces of academic research have been published during the past year or so on the pick-up in US productivity growth, and particularly on the role of information and communications technology (ICT). A summary of their findings is presented in Table A. These studies find a significant contribution from capital deepening (an increase in the amount of capital

(1) The time trends are estimated using a simple OLS estimation of a log-linear trend over two different sample periods, beginning in 1975 and 1985.

Table A
United States: sources of the acceleration in labour productivity, 1972–99[(a)]

	Jorgenson and Stiroh 1990–95/1995–98	Oliner and Sichel 1991–95/1996–99	Whelan 1974–95/1996–98	Gordon 1972–95/1995–99
	Study 1	Study 2	Study 3	Study 4
Acceleration in labour productivity	1.0	1.0	1.0	0.8 (b)
Of which:				
Capital deepening	0.5	0.5	n.a.	0.3
IT capital	0.3	0.5	0.5	n.a.
Other capital	0.2	0.0	n.a.	n.a.
Labour quality	-0.1	-0.1	n.a.	0.1
TFP	0.6	0.7	n.a.	0.3
IT production	0.2	0.4	0.3	0.3
Other	0.4	0.3	n.a.	0.0
Other factors	n.a.	n.a.	0.3	0.1 (c)
Memorandum:				
Per cent of acceleration in labour productivity related to IT	50	68	73	n.a.

n.a. = not available.

Sources: Study 1: Jorgenson and Stiroh (2000); Study 2: Oliner and Sichel (2000); Study 3: Whelan (2000); Study 4: Gordon (2000).

(a) In percentage point changes to average annual growth.
(b) Structural acceleration in labour productivity, which eliminates the increases associated with cyclical effects.
(c) Includes contribution of price measurement changes.

available to each worker), suggesting that strong investment, particularly in ICT capital, has raised the annual rate of growth of labour productivity by up to half a percentage point in recent years. But generally they find that the rise in TFP growth has explained a slightly larger part of the rise in labour productivity growth. For example, Oliner and Sichel find that capital deepening has contributed 0.5 percentage points to the 1.0 percentage point increase in annual labour productivity growth during the second half of the 1990s, while TFP growth has contributed 0.7 percentage points (the residual being largely a deterioration in labour quality). And Jorgenson and Stiroh find broadly similar effects.[(1)]

These studies all use essentially the same framework—the growth accounting methodology described earlier—but use different methods to estimate the capital stock. These techniques lead to different results at the aggregate level than using standard capital stock measures. They also allow the identification of the contribution from ICT to both capital deepening and, through ICT production, to TFP growth. In general, the studies find that ICT has accounted for at least half of the acceleration in labour productivity in the second half of the 1990s.

In particular, two factors related to capturing accurately changes in the stock of productive capital raise the contribution from capital (and the ICT component in particular), as measured in these studies, compared with using the standard wealth estimates.

A key measurement issue relates to the weights attached to different capital assets in calculating the total capital stock. The fact that prices for ICT equipment have been falling rapidly, together with shorter service lives, means that owners of these assets require a larger rental income in order to offset the loss in value. Hence, using the more appropriate rental values as measures of the marginal product of ICT assets leads to a higher weight within the overall capital stock. Given that the stock of ICT assets has risen very rapidly in recent years, this boosts the growth rate of the overall stock, and leads to a larger contribution from capital deepening to overall labour productivity growth.

The choice of depreciation profile is also important for the calculation of capital stocks. Wealth stocks are based on the current market, or replacement, value of assets, rather than their ability to produce. The value of assets will generally fall over time due to their lower remaining service life and the reduced income stream from the asset. For ICT goods, however, the equipment may remain almost fully productive until near the end of its service life. This is because the decline in value is more likely to reflect obsolescence (when more advanced products become available and replace the older equipment) than physical depreciation. As a result, depreciation profiles used in wealth estimates, which

(1) A more recent study by the Council of Economic Advisers (2001) finds a much larger contribution from TFP growth outside the IT sector. However, this study includes data for 2000 and because of the very strong growth of labour productivity in 2000 there is a larger increase to explain. It appears that neither capital deepening nor TFP growth in the ICT sector can account for the further acceleration in productivity, and so the increase in TFP in other industries is much greater.

often assume rapid depreciation early in an asset's life, may be inappropriate for ICT assets. Given the high levels of investment in ICT assets in recent years, using a less front-loaded depreciation profile for ICT assets would raise measures of both the level and the growth rate of the capital stock. Further, Whelan (2000) assumes that support costs associated with running ICT equipment reduce their service lives relative to standard measures, by allowing replacement to become profitable at an earlier stage. That would raise the contribution from ICT capital, but it does not lead to different results from, for example, Oliner and Sichel, because such effects are picked up within the assets' depreciation profile.

Whelan (2000) finds that allowing for such factors leads to a larger estimate of the productive capital stock than wealth-based estimates. Although the growth rates of the ICT component of the two series are found to be similar, the higher level of fast-growing ICT assets increases the growth contribution from capital deepening. Oliner and Sichel (2000) allow for some reduction in productive ability over time through, for example, reduced compatibility with the latest software, and this slightly reduces their estimated growth contribution of capital deepening.

Jorgenson and Stiroh (2000) find a slightly smaller growth contribution from ICT-related capital deepening than the other studies. But that reflects the wider definition of the sectors included in their analysis. All these studies exclude the government sector, but only Jorgenson and Stiroh include the flow of income from consumer durables and owner-occupied housing within their measures of private sector output and the stock of these assets in the capital stock. Because of their broader coverage of the economy, ICT has a smaller share, and therefore contributes a smaller amount to overall capital deepening.

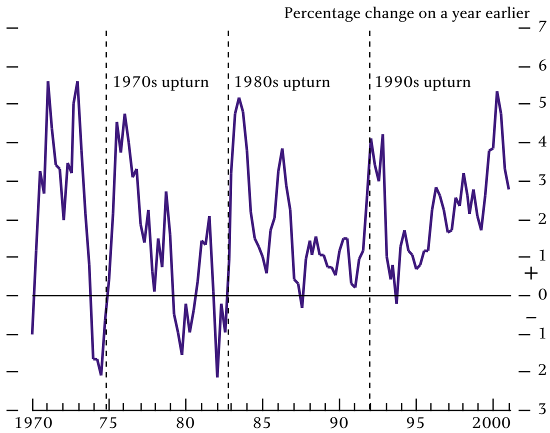
One common factor in these studies is that they all adjust for changes in labour quality, which might otherwise be picked up by the TFP term. However, this is estimated to have had little effect on productivity growth. In contrast to the other studies, Gordon (2000) focuses on the cyclical component of productivity growth (discussed later).

In the following sections, we look at the various explanations for the pick-up in productivity growth, and evaluate the evidence available from the data and from other recent work.

Cyclical factors

Productivity growth is likely to reflect both structural changes and cyclical factors. So to interpret the recent strength of productivity growth, we need to assess the normal cyclical behaviour of US labour productivity. Chart 5 shows that relative to the two previous expansions, recent US productivity growth has been unusually strong for the later stages of a cycle, particularly given the duration of the current upturn. This might suggest that the cyclical behaviour of labour productivity has changed. However, GDP growth over the most recent cycle has also been different; GDP growth has been smoother and more sustained than in the 1970s or early 1980s. Nevertheless, we might still expect that, at this late stage of the cycle, productivity growth would be falling, as firms are forced to recruit lower-quality workers to expand. In earlier cycles, similar periods of sustained above-trend productivity growth (such as in the early 1980s and late 1970s) have usually come more or less immediately after a recession. So overall there may have been some change in labour productivity growth compared with its normal cyclical pattern.

Chart 5
US non-farm business productivity



Source: Bureau of Labour Statistics.

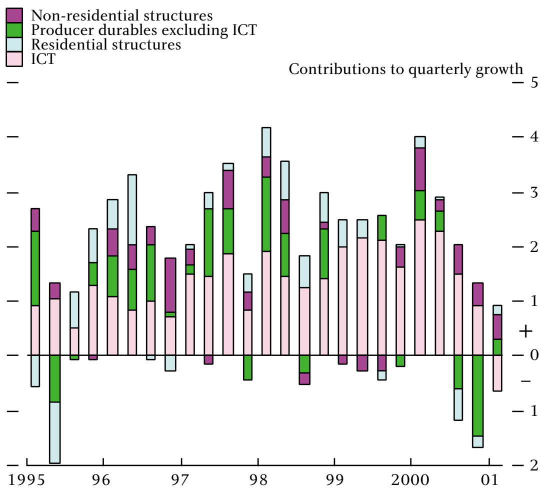
In contrast to these arguments, Gordon estimates that procyclical productivity effects lie behind much of the strength of recent productivity growth. In his recent work (Gordon (2000)), he estimates that 0.5 percentage points of the rise in annual labour productivity growth since 1996 have been due to procyclical productivity effects. In fact, after cyclical adjustment, he continues to find no evidence of an increase in structural labour productivity growth outside the durables manufacturing sector (which includes the ICT sector). And after incorporating Oliner and Sichel's estimates of capital deepening effects, he finds that structural TFP growth has fallen by 0.3 percentage points since 1995 in the non-farm private business sector outside the durables production sector.

The role of the information and communications technology (ICT) sector

(i) Investment in ICT

US investment has been substantially stronger than most models would predict during the current expansion, leading some commentators to argue that it has been investment, especially in ICT, that has increased US labour productivity. In particular, there has been a change in the composition of investment and capital growth in recent years. Chart 6 shows that investment in ICT has accounted for a large part of overall investment growth. Falls in the price of computers relative to other investment goods have led to a strong shift into ICT investment. Consistent with this, the recent studies on US productivity generally find that most of the capital deepening in recent years reflects increased ICT capital (see Table A).

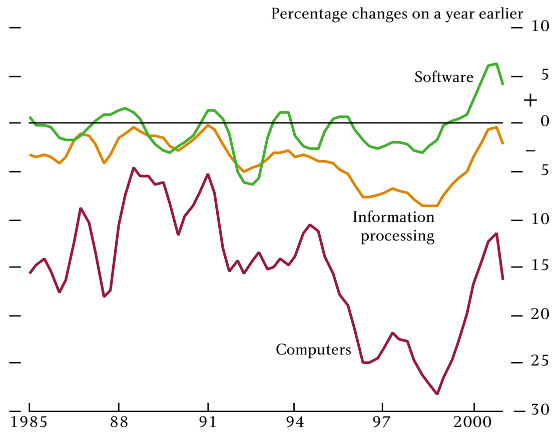
Chart 6
US investment components



Source: Bureau of Economic Analysis.

Calculations of capital deepening and TFP growth will depend on how real output and real capital are measured, an issue discussed recently by Gust and Marquez (2000). Output and investment spending data are usually collected on a nominal basis. The estimation of real measures requires the calculation of price indices, which can then be used to deflate the nominal measures to provide real (constant price) estimates. In the United States, computer prices have been calculated using 'hedonic pricing' techniques to adjust price measurement for quality changes in computers. This method attempts to quantify the quality component of a product's price by defining goods according to their characteristics and computing a quality-adjusted price based on those characteristics. In the case of computers, hedonic pricing derives a price for a bundle of computing power by estimating a relationship between the observed price and characteristics such as processor speed and memory size. With rapid increases in both these features of computers, hedonic price levels have declined rapidly (see Chart 7 for the computer price index).

Chart 7
ICT investment price inflation



Source: Bureau of Economic Analysis.

Landefeld and Grimm (2000) provide evidence that hedonic estimates are robust, and that they produce very similar price profiles to those generated by the more traditional 'matched-model' method used in some other countries. But that result requires that price changes in specific matched models are accurately tracked over time. A changing sample may mean that some quality improvements are not picked up, which could lead to an underestimate, relative to hedonic pricing, of both the real investment in and the capital stock of computers. But it is possible that the effects of quality improvements in reducing measured prices could lead to an overestimation of the productive capital stock. Although computing power has increased rapidly, certain aspects may not be fully utilised. If this is the case, then such improvements will increase the measured capital stock without increasing the true productive capacity of that stock.

(ii) TFP gains from ICT production: sectoral evidence

In contrast to Gordon's estimates, which identify a large role for cyclical factors, other studies (see Table A) find that there has been a pick-up of TFP growth both inside and outside the high-growth ICT sector. In fact, several studies find that TFP growth outside the ICT sector has contributed more to the rise in TFP growth since 1996 than the pick-up in ICT productivity growth. This reflects the small size of the ICT sector relative to the rest of the economy. In simple growth terms, the pick-up of ICT productivity has been much stronger.

This result has been used to support the view that ICT investment has finally fed through into a pick-up of economy-wide productivity growth, as might be expected if ICT was viewed as a new 'general purpose technology'. But Jorgenson and Stiroh also estimate industry-level productivity growth over the period 1958–96 and find that in many industries, TFP growth has been flat or even negative. And this result is seen in a number of industries where computer investment has been very strong—financial and other services in particular. On the basis of these results, they find that 'the new economy view that the impact of information technology is like phlogiston, an invisible substance that spills over into every kind of economic activity … is simply inconsistent with the empirical evidence'.

But there are several caveats to Jorgenson and Stiroh's results. First, they find weak or negative productivity growth in those sectors where productivity measurement problems are accepted to be at their greatest, in particular in finance, insurance and real estate services, and in the general services category. Second, they look at data up to 1996—which will largely exclude the effects of the recent upturn in productivity growth.

And they find strong productivity growth in some areas that use ICT technology intensively: in particular wholesale and retail trade, which has contributed more than any other sector to the TFP growth seen over the period of their analysis. This pattern of productivity gains could be consistent with Federal Reserve Chairman Greenspan's observation that ICT has reduced the resources required for inventory control. Data from the US Census Bureau suggest that as the overall stocks to sales ratio has declined, there has been a substantial shift in inventory holdings away from the manufacturing sector, towards centralised inventory holdings in the wholesale and retail sectors. This shift may have reduced the overall resources dedicated to inventory control, increasing productivity in both the manufacturing sector and the economy overall.

Stiroh (2001) shows that the increase in labour productivity growth in the wholesale and retail trade sectors has been particularly marked. In this more recent study, Stiroh looks at industry-level data on labour productivity growth up to 1999, and finds that the gains are broadly based and extend well beyond the ICT sector, suggesting that productivity gains do not solely reflect gains in ICT production. Further, he shows that the increase in labour productivity growth in the late 1990s for ICT-intensive industries (users rather than producers) was around 1 percentage point higher than in other industries. The correlation between ICT use and stronger productivity growth would suggest a key role for ICT investment in the pick-up in productivity growth.

(iii) Total factor productivity: firm-level evidence of ICT effects

Firm-level evidence has given more unambiguous support for a general ICT effect on productivity growth. Recent work by Brynjolfsson and Hitt (2000) applies standard growth accounting techniques to data from 600 firms, with computer and non-computer capital separately identified. They find that in the short run (of one year), computers have little effect on TFP growth. But over the longer term (3–7 years), the elasticity of output to ICT capital increases by a factor of between 2 and 8, resulting in a substantial contribution from computers to firm-level TFP growth over time. The authors view this, together with other institutional evidence, as evidence that the long-term growth contribution of computers reflects their use alongside complementary organisational investment as part of a more general firm restructuring. That is consistent with a 'general purpose technology' view of computers. And it also suggests that the recent strength of ICT investment growth could lead to continued strong productivity growth during the next few years.

Conclusion

The evidence to date suggests that the strong growth of labour productivity in the United States over the past five years is not just a cyclical phenomenon. It has been driven by large increases in investment in ICT equipment and improved production techniques within the ICT sector, which have been associated with large price falls for such goods. It seems likely that these developments have led to a step shift in the level of productivity, and this has been translated into a number of years of higher productivity growth as the application of the latest technology has diffused through the economy. The question remains as to how long the higher productivity growth rates will last. This will depend crucially both on the future rate of technological progress and on the extent to which existing technology has already fully diffused through the economy and into firms' production processes. Given the large contribution of ICT capital use and ICT production to productivity growth in recent years, the continuation of the recent productivity trend depends on continued falls in computer prices, which will be determined, in part, by the pace of innovation within the sector. Spillovers and network externalities from recent advances in the ICT sector could also help to sustain stronger productivity growth in the future. But against this, the recent cyclical slowdown has led to a sharp slowdown in investment, initially in non-ICT equipment and more recently in ICT equipment. If this is sustained, it could reduce the amount of capital deepening and its contribution to productivity growth.

The current slowdown in the US economy may well provide an indication of the size of the cyclical component, and over the next few years it should be possible to come to a firmer conclusion on this issue. A sharp slowdown in productivity growth could reflect a cyclical weakening of investment growth and factor utilisation, and so would not necessarily imply that past gains were cyclical in nature. But if productivity growth slows only modestly, this would be supportive of the evidence available so far that structural improvements have played a substantial role in recent productivity gains.

References

Brynjolfsson, E and Hitt, L (2000), 'Computing productivity: firm-level evidence', *mimeo*, MIT and Wharton School.

Council of Economic Advisers (2001), *Economic Report of the President*, 2001.

Gordon, R (2000), 'Does the 'new economy' measure up to the great inventions of the past?', *Journal of Economic Perspectives*, Fall 2000, pages 49–74.

Gust, C and Marquez, J (2000), 'Productivity developments abroad', *Federal Reserve Bulletin*, October, pages 665–81.

Jorgenson, D and Stiroh, K (2000), 'Raising the speed limit: US economic growth in the Information Age', *Brookings Papers on Economic Activity*, No. 1, pages 125–211.

Landefeld, J S and Grimm, B T (2000), 'A note on the impact of hedonics and computers on real GDP', Survey of Current Business, December, pages 17–22.

Oliner, S and Sichel, D (2000), 'The resurgence of growth in the late 1990s: is information technology the story?', *Federal Reserve Board Finance and Economics Discussion Paper Series No. 2000–20*, March.

Stiroh, K (2001), 'Information technology and the US productivity revival: what do the industry data say?', *Federal Reserve Bank of New York Staff Reports No. 115*, January.

Whelan, K (2000), 'Computers, obsolescence, and productivity', *Federal Reserve Board Finance and Economics Discussion Paper Series No. 2000–6*, January.