What's New About the New Economy? IT, Economic Growth and Productivity

Barry P. Bosworth and Jack E. Triplett*
Brookings Institution

The U.S. economy performed extraordinarily well in the 1990s. Unemployment has dropped to historically low rates; the federal government is awash with revenues, and after a quarter century of near stagnation, productivity growth is soaring. The unexpected economic strength has stimulated much discussion about the "new economy," and what the emergence of a new economy implies for the sustainability of the economic expansion in future years.

The "new economy" discussion has been inconclusive, in part because the term "new economy" means different things to different people. Some definitions of the new economy embrace a very broad notion — that the fundamental economic concepts that guided economic policy in the past have become irrelevant in an age of global competition and rapid technological change. Others have a more narrow focus — the role of information processing and communications technology (IT) in accelerating the economy's trend rate of output and productivity growth

In this article, we address primarily the narrower focus. New technologies are a fundamental part of the new economy notion, even if they represent only part of what some commentators mean by the term. One major source of contention revolves around the question of whether the economic effects of the new technologies embodied in IT are captured by conventional, or "old", economic concepts and analysis. We contend that they are, and that the impact of IT is not so much "new" as it is larger than before.

Aggregate Demand and the New Economy

The spread of information and communication technology (IT), such as computers and peripherals, computer software, communications, and related equipment, is very evident on the demand side of the economy. Beginning in the early 1990s, the U.S. economic expansion has been led by both a large and sustained growth in business investment, albeit from very low levels at the beginning of the decade, and a boom in consumption spending that has grown to exceed household income, resulting in a negative (measured) saving rate.

The rate of capital accumulation in the business sector has more than doubled since the beginning of the decade. As shown in figure 1, an overwhelming portion of the growth can be attributed to outlays for information-processing equipment and computer software. In nominal terms, this category of investment has grown from nine per cent of total business investment in 1990 to 22 per cent in 1999.[1] The real growth has been far more dramatic because of a steady decline in the relative prices of computer components.[2] Over the decade, real outlays on IT equipment have increased three-fold, accounting for about 60 per cent of the growth in the total, compared to only a 40 per cent increase in all other forms of investment.[3]

The new economy has also been one driving force behind the surge in consumer demand. Overall consumer spending has increased to a historical peak as a share of GDP, and the personal saving rate has declined from an average of seven per cent of disposable income at the beginning of the decade to zero in the current year. Many existing studies attribute the strength in consumer demand to the rise in household wealth, and in particular, the explosive rise in the value of technology stocks.

Supply-side Issues

While its impact on aggregate demand can be readily identified, the controversial aspects of the 'new economy' center around its effect on the supply side of the economy. Two phenomena are normally singled out for attention in any discussion of the economy's performance over the 1990s: a surge of productivity growth, and very low inflation in the presence of an extremely tight labour market. The discussion has also directed increased attention to the role of intangible capital in the form of intellectual property as a key element in economic growth. All of these have stimulated claims of a new economy, but the behavior of productivity is most strongly identified with the growth of IT.

The Impact of IT on Economic Growth and Productivity

Substantial post-1995 surges in labour productivity and in multifactor productivity, or MFP, are often pointed to as proof that computers are finally contributing to productivity. Equally often, this IT contribution is said to be new. In evaluating such statements, it is essential to distinguish between IT's contribution to economic growth and to labour productivity (or LP), on the one hand, and IT's contribution to multifactor productivity, or MFP, on the other. As shown below, IT contributes to economic growth and to LP through capital deepening — more capital per worker. But while IT contributes mightily to recent U.S. growth, this IT contribution to labour productivity is neither new, nor unexpected, nor is it unique to the U.S. IT capital has always contributed to U.S. (and other countries') economic growth and LP growth, even in periods when labour productivity growth was low. The only real change is that IT capital is much larger than it once was and, not surprisingly, contributes more to recent growth than it did in earlier periods.

It is also evident that there have been very rapid MFP gains in the production of semiconductors and computers that have translated into large reductions in the prices of IT capital. Those price declines are the primary factors behind the surge in IT investments in the 1990s. In turn, the surge in IT investments contributes to LP growth in IT using industries and in the economy as a whole.

The more fundamental question for new economy claims is whether the information revolution and the surge of investment in IT has stimulated increases in the productivity of the *computer-using* industries beyond the direct contribution to LP of more capital per worker — that is, has the greater use of IT contributed to the post-1995 surge in MFP? The surge in investment in IT after 1995 coincided with an unanticipated increase in U.S. MFP growth.

Sources of Growth Studies

The year 1973 is generally accepted as the starting date of a pronounced, and still largely unexplained, slowdown in the rate of productivity growth in the U.S. That slowdown was sustained for over a quarter century. The U.S. economy grew three per cent per year, in real terms, between 1973 and 1995. In the 1995-99 period, growth accelerated to 4.8 per cent annually in the nonfarm business economy. This acceleration of the rate of economic growth coincided with sharp improvements in both labour and multifactor productivity.

Two recent studies have examined contributions of IT to the late 1990s acceleration of U.S. economic growth: Jorgenson and Stiroh (2000, hereafter, JS), and Oliner and Sichel (2000, hereafter, OS). We summarize their findings, which are put into similar forms in tables 1A and 1B.[4]

Although the methodological differences affect the results to an extent, the two studies present closely compatible information about the growth acceleration. Both studies show that all the major sources of growth — capital services, labour services, and multifactor productivity — have contributed to accelerating U.S. economic growth in the 1990s. In the Oliner and Sichel (OS) estimates, acceleration in MFP accounts for a bit more than 40 per cent of the acceleration in growth; in the Jorgenson and Stiroh (JS) estimates, MFP accounts for a little under 40 per cent.

Regarding the remainder, both studies present remarkably similar findings: acceleration in the growth of capital services and of labour services together account for almost exactly one percentage point of the acceleration, with capital

Table 1-A:
Contributions to Output Growth, Oliner and Sichel U.S. Nonfarm Business

annual rates of change

Category	1973-95	1996-99	Acceleration
Growth of Output	2.99	4.82	1.83
Capital Services	1.27	1.85	0.58
Of which: ICT	0.51	1.10	0.59
Other capital	0.76	0.75	-0.01
Labour services	1.35	1.81	0.46
Of which: hours	1.08	1.50	0.42
Labour quality	0.27	0.31	0.04
MFP 0.36	1.16	0.80	

Source: Oliner and Sichel (2000), Table 1

Table 1-B:
Contributions to Output Growth, Jorgenson and Stiroh Private Domestic Economy, Including Household Sector

annual rates of change

Category	1973-95[c]	1995-98	Acceleration
Growth of Output	3.04	4.73	1.69
Capital Services	1.53	2.17	0.64
Of which:ICT [a]	0.40	0.94	0.54
Other capital [b]	1.13	1.23	0.10
Labour services	1.18	1.57	0.39
Of which: hours	0.94	1.32	0.38
Labour quality	0.24	0.25	0.01
MFP	0.34	0.99	0.65

Source: Jorgenson and Stiroh (2000), Table 2

a Includes services of consumer computers and software, but not consumer communications equipment.

b Includes services of non-computer consumer durables.

c Calculated using weighted average of columns three and four of Jorgenson and Stiroh (2000), Table 2.

Figure 1:
Investment in Information Processing

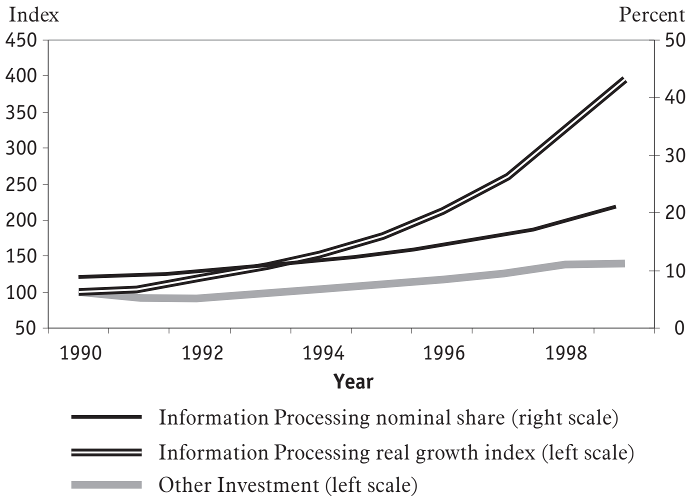
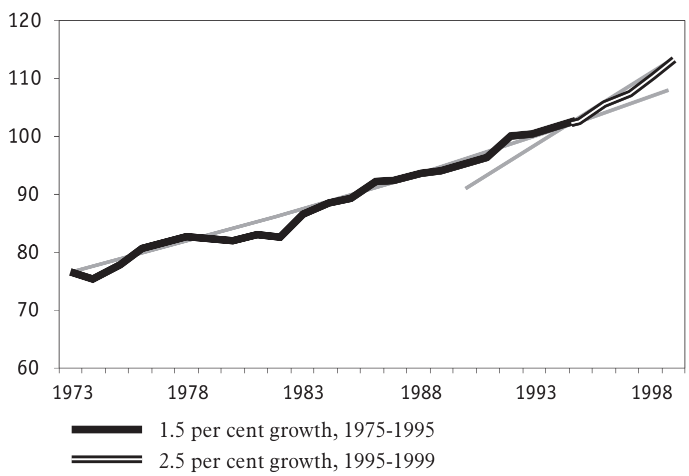


Figure 2:
Nonfarm Labor Productivity



playing a slightly greater role. The U.S. experienced an investment boom in the second half of the 1990s, which raised its capital stock, and increased the contribution of capital services to production (the increase was estimated at 0.58 points per year by OS and 0.64 points by JS). But the U.S. economy has also experienced a labour services "boom," and the growth in labour inputs has contributed nearly as much to the acceleration (0.46 points in the OS estimate, 0.39 points using the JS numbers).

To analyze the impact of IT (information and communication technology), the authors of the two studies separate the contribution of capital services to economic growth into contributions from the use of IT capital and from all other (non-IT) capital. The contribution of IT capital is much greater in the late 1990s than it was in earlier years. As the result of substantial IT investment in the U.S., those products make up a larger share of U.S. capital stock, and so they now contribute a larger share of capital services than they once did. Additionally, the stock of IT capital grew faster in the late 1990s, so the contribution of IT capital to economic growth accelerated.

Non-IT capital makes no contribution to the *acceleration* of growth in the late 1990s. Thus, the services of IT capital provide all of the *acceleration* in the growth of capital services. However, a finding that IT capital contributes to output growth is not new. What is new is that the contribution of IT is much larger than in the past (compare the IT capital line in the first and second columns of tables 1A and 1B).

Labour Productivity

Much of the discussion of recent U.S. growth has been couched in terms of labour productivity (LP), which for the nonfarm business sector has accelerated from around 1.5 per cent per year in the 1973-95 period to a substantially higher 2.5 per cent in the second half of the 1990s (Figure 2). The contributions to growth estimates, presented in tables 1A and 1B, can be translated into sources of the improvement in U.S. labour productivity. Table 2 presents transformations of the OS and JS results, to which we add estimates by Gordon (2000) and the U.S. Council of Economic Advisors (2000).

Although methodologies and definitions of output differ to an extent among the four studies, they show broadly similar findings. Around a quarter to a third of the acceleration in LP came from increased growth in capital services per worker (capital deepening), and two-thirds or more came from more rapidly growing MFP. IT capital was responsible for all of the acceleration in the capital contribution to LP.

Comparisons Across OECD Countries

Similar findings apply to other OECD countries. Schreyer (1999) found that IT made a positive contribution to LP in all G-7 countries (see Table 3). In the 1990-96 period IT capital made the largest contribution in the U.K. and the U.S. However, in the early 1990s, those two countries had LP growth rates that were among the lowest in the G-7 (the post 1996 acceleration is not represented in Schreyer's data). The smallest contribution in IT capital occurred in Japan and Germany, which interestingly enough, were leaders in labour productivity growth in this period. Schreyer's study shows that IT capital always contributes to labour productivity growth, by raising the capital labour ratio (capital deepening).

More recently, Daveri (2000) has updated Schreyer's research and extended it to another eleven OECD countries. He finds that IT adds substantially to output growth in the 1990s for all 18 countries studied, though the magnitudes differ greatly across these countries. Although the largest contribution from IT is in the U.S., several other countries (Canada, Australia, and the U.K.) have received virtually the same boost to growth from investment in IT. Continental European countries have lagged behind, with the Nordic countries and the Netherlands setting the continental pace and Italy and Spain the laggards.

Table 2:
Alternative Estimates of the Acceleration of Productivity Growth, Post-1995

annual percentage rates of change

Category	Jorgenson and Stiroh	Oliner and Sichel	Council of Economic Advisors	Robert Gordon
Labour Productivity	0.9	1.2	1.5	1.4
Cycle	n.a.	n.a.	n.a.	0.7
Trend	0.9	1.2	1.5	0.7
Contribution of:				
Capital per worker	0.3	0.3	0.5	0.3
IT capital	0.3	0.5	n.a.	n.a.
Other capital	0.0	-0.2	n.a.	n.a.
Labour Quality	0.0	0.0	0.1	0.1
Multi-factor Productivity	0.7	0.8	0.9	0.3
Production of IT	0.3	0.3	0.2	0.3
Other sectors	0.4	0.5	0.7	0.0

The acceleration is measured relative to a base of 1973-95.

The estimates of Jorgenson-Stiroh extend only through 1998.

Table 3:
IT Contribution to Labour Productivity, G-7 Countries, 1990-96

	Labour Productivity (average annual growth)	ICT Contribution
Canada	1.3	0.27
France	1.6	0.25
Germany	2.1	0.19
Italy	1.9	0.24
Japan	1.9	0.19
UK	1.4	0.40
US	1.0	0.41

Source: Schreyer (1999), Table 6, page 19.

The Link Between IT and MFP

The preceding discussion shows that the use of IT capital makes a significant contribution to economic growth (about a third of the recent acceleration) and to labour productivity. A post-1995 surge in MFP, however, contributes even more — fully 40 per cent of the acceleration in economic growth and two-thirds or more to the acceleration in LP.

What accounts for the rise in MFP? Is the recent surge in MFP caused, as some have contended, by increasing use of IT? A great amount of confusion over the relation between labour productivity and multifactor productivity has clouded the discussion. We believe that the evidence is against the view that recent improvements in MFP in the U.S. can be attributed to the use of IT equipment, though the evidence is not conclusive.

Multifactor productivity (MFP) is the amount of economic growth that is *not* explained by growth in the productive inputs. If all the productive inputs are correctly accounted for and their prices correctly measured, growth in a productive input such as IT capital should *not* affect MFP.[5] Indeed, whether a technological innovation affects multifactor productivity depends on whether or not a particular innovating activity is or is not fully paid for, and if it is paid for, whether or not it is measured correctly in economic statistics. An anecdote illustrates.

One of us once toured a machine tool manufacturing plant that made very high tech, advanced machine tools. However, the machine tool factory was built in the 19th century. Since its origin, they had always brought the purchased materials in on the ground floor, carried out subassemblies on the second, and final assembly on the third floor. As machines became larger and more complex, it proved ever more difficult to get them down from the third floor. Someone suggested sending the material to the third floor, so final assembly could take place on the ground, an idea that resulted in an immediate improvement in the plant's labour productivity (LP).

Would the innovation affect the plant's MFP? If the suggestion came from a management consulting firm that was paid according to the value of its suggestion, the innovating activity would show up as a purchased input, and therefore not as an MFP improvement. But if the suggestion came from an employee, and the employee were not fully compensated for the value of this innovation, then it would increase the plant's measured MFP, because there is no measured input that was compensated for the innovating activity.

The anecdote illustrates the impact of investment in IT capital on output and production processes. IT capital changes the way things are done — it changes business processes and it results in many new products and services. If economic statistics correctly measure these new goods and services, then what computers do will show up in the output measure, and hence in the numerator of productivity statistics, both LP and MFP. This means that what computers do will show up as a return to computers, that is, as a return to a productive input, provided computer prices are measured correctly and economic statistics also measure correctly the computer input to production. The new things that computers do will *not* show up in economic statistics in the form of enhanced MFP, because MFP is the change in output that is *not* associated with input usage. But that does not mean that the IT capital is not "productive." A successful investment will contribute to output and improve LP.

In fact, the macroeconomic studies that we have cited all treat computers as "just another piece of capital equipment." That is, computers, like any capital good from the past — steam engines, for example, or electric motors — substitute machines for workers, and to an extent, computers also substitute against non-computer forms of capital equipment.

In this view, as computers become cheaper relative to other inputs, including labour, we use more computers. Employers continue to substitute computers until further substitution is no longer cost effective. In equilibrium, investing in computers earns the same rate of return as investing in any other form of capital. This equilibrium assumption is actually embedded in the sources of growth methodology used in all of the studies reported in tables 1A, 1B, and 2.

The macroeconomic studies we have reviewed find no association between IT and MFP, which is not surprising, considering both their methodologies and the probable economic impact of IT on production processes. Furthermore, much of the increase in U.S. MFP can be directly attributed to technological innovations in the production of IT capital, computer equipment and semiconductors. The proportion of the acceleration in MFP attributed to gains within the IT producing sector ranges from about one fourth in the CEA study to 100 per cent in Gordon's analysis.

Summary: IT, LP and MFP

Although the new technologies of IT are the driving force behind the recent acceleration of labour productivity growth, their impact can be understood within the standard growth accounting framework. Productivity growth in the production of IT is a large part of the story in the U.S. The large price declines in IT equipment have stimulated a surge of investment in these technologies, leading to major increases in the contribution of capital services. However, the finding of a relationship between IT capital and labour productivity is not new. What is new is the sharp acceleration of past trends: IT capital is becoming a larger share of total capital, so its contribution to labour productivity and to economic growth, everywhere, is becoming larger in the proportion that the increased IT capital to labour ratio would lead one to expect.

After adjusting for the impact of increased capital per worker, the impacts on MFP in the computer-using sectors seem relatively small, but hard to measure with precision. However, there is room for considerable disagreement about what is happening to MFP in the IT-using industries, and several potential reasons to believe that the contribution of IT to economic growth might be understated in the studies we have discussed so far. They include assertions that computers earn a supernormal return, or contribute spillover effects. The information revolution is also in disequilibrium today, and it is possible that some of the payoffs are yet to be realized.

Microeconomic and Industry Analysis

Industry Studies

Determining the impact of IT on LP and MFP requires information about what is happening at the level of individual industries that are intensive users of the new IT technologies. The examination of the improvements in productivity at the level of individual industries has been hampered by the recent revisions in the U.S. national accounts. Most of the available analysis is based on older estimates that did not include computer software as a capital input.[6]

The five industries that are the largest purchasers of computer equipment (a narrow definition of IT) are all in the services sector — in order, financial services, business services, wholesale trade, communications, and insurance. These industries account for more than 50 per cent of U.S. investment in computers. Except perhaps for communications, these services industries pose difficult conceptual and empirical problems for constructing price indexes and real output measures, and therefore for measuring productivity. For the communications industry there are other problems of capturing the effects of the rapid introduction of new products.

An example closely tied to the use of computers, is the growth of ATM machines in banks that reduce the time spent waiting in line for teller transactions, make the transactions available on weekends, and have, with computer-assisted verification systems for credit card purchases, virtually eliminated the need to carry travelers checks on foreign travel to many countries. Prior to the 1999 revisions to the U.S. national accounts, ATM usage was not reflected in the measure of banking output in the U.S. national accounts; it is still not reflected in most countries' banking output measures (Eurostat, 2000).

Business services present even more difficult problems. An economic consulting firm is part of the business services industry. How do we measure the output of an economic consulting firm? How would we construct a price index for economic consulting? And how would we compute the productivity of economists? The science of economics is no closer to developing methods for measuring the output of economists' own activities then it is for measuring the output of banks, law firms, and insurance agents.

However, these problems need to be kept in context. Problems in measuring services output are present in U.S. statistics for both the period before and after the acceleration of MFP. In addition, only approximately 40 per cent of the output of these industries is directed to final demand. To the extent that they produce intermediate output for other firms, errors in measuring their output and productivity do not translate into comparable errors at the level of the total economy, because GDP is based on the aggregation of components of final demand, nor do these output measurement errors in intermediate products affect aggregate productivity measures.

The statistical agencies have made some progress in resolving the measurement problems. The recent revisions of the national accounts, for example, incorporated a new measure of the output of the banking industry that focuses on the benefits to consumers of services, such as ATMs; and the BLS has begun to publish price indexes for some forms of business services. While information is not yet available to re-estimate multifactor productivity at the level of detailed industries, estimates of labour productivity based on the new data do suggest some post-1995 acceleration of productivity growth in these industries.

Microeconomic Evidence

At present, most of the microeconomic analysis of the link between computers and productivity has focused on LP, where the most recent studies have found a significant positive effect of IT investments. And a few studies have found evidence of supernormal returns, suggesting a positive impact on MFP. Brynjolfsson and Hitt (2000), for example, make the more extreme claim that the macroeconomic analysis may understate the contribution of capital to growth by a factor of ten. These microeconomic studies typically find a strong correlation between output growth and IT investments, and between stock market valuations and IT investments. Substantial problems arise, however, in attempting to infer causation. IT investments may serve as a proxy for a wide range of characteristics that distinguish high and low-growth firms.

In order to make their microeconomic results consistent with the aggregate data, Brynjolfsson and Hitt argue for a new accounting framework that would reclassify a large portion of current expenditures on intangibles, including startup costs, as investment. Shifting expenditures from indirect costs to investment would initially raise the (measured) level of GDP and productivity (because investment is final output in GDP). In addition, Brynjolfsson and Hitt argue that to a greater extent than in the past the growth of GDP is understated because the current statistics fail to account for improvements in the quality of consumption products. They assert that both the growth of intangibles and unmeasured quality improvements are closely tied to investments in IT.

It is difficult to evaluate the assertion that the problem of adjusting for quality change is becoming more severe than in the past. In recent years the government statistical agencies have greatly expanded their efforts to capture changes in quality; and, in particular, they have emphasized the measurement of changes in the quality of computers and computer-related products. Yet, a disproportionate proportion of computer investments are concentrated in hard-to-measure service industries (as noted earlier). This raises the possibility that important effects of IT on output are being missed.

There is more support for the emphasis on a growing role for intangible capital. While the 1990s have witnessed a major recovery of business investment, the growth in the stock of physical capital has fallen well short of the post-1995 surge in stock market prices. The result has been a sharp rise in the value of q — the ratio of a firm's market value to the replacement cost of its capital stock. There are two plausible explanations for the inflated value of q. The first is that it is evidence of a speculative bubble in asset markets, a view well represented by Robert Shiller (2000). Alternatively, the high value of q may reflect errors in measuring the denominator of the ratio, induced by the failure to incorporate intangible capital.

Several recent studies, including Brynjolfsson and Hitt (2000), have argued that in the new high-technology industries, corporate assets are primarily intangible, rather than tangible capital. Yet, under present accounting rules, many forms of expenditures for intangibles, such as R&D and advertising, must be expensed rather than capitalized even though they are expected to generate future profits (Lev, 2000).

The treatment of expenditures on intangibles as investment would raise output in parallel with the accumulation of intangibles, while leaving the measure of capital inputs (temporarily) little changed. Thus, MFP would be increased during the accumulation phase. However, in subsequent periods the magnitude of capital inputs would be increased, leading to an offsetting reduction in MFP. Thus, the treatment of intangibles as a form of capital will change the timing of the MFP gains more than the total amount. The advantage of the accounting change would be to more closely associate improvements in MFP with the innovations that generated them. The difficulty arises from the problem of determining *a priori* what constitutes an intangible investment.[7]

B2B E-commerce

Another argument for supernormal returns to IT comes from projected cost savings from use of the internet, in the form of B2B (or business-to-business) e-commerce. A widely publicized example is the study done for Goldman-Sachs by Brookes and Wahhaj (2000). The authors claim that what they call internet "shocks" amounting to up to 39 per cent of the prices of inputs, depending on the industry, "could" raise future GDP growth by 0.25 points per year.

In their view, B2B e-commerce has four possible impacts. First, it can reduce internal processing and paperwork costs of purchasing business inputs (by automating them). Second, B2B can reduce inventory costs (facilitating "just in time" inventory control). Third, B2B can reduce costs by what Brookes and Wahhaj call "removing expensive intermediaries" — eliminating the middleman, it was once called. Finally, the internet may reduce input prices by squeezing out monopoly rents from producers of inputs.[8]

Obviously, the estimated impact on the economy from the Brookes and Wahhaj (2000) study depends entirely on the validity of the projected cost savings in individual industries, and only time will tell whether they are right. We think it implausible that intermediaries and monopoly rents can account for anything approaching 29-39 per cent of costs in electronics or 15-25 per cent in forest products or 15-20 per cent in trucking. The "middleman" has been blamed for high prices and economic inefficiency since at least the days of the Populists in the 1890s. Links in the distribution chain, however, perform economic functions. Sometimes those functions have been integrated back to the supplier or forward to the purchaser, and sometimes efficiencies result, but the functions must still be performed in some way. The idea that 15-30 per cent of the price of the product can be saved by eliminating a step in the distribution chain appears an unrealistic estimate of distributive margins. And it strikes us as naïve to think that there are huge monopoly profits in industries such as electronic components, forest products and freight transport.

We anticipate that the internet is likely to create savings in the transactions and processing costs of purchasing inputs, and perhaps reduce as well the search costs for locating new sources of supply (in this limited sense, we agree with Brookes and Wahhaj that greater "information" accessibility is part of IT's contribution to productivity). We do not know how large transactions and search costs for purchasing inputs loom in the total cost structure of American industry. However, we suspect there is simply not enough room in the cost structure for the kind of cost reductions that Brookes and Wahhaj push through their input-output table.

Measurement of IT prices and output.

James Grant (2000) raises anew questions about the measurement of IT prices and output: "By a process called hedonic price indexing, the fruits of the information-technology revolution are made to appear even plumper, riper and juicier than they actually are." This is essentially the issue raised a number of years ago by Denison (1989), who also believed that the use of hedonic indexes for computers in the U.S. national accounts recorded price declines that were too large and exaggerated computer output and investment and IT capital input.[9]

There is no question that IT equipment, particularly computers and peripheral equipment, are measured differently in different countries, and that different methodologies make a huge contribution to non-comparability of IT statistics, and indeed of GDP, across OECD countries.[10] Hedonic indexes in France (one of two European countries that presently deflate computer output with an internal hedonic price index) yield the greatest measured computer price decline in Europe, and the application of "non-hedonic" methods produces a wide variance in price indexes that are not entirely plausible within a common market.

Moreover, the German Bundesbank recently reviewed the treatment of IT equipment in the German and U.S. national accounts. It suggested that the German real investment rate in IT equipment would look much larger if U.S. methods were used for deflation in German national accounts, so that the utilization of IT in Europe is not so far behind the U.S. as one would judge from official statistics. The Eurostat Task Force (Eurostat, 1999) concluded that differences in methodology for measuring IT equipment could cumulate to as much as 0.2 points in the growth rate across EU countries. The growing importance of IT products throws into greater prominence the problems of constructing price indexes for goods and services that experience very rapid rates of technological change.

It is clear from anecdotal and other information that computer prices are declining rapidly; that the decline occurs not just in the top-line, state-of-the-art machines, but also in low-end computers that are used primarily by households; and that the price decline is international in scope, not just in the U.S. Statistical agencies in the U.S. are increasingly using hedonic methods to cope with quality changes in electronic products, and not just in computers (as a Consumer Price Index press release earlier in the year made clear). To the extent that statistical agencies in other countries are not following similar strategies, the spread of IT will create growing international incompatibility in productivity statistics.

Conclusions

Looking ahead, we would be more comfortable in projecting a continuation of the recent rate of labour productivity (LP) growth than we would with an outlook for continued moderate inflation. While the source of improvement in MFP — and hence its sustainability — remains a matter of considerable conjecture, there is little reason to believe that either the technological gains in the production of IT or the high demand for IT capital will end in the near future.

Notes

* Shortened version of a paper to appear, under the same title, in: Heidemarie C. Sherman, editor, *Impact of the Internet Revolution on the International Economy*, Insitut für Wirtschaftsforschung, Munich, Germany. Email: jtriplett@brook.edu.

1 We focus on the nominal investment rate because real shares are not meaningful when based on the chain- price aggregates of the national accounts.

2 Investment in computers refers to office equipment only. For example, it excludes investment in computer-controlled machinery such as that used on automated production lines, "embedded" logic chips and so forth.

3 It is important to note that the U.S. system of national accounts classifies computer software as a component of investment. Nominal outlays on software represented about 15 per cent of business investment in 1999 (twice that of outlays on computers) and they account for nearly all of the growth in the share of nominal investment devoted to information processing. In real terms, the contribution of software to the growth in business investment is slight less than that of computer equipment. It is a larger share, but grows at a slower rate.

4 The two studies use very similar "sources of growth" methodologies. For the two periods of interest (post-1973 and the late 1990s), both pairs of authors estimate sources of growth, which they partition into the contributions from labour services, from capital services, including IT, and from multifactor productivity (MFP). Sources for the post-1995 acceleration of growth are then simply estimated by taking the differences between each of the two periods, that is, the contribution of each input to growth post-1995, less its contribution for the interval 1973-1995.

5 There are some qualifications, to which we return at a later point.

6 Moreover, the substantial revisions to the U.S. national accounts that were introduced in late 1999 implied new estimates of the growth in output and the inputs at the level of individual industries, and these data are as yet not fully integrated into a full set of interindustry accounts that include the necessary measures of capital services required for calculating industry level MFP.

7 Discerning the role of intangibles is made even more difficult by noting that many of the laws governing patent and copyright protection have been expanded in recent years; and the 1995 trade agreement greatly extended the reach of corporations' efforts to assert protection of intellectual property on a global basis. Equity values could be inflated either by increased innovative activity or by greater protection (monopolization) of the existing flow, but only the former would be consistent with an acceleration of real output growth.

8 As Brookes and Wahhaj put it, prior to the internet "the producers of physical inputs acted like monopolists...." Brookes and Wahhaj emphasize the latter two factors — eliminating intermediary wholesalers, and reducing monopoly prices charged by the producers of inputs, what they have also called the "non-wage costs of purchasing inputs."

9 Since 1985, the U.S. has used hedonic price indexes for computer equipment to deflate its national accounts and investment data.

10 This issue was first documented by Wyckoff (1995), it is discussed extensively by Schreyer (1999), Scarpetta et al. (2000), Jorgenson and Stiroh (2000), Daveri (2000), and a Eurostat report on deflation of IT equipment in national accounts (Eurostat, 1999).

References

Brookes, Martin and Zaki Wahhaj (2000) "The Shocking Economic Effect of B2B," Goldman, Sachs & Co. Global Economics Paper No: 37, February 3.

Brynjolfsson, Erik, and Lorin M. Hitt (2000) "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," (Massachusetts Institute of Technology, Mimeo).

Council of Economic Advisers (2000) *The Annual Report of the Council of Economic Advisers* (Washington, DC: U.S. Government Printing Office).

Daveri, Francesco (2000) "Is Growth an Information Technology Story in Europe Too?" Working Paper, Universita di Parma and IGIER, September 12.

Denison, Edward F. (1989*) Estimates of Productivity Change by Industry: An Evaluation and an Alternative* (Washington, DC: The Brookings Institution).

Eurostat Task Force (1999) "Volume Measures for Computers and Software," Report of the Eurostat Task Force on Volume Measures for Computers and Software, June.

Eurostat Task Force (2000) "Price and Volume Measures for Financial Intermediation," Report of the Eurostat Task Force on Price and Volume Measures for Financial Intermediation, June.

Gordon, Robert (2000) "Does the 'New Economy' Measure up to the Great Inventions of the Past?" NBER Working paper, May 1.

Grant, James (2000) "America's Hedonism Leaves Germany Cold," *Financial Times*, September 4, pp. 15.

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

Lev, Baruch (2000) "Intangibles: Management, Measurement, and Reporting," Forthcoming in Margaret M. Blair, and Stephen M.H. Wallman, eds., *Unseen Wealth: Report of the Brookings Task Force on Understanding Intangible Sources of Value*, (Washington, D.C.: The Brookings Institution).

Oliner, Stephen D. and Daniel E. Sichel (2000) "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" Federal Reserve Board working paper, May.

Scarpetta, Stefano, Andrea Bassanini, Dirk Pilat, and Paul Schreyer (2000) "Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Level," Economics Department Working Papers no. 248, OECD, June (Paris).

Schreyer, Paul (1999) "The Contribution of Information and Communication Technology to Output Growth," Statistical Working Party (99)4, OECD, November (Paris).

Shiller, Robert (2000) *Irrational Exuberance* (Princeton, NJ: Princeton University Press).

Wyckoff, Andrew W (1995) "The Impact of Computer Prices on International Comparisons of Labour Productivity," *Economics of Innovation and New Technology*, 3, pp. 277-93.