ICT AND PRODUCTIVITY GROWTH
IN THE UNITED KINGDOM

Nicholas Oulton

Bank of England

October 2001

Paper to be presented to the 9th ACN Seminar, Paris, 21-22 November, 2001

Summary

This paper develops new estimates of investment in and output of information and communications technology (ICT). These new estimates imply that GDP growth has been significantly understated, particularly since 1994. A growth accounting approach is employed to measure the contribution of ICT to the growth of both aggregate output and aggregate input. On both counts, the contribution of ICT has been rising over time. From 1989 to 1998, ICT output contributed a fifth of overall GDP growth. Since 1989, 55% of capital deepening has been contributed by ICT capital; since 1994 this proportion has risen to 90%. ICT capital deepening accounts for 25% of the growth of labour productivity over 1989-98 and 48% over 1994-98. But even when output growth is adjusted for the new ICT estimates, both labour productivity and TFP growth are still found to slow down after 1994.

1. *Introduction*[1]

This paper seeks to measure the contribution of information and communications technology (ICT) to the growth of output and productivity, using a growth accounting approach. Four types of ICT are studied:

- Computers
- Software
- Telecommunications equipment
- Semiconductors (chips)

Telecommunications equipment is included since in recent years investment in computers and software has been strongly associated with the development of networks, both internal to companies (intranets) and external, in the shape of the internet. Semiconductors are included since it may well be technical progress here which has been fuelling technical progress in computers and telecommunications. This is summed up in the expression "Moore's Law": the tendency for the density of chips to double every 18 months to two years.

The motivation for the present study is the striking increase in the growth of US labour productivity which occurred in the second half of the 1990s. There now seems general agreement that a large part of the increase in output can be accounted for by rapid growth in the stock of ICT equipment (Bosworth and Triplett, 2000; Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000; Baily, 2001; DeLong and Summers, 2001). The ICT investment boom in turn was driven by the rapid rate of decline of computer prices, which accelerated in the second half of the 1990s. The fall in computer prices has been mainly due to rapid and indeed accelerating technical progress in

---

[1] This paper is a condensed version of a longer one, Oulton (2001a), where fuller explanation and argument plus additional references to the literature and detailed tables will be found. I am grateful to Sushil Wadhwani for much encouragement and numerous helpful discussions and insightful comments. I have also benefited from the comments of Paul Stoneman (Warwick Business School), of colleagues in the Bank of England, particularly Ian Bond, Jo Cutler, Jens Larsen and Hasan Bakhshi, and of officials of the Office for National Statistics, in particular Prabhat Vaze. I also thank Bruce Grimm of the BEA for advice on US software estimates, Steve Oliner of the Board of Governors of the Federal Reserve for supplying data on semiconductor prices, and Mary O'Mahony (National Institute of Economic and Social Research) for providing data on hours worked. Malte Janzarik provided excellent research assistance. None of these people should be blamed for any remaining errors which are my

semiconductors (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000). In the UK by contrast, the second half of the 1990s saw a decline in labour productivity growth. Since ICT products are widely traded internationally, was there a comparable investment boom in the UK? If so, why has it not apparently led to faster labour productivity growth?

This paper takes a wider view than some studies which cover the UK (e.g. Kneller and Young, 2001; Schreyer, 2000) since it includes software as well as hardware.[2] On the other hand, it does not aim to estimate the contribution of the "new economy" as a whole.[3] To do that, the scope would have to be extended to include the contributions of the internet, the digital media and e-commerce. Nor does the paper cover other aspects of the "new economy", such as changes in the labour market and in product market competition, as discussed in Wadhwani (2000). Studies which put the new economy in a wider historical perspective include Gordon (2000) and Crafts (2000).

2. *The growth accounting approach*

The framework employed here is growth accounting, based ultimately on Jorgenson and Griliches (1967); Jorgenson and Stiroh (2000) is a more recent example. Broadly the same framework is set out in OECD (2001).[4]

The fundamental equation of growth accounting is:

---

responsibility. The views expressed here are my own and do not necessarily reflect those of the Bank of England or of its Monetary Policy Committee.

2 The paper which is closest in coverage to the present one is Davies *et al.* (2000). They present estimates for the UK of the effect of ICT on both aggregate output and input, using a similar methodology to that of the present paper. Their definition of ICT is also similar. But there are some significant differences between their estimates and the ones presented here. Schreyer (2000) includes computers and telecommunications but omits software. He uses proprietary data to estimate ICT stocks. He estimates the contribution of ICT to input but not output. Kneller and Young (2001) estimate the effect of computers on aggregate input but not aggregate output, i.e. they exclude software and telecommunications equipment. Daveri (2000) uses the same database as in Schreyer (2000) to do a growth accounting analysis for 18 countries, of which 13 including the UK are in Europe; his comparisons cover software too.

3 Computers themselves are of course far from "new". The year 2001 will see the 50th anniversary of the first computer to be introduced into commercial service in the UK, by J. Lyons and Co. In 1954 there were 12 computers in the UK, by 1964 this had risen to 982 and by 1970 to 5,470 (Stoneman, 1976, page 69 and Table 2.2, page 20).

4 An alternative framework centring round the concept of "investment-specific technological change" has been proposed by Greenwood *et al.* (1997). The relationship between this framework and growth accounting is discussed in Oulton (2001b).

Growth of aggregate output = growth of aggregate input plus growth of TFP (1)

In turn, the growth of aggregate output equals the share-weighted average of the growth rates of each type of real final output. Here the shares are the value of each type of output as a proportion of nominal GDP. The growth of aggregate *input* is a share-weighted average of the growth rates of the individual inputs. In this case, the shares are the income attributable to each input as a proportion of nominal GDP. The rationale for weighting by income shares is marginal productivity: inputs are assumed to be paid the value of their marginal products.

Labour's share is just the wage bill as a proportion of GDP. In the case of capital input, services are considered to be proportional to the capital stock. The stock of any type of capital is accumulated investment, after allowing for depreciation. At the aggregate level, capital's share is the profit share, i.e. profit before depreciation and tax as a proportion of GDP.

The contribution of any particular type of output, such as computers, to GDP growth is therefore:

Share of final output of computers in GDP *times*
growth rate of final output of computers

Here final output of computers (or of any other type of output) is defined as:

Final output = Consumption + Investment + Exports – Imports

(Government expenditure is potentially included in all these categories). Note that final output can be smaller than investment to the extent that domestic demand is met from imports. Conceivably, ICT investment might be large while final output is small, and so ICT might make a large contribution to aggregate input, but only a small contribution to aggregate output.

Computers also contribute to aggregate *input* since they are a form of capital. The contribution of computers to aggregate input is:

> Profit attributable to computers as a proportion of GDP *times* growth rate of the services of the stock of computers

Semiconductors are an intermediate product for which by definition consumption and investment are zero. In a closed economy, their contribution to either output or input would be zero, using the present approach. But the UK is an open economy and so their contribution to *output* is measured as exports net of imports and hence may be negative. Of course, domestically produced semiconductors do contribute indirectly to output if they are incorporated into other ICT products. But it would be double counting to count both the semiconductors and the computers (and telecommunications equipment) of which the semiconductors form a part.

Semiconductors make no direct contribution to aggregate *input*. Their contribution is measured implicitly as part of the contributions of the other ICT categories.

Labour productivity and TFP

The "fundamental equation" above can be rewritten in terms of the growth of labour productivity (output per hour):

Growth of output per hour = "capital deepening" *plus* TFP growth (2)

where capital deepening is the share of capital (profit share) times the growth rate of capital services per hour. Our aim is to quantify the elements of this equation.

The scale of investment in ICT: a US-UK comparison

By way of motivation, we start by comparing the scale of investment in the UK and the US in the three categories of ICT investment and in total. We make the comparison in terms of shares of GDP at current prices.

Investment in ICT as a proportion of GDP (current prices)

Chart 1

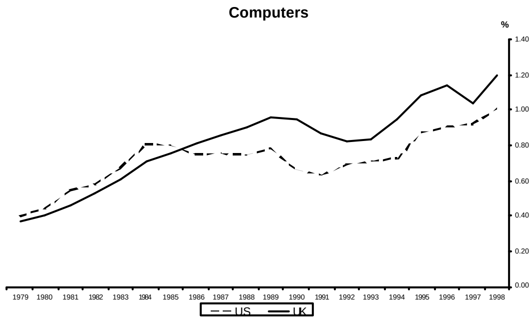


Chart 2

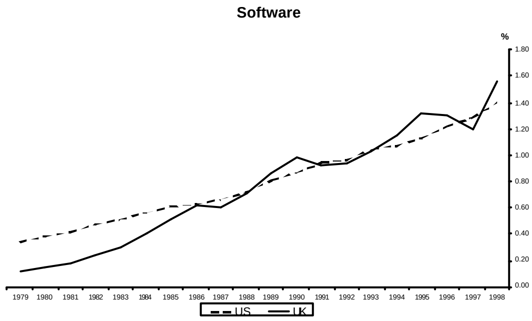


Chart 3

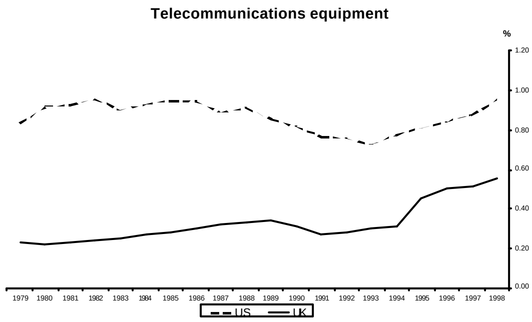
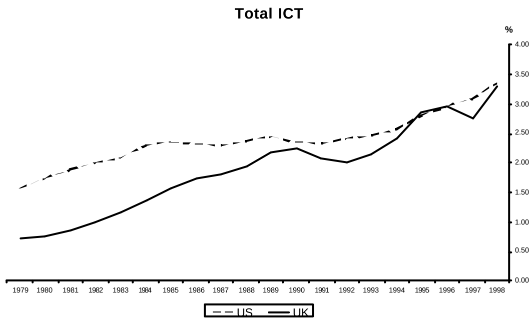


Chart 4



Source US NIPA for the US and own calculations for the UK (see section 4 below).

The UK's total investment in ICT is now rather more than 3% of GDP and is as large as that of the US. In computers, the UK invests relatively more and in software about the same. In both cases, the UK achieved convergence by the mid 1980s. Only in telecommunications does there still remain a substantial gap, though this may be affected by incompatibilities between the two countries' systems of industrial classification. Two caveats should however be noted. First, the UK's performance in software is obviously strongly affected by the large correction to the official figure — multiplication by three — which we argue below is justified. Second, since US GDP per capita is substantially larger, the result would be less flattering to the UK if investment per capita were being compared.

3. Measuring ICT

My estimates make two main adjustments to the underlying data which come from the United Kingdom's Office for National Statistics (ONS):

- I use US producer price indices for ICT, adjusted for exchange rate changes, to deflate UK investment and output.
- I argue that the level of software investment in current prices is at least three times higher than the official figure. I treat this as an addition to total investment.

US producer price indices for computers and software have been falling much more rapidly than the corresponding UK price indices which are used by the ONS to deflate output and investment. So employing US indices is bound to raise the growth rates of output and investment.

The argument for using US price indices is threefold:

- ICT products are widely traded in highly competitive markets, so their prices should fall at about the same rate in all countries
- US agencies, such as the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS), have done a considerable amount of research on this topic (eg Cole *et al.*, 1987; Aizcorbe *et al.*, 2000)
- The UK *retail* price of computers (which is part of both the Harmonised Index of Consumer Prices and the Retail Price Index) is falling at about the same rate as its US counterpart, but considerably faster than the UK *producer* price index. This suggests that there may be a problem with the producer price index.

For software, two alternative price indices are used. The first is the official US one, which is conservative. The second is the pre-packaged component of the official index which falls more rapidly. This gives rise to two sets of estimates, called below the "low" and "high" variants respectively.

The argument for tripling the level of software investment is again threefold:

- In the UK software investment was about 39% of computer investment in the 1990s using the official figures, while in the US software investment was 140% of computer investment. Such a large discrepancy is implausible.

- There is also a striking discrepancy in the proportion of the sales of the computer services industry that are classified as investment in the two countries. In the US this proportion was about 60% in 1996, while in the UK it was only 18%.[5]
- A re-examination of the survey which was the basis for the official software series plus the application of US methods to estimating so-called "own account" software supports at least a tripling.

My methodology for measuring capital services differs from the one currently used by the ONS and this affects the results significantly too. The capital stock of each asset is estimated by cumulating investment, with depreciation assumed to be geometric at the rates used by the BEA. To get the aggregate stock, assets are weighted together using rental prices, not asset prices.

4. The contribution of ICT

The ICT share in output

The share of ICT output in GDP in current prices was 0.6% in 1979 but has risen fairly steadily since then and by 1998 had reached 3.1% of GDP: see chart 5. The computer share has fallen a bit since 1996 but recall that the output share is influenced by the net trade position which has deteriorated. Software output was 1.6% of GDP in 1998. Recall that this proportion is three times larger than the ONS one. The semiconductor share is included in the total from 1992 onwards but not shown separately in the chart. It was in fact very small, averaging –0.1% over 1992-98.

The ICT adjustment to GDP growth

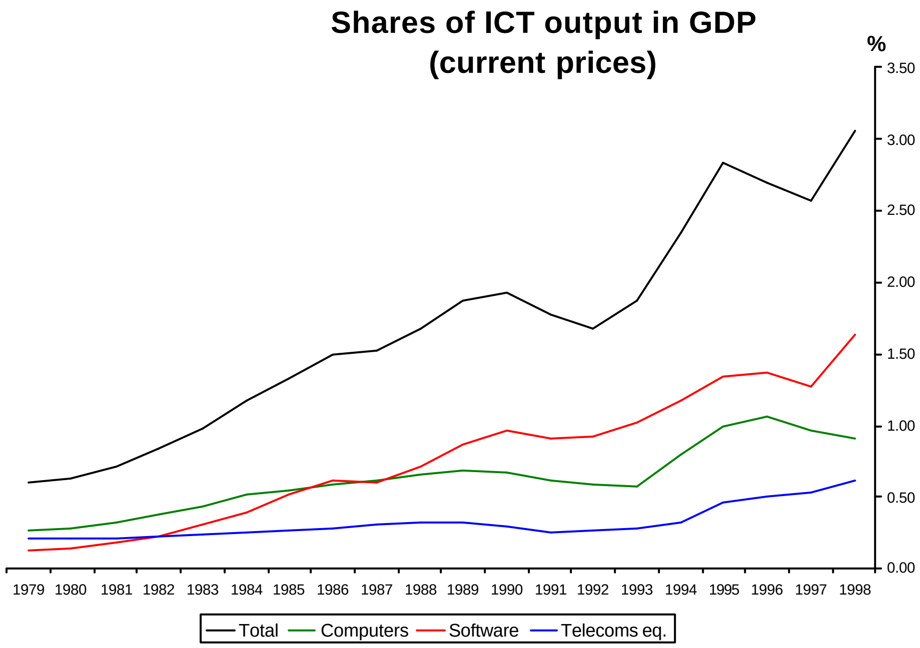
The first question is, by how much do the new estimates of ICT output change the official estimates of GDP? Table 1 shows the size of the adjustment has been rising. In 1994-98, the effect is to increase GDP by on average between 0.26 and 0.33 percentage points per annum The contributions of computers and software to the

---

[5] The UK also appears to be out of line with other European countries. Lequiller (2001) has compared France with the US. He finds that the ratio of software investment to IT equipment investment was about the same in the two countries in 1998 (his page 25 and chart 5). He also finds that the ratio of software investment to intermediate consumption of IT services is substantially lower in France than in the US (page 26-27). This ratio is exceptionally high in the US, but equally his chart 6

adjustment are roughly equal, while that of telecommunications is small. About half of the total effect is due to the software levels adjustment (see Oulton (2001a) for more detail on this).[6]

Chart 5



Note Semiconductors included in total from 1992 onwards but not shown separately.

shows that it is exceptionally low in the UK. In fact, the reported UK ratio is substantially lower than in France, the Netherlands, Italy and Germany.

6 Vaze (2001) finds somewhat smaller effects but he does not make the software levels adjustment.

Table 1
Effect of ICT adjustment on GDP growth (percentage points per annum)

	Low software		*High software*	
Software level adjustment (x 3 factor)?	*Yes*	*No*	*Yes*	*No*
1979-89	+0.09	+0.03	+0.14	+0.04
1989-98	+0.21	+0.12	+0.30	+0.15
1989-94	+0.18	+0.12	+0.27	+0.15
1994-98	+0.25	+0.13	+0.33	+0.16

The ICT contribution to aggregate output

A second and different question is this: conditional on these new ICT output estimates being accepted, how much in fact has ICT output contributed to the growth of aggregate output? This question is answered in Table 2 for the high software variant; results are similar for the low one. Table 2 shows that despite its small share in GDP, ICT accounted for 13% of output growth in 1979-89 and 21% in 1989-99. In absolute terms, the ICT contribution is clearly on a rising trend. Over 1994-98, ICT added on average 0.57 percentage points per annum to GDP growth. The rising level of the ICT contribution is not due to ICT output growing more rapidly in the 1990s — in fact, output was growing more rapidly in the 1980s — but rather to the steadily rising share ICT share (chart 5).

Because of the phenomenal rate at which their prices are falling, semiconductors have the potential to make a major contribution to output growth. In fact, from 1994 to 1998, exports of semiconductors grew at an extraordinary 41.8% p.a. Taken by themselves, exports of this one small sector would have contributed 0.38 percentage points per annum to annual growth over this period. But imports were growing at a still more extraordinary 60.4% p.a., which reduced GDP growth by 0.49 percentage points per annum So the net effect of semiconductors was to reduce GDP growth by 0.11 percentage points per annum

Table 2
Contributions of ICT and non-ICT output to GDP growth: annual averages (high software variant)

	Non-ICT		*ICT*		*Growth of GDP*
	Contrib-ution	*Prop-ortion of GDP growth*	*Contrib-ution*	*Prop-ortion of GDP growth*	
Period	*p.p. p.a.*	*%*	*p.p. p.a.*	*%*	*% p.a.*
1979-89	2.18	86.7	0.33	13.3	2.52
1989-98	1.75	79.3	0.46	20.7	2.21
1989-94	1.08	74.8	0.36	25.2	1.44
1994-98	2.59	81.8	0.57	18.2	3.16

The ICT contribution to aggregate input

The contribution of ICT capital to the growth rate of the aggregate capital stock is the share of aggregate profits attributable to ICT capital multiplied by the growth rate of ICT capital. Chart 6 shows the ICT profit share. In 1998 it was 15%. It has tripled since 1979. Since the overall profit share has not changed very much, chart 6 also tracks the share of profits due to ICT in GDP; this share now stands at about 3%, very similar to the output share in GDP. Chart 7 shows the growth rates of ICT and non-ICT capital services. ICT growth is much higher and considerably more volatile. Chart 8 shows the effect of incorporating these adjustments into the aggregate capital stock. The ICT-adjusted estimates have a similar profile but lie uniformly above the baseline estimate, which makes no adjustment for ICT. The adjustment clearly has a substantial effect on the aggregate growth rate. As Table 3 shows, ICT capital (high software variant) was growing at 21.49% p.a. over 1989-98 while non-ICT capital grew at only 2.34% p.a. The result was that, compared to the baseline estimate of 3.13 % p.a., the high software variant of aggregate capital services grew at the substantially faster rate of 4.76% over the same period.

Table 3
Growth of capital services: ICT, non-ICT and total

	Non-ICT	*ICT (low software)*	*ICT (high software)*	*Aggregate capital services (low software)*	*Aggregate capital services (high software)*	*Aggregate capital services (baseline)*
Period	*% p.a.*	*% p.a.*	*% p.a.*	*% p.a.*	*% p.a.*	*% p.a.*
1979-89	2.16	28.19	31.46	3.63	3.84	2.62
1989-98	2.34	17.82	21.49	4.32	4.76	3.13
1989-94	2.62	16.78	21.07	4.05	4.51	3.12
1994-98	2.01	19.11	22.01	4.65	5.08	3.14

Note Dwellings excluded from all these series.

Chart 6

Profits due to ICT capital:
proportion of total profit (current prices)

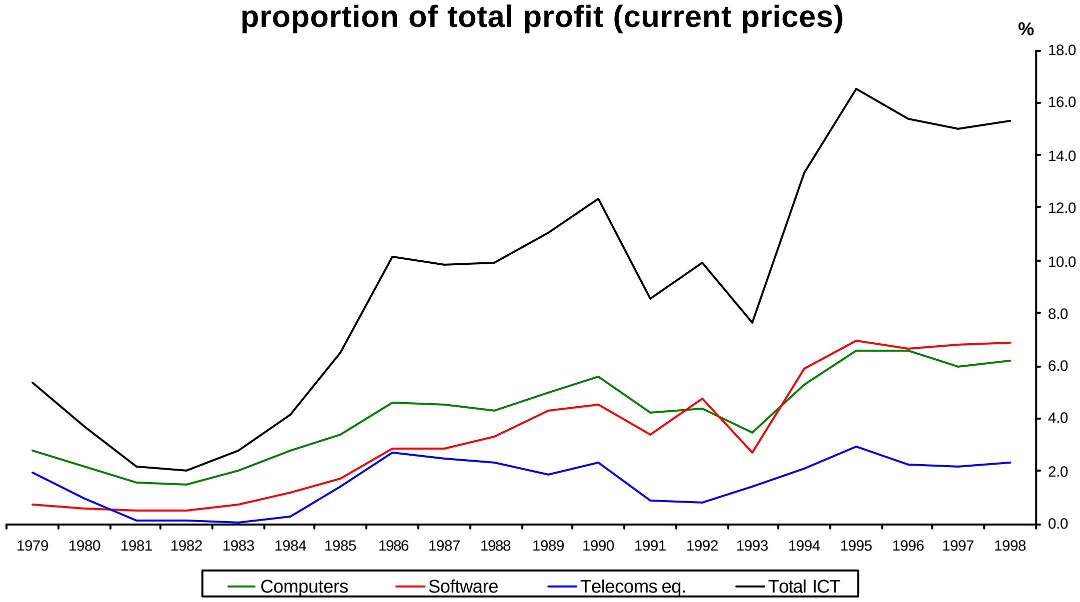


Chart 7

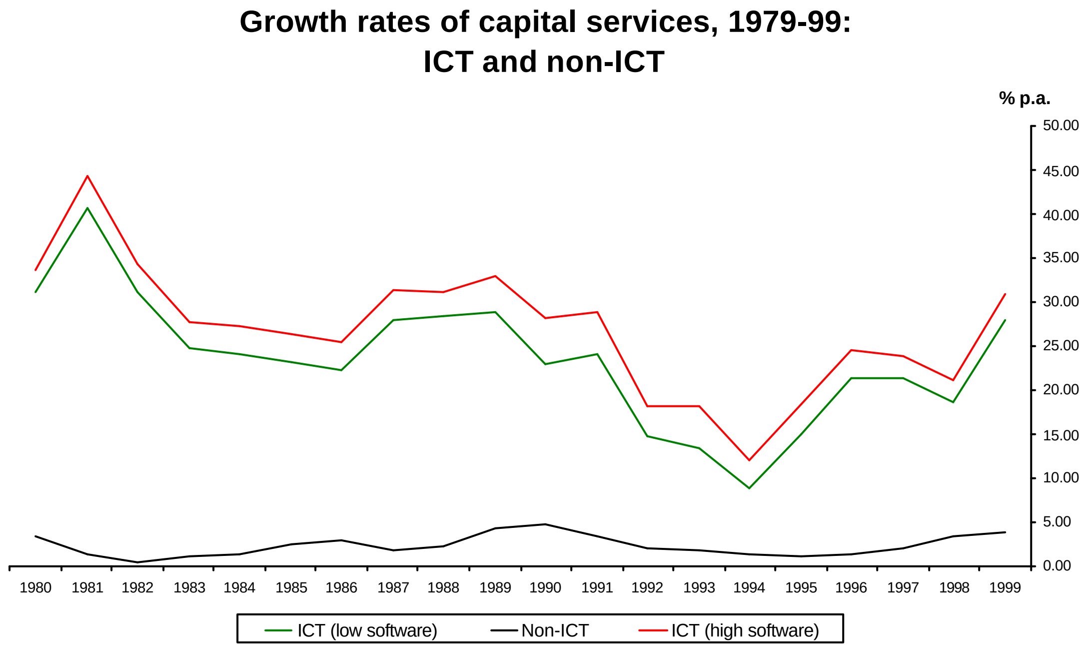
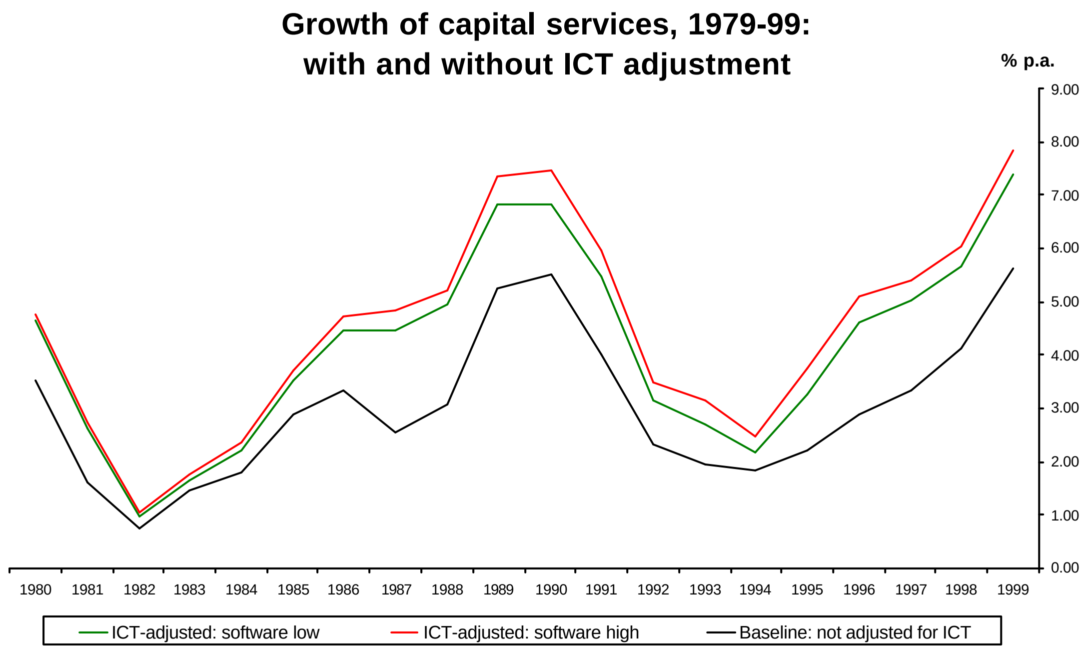


Chart 8



ICT and TFP growth

The ICT adjustments increase the growth rates of both output and capital services. It turns out that these effects are of fairly similar size. Hence the impact on TFP growth, relative to an estimate which does not make adjustments for ICT, is also fairly small: TFP growth is reduced by 0.11 percentage points per annum over 1989-98. Including the adjustments, TFP growth has been below its 1979-98 average from 1995 onwards.

Labour productivity growth: the contributions of ICT and non-ICT capital and of TFP
We can now assess the contribution of ICT to capital deepening and hence to the growth of labour productivity (output per hour worked), using equation (2). Table 4 shows the absolute amounts contributed by capital deepening and TFP to the growth of labour productivity on an hours basis. We concentrate on the high software variant since results are similar for the low software one (and also for labour productivity on a heads basis).

It is a remarkable fact that since as early as 1979 ICT has contributed around half of all capital deepening: 45% in 1979-89, 55% in 1989-98, and no less than 90% in 1994-98. Capital deepening due to ICT has accounted for 15% of labour productivity growth in 1979-89, 25% in 1989-98 and no less than 48% in 1994-98. The contribution of TFP has been shrinking in both proportional and absolute terms.

Does the ICT adjustment alter the received picture of a slowdown in labour productivity growth from 1995 onwards? The answer is no. Over these last four years, labour productivity has been growing at below its average rate since 1979 (as has TFP too).

Table 4
Contributions of capital deepening and TFP to growth of output per hour, 1979-98, by period: absolute amounts

		Capital deepening			
	Growth of output per hour	*ICT*	*Non-ICT*	*Dwellings*	*TFP*
Period	*% p.a.*	*p.p. p.a.*	*p.p. p.a.*	*p.p. p.a.*	*p.p. p.a.*
Low software					
1979-89	2.75	0.37	0.51	0.17	1.70
1989-98	2.33	0.51	0.49	0.15	1.17
1989-94	3.01	0.40	0.83	0.27	1.51
1994-98	1.47	0.64	0.08	0.00	0.75
High software					
1979-89	2.80	0.42	0.51	0.17	1.70
1989-98	2.41	0.61	0.49	0.15	1.16
1989-94	3.10	0.51	0.82	0.27	1.50
1994-98	1.55	0.74	0.08	0.00	0.73

Note Calculated in accordance with equation (2).

5. Why has the ICT effect in the UK not been as large as in the US?

It is well known that US labour productivity growth accelerated in the second half of the 1990s. Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) ascribe virtually all this acceleration to ICT. So why don't we observe anything comparable in the UK? Table 5 attempts to answer this question by setting out the relevant data from the Oliner-Sichel study side-by-side with comparable results for the UK. It shows the acceleration or deceleration which occurred in both countries between the first and second halves of the 1990s. The time periods in the two studies are not identical but probably close enough for the present purpose.

Labour productivity growth was actually substantially higher in the UK up to 1994/95. This is not too surprising since the UK's productivity level has always been considerably lower (O'Mahony, 1999). Both countries saw an improvement in the first half of the 1990s. But then in the second half US productivity accelerates while the opposite occurs in the UK. Note however that output growth accelerates in both countries, so the difference is in the behaviour of labour input (hours).

On the input side, the contribution of ICT capital is rising in both countries, but is smaller in the UK. In the most recent period, the UK contribution is about 67% of the US one. The main reason why the ICT contribution is lower in the UK is not that ICT inputs are growing more slowly but rather that their income shares are lower: in the latest period, the aggregate ICT share is 3.6% in the UK compared with 6.3% in the US (see Oulton 2001a, Table 11).

Part of the UK productivity slowdown can be ascribed to a falling contribution from other capital (a fall of 1.02 percentage points per annum). There was no parallel to this in the US, where other capital makes a minor contribution throughout the 1990s. But the most surprising feature of Table 5 is that TFP growth fell in the UK by 0.76 percentage points per annum while it rose by 0.55 percentage points per annum in the US. Up till 1994/95, TFP growth like labour productivity growth has been substantially higher in the UK. According to Oliner and Sichel, part of the reason for the rise in US aggregate TFP growth is that TFP growth rose in the computer and semiconductor industries. But they also find that TFP growth accelerated in the rest of the non-farm business sector. A rise in TFP growth in the ICT sector seems likely to have been a world-wide phenomenon, from which the UK should have benefited too, even if to a lesser extent than the US. This makes the UK slowdown in aggregate TFP growth even more puzzling.

Table 5
Productivity acceleration/deceleration in the second half of the 1990s: the US and UK compared (percentage points per annum)

	US	*UK*
	1995-99 over 1990-95	*1994-98 over 1989-94*
Growth of output per hour	+1.04	-1.54
Growth of output	+2.07	+1.73
Contributions from:		
ICT capital	+0.45	+0.24
Other capital	+0.03	-1.02
TFP plus labour quality	+0.55	-0.76
Memorandum items		
ICT income share (% of GDP)	+1.00	+1.48
Growth rates of inputs (% p.a.)		
Computers	+18.40	+9.78
Software	+0.30	-5.20
Telecommunications eq.	+3.60	+4.86

Note US figures relate to the non-farm business sector, UK ones to the whole economy (low software variant). For the UK, other capital includes dwellings. Income shares are profits attributable to each asset as a proportion of GDP.
Source US: Oliner and Sichel (2000), Tables 1 and 2. UK: Oulton (2001a).

A possible explanation is that the realised rate of return on ICT investment has been lower than that on other assets, contrary to the assumption embodied in our method (see section 2). The result would be that we have overestimated the contribution of ICT capital, and in fact of capital in general, through giving too large a weight to the fastest growing part of the capital stock. The corollary would be that we have underestimated TFP growth. Note that the contrary is frequently argued: the contribution of ICT is larger than allowed for by growth accounting (it is claimed) since network externalities generated by ICT investment are, wrongly, swept up in TFP. Alternatively, ICT investment may have incurred large adjustment costs which our method does not allow for (Kiley, 1999), in which case we would expect a revival of measured TFP growth to occur in due course. An alternative explanation for the slowdown is special conditions in manufacturing, e.g. the strong pound, particularly in the period 1995-98. The official figures for labour productivity growth certainly suggest that the slowdown was much more pronounced there than in the rest of the economy.

6. How large will ICT's contribution be in the future?

Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) both argue that the acceleration in US productivity growth has been driven by an acceleration in technical progress in the semiconductor industry, which Oliner and Sichel at least treat as an acceleration of TFP in that sector. This suggests that to assess the future contribution of ICT we need to forecast technical progress in this crucial sector: will Moore's Law continue to hold?

There is another more economic aspect. As stated above, the contribution to output growth of any sector is its share in GDP (in current prices) multiplied by the growth rate of its final output. If the output share is 3% and the volume growth is 20% p.a., then the contribution to GDP growth is 0.6 percentage points per annum, which is substantial. But suppose that prices are falling at 30% p.a. Then the share in GDP is falling too and in the next period will be less than 3% (in fact, about 2.7%). So even if prices continue to fall at 30% and volumes to rise at 20%, the contribution to GDP growth will steadily diminish and will in fact approach zero.

A similar point applies on the input side. Here the contribution of ICT capital to the growth of aggregate input is the share in GDP of profits attributable to ICT capital, multiplied by the growth rate of ICT capital. However rapidly the stock of ICT capital is rising, the contribution of ICT capital to aggregate input will go to zero if the ICT share of profits is going to zero.

It seems quite plausible that initially as prices fall there should be a phase where the share of expenditure rises, i.e. demand is elastic. But eventually, as prices continue to fall, demand will become inelastic, so the share will decline. Indeed this is just the pattern implied by the textbook linear demand curve. So the fact that the ICT share in GDP has been rising does not necessarily imply that it will continue to do so.

However up to now the software industry has been successful in inventing new uses for computers. In fact, one could argue that developments in the software, computer and semiconductor industries mutually reinforce each other. New types of software, such as those involving graphics, make greater demands on hardware, thus increasing the demand for more sophisticated machines. And the availability of more sophisticated machines makes it worthwhile to develop software which can make use of the increased power now on offer.

Furthermore, from the point of view of the UK, any potential fall in the income share of ICT seems likely to be some way in the future: as we have just seen, the share is still only about two thirds of the US level. All this suggests that the contribution of ICT to growth in the United Kingdom, on both the output and the input sides, is likely to go on rising, once current difficulties have been overcome.[7]

7. Conclusions

The main conclusions are:

- On the basis of the new estimates of ICT output and investment presented here, there has been a substantial and growing understatement of GDP growth. From 1994 to 1998, accepting the new estimates would add between 0.25 and 0.33 percentage points per annum to the growth rate.
- The share of ICT output in GDP has been rising fairly steadily but still only reached 3% by 1998. Despite this, the growth of ICT output has contributed about a fifth of GDP growth from 1989 to 1998.
- On the input side, since 1979 about half of the growth of capital services has been accounted for by the growth of ICT capital. Since 1989, 55% of capital deepening (the growth of aggregate capital services per hour worked) has been contributed by ICT capital. From 1994 to 1998, ICT capital accounted for a remarkable 90% of capital deepening.

---

[7] A similar view is expressed by Baily (2001) and by DeLong and Summers (2001) about the US economy.

- The proportion of labour productivity growth which can be accounted for by the growth of ICT capital per unit of labour is rising. ICT capital deepening accounted for 25% of the growth of output per hour in 1989-98 and 48% in 1994-98.
- Despite the ICT adjustments, there is still a slowdown in the growth rate of labour productivity after 1994. Part of the slowdown can be ascribed to a fall in the contribution of non-ICT capital but part is due to a slowdown in TFP growth, the reasons for which are at the moment mysterious. By contrast, the US labour productivity acceleration has been accompanied by rising TFP growth (in both the ICT and non-ICT sectors of the economy).

The picture which emerges for the UK bears some similarities to the US experience. There has been no sudden emergence of a new economy. ICT has always been there but its impact has been growing steadily and has only recently become a dominant force. ICT has made its impact through investment and capital accumulation, and not through TFP. But by contrast with the US, there has been no upsurge of TFP growth, but rather a slowdown. Since the ICT income share in the UK, though rising, is still only two thirds that in the US, we may expect the contribution of ICT capital to economic growth to continue to increase, once current difficulties are overcome.

The present paper has taken an aggregate approach. But in order to understand better the role of ICT it is necessary to break down the aggregate estimates of capital deepening and TFP by sector. We know that investment in ICT is highly skewed towards some of the services industries such as finance and business services. Understanding how investment in these sectors generates productivity growth at the whole economy level is an important task for future research.

References

Aizcorbe, A., Corrado, C. and Doms, M. (2000). "Constructing price and quantity indices for high technology goods". Mimeo. Washington, D.C.: Board of Governors of the Federal Reserve.

Baily, M.N. (2001). “Macroeconomic implications of the new economy”. Paper prepared for the symposium on “Economic Policy in the Information Economy”, sponsored by the Federal Reserve Bank of Kansas City, in Jackson Hole, Wyoming, August 30th-September 1st, 2001.

Bosworth, B.P. and Triplett, J.E. (2000). “What’s new about the new economy? IT, economic growth and productivity”. Mimeo. Brookings Institution.

Cole, R., Chen, Y.C., Barquin-Stolleman, J.A., Dulberger, E., Helvacian, N. and Hodge, J.H. (1986). “The application of a hedonic model to a quality-adjusted price index for computer processors”. *Survey of Current Business*, 66 (January), 41-50.

Crafts, N. (2000). “The Solow productivity paradox in historical perspective”. Mimeo.

Davies, G., Brookes, M., and Potter, S. (2000). “The IT revolution — new data on the global impact”. Goldman Sachs, *Global Economics Weekly*, Issue No. 00/37, 18th October 2000.

Daveri, F. (2000). “Is growth an information technology story in Europe too?” University of Parma and IGIER. Mimeo.

DeLong, J.B. and Summers, L.H. (2001). “The ‘new economy’: background, questions, and speculations”. Paper prepared for the symposium on “Economic Policy in the Information Economy”, sponsored by the Federal Reserve Bank of Kansas City, in Jackson Hole, Wyoming, August 30th-September 1st, 2001.

Gordon, R.J. (2000). “Does the “new economy” measure up to the great inventions of the past?”. *Journal of Economic Perspectives*, 14 (Fall), 49-74.

Greenwood, J , Hercovitz, Z. and Krusell, P. (1997). “Long–run implications of investment-specific technological change”. *American Economic Review*, 87(3), 342-362.

Jorgenson, D.W., and Griliches, Z. (1967). “The explanation of productivity change”. *Review of Economic Studies*, 34, 249-283.

Jorgenson, D.W., and Stiroh, K.J. (2000). “Raising the speed limit: U.S. economic growth in the information age”. *Brookings Papers on Economic Activity*, 1, 125-211.

Kiley, M.T. (1999). “Computers and growth with costs of adjustment: will the future look like the past?”. Washington, D.C.: Board of Governors of the Federal Reserve System.

Kneller, R. and Young, G. (2001). "The new British economy". *National Institute Economic Review*, No. 177 (July), 70-84.

Lequiller, F. (2001). "The new economy and the measurement of GDP growth". INSEE, working paper no. G 2001 / 01, Paris.

OECD (2001). *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth.* Paris.

Oliner, S.D. and Sichel, D.E. (2000). "The resurgence of growth in the late 1990s: is information technology the story?". *Journal of Economic Perspectives*, 14, Fall, 3-22.

O'Mahony, M. (1999). *Britain's Productivity Performance 1950-1996: An International Perspective.* London: National Institute of Economic and Social Research.

Oulton, N. (2001a). "ICT and productivity growth in the UK". Bank of England Working Paper No. 140. Available at http://www.bankofengland.co.uk.

Oulton, N. (2001b). "Investment-specific technological progress and growth accounting". Bank of England. Mimeo.

Schreyer, P. (2000). "The contribution of information and communication technology to output growth: a study of the G7 countries". STI Working Paper 2000/02. Paris: OECD.

Stoneman, P. (1976). *Technological Diffusion and the Computer Revolution: the UK Experience*. University of Cambridge Department of Applied Economics Monographs: 25. Cambridge: Cambridge University Press.

Vaze, P. (2001). "ICT deflation and growth: a sensitivity analysis". *Economic Trends*, No. 572 (July), 45-52.

Wadhwani, S. (2000). "Monetary challenges in a new economy". Speech delivered to the HSBC Global Investment Seminar, 12th October 2000. Reprinted in *Bank of England Quarterly Bulletin*, 40 (November), 411-421.