

# ICT, Output and Productivity Growth in the United Kingdom: A Sectoral Analysis

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THE SECOND HALF OF THE 1990s witnessed a strong acceleration of labour and total factor productivity growth (TFP) in the United States. This period coincided with major investment in and the diffusion of information and communication technologies (ICT). Rapid technological progress and falling prices in the semi-conductor industry drove down prices of products using semi-conductor technology (computers, software and communications equipment). This spurred an investment boom in these technologies by firms and households substituting to relatively cheaper inputs.

These advances in the production and adoption of ICT have prompted significant debate about its contribution to the U.S. growth and productivity revival of the 1990s, and the potential for permanently higher long-term GDP and productivity growth. The prevailing view is that economic growth was stimulated by investment in information technology, as shown in a number of studies based on aggregate data (Bosworth and Triplett, 2000; Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000) and at the industry level (Bos-

worth and Triplett, 2003; Jorgenson, Ho and Stiroh, 2002).

Compared to the United States, the United Kingdom also experienced an enviable combination of higher growth and lower inflation towards the end of the 1990s coupled with rapidly increasing levels of ICT investment. However, U.S.-style gains in productivity growth failed to materialize, with both labour productivity and TFP growth actually declining in the mid to late 1990s (see, for example, O'Mahony and de Boer, 2002). This raises the question of why the economic performance of the United Kingdom and more generally that of other leading European economies has not mirrored that of the United States.

This paper contributes to the recent debate on growth and productivity in the United Kingdom over the 1990s by quantifying the sources of economic growth in eleven sectors of the UK economy. We also investigate whether and to what extent weaker output and labour productivity growth in the United Kingdom, relative to the United States, is due to a slower growth of ICT and non-ICT capital, labour and/or to sluggish TFP growth. The main novelty of this

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study is that we use a bottom-up approach, whereby economy-wide estimates are obtained from (and are consistent with) the underlying sectoral data.

The paper uses standard growth accounting methodology to measure the sources of output and labour productivity growth on a sectoral basis. Details on the methodology are provided in the unabridged version of the paper. Generally, two sources of growth in output can be identified: growth in production inputs (broadly defined as capital and labour) and a residual term (the so-called TFP growth) due to some unmeasured technological progress. Growth accounting does not explain growth in the usual sense of the word. It is merely descriptive, but it allows one to focus on the relative importance of the various factors determining growth.

The paper is divided into five sections. The first section briefly reviews the recent literature on UK productivity developments. The second section describes data sources and the third presents the sectoral results on the sources of output and labour productivity growth for the 1993-2000 period and 1993-1997 and 1997-2000 sub-periods for the United Kingdom. The fourth section presents the results at the aggregate level. The fifth and final section concludes.

## Recent Productivity Studies

A growing body of research has recently addressed the issue of why the economic performance of the United Kingdom, and more generally that of other leading European economies, has not mirrored that of the United States, though definitive conclusions are not in sight at present. Oulton (2001) is one of the first studies that measures the full contribution of ICT to output and labour productivity growth in the United Kingdom. Using aggregate data over 1979-1998, the study finds a substantial contri-

bution of ICT to UK GDP growth and capital deepening at the macro level. However, due to slower accumulation of non-ICT capital and a slowdown in TFP, labour productivity growth weakens after 1994.

Basu, Oulton and Srinivasan. (2003) investigate whether there is a link between ICT usage and TFP growth. Their working hypothesis is that the full realization of benefits from ICT requires substantial complementary investments in learning, reorganization and the like, so that the payoff may be long delayed.<sup>2</sup> Contemporaneously, investments in ICT may in fact be associated with lower TFP as resources are diverted to reorganization and learning. Their results for the United States indicate that current TFP growth is positively correlated with past ICT investments and negatively with current ICT investments. The results are more mixed for the United Kingdom.

Inklaar, O'Mahony, and Timmer (2003) use industry-level data to analyze sources of labour productivity growth in four European countries: France, Germany, Netherlands and the United Kingdom (EU-4), in comparison with the United States over 1979-2000. They find that a small set of service industries is mainly responsible for the acceleration in ICT capital deepening in both regions, but their contribution to growth is lower in the EU-4 than in the United States. In addition, widespread deceleration of TFP growth and non-ICT capital account for almost 80 per cent of the labour productivity slowdown in the EU-4.<sup>3</sup>

## Data sources

We draw on data from different sources to construct the sector-level panel data required for our growth accounting exercise. Value added at constant prices is our measure of output. Time series for each sector were made available

2 See, for example, Brynjolfsson and Hitt (2000) for a discussion of the kinds of complementary investments and co-invention that firms undertake in order to benefit from ICT.

3 For a wider perspective on EU productivity and competitiveness, see O'Mahony and van Ark (2003).

by the UK Office of National Statistics (ONS).<sup>4</sup> Value added in current prices and employee compensation estimates by sector were obtained from the ONS Detailed Supply and Use Tables, available on the ONS website for the period 1992-2000.

Labour input is measured as hours worked. The total number of hours worked is calculated as the total number of persons employed (including self-employed) times the average number of hours worked. Data on the total number of persons employed is available on a sectoral basis from 1993 onwards from the ONS Blue Book.<sup>5</sup> Data on average hours worked come from the Labour Force Survey, which is also available from the ONS on a quarterly basis over the period 1984-2002. We have used average hours worked in the spring period (the only data available before 1998 on a sectoral basis) as a proxy for the yearly data.

Constant price capital stock data were sourced from the National Institute of Economic and Social Research (NIESR). This dataset contains information on capital stocks for six asset types: structures, vehicles, buildings, computers, software, and telecommunication equipment from 1950 to 1999.<sup>6</sup> Following Oulton (2001) and Jorgenson and

Stiroh (2000), capital services are assumed to be proportional to the stock available at the beginning of the period.

The estimation of rental prices requires information on asset-specific price indices and depreciation rates. Since the ONS does not currently produce price indices for ICT goods adjusted for quality change, we have used U.S. Bureau of Economic Analysis (BEA) price indices for computers, software<sup>7</sup> and telecommunications equipment, which use hedonic techniques to correct for quality change.<sup>8</sup> In our analysis, we have adjusted these BEA price indices for movements in the dollar-pound exchange rate. A price deflator for non-ICT investment has been generated by using a UK Producer Price Index (PPI), available from the ONS, adjusted to exclude the ICT components.

Sector-specific depreciation rates for each type of asset have been made available by the NIESR. Essentially, these depreciation rates are constructed by multiplying the rates estimated by Hulten and Wykoff (1981) and reproduced in Fraumeni (1997) by their shares of industry investment as explained in O'Mahony (1999). Information on corporate tax rates and depreciation allowances has been supplied by the Inland Revenue.

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4 The ONS does not currently produce separate constant price value added series for transport and storage, and post and communication, but only for their aggregate. The series for each sub-sector have been constructed by using their time-varying shares in the wider aggregate, available from the ONS Supply and Use Tables. It is important to note that double-deflation is not consistently used in the UK National Accounts to construct constant price value added series.

5 These series are not separately available for transport and storage, and post and communication, but only for their aggregate. The series for each sub-sector have been constructed by using their time-varying shares in the wider aggregate, available from National Institute sectoral productivity dataset (NISEC02).

6 The National Institute sectoral productivity dataset (NISEC02) contains data series for up to 48 sectors and industries used in the construction of measures of the relative productivity of the United Kingdom, the United States, Germany, France and Japan. For more information on the construction of this data and for a discussion of various adjustments made to the original series, see O'Mahony and de Boer (2002).

7 Software investment has three components: pre-packaged software, e.g. an office suite sold separately from the computer on which it is to be run; custom software, usually written by a software company specifically for sale to another company; and own account software, written in-house for a company's own use. In the United States, each of these three types of software has a different price index (Parker and Grimm, 2000). We use two alternative price indices in our estimates: the official U.S. price index for software ("low software" case) and the U.S. pre-packaged software price index ("high software" case).

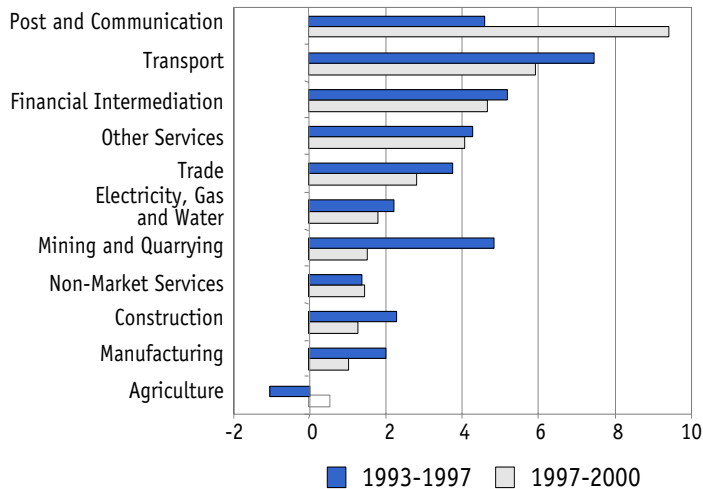
8 These price indices are the ones employed in the U.S. National Income and Product Accounts (NIPA).

**Table 1**  
**Contributions to Sectoral Output Growth, 1993-2000**  
 (percentage points)

Sector	Output growth	ICT contrib.	Non-ICT contrib.	Labour contrib.	TFP growth
Agriculture	-0.37	0.10	0.02	-1.35	0.87
Construction	1.86	0.03	0.42	0.60	0.81
Electricity, Gas and Water	2.01	0.24	0.67	-1.90	2.99
Financial Intermediation	4.94	1.05	1.00	1.68	1.21
Manufacturing	1.59	0.34	0.08	-0.09	1.27
Mining and Quarrying	3.41	-0.03	0.10	-0.39	3.72
Non-Market Services	1.39	0.22	0.25	1.24	-0.31
Other Services	4.17	0.38	0.67	1.93	1.19
Post and Communication	6.65	3.51	0.18	1.29	1.67
Transport	6.79	0.34	0.59	0.98	4.87
Trade	3.33	0.44	1.21	0.39	1.30

Notes: All figures are average annual growth rates; non-market services is the aggregate of Public Administration (SIC92 Section L), Education (SIC92 Section M) and Health and Social Work (SIC92 Section N).

**Chart 1**  
**Output Growth by Sector and Sub-period**



To summarize, our panel data consists of eleven sectors, representing the entire UK economy over the period 1993-2000.

### Sectoral Results

Our estimates of the sources of output and labour productivity growth over the period 1993-2000 are based on the 'low' variant of the price deflator for software investment. Estimates based on the 'high' variant price deflator are provided in the unabridged version of the

paper. They differ only marginally from the 'low' variant estimates.

### Output growth

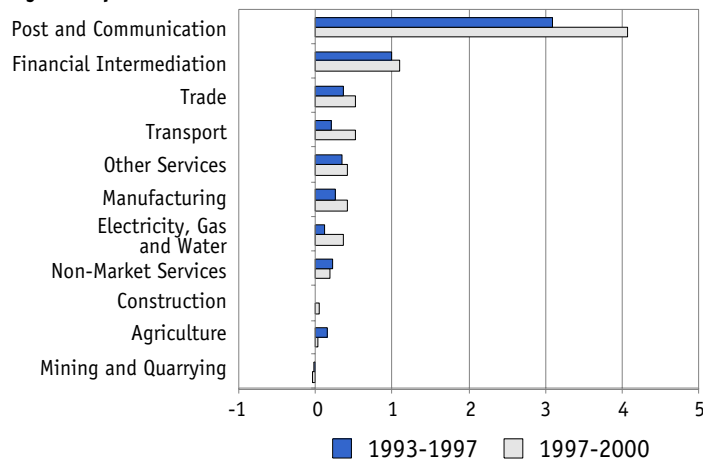
Table 1 reports our estimates of the sources of output growth within each sector of the UK economy. The growth of output is the sum of the contributions of ICT and non-ICT capital, labour and TFP. For the period 1993-2000, output growth was positive for every sector of the economy with the exception of agriculture. Transport, post and communication, and financial intermediation were the most dynamic sectors of the UK economy, with output growth well above 4 per cent per year. ICT capital made a positive contribution to output growth in all sectors, except mining and quarrying. This (absolute) contribution was the highest in post and communication (3.51 per cent per year), followed by financial intermediation (1.05 per cent per year) and trade (0.44 per cent per year). Moreover, ICT capital made a strong relative contribution to output growth in these three sectors as well as in manufacturing. Non-ICT capital made a positive contribution to output growth in each sector.

The contributions of labour input were negative for four sectors. The largest negative contribution was in electricity, gas and water; this was a consequence of the program of privatization and liberalization undertaken in this sector in the 1990s. TFP growth is the final source of output growth identified in Table 1. It makes a positive contribution to output growth in every sector except agriculture and non-market services. Manufacturing and transport were the sectors where TFP growth was particularly significant, with a contribution to output growth above 70 per cent. TFP growth was also relatively important in construction and trade and to a lesser extent in post and communication and financial intermediation, the sectors that invested more heavily in ICT assets. A comparison with similar calculations for the United States for the period 1995-2000 (reported in Inklaar et al., 2003) reveals smaller contributions of TFP growth in trade and post and communications and higher contributions in financial intermediation and transport in the United Kingdom.

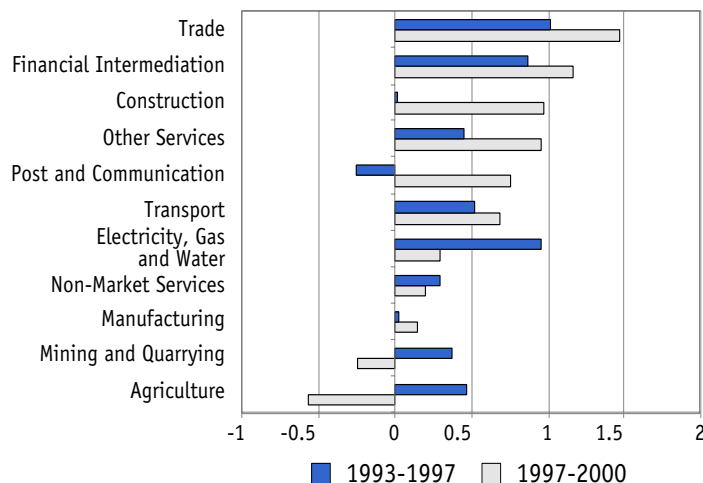
Chart 1 plots output growth for two sub-periods of our sample, 1993-1997 and 1997-2000. Output growth decelerated in all sectors of the UK economy between these two periods except in post and communication, agriculture and non-market services. Mining and quarrying was the sector with the sharpest slowdown.

In Chart 2 we display the contribution of ICT capital to output growth in 1993-1997 and 1997-2000. With the exception of agriculture and non-market services, the contribution of ICT to output growth increased over time in all sectors, in parallel with higher investment in ICT assets. This increase was greatest in the case of post and communication (almost a full percentage point). Financial intermediation and manufacturing experienced a somewhat lower increase, though if we weight these contributions by the sectors' shares in total GDP, their contribution to the acceleration of total GDP growth during 1997-

**Chart 2**  
**Contribution of ICT Capital to Output Growth by Sub-period**



**Chart 3**  
**Contribution of Non-ICT Capital to Output Growth by Sub-period**

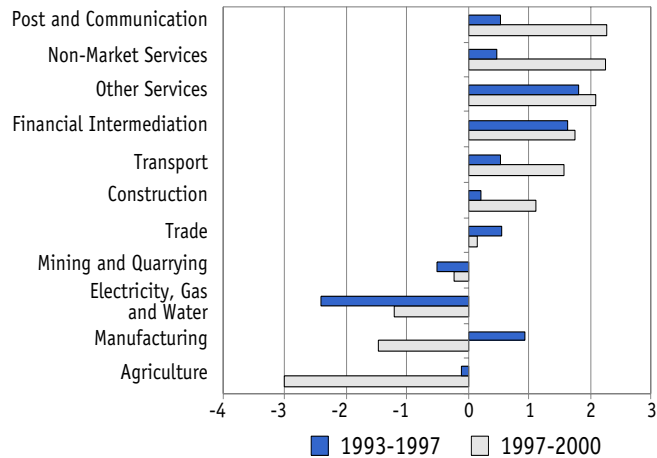


2000 becomes commensurable to that of post and communication.

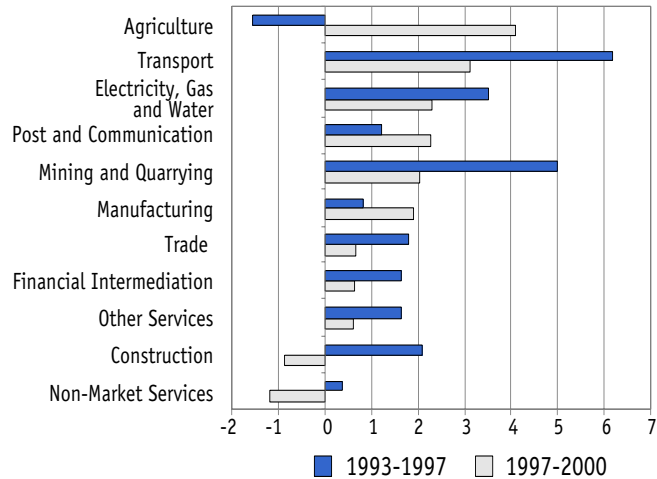
Chart 3 illustrates the contribution of non-ICT capital to output growth in 1993-1997 and 1997-2000. This contribution increases in the majority of the sectors towards the late 1990s. Trade is the sector where this contribution was highest in both the sub-periods and increasing faster than that of ICT capital (Chart 2).

Chart 4 displays the contribution of labour to output growth for the 1993-1997 and 1997-

**Chart 4**  
**Contribution of Labour to Output Growth**  
**by Sub-period**



**Chart 5**  
**Contribution of TFP to Output Growth by Sub-period**



2000 periods. This contribution increased over the 1990s in most sectors. Non-market services posted the largest increase, followed by post and communication. Manufacturing is the only large sector of the economy where the contribution of labour became negative in the late 1990s.

Chart 5 shows the average contribution of TFP to output growth in 1993-1997 and 1997-

2000. Agriculture, post and communication and manufacturing were the only sectors to show an acceleration of TFP growth toward the end of the 1990s. For the remaining sectors the contribution of TFP decreased over time and in some cases turned negative (construction and non-market services).

The unabridged version of this paper reports estimates of the sources of output growth based on the high variant of the deflator for software investment.<sup>9</sup> These estimates are based on the assumption that it is appropriate to deflate all software investment by the price index of pre-packaged software. As expected, use of the high software deflator marginally increases the contribution of ICT capital and reduces that of non-ICT capital and TFP growth.

### Labour productivity growth

In this section we decompose labour productivity growth into ICT and non-ICT capital deepening effects, and TFP growth. Table 2 reports such estimates for the period 1993-2000. Labour productivity growth was positive in every sector of the economy, with electricity, gas and water, transport and mining and quarrying showing the fastest growth for the period. Post and communication, and trade also had relatively high labour productivity growth rates.

The contribution of ICT capital deepening to labour productivity growth was positive for all sectors except mining and quarrying. ICT capital deepening accounted for more than 70 per cent of labour productivity growth in post and communication and financial intermediation. Manufacturing and other services also displayed sizeable contributions (above 20 per cent). The contribution of non-ICT capital deepening to labour productivity growth was positive with the exception of three sectors.

<sup>9</sup> The high variant is the U.S. pre-packaged software price index. See footnote 7 for more information on U.S. software price deflators.

**Table 2****Contributions to Sectoral Labour Productivity Growth, 1993-2000**

(percentage points)

Sector	Labour productivity growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture	2.00	0.13	1.01	0.87
Construction	1.12	0.02	0.29	0.81
Electricity, Gas and Water	7.40	0.56	3.77	2.99
Financial Intermediation	1.28	0.87	-0.73	1.21
Manufacturing	1.68	0.34	0.07	1.27
Mining and Quarrying	4.71	-0.02	0.95	3.72
Non-Market Services	0.00	0.19	0.13	-0.31
Other Services	1.49	0.32	-0.05	1.19
Post and Communication	4.62	3.23	-0.18	1.67
Transport	5.58	0.32	0.39	4.87
Trade	2.76	0.42	1.05	1.30

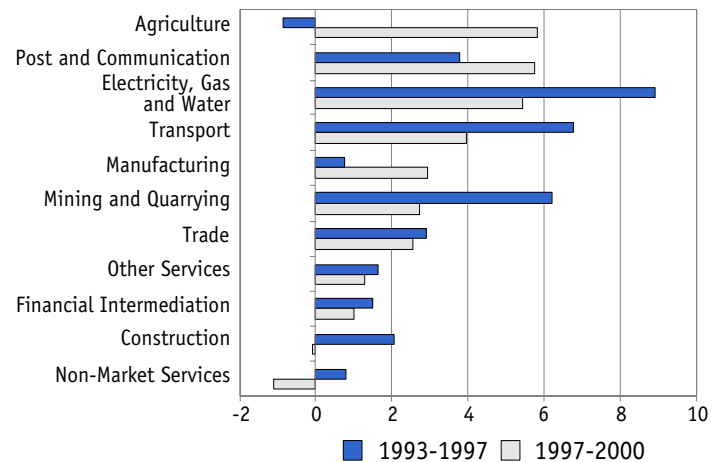
Notes: All figures are average annual growth rates; Non Market Services is the aggregate of Public Administration (SIC92 Section L), Education (SIC92 Section M) and Health and Social Work (SIC92 Section N).

Chart 6 shows labour productivity growth in 1993-1997 and 1997-2000. The most striking feature of the chart is that labour productivity growth decelerated in all sectors over the 1990s, except in agriculture, post and communication, and manufacturing.

Chart 7 displays the contribution of ICT capital deepening to labour productivity in 1993-1997 and 1997-2000. This contribution increased in most sectors, with post and communication showing the highest increase.

In Chart 8 we show the contribution of non-ICT capital to labour productivity growth in 1993-1997 and 1997-2000. This contribution increased (or became less negative) over the 1990s in seven sectors and decreased in the other four. The largest contribution from non-ICT capital deepening was in electricity, gas and water though it fell significantly between periods.

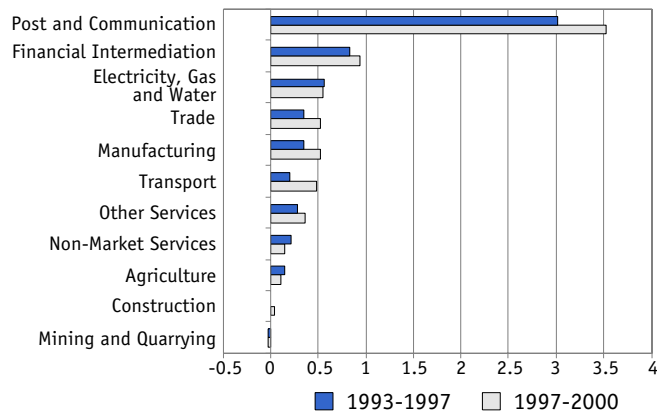
The unabridged version of this paper reports decompositions of labour productivity growth based on the 'high' software deflator. As expected, the effect of using this deflator is to increase the contribution of ICT capital deepening and to decrease that of non-ICT capital deepening and TFP.

**Chart 6****Labour Productivity Growth by Sector and Sub-period****Aggregate Results**

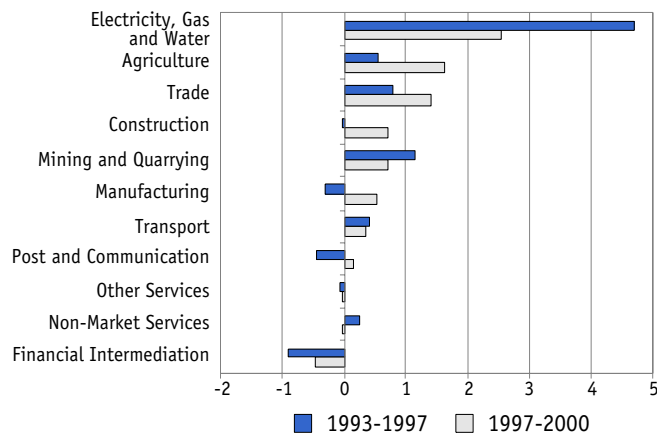
This section of the paper aggregates for the whole economy the sources of output and labour productivity growth presented in previous tables. We also compare our results for the UK economy with the corresponding figures for the U.S.

Table 3 reports the contribution of ICT and non-ICT capital, labour and TFP to output growth for the period 1994-2000. Aggregate output grew 3.19 per cent per year. TFP was the primary driver of output growth in the United

**Chart 7**  
**Contribution of ICT Capital to Labour Productivity Growth by Sub-period**



**Chart 8**  
**Contribution of Non-ICT Capital to Labour Productivity Growth by Sub-period**



Kingdom, followed by labour, non-ICT capital, and ICT capital. Comparing the sources of output growth in the United Kingdom with those in the United States for the period 1995-2000, one observes that the latter shows sizeably higher contributions of ICT and non-ICT capital and, to a lesser extent, labour.<sup>10</sup>

Table 4 displays the economy-wide contributions of ICT and non-ICT capital deepening and TFP growth to labour productivity growth. For the period 1993-2000, labour productivity grew 1.96 per cent per annum. TFP growth accounted for more than 60 per cent of labour productivity growth and ICT capital more than one quarter. Comparing the United Kingdom with the United States one finds that slower labour productivity growth in the United Kingdom is primarily attributable to less pronounced ICT and non-ICT capital deepening.

Finally, we would like to stress that, while being built up from the detailed sectoral results presented earlier, our economy-wide estimates of the contribution of ICT to output and labour productivity growth in the United Kingdom are quantitatively consistent with those reported by Oulton (2001) for the United Kingdom.<sup>11</sup>

## Conclusion

This paper uses a standard growth accounting framework to quantify the sources of output and labour productivity growth for eleven sectors of the UK economy over the period 1993-2000. Our methodology allows also to separate the contribution of capital to growth in its ICT and non-ICT components.

Our results indicate that ICT capital makes a substantial contribution to output growth in the largest sectors of the UK economy in the 1990s. This contribution increases over time in parallel with continued investment in ICT assets. TFP growth accounts for a substantial proportion of output growth in most of the UK sectors. In the case of financial intermediation and transport, the contribution of TFP

<sup>10</sup> We do not compare TFP growth across the two studies because there are a number of methodological differences that affect the measurement of TFP. The difference between the two estimates of TFP growth for the United States in Table 5 and Table 6 reflect methodological differences between Jorgenson et al. (2002) and Inklaar et al. (2003).

<sup>11</sup> For example, the estimates reported by Oulton (2001) suggest that, in the low software case, the average (absolute) contribution of ICT to aggregate output growth over the period 1994-1998 is about 0.6 percentage points per annum; our results suggest an aggregate contribution of about 0.52 points for the same period.



**Table 3**  
**Economy-wide Sources of Output Growth, 1993-2000**

Country	Output growth	ICT contrib.	Non-ICT contrib.	Labour contrib.	TFP growth
UK (percentage points)	3.19	0.57	0.59	0.82	1.20
% contribution		18.0	18.7	25.6	37.8
U.S. (1995-2000) (percentage points)	4.20	1.11	1.15	1.30	0.63
% contribution		26.4	27.4	31.0	15.0

Notes: Contributions for the United States are from Jorgenson et al. (2002).

**Table 4**  
**Economy-wide Sources of Labour Productivity Growth, 1993-2000**

Country	Labour productivity growth	ICT capital deepening	Non-ICT capital deepening	TFP growth	Reallocation of hours
UK (percentage points)	1.96	0.52	0.15	1.20	0.09
% contribution		26.3	7.8	61.3	4.6
U.S. (1995-2000) (percentage points)	2.46	0.86	0.43	1.27	-0.09
% contribution		35.0	17.5	51.6	-3.7

Notes: Contributions for the United States are from Inklaar et al. (2003).

to sectoral output growth is higher than in the United States. In addition, our results confirm that ICT capital makes sizeable contributions to labour productivity growth in all sectors of the economy, except mining and quarrying.

When compared to the United States, it appears that the less impressive output and productivity performance of the United Kingdom is mainly attributable to slower accumulation of ICT and non-ICT capital.

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