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What Happened to the Knowledge Economy? ICT, Intangible Investment and Britain's Productivity Record Revisited

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What Happened to the Knowledge Economy? ICT, Intangible Investment and Britain's Productivity Record Revisited*

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Abstract

A major puzzle is that despite the apparent importance of innovation around the "knowledge economy", UK macro performance appears unaffected: investment rates are flat, and productivity has slowed down. We investigate whether measurement issues might account for the puzzle. The standard National Accounts treatment of most spending on "knowledge" or "intangible" assets is as intermediate consumption. Thus they do not count as either GDP or investment. We ask how treating such spending as investment affects some key macro variables, namely, market sector gross value added (MGVA), business investment, capital and labour shares, growth in labour and total factor productivity, and capital deepening. We find (a) MGVA was understated by about 6% in 1970 and 13% in 2004 (b) instead of the nominal business investment/MGVA ratio falling since 1970 it is has been rising (c) instead of the labour compensation/MGVA ratio being flat since 1970 it has been falling (d) growth in labour productivity and capital deepening has been understated and growth in total factor productivity overstated (e) total factor productivity growth has not slowed since 1990 but has been accelerating.

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1 Introduction

According to common debate, the "Knowledge Economy" is all around us. Think tanks and commentators argue that developed countries have no future in a globalised economy unless they specialise in knowledge-intensive activities. Whole goods and occupations, many based on ICT, that were almost unheard of even five years ago, proliferate (think of iPods, SatNavs and Search Engine Programmers). Pressure groups extol both the virtues and contribution of the UK design and creative industries.

Where has all this shown up in UK economic performance? The ratio of nominal investment to nominal GDP has stayed more or less where it was since the 1950s, which is hard to square with the perception that firms are investing in knowledge assets in the teeth of a technological revolution. The share of profits in GDP has also remained quite stable, so if firms are investing more, this is not being reflected in additional profits. UK productivity performance over the 1990s remains a puzzle. According to existing studies[1] UK productivity growth deteriorated after 1995. This is in contrast to the US experience, where there was a well documented productivity acceleration associated with the ICT investment boom[2]. The UK also experienced an ICT investment boom in the late 1990s, so why the productivity slowdown?

Two possible answers could explain these puzzles. The first is that the investment in and/or the impact of the knowledge economy is in fact much less than popular discussion would suggest. The second is that the impact is hidden by measurement problems.

This paper examines the second view for the UK[3] building on previous work by Oulton and Srinivasan (2003), Basu et al (2004) and Oulton and Srinivasan (2005). Work by Oulton and Srinivasan (2003, 2005) examined a number of measurement issues. They incorporated software into output; measured capital as capital services, not capital assets; built the capital data from a disaggregated level, and measured labour quality rather than just hours. Basu et al (2004) specifically looked at whether ICT measurement could explain missing UK productivity growth in the 1990s. The productivity growth slowdown still remained in all these studies and the authors argued that it was likely due to unmeasured investment in organisational capital. We build on this work by using all these elements in our data but also adding intangible assets (where we think of spending on intangible assets as describing spending on a broad range of knowledge-type assets, such as R&D, software, organisational capital etc, details below). Since one of our assets is organisational capital, given the previous work, it is of interest to see if incorporating this can change the picture of UK productivity performance in the late 1990s.

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[1] O'Mahony and De Boer (2002), Oulton and Srinivasan (2003) and Oulton and Srinivasan (2005).

[2] Oliner and Sichel (2000), Jorgenson and Stiroh (2000a and b), Stiroh (2002) and Gordon (2003)

[3] The measurement problems addressed in this paper are not problems with the existing UK National Accounts, which continue to be compiled based on internationally agreed definitions. The focus of this paper relates to what the impact would be of extending the agreed definition of capital assets to include a broader range of intangible assets. As such, the output and productivity estimates should not be regarded as corrections to existing National Accounts rather as adjustments to National Accounts data for the wider definition of intangible capital we adopt.

Whilst there have been some studies for the US on the impact of intangibles on GDP, such as Corrado, Hulten and Sichel[4] (2004, 2006) and Nakamura (1999, 2001, 2003) there has not been anything for the UK. In this paper we follow the central observation in those US papers that in practice, spending on most knowledge assets is, in accounting terms, like spending on other intangible assets, such as software. Spending on *tangible* assets has a long measurement tradition; it is part of investment and therefore also part of GDP. However, spending on *intangible* assets, with a few exceptions, is treated as intermediate expenditure. In constructing GDP therefore, spending on R&D for example, is treated like spending on electricity, i.e. it is assumed not to be investment and so produces no asset at the end of the period. As an intermediate it does not appear in either investment or GDP data.[5]

This paper tries to answer the following question: what are the consequences for a range of macroeconomic variables, including productivity, of treating knowledge expenditure as investment rather than as intermediate expenditure? We do this as follows. First, following the approach of CHS, we assemble data on knowledge investments for a range of intangible assets. These are wider than the usual R&D and software and include design, spending on reputation and human capital. Using these data we analyse the relative quantities of different types of expenditure and how they have changed over time. We believe this question of interest since we have little information on whether expenditure on software is more or less than expenditure on design, training etc. and also on how such expenditure has changed over time.

Second, we look at the consequences for overall business investment and market sector GVA, henceforth MGVA[6]. We believe this to be of interest since some have conjectured that ignoring intangibles explains why the traditionally-measured (i.e. focussed on tangible capital) business nominal investment to MGVA ratio has remained so flat in the UK despite the perception that the underlying conditions for investment have been so favourable in recent years. We also think it of importance if the level of market sector GVA has been systematically understated.

Third, we look at the consequences for market sector labour productivity. Since the level of MGVA rises, the level of labour productivity rises. But labour productivity growth will only rise if the level of MGVA rises increasingly over the period; so the answer to this question is not as clear. The reason why labour productivity rises is that there is an extra input in the economy, namely an intangible capital stock, in addition to the tangible capital stock. Thus we think a question of interest is: how much has the change in the intangible capital stock contributed to productivity growth along with other inputs? The systematic method of answering this question is via growth accounting and so we extend previous UK growth accounting studies by including intangible capital. Note to that not only has MGVA and input changed, but

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[4] We refer to Corrado, Hulten and Sichel as CHS from here onwards.

[5] Michael Mandler's (2006) Business Week article for example describes the treatment of Apple by national income accountants as " ..they count each iPod twice: when it arrives from China, and when it sells. That, in effect, reduces Apple -- one of the world's greatest innovators -- to a reseller of imported goods."

[6] Owing to the difficulty of measuring productivity and intangible spending in the government sector we focus on the market sector rather than the whole economy. Hence our estimates are based on market sector GVA rather than GDP.

the factor shares will have changed as well, since the extra MGVA due to intangibles is matched on the income side by extra income to capital.

It is worth pointing out that we present estimates of MGVA, labour productivity growth and growth accounting both with and without intangibles. Thus the reader uninterested in intangible assets can therefore obtain, we hope, some interesting data from the paper. In particular, our (non-intangible) estimates are consistent with the 2006 *Blue Book* and give data up to 2004.[7]

Our main findings are as follows. First, nominal business investment in intangible assets in 2004 is about equal to nominal business investment in tangibles (each is around 15% of MGVA). Of that intangible investment, around 50% of the total is on economic competencies (investment in reputation, human and organisational capital), 35% on innovative property (mainly scientific and non-scientific R&D and design) and 15% on computerised information (mainly software). Since 1970, nominal investment in intangibles has grown from about 6% of nominal MGVA to about 15%. Interestingly, the patterns of growth look remarkably like those in the US, although the UK has a bit less R&D investment and a bit more investment in design.

Second, accounting for intangibles makes a considerable difference to measured market sector GVA and the share of that output accounted for by investment and payments to capital and labour. The level of nominal market sector GVA rises by about 13% in 2004[8]. The share of nominal investment and payments to capital also rise.

Third, accounting for intangibles affects labour productivity growth (LPG) and total factor productivity growth (TFPG) in the market sector. Without intangibles, we confirm previous work that LPG and TFPG both slow down between 1990-95 and 1995-00[9]. We also document a further slight slowdown in 2000-04 in LPG but a speeding up in TFPG. With intangibles, the picture changes interestingly. First, both LPG and TFPG accelerate between 1990-95 and 1995-00, suggesting that the UK economy was building sufficient intangibles during that period such that their omission affected the productivity statistics in important ways. Second, even with intangibles, the post 2000 slowdown in LPG still remains.

There are of course a host of measurement problems in estimating investment in intangible assets. We therefore assess the robustness of our findings to different measurement methods. There are a number of findings. First, our major findings (on the shares of nominal investment and wages and LPG and TFPG) are robust to changes in the depreciation rates e.g. doubling or halving them. The reason is that the CHS assumed depreciation rates are 20% or above so that these assets depreciate away relatively quickly. Therefore, our results depend more on the measured investment levels. Second, regarding levels, around

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[7] There are no official UK TFP estimates, so those available are by Oulton and Srinivasan (2005), who give data up to 2000, and the OECD and Timmer, Ypma and van Ark (2003 updated 2005), who give data to 2004. See Appendix 1 for an outline. None of these papers look at the range of intangibles we cover (they do include software).

[8] This is less than the share of intangible investment in MGVA because some intangible investment (some software, mineral exploration and copyright costs) is already included in MGVA (about 2%). It is slightly more than the figure in Giorgio Marrano and Haskel (2006), but that reported intangible investment as a proportion of GDP.

60% of intangible spending comes from official surveys (e.g. the R&D survey, software investment surveys, training surveys). The rest comes either from assumptions built on official surveys or from wages and salary surveys used to measure the costs spent by occupations in e.g. organisational capital production. We look at the robustness of our main findings to varying the levels of investment in these non-official surveys and find they are quite robust. Thirdly, we look at different time periods, such as peak-to-peak, to ensure our growth accounting results are robust to selecting different time periods. Finally, we rely on an implied market sector GVA deflator for many of the intangible assets, the main exception being software. Without other data on this, we cannot explore robustness to this assumption and so this remains an area to be explored.

The outline of the rest of this paper is as follows. In the next section, we set out how intangibles affect market sector GVA and growth. Section three describes the data used to try to measure the impact of treating intangibles spending as investment (in our case the impact on business investment and market sector gross value added), and section four outlines our growth accounting approach. Section five presents our growth accounting results and section 6 concludes.

2 Model

We follow CHS in setting out the following model. Suppose there are three goods produced, a consumption good, with real output volume C_t and price P_t^C, a tangible investment good, I_t with price P_t^I and an intangible investment good N_t with price P_t^N, where the *t* subscript denotes time.

2.1 Intangibles treated as intermediates

Suppose first that the intangible investment good is regarded as an intermediate. Then the tangible capital stock K_t is assumed to accumulate according to the perpetual inventory model

$$K_t = I_t + (1-\delta_K)K_{t-1} \quad (1)$$

with depreciation rate δ_K (assumed constant over time). Then we can write the production function for each sector and, assuming factors are paid their marginal product and the production function is homogenous of degree one, the money flows for each sector as follows

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[9] O'Mahony and De Boer (2002), Oulton and Srinivasan (2003) and Oulton and Srinivasan (2005).

$$
\begin{aligned}
&\text{(a) Intangible sector}: N_t = F^N(L_{N,t}, K_{N,t}, t); \quad P_t^N N_t = P_t^L L_{N,t} + P_t^K K_{N,t} \\
&\text{(b) Tangible sector}: I_t = F^I(L_{I,t}, K_{I,t}, N_{I,t}, t); \quad P_t^I I_t = P_t^L L_{I,t} + P_t^K K_{I,t} + P_t^N N_{I,t} \qquad (2) \\
&\text{(c) Consumption sector}: C_t = F^C(L_{C,t}, K_{C,t}, N_{C,t}, t); \quad P_t^C C_t = P_t^L L_{C,t} + P_t^K K_{C,t} + P_t^N N_{C,t}
\end{aligned}
$$

where the superscripts *N*, *I* and *C* refer to the three sectors. So, for example, in equation (2a), the left hand side production function in the intangible sector says that the output of intangibles is produced by labour in the sector and tangible capital the sector. The right hand side equation says that with factors paid their marginal products, the value of the intangibles produced equals the returns to labour and tangible capital used in that sector.

Since intangibles are assumed to be intermediates, the production functions in 2b and 2c for the tangible and consumption sector show that the volume of intangible output is simply an input into the production of tangible and consumption goods (we omit other intermediates which similarly net out). Since they are intermediate inputs intangibles do not appear in total output which can be written[10]

$$P_t^{Q'} Q_t' = P_t^C C_t + P_t^I I_t = P_t^L L_t + P_t^K K_t \quad (3)$$

where the prime $'$ indicates the case where intangibles are treated as intermediate expenditure and $L = L_N + L_I + L_C$ and $K = K_N + K_I + K_C$.

2.2 Intangibles treated as capital

Now suppose that the intangible investment good is regarded as capital. Then as well as the tangible capital accumulation, intangible capital stock, R_t also accumulates according to

$$R_t = N_t + (1-\delta_R) R_{t-1} \quad (4)$$

where *R* depreciates at rate δ_R. The production function and money flows for each sector can be written

[10] This equation shows the equality of GDP on the expenditure side (consumption plus investment) and income side (rewards to the non-intermediate factors labour and capital). On the production side, value added in the C, I and N sectors are, respectivey, the value of consumption less payments to intangibles used in the consumption sector (the intermediate good), the value of investment less payments to intangibles in the investment sector and the value of intangibles. Adding these up gives economy value added as the value of consumption plus investment, which with factors being paid their marginal product is equal to wages and capital payments in all three sectors.

$$
\begin{aligned}
&\text{(a) Intangible sector}: N_t = F^N(L_{N,t}, K_{N,t}, R_{N,t}, t); \quad P_t^N N_t = P_t^L L_{N,t} + P_t^K K_{N,t} + P_t^R R_{N,t} \\
&\text{(b) Tangible sector}: I_t = F^I(L_{I,t}, K_{I,t}, R_{I,t}, t); \quad P_t^I I_t = P_t^L L_{I,t} + P_t^K K_{I,t} + P_t^R R_{I,t} \qquad (5) \\
&\text{(c) Consumption sector}: C_t = F^C(L_{C,t}, K_{C,t}, R_{C,t}, t); \quad P_t^C C_t = P_t^L L_{C,t} + P_t^K K_{C,t} + P_t^R R_{C,t}
\end{aligned}
$$

Note that in contrast to (2) the stock of intangible capital, R_t, rather than intangible output, appears as an input in the production functions and the payments to that stock, $P_t^R R_t$, appears in the payment equations rather than payment for the entire used up intermediate output. The corresponding output identity now includes the value of output of the intangible good on the production side, $P_t^N N_t$, and the payments to the stock of intangibles, $P_t^R R_t$, on the income side

$$
P_t^Q Q_t = P_t^C C_t + P_t^I I_t + P_t^N N_t = P_t^L L_t + P_t^K K_t + P_t^R R_t \qquad (6)
$$

where the total output of the intangible good $N = N_N + N_I + N_C$ and the intangible stock is $R = R_N + R_I + R_C$.

Thus the following points are worth noting. First, output is increased under the second approach from $P_t^{Q'} Q_t'$ to $P_t^Q Q_t$. Second, the investment rate increases from $P_t^I I_t / P_t^{Q'} Q_t'$ to $(P_t^I I_t + P_t^N N_t)/P_t^Q Q_t$ and the labour share falls from $P_t^L L_t / P_t^{Q'} Q_t'$ to $P_t^L L_t / P_t^Q Q_t$, where the labour share is the proportion of total income paid to labour.

Finally, to understand the implications for TFPG, we may write a growth accounting relation from the production functions above

$$
\begin{aligned}
&(a) \quad \Delta \ln TFP' = \Delta \ln Q_t' - s_t'^L \Delta \ln L_t - s_t'^K \Delta \ln K_t \\
&(b) \quad \Delta \ln TFP = \Delta \ln Q_t - s_t^L \Delta \ln L_t - s_t^K \Delta \ln K_t - s_t^R \Delta \ln R_t
\end{aligned} \qquad (7)
$$

where the top equation (a) shows the expression for TFPG=ΔlnTFP in the case where intangibles are expensed and the lower equation (b) where they are capitalised and the shares of each factor are denoted with an s.[11] As the equations show, the effect of including intangibles on TFPG is ambiguous. Whilst the level of output has risen, the growth rate may or may not rise depending on the growth rate of real intangible investment. So the effect on ΔlnQ is ambiguous. In addition, the capitalisation of intangibles means that

[11] The shares are the payments to each factor as a share of total payments to all factors. Total payments add up to output which of course consists of payments to two factors when intangibles are intermediates and payments to three factors when expensed, thus the shares are different between (a) and (b).

(the growth in) an additional input has to be included as a determinant of growth. Thus we have more capital assets accounting for ΔlnQ so that TFPG may rise or fall. Note finally that the shares differ between (a) and (b) since both output and the payments to capital differ.

The extra output from now including intangible output (with value $P_t^N N_t$) is mirrored by the payments to the extra factor of production, namely the intangible capital stock. Since it is a part of capital, this increases the overall payments to capital.

Also, the production functions make clear that the intangible input is the volume of intangible spending in the first case and the (flow of services from the capital) stock of intangible capital in the second. This means that the income flows have be evaluated using the rental rates of labour, tangible and intangible capital services.

It is worth noting that GDP has been criticised as a useful measure for capturing the New Economy. One criticism is the use of gross output in a situation where increasingly short-lived assets, such as computers, are appearing in the economy, thus raising depreciation payments. The distinction between gross and net output is discussed in Hulten (2000). Weitzman (1976) studies an economy maximising the discounted sum of future consumption subject to two constraints: (a) the capital accumulation constraint (similar to (2) above) and (b) the constraint that total output is split between either consumption or investment (i.e. a production function constraint Y=C+I =F(K,L), where Y is output, C is consumption, I is investment, K is capital and L is labour). He finds that the optimal consumption path is in fact equal to (nominal) net national product (NNP) which differs from GDP by depreciation, which accords with the intuition that an economy with increased depreciation payments may be no better off when considering the available resources available for consumption (taking account of the need to invest in order to consume in the future). Oulton (2004) notes that one needs all the information in GDP to calculate depreciation in order to get to NNP and that as a matter of data, depreciation payments as a fraction of GDP have remained about the same. He highlights that US real NNP and real GDP both have accelerated at the same rate post-1995. Hence, whilst real NNP might be a superior welfare measure, in practice it has grown at the same rate as real GDP in recent years in the US at least. Hulten (2000) argues that the correct interpretation is that whilst the growth in NNP, under these assumptions, corresponds to the growth in welfare, growth in GDP represents the rise in the supply-side constraint. Thus the analysis of GDP is an analysis of the constraint not an analysis of the outcome of an objective function and a constraint. Kay (2001) suggests that since welfare depends on real consumption, the investment component of nominal GDP should be deflated by contemporaneous consumption prices and not by hedonically adjusted investment prices as is the practice when computing real GDP. However, as he acknowledges, the hedonic adjustment is consistent with the measurement of services from computers, which is the theoretically appropriate measure in a production function context. It is also consistent with the real GDP convention of measuring real consumption plus real investment.[12]

3 Intangible spending and the overall investment and labour shares

Section four sets out how we undertook our growth accounting analysis. Here we discuss our data on intangible spending, investment and the overall investment and labour shares.

We follow CHS in identifying three main intangible asset classes:
A. computerised information (mainly software),
B. innovative property (mainly scientific and non-scientific R&D) and
C. firm competencies (company spending on reputation, human and organisational capital).

These categories accord with, for example, categories used by the UK competition authorities in calculating intangible assets for the purposes of competition analysis, see Giorgio Marrano and Haskel (2006) (GH).

3.1 Spending on intangible assets

Table 1 shows our choice of intangible assets, their data sources, the expenditure figures, the proportion of the expenditure assumed to be investment (following the assumptions of CHS), the percentage of total intangible investment, their deflators and depreciation rates. In this paragraph we will limit our attention to the first six columns.

The first column shows the type of intangible asset. The second column shows the data source used to measure the expenditure for the various assets for the 2004 cross section. Column three shows the sources for the time series estimates. Column four shows the expenditure figures for 2004 (as previously reported in GH (2006)). Column five shows the proportion of expenditure that is assumed to be investment[13]. Column six shows the percentage of total intangible investment accounted for by each of the separate intangible assets.

The type of intangibles, column one, and the data sources for the cross section, column two, have been extensively described in GH (2006). There are two minor changes with respect to the last paper: all the data are now consistent with the 2006 *Blue Book* and therefore they include any revisions, and in the asset

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[12] This argument is related to that used to try to explain why the acceleration in US productivity measured as GDP per person has not translated into increased wages per person. Baker (2007) argues that wages can rise with increases in NDP and not GDP insofar as rises in GDP are increasing due to extra depreciation and that what he calls "usable productivity" has been rising at 2.31% 2001:1 to 2006:2, against GDP productivity which has been rising at 3.19%. As a matter of data, Oulton (2004) argues that whilst US NDP grows more slowly than GDP, both have accelerated at the same rate post 1995 since depreciation payments are roughly unchanged. In addition, to calculate NNP one has to work out depreciation and so one needs to undertake a hedonic adjustment to do this.

[13] We follow the assumptions of CHS (2004). For detailed discussion on the proportion of expenditure assumed as investment see CHS (2004).

"new architectural and engineering design" we include also twice the turnover of the SIC 74782 "Speciality designs activities" (around £4bn in 2004). Below we will focus on the time series estimates.

3.1.1 Computerised information

This is straightforward. As pointed out in GH (2006) for computer software, row 1 column 2, we use ONS data published in Chamberlin et al (2006). The data are available from 1970 as shown in row 1 column 3.

3.1.2 Innovative property

For Scientific R&D, row 2 column 2, we use expenditure on R&D as published in BERD. In row 2 column 3 we show the time series availability: we have BERD data back to 1981. We backcast it back to 1970 using the expenditure on R&D in private sector (MA14) published in the Annual Abstract of Statistics. Note that we exclude R&D reported in the computer industry in order to try to minimise double counting with software. For Mineral exploration and Copyright and license costs, as shown in row 5 column 2 and row 6 column 2, we use data from the National Accounts. The series go back to 1970 as indicated in column 3.

New product development costs in the financial industry, row 8 column 2, is estimated, in the absence of better data, as 20% of intermediate consumption by the Financial Services Industry. Row 8 column 3 shows the time series availability: we have data on intermediate consumption from the annual Input-Output analysis back to 1992. We backcast the series using the growth rates of the turnover of the sector "Banking, finance, insurance, business services, leasing" from the *Blue Book* (after constructing a consistent time series using various *Blue Book* editions).

For new architectural and engineering design, row 9 column 2, we use 50% of turnover data for the SIC category 742 reported in the ABI plus twice the turnover of the speciality design sector, SIC74782 (with the twice figure based on data from the design council who estimated 50% of the sales of this sector was own-account spending). As row 9 column 3 shows these data goes back just to 1995. For the period 1994-1992 we use the turnover data from the Service Sector Review that is roughly consistent with the ABI data. As shown in the table, we then backcast the series form 1991 to 1985 using the growth rate of the turnover of architect and engineers as published in the Business Monitor. From 1984 to1979 we backcast using the growth rate of the turnover of the total business service sector as published in the Business Monitor. We then backcast further the series to 1970 using the growth rate of the turnover of the sector "Banking, finance, insurance, business services, leasing" from the *Blue Book* mentioned above.

R&D in social science and humanities, row 10 column 2, is estimated as twice the turnover of the SIC 73.2 industry. We have ABI turnover data back to 1995. For the years 1994-1992 we use turnover data for this SIC category published in the Service Sector Review We backcast the series to 1986 using the growth rates of the turnover of the sector "research and development services" published in Business Monitor. For the period 1985-1981 we backcast using the growth rate of R&D form BERD. Finally, we backcast the resulting series to 1970 using the growth rate of R&D in the Annual Abstract of Statistics.

3.1.3 *Economic competencies*

For advertising expenditure, row 13 column 2, we use data from the Advertising Association that goes back to 1956. We estimate market research, row 14 column 3, as twice the turnover of the industry. We have data on turnover from ABI back to 1995. As above, we use the turnover data from Service Sector Review for the years 1992-1994 and we backcast the resulting series with growth rates of advertising expenditure.

We turn now to firm-specific training. As shown in row 16 column2 we used NESS2005, a survey on employer provided training that provides expenditure data for 2005. Unfortunately there is no consistent previous survey and so we are forced to backcast our data. To do this, we used trends in wage costs and the industrial structure of the workforce to extrapolate the results of this survey. We used the data in NESS2005 of training expenditure by one digit industry. To this we matched a series for the wage bill for the corresponding sector (using the OECD/STAN industry data). We calculated the ratio between 2005 training expenditure and the wage bill for 2005 and applied this ratio to the wage bill series. This then assumes a constant incidence of training by sector over the period. We then assumed, following CHS, a 2% yearly increase in incidence of training.

Turning finally to investment in organisational capital/structure we need purchased and own account. For purchased, see row 18 column 2, we use turnover of management consultants provided by the Management Consultancy Association (MCA) for 2004 and we backcast using the growth rate of the turnover of the SIC 7414. back to 1995 and for 1994-1992 with Service Sector Review. Prior to that we use the turnover of management consultants as shown in the Business Monitor to backcast to 1985 and the turnover of the whole business sector back to 1979. From 1979 to 1970 we use *Blue Book* data mentioned above. We estimate own account spending, on organisational structure, row 13 column 3, as one fifth of a subset of managers' earnings. We backcast ASHE 2004 data using ASHE and NESPD earnings series (after constructing a consistent time series). For the years using 1974-1970 we backcast using sector average wage growth from STAN (OECD).

3.2 *Investment in intangible assets*

Column five shows the fraction of current spending, following CHS, that is assumed to be investment. There are no clear empirical guides here. The main deviations from unity are for brand equity, and purchased organisational capital spending. For brand equity CHS assume that 60% of spending on advertising is building a reputational asset. One reason why asset investment might be less than total spending can be seen by considering for example spending on advertising by a duopoly where spending is boosted by the competitive desire to build market share, but where whole economy brand capital might not necessarily be increased. In addition, CHS assume that 80% of purchases of management expertise are capital spending, the rest perhaps being day to day advising. We shall discuss the sensitivity of our results to varying these parameters below.

3.3 Cross section results

To give some idea of the scale of expenditures, column 4 sets out expenditure on each asset for 2004. This is then converted to investment using the fraction in column 5. Column 6 then shows the fractions of total intangible investment each row accounts for. The following points are worth noting. First, around 50% of total investment is on firm spending on reputation, human and organisational capital (economic competencies). About 35% is on innovative property and 15% on computerised information. Second, according to these numbers, investment in R&D is just one part of investment in knowledge assets. In fact, R&D investment is less then investment in software for example.[14] Third, the biggest single figure is training investment.

3.4 Time series results

Figure 1 shows the time series for nominal intangible investment for the aggregated categories as a share of adjusted nominal market sector GVA (see section 4.5). The first chart shows the time series for the US from CHS (2006) while the second reproduces the estimates for the UK. It is a cumulative graph so that that top (black) line shows the share of total intangible investment in intangible-adjusted market sector GVA.[15] The lowest line shows the share of brand equity and the line above that shows the share of brand equity plus the firm-specific resources. Thus the gap between the lines is the share of each category of investment.

A number of points are worth making. First, the total line shows the growing importance of nominal intangible investment in the economy, rising from around 6% of market sector GVA in the 1970s to 13% in 2004 (6% to 15% of unadjusted market sector GVA, which includes some software i.e. as currently measured in the National Accounts). Second, all investment types have risen, with the exception of brand equity, which is more or less flat. The most marked increases are for computerised investment and firm-specific resources. These two groups show therefore the biggest increases in the share of overall intangible investment.

3.5 Labour shares

The labour share is calculated as the ratio between compensation of employees and the sum of labour compensation and capital compensation, the latter called operating surplus in the UK National Accounts (in turn, for the whole economy, this adds up to nominal GDP, subject to some minor tax/subsidy and statistical adjustments). One problem in calculating this is the treatment of the income of the self-employed, whose income, termed "mixed income", might be considered a combination of labour and capital income. It is included, in the UK market sector data, with operating surplus. This boosts the capital share of course and

[14] Although the two types of spending might have quite different potential spillovers.

[15] That is, the denominator is gross value added in the market sector, adjusted for the presence of intangible investment, see below for how we calculate this.

thus potentially boosts the fraction of market sector GVA growth that is capital deepening.[16] We decided to split mixed income into labour and capital income. One way of doing it is to use the Labour Force Survey to work out the pay of employed workers with a similar age, skill etc. profile to the self-employed. When we do this, we find that, apparently almost all of mixed income is labour income (about 98%). The other method is to allocate mixed income according to the labour and capital ratios calculated after subtracting the mixed income from the operating surplus. We apply these ratios to the mixed income and we add the relevant quantity to the operating surplus and labour compensation. We settled on the final option and as a consequence, the labour share is higher than in the case in which the mixed income is left in the operating surplus.

Figure 2 shows the time series for the labour share in the both the UK and the US (again based on CHS (2006) excluding and including intangibles. The first chart shows the labour share from 1970 to 2003 for the US while the second chart for the UK. A number of points are worth noting. First, the level of the labour shares are similar, with the 1970 level being about 68% excluding software and intangibles and 63% including them (the US figures are 71% and 66%). Second, the overall trend in both countries is flat when excluding intangibles and falling when including them. If anything the trend is smoother in the US, reflecting the UK change from the peak in the mid 70s, (well known union push) and the trend downwards to the early 1980s.

3.6 Investment shares

Figure 3 shows nominal investment shares as a percentage of MGVA for the UK and US including three cases: traditional National Accounts excluding software, including software (this is not shown in the US graphs) and including all intangibles (where in the UK data the MGVA denominator excludes software, includes software and includes all intangibles respectively). There are two major findings. First, in both countries, without intangibles, the nominal investment share is flat or a little bit decreasing and is a similar amount (around 15%). Second, once we include intangibles it increases in levels, to around 25% by the end of the period and the trend is upwards.

4 Growth accounting

To implement the growth accounting set out in section 2, we proceed as follows. First, we measure labour input L as employee hours. Second, we express MGVA and capital in per employee hour terms. Third, in practice the quality of labour likely varies and so we distinguish between employee hours, L and quality adjusted employee hours, L^{QA}. Thus our growth accounting expressions are

---

[16] Indeed calculated on this basis the UK capital share is about 10 percentage points above the non-farm business US capital share. None of the international comparisons of labour shares that we could find gave this kind of difference; in most of them, capital shares are much closer across countries.

$$
\begin{aligned}
&(a) \quad \Delta \ln TFP'_t = \Delta \ln(Q'/L)_t - s'^L \Delta \ln(L^{QA}/L)_t - s'^K \Delta \ln(K/L)_t \\
&(b) \quad \Delta \ln TFP_t = \Delta \ln(Q'/L)_t - s^L \Delta \ln(L^{QA}/L)_t - s^K \Delta \ln(K/L)_t - s^R(t) \Delta \ln(R/L)_t
\end{aligned}
\qquad (8)
$$

A number of points are worth noting regarding (8). First, the shares are averages of shares over which the time difference it taken, so that (8) is a Tornquist index number. Second, the share of capital is defined as one minus the share of labour. This is accurate if there are constant returns to scale at the overall economy level, but clearly an area where better measurement would be helpful. Third, since there are in practice many capital assets (for tangibles, plant, buildings, vehicles and computer hardware; for intangibles, software, R&D etc.) the ΔlnK and Δln R terms have to be constructed to incorporate these many types. This is done following Oulton and Srinivasan (2003), who in turn follow Jorgenson and Griliches (1967), by noting that the theoretically correct capital measure in a production function is the services that capital provides into output. In turn the services for each type of capital can be measured by the rental payments that a profit-maximising firm would pay were it renting its capital. Since in practice firms rarely do this but buy the capital asset for a price p^A and then use it over its lifetime, the market-clearing rental payment for an asset B (where B can be tangible or intangible assets), p^B, can be derived as

$$
p_{it}^B = T_{it}\left[r_{it} \cdot p_{i,t-1}^A + \delta_{it} \cdot p_{it}^A - (p_{it}^A - p_{i,t-1}^A) \right], \qquad B = K, R \qquad (9)
$$

where T is a tax adjustment and r is the rate of return on the asset.[17] This equation holds for each type of capital *i*. The relation between this and the Δln*K* and Δln*R* terms in (8) can be derived as follows. First, the overall level of profit in the economy, Π, is, by definition, the overall payments to capital, which is the sum of all rental payments to each capital type. This can be written as

$$
\Pi_t = \sum_{i=1}^{n} p_{it}^K K_{it} + \sum_{i=n+1}^{m} p_{it}^R R_{it} \qquad (10)
$$

where there are n tangible assets and n+1 to m intangible assets. Second, the overall volume index of capital services (VICS) can be shown to be a share-weighted average of all the asset-specific Δln*K* and Δln*R* terms

$$
\begin{aligned}
\Delta \ln K_t &= \sum_{i=1}^{n} \left(p_{i,t}^K K_{it} / \Pi_t \right) \Delta \ln K_{it} \\
\Delta \ln R_t &= \sum_{i=n+1}^{m} \left(p_{i,t}^R R_{it} / \Pi_t \right) \Delta \ln R_{it}
\end{aligned}
\qquad (11)
$$

[17] The derivation of (10) is set out in Oulton and Srinivasan (2003). If firms buy the capital good for p_t^A, they earn a rate of return r, but suffer a capital loss as it depreciates via wear and tear (δ) and a loss or gain if it changes in value (p_t^A- p_{t-1}^A). At the margin, the firm must be indifferent between renting the asset for (the unobserved price) p_t^K and buying it and this formula ensures this is the case.

where the shares are the flow of rental payment for each asset as a share of total rental payments (Π).[18] As an empirical matter, we have to take a number of steps. First, we do not have information on time-varying depreciation rates and so set them constant over time. Second, we do not have information on asset-specific rates of return, r_i. In a competitive market, r_i will equalise across assets. If we assume this then we have two equations (9) and (10) in two unknowns, namely r and p^K which we can solve for, which enable us to calculate . The economic intuition of this is that since we know the overall payment to capital, Π in the economy, from National Accounts, we can solve for the unobserved asset-specific rental prices that would ensure that all payments to capital assets added up to Π. Third, in line with the Tornquist method above, the weights in (11) are the time-averaged weights over which the difference is taken.

To summarise, we therefore implement growth accounting in the following steps.

1. Collect a time series of nominal investment in intangible and tangible assets, deflate to get real investment series, and build a real capital stock using perpetual inventory method, see equations (1) and (4).
2. Re-calculate market sector GVA to include intangibles, see equation (6)
3. Adjusted the operating surplus Π for market sector GVA, see equation (10)
4. Build a Hall/Jorgenson VICS measures of all capital inputs, ensuring the asset rental payments are consistent with the adjusted operating surplus, see equations (9) to (11)
5. Build a quality adjusted labour index to measure L^{QA} in (8)
6. Undertake growth accounting, in (8)

The next sections describe how to do this.

4.1 Collect a time series of nominal investment in intangible and tangible assets

Investment in intangible assets is set out above. For tangible assets, we use the data from Wallis (2007) (see also Wallis, 2005). Briefly, the dataset consists of a long back-history of constant price investment data, *Blue Book* 2006 consistent, classified by SIC92 industries. The asset breakdown of the investment series is: buildings, plant and machinery and vehicles. In order to treat computers as a separate asset, computer investment is separated from investment in plant and machinery and the associated price deflators adjusted to account for this. The data are then aggregated to market sector levels.

4.2 Deflate to get real investment series

The choice of deflators, as CHS discuss, is a difficult one. One possibility is to develop a price index for the particular intangible according to the costs incurred in developing it, so that, for example, if most of the costs of R&D is payments to scientists, then the deflator might be the wage of scientists. As CHS show however, this implicitly assumes that scientists have no increase in productivity in the R&D process.[19] A second possibility is to use the output deflator. This is sometimes justified in studies of, for example, R&D, where a physical unit, this case of knowledge, has little meaning and so it is felt best to deflate by the price of the good which presumably embodies the knowledge that the R&D is generating. Triplett and Bosworth (2004 p.260), citing Bailey, offer a similar justification for management consultants.

Our deflators are set out in more detail in Table 1. For computer hardware, we use data from the ONS the Bank of England and the National Institute of Economic and Social Research (NIESR). They are close to each other only in some years. ONS stops in 1984 and so we backcasted using NIESR data. We have explored US deflators and the results are robust to this change. Software deflators are taken as follows. For own account we use wages of the relevant occupations and then a 2.5% productivity adjustment. Whilst this has the problem similar to the R&D deflator above, it is used by the ONS and so has the benefit of being consistent with their practices (which is useful in our context since the at least part of software is incorporated into the National Accounts; it is also consistent with the US treatment of software). For purchased software we use the ONS purchased software deflator. Turning to the remaining tangible assets we use deflators for plant, vehicles, non-IT machinery, and buildings consistent with the UK National Accounts (see Wallis, 2005).

4.3 Build real capital stock using perpetual invent method

A constant depreciation rate assumes geometric depreciation, the accuracy of which is of course open to question as well as requiring one to settle on a depreciation rate. Given the doubts and uncertainty over this, we settle here on applying conventional assumptions about tangible assets to the accumulation of intangible assets. Table 1 sets out our assumed rates. For intangible assets these are based on CHS (2006) assumptions. For tangible capital we use existing National Accounts deflators. Our sensitivity analysis included varying the assumptions on the intangible asset side.

4.4 Adjusting operating surplus of market sector GVA.

The ONS publishes market sector operating surplus series back to 1992. In order to perform a productivity analysis we are interested in the productive stock and therefore we subtract household operating surplus (that includes the imputed rental from housing) and actual rental from housing. We back cast the series to 1970 using the gross operating surplus growth rates for the whole economy. To adjust the operating surplus for the intangibles we simply add nominal intangible investment. We build three versions of market sector gross

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[18] By contrast the wealth stock, which is often presented as a measure of capital, is the share-weighted sum of capital stocks, where the shares are the asset prices.

[19] Consider for example the CRS relation 2a. Differentiating with respect to time, the growth rate of the price of the intangible good is the growth rate of the prices of the inputs, weighted by their shares in overall GDP less any TFP growth in the intangible production process. Assuming that the price growth rate is just wages assumes no other factors

operating surplus. The first version excludes software investment already present in the National Accounts. The second includes this investment and add also the future revision to National Accounts software estimates presented in Chamberlin et al (2006). The third includes all intangibles

Concerning labour compensation, the ONS publishes market sector labour compensation series back to 1992. We back cast the series using the growth rate of the OECD estimated wage bill.

4.5 Re-calculate market sector GVA to include intangibles.

The ONS publish a time series back to 1992 of market sector GVA at current prices. For productivity analysis we subtract actual and imputed rental from housing (consistent with the treatment of operating surplus above). We backcast the series using the growth rate of the sum of the market sector labour compensation and operating surplus. To adjust for the intangibles we simply add the nominal investment in intangibles (note not spending but investment) to nominal market sector GVA ensuring that we do not double count any intangibles already included (such as some software and mineral exploration).

Regarding the real market sector growth rate, the ONS publishes time series that goes back at least to 1970. We adjusted the real growth rate for intangibles devising an index of changes in real market sector adjusted GVA as a share-weighted change of real market sector GVA and real intangible investment, with the weights being the share of each expenditure category in overall GVA.

As for the gross operating surplus we build three versions of GVA. The first version excludes software investment already present in the National Accounts. The second includes this investment and adds the planned revision to the software estimates. The third includes all intangibles.

From the nominal market sector series and real market sector series we derive an implicit deflator that we used to deflate all intangibles except software.

4.6 Build Hall/Jorgenson VICS measures of all capital assets

To do this we use method described above (equations (9), (10) and (11)). We smooth the rate of return and the capital gain term by taking a three-year moving average. All rates of return are positive, but for some years in the middle 1970s the building rental rates were negative. We set them equal to the nearest positive rate.

4.7 Quality adjusted labour index

We use here the Bank of England index that adjusts hours for education, gender and age, see Bell, Burriel-Llombart, and Jones (2005), kindly provided to us by Nick Oulton and Sally Srinivasan.

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are used in production and there is no TFP growth in the production of intangibles. An alternative is to develop a price index based on the weighted shares, which assumes zero MFP growth in the process generating the good.

5 Growth accounting results

5.1 Overall

In the results that follow we use the following conventions. The growth in capital services and labour quality are Tornquist indices as is the growth in market sector GVA. The averages reported are 100 times the arithmetic averages of year-on-year Tornquist growth rates (e.g. 2000-04 is average of 2000-1, 2001-2, 2002-3, 2003-4). TFP growth is residual and the capital and labour shares add to 1. Our growth accounting decompositions start in 1979 with our intangible capital data set equal to zero in 1970. However, due to the period we are most interested in being the 1990s and our data being of better quality from 1990 onwards our analysis focus on 1990 onwards. This also allows us to ignore any initial conditions problems in association with the intangible capital stock.[20]

We undertook two main checks on the data. First, the ONS *Blue Book* 2006 does no growth accounting but does include some software in output. Thus we generated market sector GVA data excluding all software, including just software, and including all intangibles. We checked our data that included software against the ONS data and found the growth rates very close [21]. Second, Oulton and Srinivasan have undertaken a major industry-level study that includes software both in their output data and their capital services data (Oulton and Srinivasan, 2005). These results were up to 2000 and were consistent with the 2002 ONS *Blue Book*. The 2002 *Blue Book* data had limited coverage of software so a major contribution of Oulton and Srinivasan (2005) was to add in software to both output and capital services. In recent unpublished worked, they use data to 2003, consistent with the 2005 ONS *Blue Book*, again incorporating software. A change here is that ONS have revised their employee-hours data to be consistent with the 2001 population Census and Oulton and Srinivasan have revised their data accordingly. We use their labour hours and quality measure, that they kindly supplied us. This allows us to make a better comparison of our baseline results, without intangibles, with theirs.

5.2 Growth accounting results, 1990-2004

Table 3 shows the growth accounting results for 1990-2004. We look at this period to compare the results with Oulton and Srinivasan (2005) and to explore a major "fact" in the UK, namely the 1995-2000 slowdown in both LPG and TFPG (in stark contrast to the US speed up).

Table 3 has three panels. The top panel shows growth accounting results when we exclude software. The middle panel includes software and the bottom panel includes all intangibles. Each panel has three rows: the first row shows the period 1990-1995, the second 1995-2000 and the third 2000-2004. The columns show averages of the annual Tornquist growth rates for each period. The first column shows LPG (recall this is

[20] The tangible capital stock is based on a very long run of investment data, back to the 1800's in some instances, so there are no initial conditions problems to deal with.

[21] The *Blue Book* 2006 includes somewhat less software than we do for example, for 2004, our data is about £21bn while in the *Blue Book* 2006 is about £11bn.

growth per hour in market sector labour productivity), the second capital deepening (the change in capital services per hour times the share in capital), the third human capital deepening (the change in quality-adjusted labour services per hour times the share of labour) and the fourth TFPG. TFPG is the first column less the sum of the second and the third. Before considering our results in detail, we wish to check that the number accord with other sources. As mentioned above, Oulton and Srinivasan (2005) is one benchmark for the comparison of the results. That paper published growth accounting results for the period 1970-2000 based on the Bank of England Industry data set (BEID)[22]. In turn, the BEID is based on the then current National Accounts with an adjustment for software.[23] More recently, Oulton and Srinivasan have revised and updated their data to 2003. They kindly provided us with their updated quality-adjusted labour inputs and hours data, both of which we have used here[24].

Their updated data are unpublished, but turn out to be quite similar to the results here, where the appropriate panel for the comparison is the one including software (the middle panel of Table 3). The main difference is that our 1995-00 LPG is a bit faster. Looking at their raw series, we find this difference arises from the fact that in the updated BEID set there is a dip in growth of labour productivity in 1998-9 whereas we do not have so much of a dip.

It is worth noting in passing however that there is a major difference between these results and the Oulton and Srinivasan (2005) results. In those data, there was a major fall in LPG between 1990-95 and 1995-00 of 1.05 percentage points per annum (pppa). LPG in the two periods was 3.99pppa and 2.93pppa. In our data this is much smaller (see the middle panel). This is because we use the BEID new set of hours data, which is in turn based on that from the ONS. The old hours data were very different, more negative in 1990-95 and more positive in 95-00. With these new hours data, based on the 2001 Census of population, the slowdown is much less pronounced.

Turning to the other results, the main results are as follows. First, adding software increases LPG in every period. As set out above, the addition of software raises market sector GVA, so that the *level* of labour productivity rises, and this table shows that the *growth* of labour productivity rises too. Note that adding the rest of the intangibles further raises LPG except in the very last period where it falls slightly relative to the last period in the middle panel. This suggests that the pace of intangibles expansion is less over that period.

Second, the addition of intangibles gives a different picture to the 1990s LPG slowdown mystery. Looking at the top panel, when software and other intangibles are excluded we see that LPG slowed down

[22] The Bank of England Industry data set is described in Oulton and Srinivasan (2003b).
[23] And a few other adjustments such as to financial services output, see Oulton and Srinivasan (2005).
[24] We collected data for intangible spending and market sector GVA up to 2004. The Bank of England data on hours and labour quality however goes up to 2003. Thus we interpolated these variables for one year by running a regression of them on two lags of themselves and current and lagged GDP. To check the data we compared the new hours data with an ONS market sector hours series and an ONS whole economy labour quality measure (kindly supplied by Peter Goodridge) (both start in 1999 and so we cannot use them for the full data period). Our single interpolated year matched the behaviour of these ONS series well.

from 2.93pppa to 2.72pppa. Looking at the middle panel, where we include software, we see a similar slowdown, from 3.01pppa to 2.91pppa. However, the results in the final panel are most interesting: there we see a speed up, from 3.09pppa to 3.23pppa. If these measures of intangibles are correct then, the mid 1990s slowdown was a statistical illusion caused by not accounting for investment in intangibles. Clearly our estimates are subject to a wide range of assumptions but these data do suggest that measurement is likely to be a first-order issue in understanding the mid-1990s slowdown. In the section below we show how robust this slowdown is to changes in our assumptions.

Third, consider capital deepening. Adding software increases capital deepening in every period (compare the top and middle panels). There are two possible explanations for this. Recall that capital deepening is the product of the capital share and growth rate of capital services. When including software the share of capital goes up and therefore, *ceteris paribus*, capital deepening rises. The growth rate of capital services per hour in theory, could increase, remain the same or decrease[25]. Table 4 shows the reason for the rise in capital deepening. The top panel shows capital deepening without including software, the middle panel shows the inclusion of software and the bottom panel shows the inclusion of all intangibles. The two right hand panels divide up the capital deepening into the income shares and the growth of capital services per hour, dividing these terms in turn between the contributions of ICT and non-ICT. As Table 4 shows, if we look at the top and middle panel, the share of capital (column 9) and the capital services per hours (column 12) increases in all periods when we include software.

Returning to Table 3, when we include all intangibles (see bottom panel) capital deepening increases further in every period by an amount of between 0.37pppa and 0.28pppa. Table 4 shows that the increase is mainly due to the share of capital increasing as the total capital services per hour growth rate stays roughly the same.

Fourth, regarding TFPG, the top panel shows the results already established in the literature, namely a fall in TFPG in the middle 1990s. Note an acceleration in 2000-04, which is a new result. The middle and lower panels show the effects of introducing software. Recall that, as the earlier theory section noted, the effect of the inclusions of extra investment can increase, decrease or have no effect on TFPG. The middle panel shows that TFPG still slows down in the mid90s, but speeds up in 2000-04. The lower panel most interestingly shows that TFPG speeds up in the mid90s, and speed up again 2000-04. Thus with these data at least, the 1990s TFPG puzzle is removed, namely there was a speed-up at that time which had been masked by the failure to adjust market sector GVA for intangible investment and is apparent even thought the new TFPG numbers include the extra knowledge input. There was then further speeding up in TFPG (and LPG) in the early part of this century.

---

[25] Capital services growth is a rental cost weighted sum of individual capital services growth, where the rental prices are determined exogenously to exhaust overall payments to capital. Thus adding new capital assets changes the weights and so the growth of capital services might rise or fall.

To shed further light on this, consider similar data for the US. The post-2000 record for the US is set out in Jorgenson, Ho and Stiroh (2007). They document a *rise* in LPG from 2.70pppa 1995-00 to 3.09pppa 2000-05, with rises in capital deepening (1.51pppa to 1.56pppa), labour quality (0.19pppa to 0.36pppa) and TFPG (1.00pppa to 1.17pppa). Our nearest comparison would be the middle panel, which includes software. We have falls in LPG, capital deepening and human capital deepening, but a rise in TFPG. Thus the question raised by these data is not the behaviour of TFPG, but rather what were the set of incentives that led the US to raise its capital deepening that did not operate in the UK.[26]

5.3 The role of ICT

Before turning to the comparison with the US we return to Table 4 to examine the role of ICT. The two left hand side panels for the top and middle rows divide capital deepening into ICT and non-ICT and into ICT, non-ICT tangible and other intangibles for the bottom panel. This decomposition is first shown with the actual figures and then with the proportions. If we look at the left hand side of the middle panel and look at the rows corresponding to the years 1990-1995 and to years 1995-2000 we can see that the ICT capital deepening increased while the non-ICT decreased; in the middle panel in the period 1990-1995 ICT capital deepening was 44.7% of total capital deepening while non ICT was 55.4%. In the period 1995-2000 it is reversed: ICT accounts for 74.6% of capital deepening while non-ICT just 25.4 %. In the most recent period up to 2004, ICT again accounts for the lion's share of capital deepening. Turning to the right hand side panel we can see that both the share of ICT and the capital services per hour increased in the late nineties while for non-ICT the share remained the same the capital services decreased. Finally, the fall in capital deepening 2000-04 is entirely due to a fall in ICT hardware capital investment.

5.4 Growth accounting results 1979-04 and a comparison with the US

In Table 5 we set out the comparison with the US where the US data are taken from CHS (2006). Note that our pre-95 data starts in 1979 and our data finishes in 2003 as opposed to 2004 in earlier tables (to be consistent with CHS). As before, for the US there are three panels. The top one excludes software, the middle panel includes software only and the bottom panel all intangibles. For comparison we therefore show our versions which respectively exclude software, include software only and all intangibles.

The most direct comparison is for the years 1995-2003 and it is summarised in rightmost panel, with each contribution a percentage of LPG, with LPG shown in the top row. The key results are the following. First, looking at overall LPG for 1995-2003, we see that is somewhat higher in the US whether intangibles

[26] It may seem surprising that the UK performance is so similar to the US performance given all the discussion about superior US economic performance since 2005. Two points are worth bearing in mind. First, Timmer, Ypma and van Ark (2003, updated 2005) note that between 1995 and 2004, US LPG has been 1.8%, EU 1.4% and UK 1.6%. So the UK has been doing somewhat better than the US. Second, the EU was growing much faster than the US before 1995 and now the opposite is the case, and so much of the mystery is about the relative lack of acceleration rather than the relative growth rates.

are included or not, but is similar. What is dissimilar is that US LPG accelerated sharply after 1995, whereas the UK productivity growth did not, although it was growing much faster during that pre-95 period.

Second, turning to the contributions to LPG over the comparable period 1995-03, we see that capital deepening is a higher share of LPG in UK than in US. It is about 64% (top right panel) while for the US is 35%. Note that in most international comparisons the European share of capital deepening in LPG is usually higher than the US (as EU catches up to US by installing capital). Note too that the contribution of capital deepening rises as more intangibles are included: 64% of LPG with no software, 67% with software and 73% with all intangibles. In addition, comparison of rows 3 and 2 in the bottom panel shows about 75% (1.54/2.14) of UK capital deepening is due to tangible capital compared to just 50% (0.85/1.68) in the US.

Third, the contribution of human capital deepening in 1995-2003 is very similar in both countries, at about 14% of labour productivity (top right panel). Fourth, in all cases, the contribution of TFP is less as a share of LPG in the UK than in the US. Fifth, we can get some idea of the contribution of intangibles by looking at the bottom panel. Comparing row 3 and row 6 in the right panel we see that 53% of UK LPG is due to tangibles and 28% in the US this shows a bigger contribution to LPG of intangibles in the US.

5.5 Contributions of each intangible asset

In Table 6 we look at intangible capital deepening and how much each component accounts for. As above the table shows the US and UK comparison pre-95 and post-95, with rightmost panel showing post-95 fractions of intangible capital deepening accounted for by each intangible category. The main results are the following. First, if we look at the right panel in the US there is a large contribution of R&D while in the UK has more of contribution from non-scientific R&D. Indeed the share of overall contribution of scientific R&D is almost zero in the UK. This is an interesting result that accords with popular discussion that UK design etc. is "strong" whilst UK R&D lags behind the US.

Second, in UK there is a bit more contribution of firm-specific capital. This confirms the finding on other data sets that firm specific training is higher in the UK relative to the US (see GH, 2006).

5.6 Comparison of the effects of adding intangibles in the US and UK

Finally, we ask the question what difference does the inclusion of intangibles make in each country? To answer that, Table 7 shows the differences between LPG and its constituent parts with and without intangibles, for US and UK. The upper panel shows the difference when we include all intangibles against when we exclude all intangibles and include software. The lower panel shows the difference between when we include all intangibles against when we include just software.

The main results are that the sign of the difference is the same in all cases: when we include intangibles in both the US and the UK, LPG and capital deepening rises and TFP falls. Turning to the details, the upper panel shows the increase in LPG from including intangibles with respect to the case in which we exclude software is quite similar in both countries: 0.31 in the US and 0.34 in the UK. The increase in capital deepening is higher in the US, but this could be because capital deepening in the UK is already quite high. The decline in TFP is more in US, but again this because US MFP higher than UK

The lower panel shows that the increase in LPG is similar in both countries, the increase of capital deepening is slightly higher in the US and, as above, the decrease in TFP is higher in the US. If we compare the LPG of each country in both panels we can see that a big part of the effect of intangibles is due to software. If we look at UK, for example we see the increase in LPG from zero intangibles to all intangibles is 0.31 but this increase is reduced to 0.14 when we account for software.

5.7 Sensitivity of results

Given the range of assumptions that we have had to make, an obvious question is how robust our results are. Since we have quite a lot of results, we organise our robustness checks around three main results: the path of the investment share, the path of the labour share and the difference in LPG, capital deepening and TFPG over the 1990s. Table 8 shows some selected sensitivity analysis from a wider range of sensitivity analysis we conducted[27] together with the base case (our chosen estimates as presented above). It consists of six panels. Each shows the investment shares (columns 1 and 2) and labour share (columns 3 and 4) over the decades 70-80 and 94-04 and the difference between the growth rates of 95-00 and 90-95 for labour productivity, capital deepening and MFP (columns 5, 6 and 7). The base case in the top panel shows results for the three cases: excluding software, including software, including all intangibles; the other panels show results for the two cases of with software and with all intangibles.

Panel (a) shows the base case. As mentioned in the previous paragraphs when we include intangibles we see an increase in the nominal investment share of market sector GVA and a decrease of the labour share. We also do not have a slowdown for productivity and MFP in the period 95-00 but a speed up.

Panel (b) shows the same table when all conversion factors (the factors that convert intangible spending into intangible investment, set out in Table 1, column 5) are divided by two. This is equivalent to halving all intangible investment, quite a drastic change. As the second panel shows, we still have an increase in the nominal investment share and a fall in the labour share although it is reduced. Adding intangibles does not lead to a speed up in LPG and MFPG but to a substantial reduction in the slowdown.

Panel (c) shows the results when we halve all the conversion factors except the one for software. The same observation as for panel 2 applies, although the reduction of the "intangible effects" is reduced compared to panel 2 (there is for example a small speed up in LPG).

Panel (d) shows the results when we double all depreciation rates (note that for brand equity we set the rate equal to 0.9 as it is already 0.6). The results are very similar to the base case suggesting that the results are robust to the changes in the depreciation rates. The only difference with panel one is a slower speedup in TFPG (row three column 7).

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[27] We focus on those that have the largest impact on the results. These also happen to be the ones that are the most interesting.

Panels (e) and (f) show results when we, respectively, add and subtract 50 percent of each component of intangible investment. We make these changes to the figures just for the assets that we consider more uncertain either in the definition and/or the measure, recall that they are about 40% of intangible spending. They are new product development for the financial sector, new architectural and engineering design, human sciences R&D and organisational structure both purchased and own account. When we add the 50 percent, in panel 5, all our findings (on the investment and labour share and LPG and TFPG) are re-enforced. When we subtract this amount the investment share increase and the labour share decrease is reduced compare to the base case and so is the LPG and MFPG speed up.

Figure 4 shows the same results for LPG and TFPG in diagrammatic form for ease of presentation. The figure shows LPG and TFPG with all intangibles in the periods 90-95, 95-00, 00-04 and the pattern when we change the assumptions as in table 8. So in panel (a) for example, we show LPG (left panel) and TFPG (right panel) in (a) the base case, (b) halving all the conversion factors used to multiply expenditure into investment (see table 1, column 5) (c) halving all factors bar software. The LPG slowdown in the 2000s is consistent, as is the TFPG speedup. The 1990s TFPG slowdown is apparent in both the robustness checks. Looking at the other pictures, the TFPG speedup over the whole period is mostly maintained, along with the 2000s LPG slowdown.

In summary the quantitative results are robust to large changes in the depreciation rate and conversion factors. The qualitative direction of these effects for LPG and TFPG is robust but the quantitative effect is somewhat reduced, the slowdown in LPG and TFPG is rather reduced. The robustness of our results suggest that, despite the associated measurement issues and number of assumptions needed, our results shed light on the UK productivity record and the importance of intangible investment in understanding recent productivity performance.

We also undertook some further robustness checks including a growth accounting analysis for 1990-2000, which encompasses an entire business cycle (peak-to-peak). We found that the inclusion of the intangibles raises LPG from 2.83pppa to 3.16pppa, and decreases TFPG from 0.58pppa to 0.50ppa. That intangibles continue to have an important impact when looking at an entire business cycle shows that our results are not just driven by our choice of periods for growth accounting.

6 Conclusion

This paper has tried to understand better the impact of the "knowledge economy" on recent UK economic performance. The central question is one of measurement and follows the important papers by Oulton and Srinivasan (2003), Basu et al (2004) and Oulton and Srinivasan (2005). We explore the consequences for a range of macroeconomic variables of treating knowledge expenditure as investment.

We do this by assembling investment data on a range of knowledge assets, such as scientific R&D, but also including software, design, non-scientific R&D and spending by firms on reputation, human and organisational capital. We look at the consequences for market sector GVA and business investment. We then look at the consequences for productivity by calculating the new implied labour productivity growth and total factor productivity growth.

Our main findings are as follows. First, our data on investment in intangible assets look remarkably like those in the US. Nominal intangible investment in 2004 was about equal to nominal tangible investment spending, each around 15% of MGVA. Around 50% of total intangible investment is on economic competencies, 35% on innovative property and 15% on computerised information. Since 1970, nominal investment has grown from about 6% of nominal MGVA to about 15%. Second, accounting for intangibles raises MGVA (by about 6% in 1970 and 13% in 2004) and also the shares of nominal investment and capital. Third, accounting for intangibles also affects labour productivity growth (LPG) and total factor productivity growth (TFPG). Without intangibles, we confirm previous work that LPG and TFPG both slow down between 1990-95 and 1995-00. We also document a further slight slowdown in LPG 2000-04, but a speedup in TFPG. With intangibles, the picture changes interestingly. First, both LPG and TFPG speedup between 1990-95 and 1995-00. Second, even with intangibles, the post 2000 LPG slowdown still remains but TFPG speeds up.

We compare our estimates to the US study by CHS (2006). Like them, from 1995-03, including intangibles raises LPG and lowers TFPG but there are some interesting differences. First, in the UK more of LPG is capital deepening and more of that capital deepening is tangible capital deepening. Second, there are slightly different contributions from different intangible types: R&D makes more of a contribution to capital deepening in the US, but design and training more of a contribution in the UK.

Clearly much future work could be done to improve the estimates presented in this paper. Our robustness checks indicate a number of areas where more work might particularly inform our estimates. Perhaps the biggest is that whilst we think that company organisational capital is quantitatively important we do not have a very good measure of it, either own account spending or bought in knowledge e.g. from consultants. Nor do we have very good deflators for many intangible assets at the moment. However, it is worth noting that our main results are robust to varying a number of these measures. All this suggests that the view of macro performance changes quite substantially with different measurement and so these questions are worth pursuing.

Table 1: Intangibles

	Type of intangible investment	2004 Cross Section (GH 2006)	Time series	Total spending £bn, 2004	Proportion of spending considered as investment	% of total intangible investment, 2004	Deflator	Depreciation rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Computerized information							
(1)	**Computer software**	ONS estimates	**2004-1970** ONS data	21.59	1	16.7	ONS deflators	0.33
(2)	**Computerised databases**	Included in our software estimates						
(3)	**Total**			**21.59**		**17.7**		
	Innovative property							
(4)	**Scientific R&D**	Current expenditure on R&D from BERD. R&D in computer industry subtracted	**2004-1981** BERD **1980-1970** Backcast using the growth rate in the Annual Abstract of Statistics.	12.4	1	10.2	Implied market sector GVA deflator	0.2
(5)	**Mineral exploration**	National Accounts	**2004-1970** ONS data	0.4	1	0.3	Implied market sector GVA deflator	0.2
(6)	**Copyright and license costs**	National Accounts	**2004-1970** ONS data	2.4	1	2	Implied market sector GVA deflator	0.2
(7)	***Other product development, design and research***				1			
(8)	**New product development costs in the financial industry**	20% of all intermediate purchase by Financial Services industry, ONS data. Intermediate purchases reduced by purchases of adv, software, consulting and design.	**2003-1992** 20 % of intermediate consumption of the financial sector (SIC 65, 67 I-O 100,102). Source: Input - Output Analysis **1991-1970 B**ackcasted using the growth rate of the turnover of the sector "Banking, finance, insurance business services, leasing" from the Blue Book (after constructing a "consistent" time series with the Blue Book data).	6	1	4.9	Implied market sector GVA deflator	0.2
(9)	**New architectural and engineering designs**	Estimated as half of the total turnover of the architecture and design industry SIC 742, ABI data. Turnover reduced by purchases of adv, software, consulting.Includes also turnover of "speciality design activities" SIC 74782 multiplied by 2 two to consider also own account	**2004-1995** 50% of the turnover of the industry SIC 72, source ABI published data. **1994-1992** 50% of the turnover of the industry SIC 72, source Service Sector Review. **1991- 1985 B**ackcasted using the growth rate of the turnover of architects and engineers as published in Business Monitor. **1984 - 1979 B**ackcasted above using the growth rate Assumption: Turnover of SIC 74.2 grew at same rate as total business services **1979 – 1970** Backcasted using the growth rate of the turnover of the sector "Banking, finance, insurance business services, leasing" from the Blue Book (after constructing a "consistent" time series with the Blue Book data).	18	1	14.7	Implied market sector GVA deflator	0.2
(10)	**R&D in social science and humanities**	No broad statistical information. Estimated as twice industry revenues of social science and humanities R&D industry	**2004-1995** Two times the turnover of the SIC 73.2. Source: ABI **1994-1992** Two times the turnover of SIC 73.2. Source: Service Sector Review **1991-1986** Backcast using the growth rate of the turnover of "Research and Development services" as in Business Monitor. Assumption: The Business monitor survey although different captures the same trends of the sector **1985-1981** Backcast using the growth rate of R&D Berd. Assumption: R&D Berd (mainly scientific) and R&D in human sciences grew at the same rate **1981-1970** Back cast using the growth rate of R&D as in the Annual Abstract of Statistics.	0.3	1	0.28	Implied market sector GVA deflator	0.2
(11)	**Total**			**39.5**		**32.4**		

Continued on next page

Table 1 continued

	Type of intangible investment	2004 Cross Section (GH 2006)	Time series	Total spending £bn, 2004	Proportion of spending considered as investment	% of total intangible investment, 2004	Deflator	Depreciation rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Economic competencies							
(12)	***Brand equity***							
(13)	**Advertising expenditure**	Total spending on advertising as reported by Advertising Association, less expenditure on classified ads	**2004-1970** Advertising Association data	14	0.6	6.9	Implied market sector GVA deflator	0.6
(14)	**Market research**	Twice revenues of the market and consumer research industry as reported in ABI.	**2004-1995** Twice the turnover of industry 74.13 source ABI **1994-1992** Turnover of the sector from Service sector review **1991-1970** Backcast using Advertising Association growth rate of turnover. Assumption: the turnover of the market research industry grew at same rate as the one of the advertising industry	4.5	0.6	2.2	Implied market sector GVA deflator	0.6
(15)	***Total***			18.5	1	9.1		
(16)	***Firm-specific human capital***	NESS05, a similar survey of employer provided training, adjusted to consider private sector expenditure and all UK	**1970-2004** Backcast using trends in wage costs and the industrial structure of the workforce to extrapolate the results of the NESS05 survey (see section 3.1.3)	28.8	1	23.7	Implied market sector GVA deflator	0.4
	Organizational structure							
(17)	**Purchased**	Data on revenues of managment consulting industry from Management Consulting Assocation. To obtain the private sector expenditure we applied the private sector/total expenditure of the MCA to the grossed up total of the industry (still provided by the MCA)	**2004-1992** MCA data for 2004 adjusted to cover just the private sector backcasted using growth rate of turnover of SIC 7414 excluding PR source: ABI from 1995-2004 and using Service Sector Review for 1992-1994 **1991-1985 B**ackcasted using growth rate of turnover of category "management consultant" source Business monitor **1984-1979 B**ackcasted using growth rate of the total business services as published in Business Monitor **1979-1970 B**ackcasted using data above using turnover of the sector "Banking, finance, insurance business services, leasing" from the Blue Book (after constructing a "consistent" time series with the Blue Book data)	7	0.8	4.6	Implied market sector GVA deflator	0.4
(18)	**Own account**	No broad statistical information. Estimated as 20% of value of executive time using ASHE data on wages in executive occupations, excluding software occupations.	**2004-1975** Managers earnings 2004 backcasted using ASHE and NESPD (constructing a consistent time series) **1974-1970** Backcast using highest average wage from STAN	15.3	1	12.5	Implied market sector GVA deflator	0.4
(19)	***Total***			22.3		17.1		
(20)	**Total**			**69.6**		**49.9**		
(21)	**GRAND TOTAL**			**130.8**		**100**		

Source: Our calculations

Notes: Column (1) shows the type of intangible investment. Column (2) indicates the data sources used for the cross section 2004. Column (3) shows the data sources for the time series. Column (4) shows the expenditure for each asset for 2004. Column (5) indicates the percentage of the expenditure assumed as investment. Column (6) shows for each intangible asset which percentage of total intangible investment it represents. Column (7) indicates the deflator used and Column (8) the depreciation rate .ONS is the Office for National Statistics. BERD is Business Enterprise Research and Development. ABI is Annual Business Inquiry. ASHE is Annual Survey Hours and Earnings. STAN is the structural analysis database of the OECD. SIC is Standard Industrial Classification. NESS05 is the National Employer Skills Survey.

Table 2: Tangibles

	Asset type	Time series	Deflator	Depreciation rate
	(1)	(2)	(3)	(4)
(1)	**Computer hardware**	National Accounts consistent investment series (see Wallis, 2005 for details)	ONS delflator (for 1983-1970 backcasted using growth rates of NIESR's hardware delfator)	0.4 (National Accounts)
(2)	**Buildings**	National Accounts investment series. Consistent with 2006 Blue Book. Net stock estimates based on Wallis (2007).	National Accounts capital stock deflators	0.025 (BEA)
(3)	**Plant and Machinery**	National Accounts investment series. Consistent with 2006 Blue Book. Net stock estimates based on Wallis (2007). Computer hardware excluded following method described in Wallis (2005).	National Accounts capital stock deflators	0.13(BEA)
(4)	**Vehicles**	National Accounts investment series. Consistent with 2006 Blue Book. Net stock estimates based on Wallis (2007).	National Accounts capital stock deflators	0.25 (BEA)

Source: Wallis (2007)
Notes: Column (1) shows the asset type. Column (2) indicates the data sources for the time series. Column (3) shows the deflator used and column (4) the depreciation rate. BEA is Bureau of Economic Analysis. NIESR is National Institute of Economic and Social Research.

Table 3: LPG growth accounting
(All data are average percentage growth rates per annum)

	Excluding software			
Period	LPG	Capital deepening	Human capital deepening	TFPG
1990-1995	2.93	1.40	0.83	0.70
1995-2000	2.72	1.82	0.44	0.46
2000-2004	2.53	1.18	0.29	1.07

	Including software			
Period	LPG	Capital deepening	Human capital deepening	TFPG
1990-1995	3.01	1.55	0.81	0.65
1995-2000	2.91	2.00	0.43	0.48
2000-2004	2.64	1.35	0.28	1.00

	Including all intangibles			
Period	LPG	Capital deepening	Human capital deepening	TFPG
1990-1995	3.09	1.90	0.73	0.46
1995-2000	3.23	2.27	0.38	0.57
2000-2004	2.61	1.71	0.25	0.65

Source: Our calculations.
Notes: LPG: labour productivity per hour growth. Capital deepening: share of capital times the growth rate of capital services per hour. Human capital deepening: share of labour times the difference between quality adjusted and non-adjusted hours growth. TFPG: growth rate in total factor productivity calculated as LPG minus capital deepening and human capital deepening. Data are averages in percent per annum.

Table 4: Analysis of capital deepening

	GHW excluding software											
	Capital deepening: average annual growth rates, % per annum			Proportion of total capital deepening' % per annum			Income shares (% of market sector GVA)			Capital services per hour: growth rates (% per annum)		
Period	ICT capital (hardware)	Non ICT capital	Total capital	ICT capital (hardware)	Non ICT capital	Total capital	ICT capital (hardware)	Non ICT capital	Total capital	ICT capital (hardware)	Non ICT capital	Total capital
1990-1995	0.55	0.85	1.40	38.96	61.04	100	4.06	28.22	31.41	16.90	3.17	4.55
1995-2000	1.32	0.51	1.82	72.30	27.70	100	5.47	27.72	31.99	29.55	1.87	5.71
2000-2004	0.69	0.49	1.18	58.31	41.69	100	5.89	24.66	30.10	15.51	1.95	4.03

	GHW including software											
	Capital deepening: average annual growth rates, % per annum			Proportion of total capital deepening' % per annum			Income shares (% of market sector GVA)			Capital services per hour: growth rates (% per annum)		
Period	ICT capital	Non ICT capital	Total capital	ICT capital	Non ICT capital	Total capital	ICT capital	Non ICT capital	Total capital	ICT capital	Non ICT capital	Total capital
1990-1995	0.69	0.86	1.55	44.65	55.35	100	4.34	28.05	32.57	15.70	3.17	3.39
1995-2000	1.49	0.51	2.00	74.61	25.39	100	5.93	28.03	33.60	25.04	1.87	7.03
2000-2004	0.86	0.49	1.35	63.66	36.34	100	6.43	25.32	32.12	13.23	1.96	4.22

	GHW including all intangibles															
	Capital deepening: average annual growth rates, % per annum				Proportion of total capital deepening' % per annum				Income shares (% of market sector GVA)				Capital services per hour: growth rates (% per annum)			
Period	ICT	Non ICT tangible	Other intangibles	Total	ICT	Non ICT tangible	Other intangibles	Total	ICT	Non ICT tangible	Other intangibles	Total	ICT	Non ICT tangible	Other intangibles	Total
1990-1995	0.65	0.90	0.36	1.90	33.97	47.24	18.80	100	4.06	28.22	7.59	39.43	15.69	3.20	5.45	4.90
1995-2000	1.38	0.51	0.39	2.27	60.54	22.48	16.98	100	5.47	27.72	8.75	41.05	25.00	1.89	4.75	5.54
2000-2004	0.79	0.49	0.42	1.71	46.31	28.96	24.68	100	5.89	24.66	9.99	40.14	13.21	2.01	4.61	4.31

Source: Our calculations

Notes: The top panel shows capital deepening without including software, the middle panel includes software and the bottom panel includes all intangibles. The two right hand panels divide capital deepening into the income shares and the growth of capital services per hour, dividing these terms in turn between the contributions of ICT and non-ICT. Data are averages in percent per annum .The capital deepening figures in the left hand side are not quite the same as the income shares times the capital services because of averaging.

Table 5 Comparison with US: Annual change in Labour productivity on farm business sector (market sector for the UK)

		US		UK			US	UK
		1973-1995	1995-2003	1979-1995	1995-2003		1995-2003	1995-2003
		(1)	(2)	(3)	(4)		(5)	(6)
	Excluding software						**Excluding software**	
1	Labour productivity growth	1.36	2.78	2.55	2.59		2.78	2.59
2=3+4	Capital deepening	0.6	0.98	1.23	1.64	2/1	35	64
3	IT equipment	*0.33*	*0.7*	*0.50*	*1.13*	3/1	25	44
4	Other tangible capital	*0.27*	*0.28*	*0.73*	*0.51*	4/1	10	20
5	Human capital deepening	0.28	0.38	0.55	0.36	5/1	14	14
6=1-5-2	TFP growth	0.48	1.42	0.78	0.58	6/1	51	22
	Including software						**Including software**	
1	Labor productivity growth	1.47	2.95	2.67	2.73		2.95	2.73
2	*Contribution of components:*							
3=4+5	Capital deepening	0.73	1.26	1.35	1.82	3/1	43	67
4	IT equipment and software	*0.46*	*0.99*	*0.62*	*1.31*	4/1	34	48
5	Other equip. and structures	*0.27*	*0.27*	*0.73*	*0.52*	5/1	9	19
6	Human capital deepening	0.27	0.37	0.54	0.35	6/1	13	13
7=1-6-3	TFP growth	0.47	1.32	0.78	0.56	7/1	45	20
	Including intangibles						**Including intangibles**	
1	Labour productivity growth (percent)	1.63	3.09	2.86	2.93		3.09	2.93
2=3+6	Capital deepening	0.97	1.68	1.66	2.14	2/1	54	73
3=4+5	*Tangibles*	*0.55*	*0.85*	*1.21*	*1.54*	3/1	28	53
4	IT equipment	*0.3*	*0.6*	*0.46*	*1.02*	4/1	19	35
5	Other	*0.25*	*0.24*	*0.75*	*0.52*	5/1	8	18
6=7+8	*Intangibles*	*0.43*	*0.84*	*0.44*	*0.60*	6/1	27	20
7	Software	*0.12*	*0.27*	*0.12*	*0.18*	7/1	9	6
8	Other (new CHS)	*0.31*	*0.57*	*0.32*	*0.41*	8/1	18	14
9	Human capital deepening	0.25	0.33	0.49	0.31	9/1	11	11
10=1-9-2	TFP growth	0.41	1.08	0.72	0.48	10/1	35	16

Source: UK data our calculations. US data CHS (2006).

Notes: the Table shows the comparison between UK and US. UK data starts in 1979. The top panel excludes software, the middle panel includes software only and the bottom panel all intangibles. In the top panel the first row shows the growth rate of labour productivity per hour. The second row shows capital deepening defined as share of capital times the growth rate of capital services per hour. Capital deepening is split in IT equipment (hardware in this case) and other tangible capital. Row 5 shows human capital deepening as in table 3. Row 6 indicates the growth rate of TFP calculated as row (1)-row (2) - row (5). The middle panel shows the same information as the top panel, the only difference is that IT equipment includes also software. In the bottom panel the first row shows the growth of labour productivity per hour as above. The second row shows capital deepening, which is split into tangibles (row 3) and intangible (row 6). Tangibles are in turn spilt in IT equipment and other (which includes also the intangible already in the NA) and Intangibles is split into software and other intangibles. Row shows human capital deepening and row 10 TFP growth defined as above. The most direct comparison is for the years 1995-2003 and it is summarised in rightmost panel, with each contribution as percentage of Labour productivity growth (LPG) with LPG shown in the top row. Data are averages in percent pen annum.

Table 6 Table Contribution of Intangible capital deepening to the Annual Change in Labour Productivity, Non farm business sector (percentage points) (market sector for UK)

		US		UK			US	UK
	all intangibles	1979-1995	1995-2003	1979-1995	1995-2003		1995-2003	1995-2003
		(1)	(2)	(3)	(4)		(5)	(6)
1	Intangible capital deepening	0.43	0.84	0.47	0.59			
2	Computerized information	0.12	0.27	0.12	0.18	2/1	32	31
3=4+5	Innovative property	0.13	0.22	0.16	0.14	3/1	26	24
4	Scientific	*0.05*	*0.08*	*0.06*	*0.01*	4/1	10	1
5	Nonscientific	*0.08*	*0.14*	*0.09*	*0.14*	5/1	17	24
6=7+8	Economic competencies	0.17	0.35	0.19	0.26	6/1	42	45
7	Brand equity	*0.04*	*0.08*	*0.04*	*0.04*	7/1	10	6
8	Firm-specific resources	*0.13*	*0.27*	*0.15*	*0.23*	8/1	32	39

Source: UK data our calculations. US data CHS (2006).
Notes: The Tables splits intangible capital deepening, defined as the share of intangible capital times the growth rate of intangible capital services per hour, into its components. Brand Equity includes: advertising and market research. Firm specific resources include: firm specific human capital and organisational structure. Scientific R&D includes: scientific R&D and mineral exploration. Non scientific R&D includes: copyright and licences costs, new product development costs in the financial industry, new architectural and engineering design and R&D in social science and humanities. Computerized information includes: software. The most direct comparison is for the years 1995-2003 and it is summarised in rightmost panel, with each contribution as percentage of Intangible capital deepening. Data are averages in percent per annum. Data are averages in percent per annum.

Table 7 Difference between LPG (and constituent parts) with and without intangibles for US and UK

	US	UK
	1995-2003	1995-2003
Differences between data including all intangibles and data excluding software		
	(1)	(2)
Labour productivity	0.31	0.34
Capital deepening	0.70	0.50
Human capital deepening	-0.05	-0.05
TFP growth	-0.34	-0.10
Differencess between data including all intangibles and data including software		
Labour productivity	0.14	0.19
Capital deepening	0.42	0.32
Human capital deepening	-0.04	-0.04
TFP growth	-0.24	-0.08

Source: Table 5

Notes: The Table shows the differences between Labour productivity growth and its constituent parts with and without intangibles, for US and UK. The upper panel shows the difference when we include all intangibles against when we exclude all intangibles (also software). The lower panel shows the difference between when we include all intangibles against when we include software. Labour productivity is per hour, Capital deepening is share of capital times the growth rate of capital services per hour. Human capital deepening is share of labour times the difference between quality adjusted and non adjusted hours growth TFPG: growth rate in total factor productivity calculated as Labour productivity growth minus capital deepening and human capital deepening. Data are averages in percent per annum.

Table 8: Sensitivity analysis

Base case

(a)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
without software	16.87	14.46	68.89	68.46	-0.21	0.42	-0.25
with software	17.04	16.32	68.73	66.78	-0.10	0.45	-0.16
with all intangibles	22.15	24.79	63.98	59.26	0.14	0.37	0.12

All conversion factors (from expenditure to investment) divided by 2

(b)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
with software	17.00	16.01	68.77	67.06	-0.18	0.45	-0.25
with all intangibles	19.64	20.50	66.30	63.04	-0.05	0.41	-0.09

All conversion factors divided by 2 except software

(c)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
with software	17.04	16.32	68.73	66.78	-0.10	0.46	-0.16
with all intangibles	19.68	20.78	66.27	62.80	0.03	0.42	-0.01

Double depreciation rate (brand equity = 0.9)

(d)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
with software	17.04	16.32	68.73	66.78	-0.10	0.49	-0.20
with all intangibles	22.15	24.79	63.98	59.26	0.14	0.49	0.00

Expenditure on uncertain intangibles = exp+50%exp

(e)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
with software	17.04	16.32	68.73	66.78	-0.10	0.45	-0.16
with all intangibles	22.94	26.57	63.25	57.70	0.20	0.36	0.18

Expenditure on uncertain intangibles = exp-50%exp

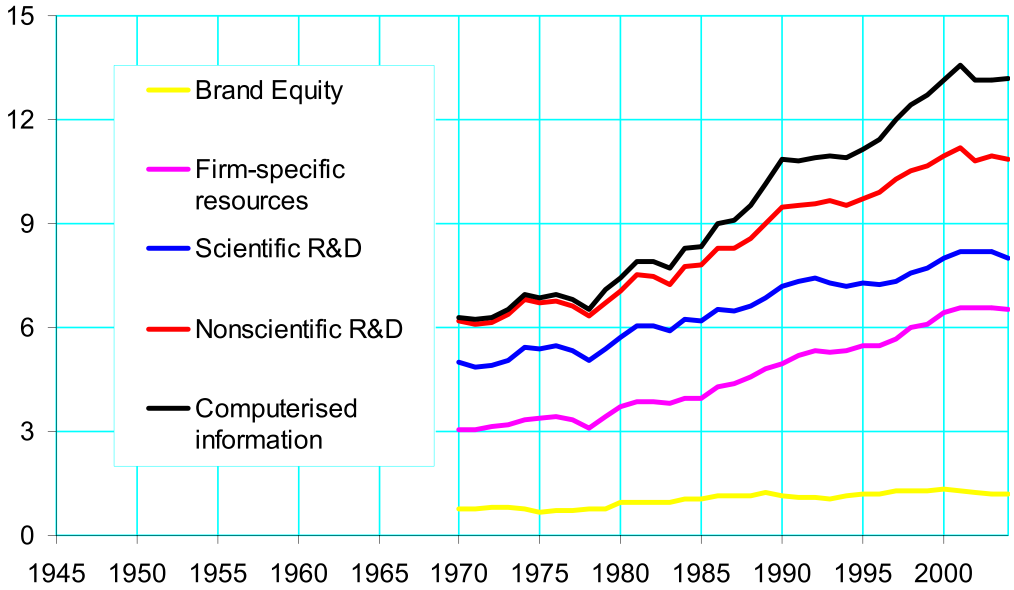
(f)	inv/mGVA 70-80	inv/mGVA 94-04	wl/mgva 70-80	wl/mgva 94-04	LPG 95/00-90/95	KDEP 95/00-90/95	TFPG 95/00-90/95
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
with software	17.04	16.32	68.73	66.78	-0.10	0.45	-0.16
with all intangibles	21.35	22.92	64.72	60.90	0.08	0.38	0.05

Source: Our calculations

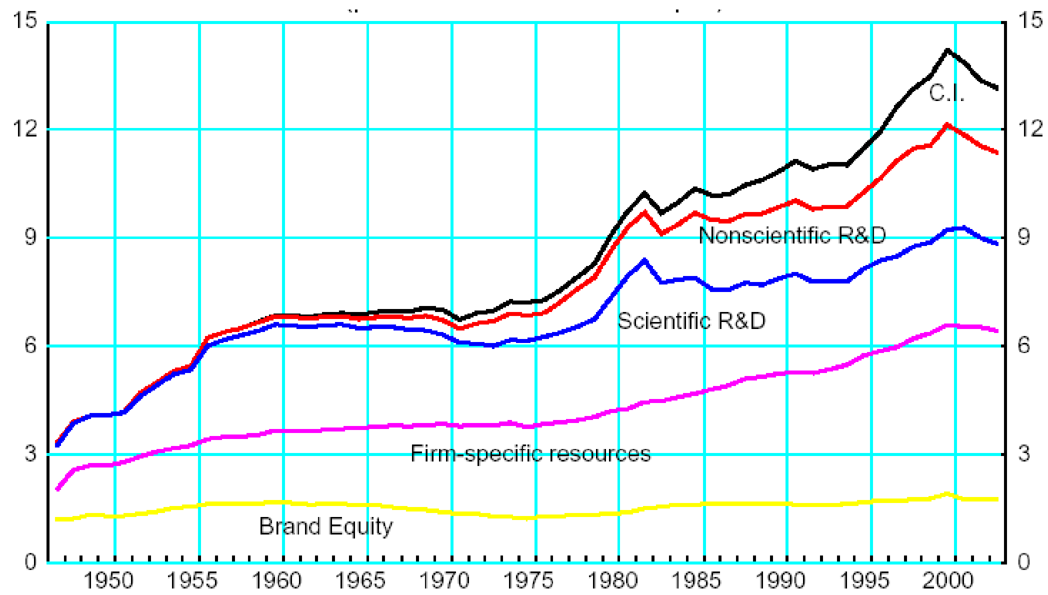
Notes: inv/mGVA is the nominal investment as a share of market sector GVA. wl/GVA is the labour as a share of market sector GVA. LPG is labour productivity, market sector GVA per hour for all persons. KDEP is capital deepening. TFPG is total factor productivity growth. Columns (5) (6) and (7) show the difference between the values the relevant variable takes in period 1995-2000 and 1990-1995. Panel (a) shows the base case. Panel (b) shows the results when we divide all the conversion factors used to multiply expenditure into investment (see table 1, column 5) by two. Panel (c) shows the results when we halve all conversion factors except the one for software. Panel (d) shows the results when we double all the depreciation rates except brand equity, which is set to 0.9. Panel (e) shows the results when we double the expenditure on each intangible investment series that are considered more uncertain, see text. These are new product development costs in the financial industry, new architectural and engineering design, R&D in social science and humanities, market research, purchased organisational structure and own-account organisational structure. Panel (f) shows the results when we halve these uncertain expenditures.

Figure 1: Intangible Investment (percentage of output)

(a) UK



(b) US

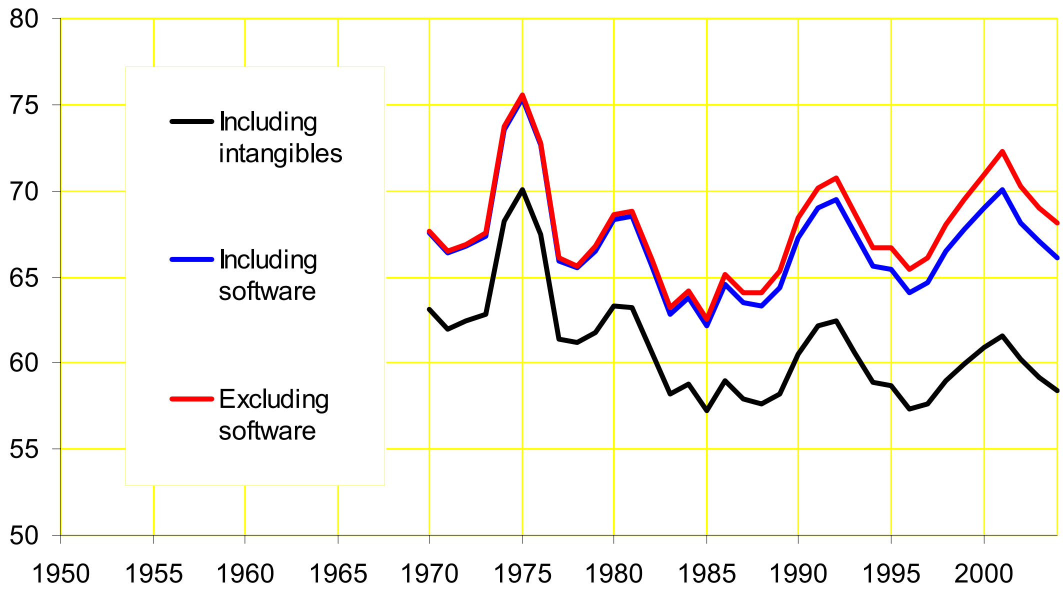


Source: UK data our calculations. US data CHS (2006).

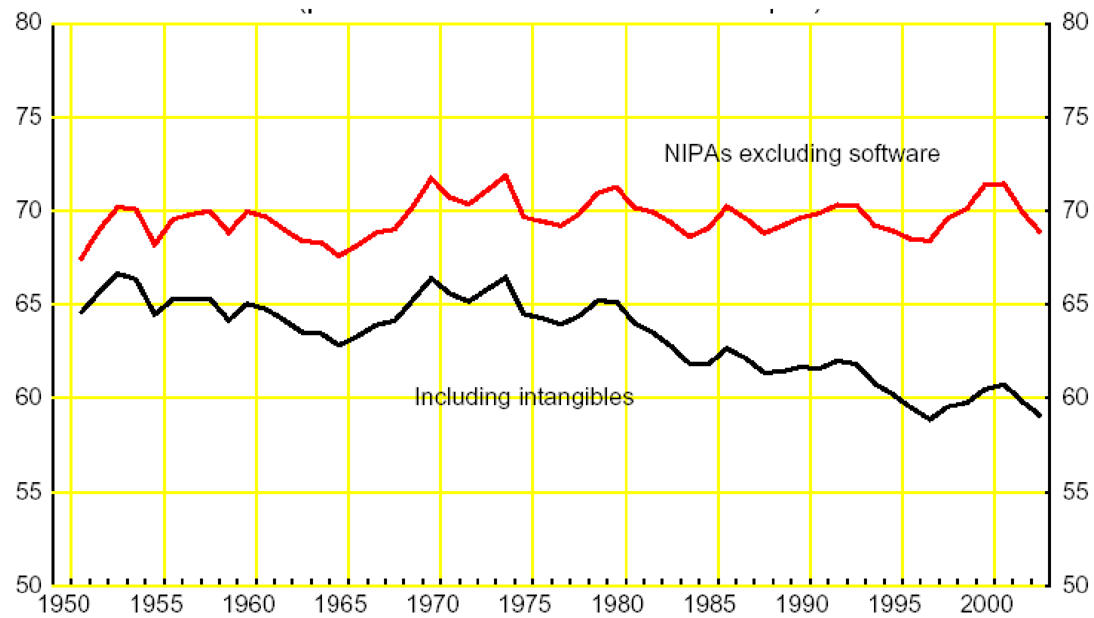
Note: The figure shows the time series for intangible investment for the aggregated categories as a share of market sector output. For the UK output is market sector GVA adjusted to include all intangibles. For the US output is non-farm business output. The first chart (a) shows the time series for the UK while the second (b) shows the time series for the US. It is a cumulative graph so that that top (black) line shows the share of total intangible investment in intangible-adjusted market sector GVA. The lowest line shows the share of brand equity and the line above that shows the share of brand equity plus the firm-specific resources. Thus the gap between the lines is the share of each category of investment. Brand Equity includes: advertising and market research. Firm specific resources include: firm specific human capital and organisational structure. Scientific R&D includes: scientific R&D and mineral exploration. Non scientific R&D includes: copyright and licences costs, new product development costs in the financial industry, new architectural and engineering design and R&D in social science and humanities. Computerised information includes: software

Figure 2: Labour shares (percentage of output)

(a) UK



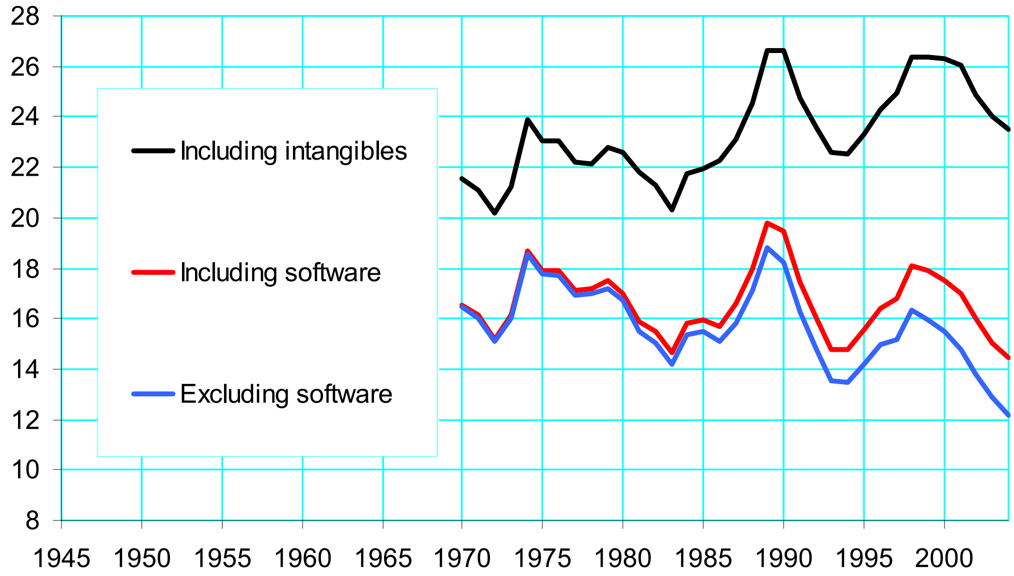
(b) US



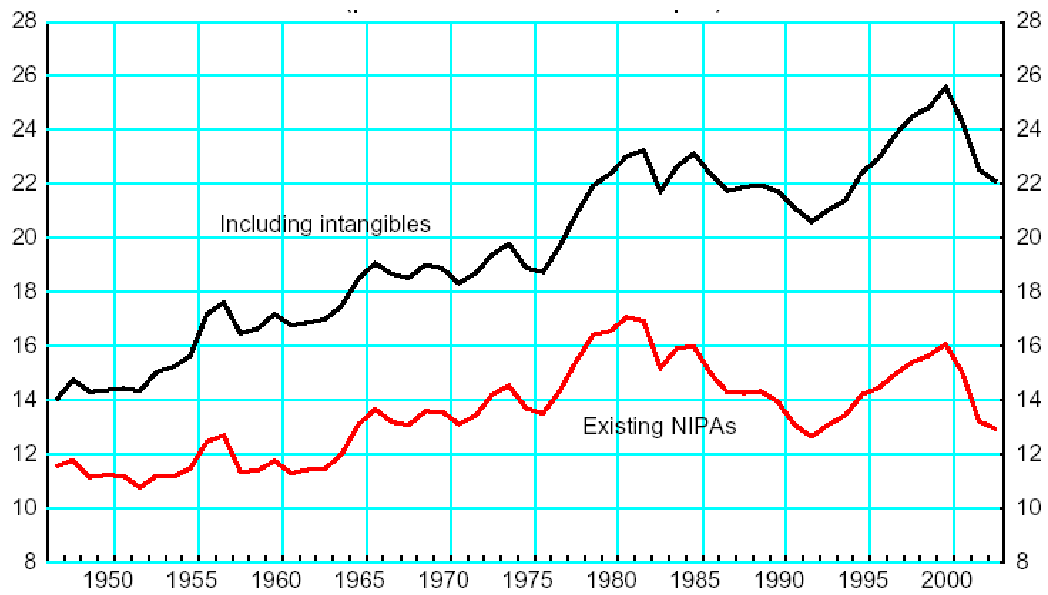
Source: UK data our calculations. US data CHS (2006).
Note: The figures show the time series for the labour share in the both the UK and the US excluding and including intangibles. The first chart (a) shows the labour share from 1970 to 2004 for the UK while the second chart (b) shows the labour share from 1950 to 2003 for the US. For the UK output is market sector GVA adjusted to be consistent with the amount of intangibles included. For the US output is non-farm business output.

Figure 3: Nominal investment shares (percentage of output)

(a) UK



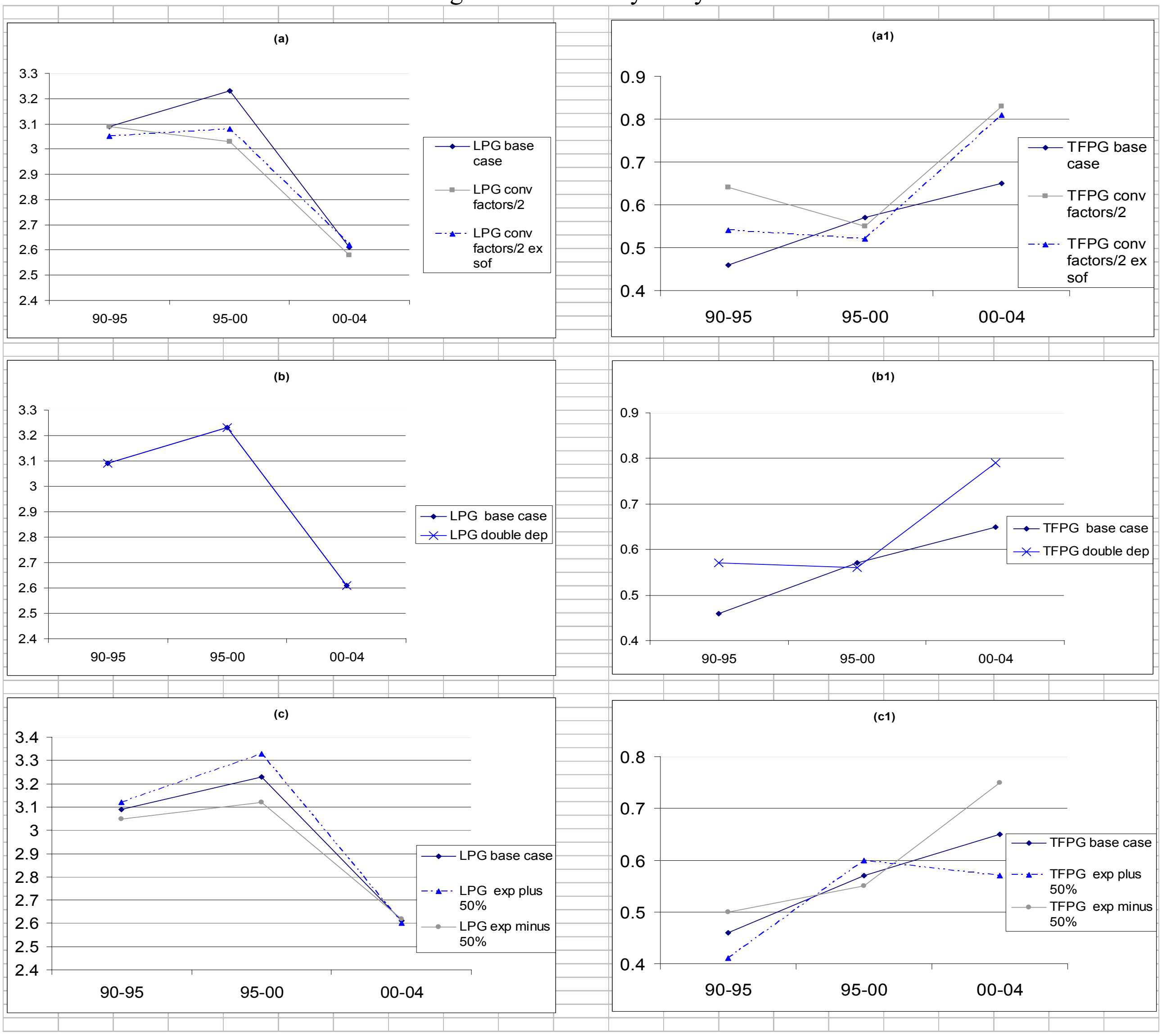
(b) US



Source: For US data CHS (2006) for UK data our calculations

Notes: The figures show investment shares as a percentage of market sector GVA for the UK and non-farm business output for the US in three cases: traditional National Accounts excluding software, including software (this is not shown in the US graphs) and including all intangibles. In each case the market sector GVA for the UK is the appropriate version for the amount of intangibles included.

Figure 4: Sensitivity analysis



Source: Our calculations

Notes: The figure shows the sensitivity analysis for labour productivity growth and total factor productivity growth for the case in which we include all intangibles.. LPG is labour productivity, market sector GVA per hour for all persons, growth. TFPG is total factor productivity growth. Panels on the left hand side show the sensitivity analysis for LPG while panels on the right hand side for TFPG. Each panel shows the base case and the results when we change the assumptions. In panel (a) we halve all the conversion factors used to multiply expenditure into investment (see table 1, column 5). It shows also the case in which we halve all the factors except the one for software. Panel (b) shows the results when we double all the depreciation rates except brand equity which is set to 0.9 as in the base case is already 0.6. Panel (c) shows the results when we double and we halve the expenditure on each item which we consider uncertain, see text. The uncertain items are new product development costs in the financial industry, the new architectural and engineering design, R&D in social science and humanities, market research, purchased organisational structure and is own account organisational structure.

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Appendix 1: Comparison of growth accounting estimates

Official TFP estimates are not produced in the UK. Thus we have found the following three sources for UK growth accounting: Oulton and Srinivasan (2005), the OECD statistical portal, and the EU KLEMS database.

The Oulton and Srinivasan (2005) results are discussed in section 5.1. Note the strong LPG and TFPG slowdowns, which, with the new hours data are much less pronounced. In this appendix we focus on the comparison with the recent estimates of EU KLEMS and the OECD statistical portal. In order to compare we present an output growth decomposition instead of a productivity growth of our results. In the table below we set out the different results.

Figure A1: Comparison of growth accounting estimates

(Note these data are not per person hour as in the main text)

	GWH (including software)			
	Output growth	Labour contrib	Capital contrib	TFPG
1990-95	1.54	-0.21	1.11	0.65
1995-00	3.99	1.13	2.37	0.48
2000-04	2.54	0.21	1.32	1.00
1995-04	3.34	0.72	1.91	0.71
	EU KLEMS			
	Output growth	Labour contrib	Capital contrib	TFPG
1990-95	1.7	-1.0	0.9	1.7
1995-00	3.8	1.2	2.0	0.6
2000-04	2.8	0.5	0.9	1.3
1995-04	3.3	0.9	1.5	0.9
	OECD			
	output growth	labour contrib	capital contrib	tfpg
1990-95	1.69	-0.78	0.88	1.59
1995-00	3.18	0.69	0.99	1.50
2000-03	1.39	0.17	0.54	0.68
1995-03	2.82	0.48	0.91	1.44

The first panel shows our output growth decomposition when we include software. The second panel shows the EU KLEMS results for market sector. In the longer period, 1995-04, the results are quite similar. In the shorter periods the results remain similar except in 1990-95 (first row) for TFPG (fourth column). Our figure is smaller than EU KLEMS one because we have a bigger labour contribution. The difference seems to be due to different hours and quality adjustment series.

The third panel shows the OECD results for the whole economy. Note that the data are available up to 2003 therefore the results for the period 2000-2003 are not strictly comparable with the other sources. The results are rather different in comparison with our results, the main differences being: b) a smaller speed up for Capital contribution in period 95-00 c) no slowdown for TFPG in 95-00. Note however that the OECD explicitly states that their data should be used for international comparisons and not for individual country analysis. Their Output growth numbers are similar to ours in the pattern of the speed up in the late nineties although the magnitude is smaller, but the main difference is that we have a rise in capital deepening in the late 90s that they do not have. Note that this mid90s increase in capital deepening is in both our data and the EU KLEMS data.

Appendix 2: Note on treatment of capital stocks

Following Oulton and Srinivasan (2003), we assume that capital stocks in place in the middle of the period yield output over the course of the period. The capital stock in the middle of period *t* is estimated as the geometric mean of the stocks at the beginning and end of the period.

$$K_{it} = \overline{A}_{it} = \left[A_{i,t-1} \cdot A_{it} \right]^{1/2}, \qquad i = 1,\ldots,n$$

The accumulation of capital is as per above

$$B_{it} = I_{it} + (1-\delta_i) \cdot B_{i,t-1}$$

but the amount of the capital asset in place is assumed to depreciate evenly over the year and so is given by

$$A_{it} = (1-\delta_i/2) \cdot B_{it}$$

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