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Treasury Economic Working Paper No. 1

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Intangible investment and Britain's productivity

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Abstract

Despite the clear importance of innovation and advancements around the 'knowledge economy', UK macroeconomic performance appears to have been largely unaffected. We investigate whether measurement issues might account for this puzzle. The standard National Accounts treatment of most spending on 'knowledge' or 'intangible' assets is as intermediate consumption. We ask how treating such spending as investment might affect some key macroeconomic variables. We find (a) market sector gross value added (MGVA) was understated by about 6 per cent in 1970 and 13 per cent in 2004 (b) instead of the nominal business investment/MGVA ratio falling since 1970 it 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.

JEL reference: O47, E22, E01

Keywords: intangible assets, productivity, R&D, training, organisational capital, investment

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Contents

1 INTRODUCTION

1.1 As the global economy becomes more competitive and technological change accelerates there will be increasing rewards for innovation and knowledge-based sectors will grow in importance. Success in these areas will require firms investing in knowledge intensive activities, such as research and development (R&D), in finding new and innovative ways to organise the production of goods and services, and having access to a skilled and flexible labour force.[1]

1.2 This paper examines the impact of these developments on recent UK macroeconomic performance. It considers whether traditional methods of measuring investment and productivity in the economy are fully capturing the importance of the intangible assets which are central to the knowledge economy such as scientific R&D, software, design and spending by firms on reputation and on human and organisational capital. In particular, current spending on intangibles is mostly treated as intermediate consumption for the firm rather than as an investment. But if a firm is spending money on intangibles to provide it with higher value added in the future there is a strong case to treat such spending as investment.

1.3 This may help to solve some potential inconsistencies in past UK macroeconomic data. Rapid advances in technology would be expected to lead to higher investment as firms seek competitive advantage from these technologies. This technology should also allow firms to produce goods and services more efficiently so increasing productivity.

1.4 But in fact, the ratio of investment to gross domestic product (GDP) has been more or less constant since the 1950s. Also, according to existing studies the UK's productivity growth rate slowed down in the period 1995 to 2000 compared with the period 1990 to 1995[2], despite experiencing an ICT investment boom in the late 1990s. This is in contrast to the US, where there was a productivity acceleration after 1995 associated with the ICT investment boom.[3]

1.5 Two possible answers could explain this. The first is that investment in and/or the impact of the knowledge economy is much less than we think. The second is that the impact of this investment in the knowledge economy is hidden by measurement problems.[4]

[1] The importance of innovation and knowledge-based activities for the British economy was discussed in a recent article in the *Economist* – 'The good, the bad and the ugly', August 4th-10th 2007, pp. 23-24.

[2] O'Mahony and De Boer (2002), Oulton and Srinivasan (2003) and Oulton and Srinivasan (2005). Comparing average productivity growth over fixed time periods can sometimes be misleading due to the cyclical nature of productivity. The Treasury approach to measuring productivity growth is to measure it over the economic cycle so as to remove cyclical fluctuations. Trend growth in output per hour worked over the 1986Q2-1997H1 cycle was 1.9 per cent per year. Since 1997H1, average output per hour growth has been 2.4 per cent per year.

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

[4] Measurement of productivity in a dynamic economy developing new technologies has always been difficult. Robert Solow famously said that "computers are everywhere except in the productivity statistics."

Main findings **I.6** This paper explores the second explanation by examining the consequences for investment and productivity of treating expenditure on intangibles as investment rather than as intermediate consumption.[5] The main findings are as follows:

- business investment in 2004 would have been about double the traditional measure. Investment in intangibles was £123bn, compared with tangible investment of £96bn;
- the value of measured market sector output[6] would have been higher by about 6 per cent in 1970 and 13 per cent in 2004;
- instead of the ratio of nominal business investment to market sector output falling since 1970, it would have been rising;
- growth in labour productivity and capital deepening would have been higher than previously estimated;
- total factor productivity growth would not have slowed down since 1990, as it appears on current measures, but would have been picking up; and
- comparing the results with the US shows that the share of intangible investment in market sector output is similar in both countries.

I.7 The results in this paper suggest that traditional measures of investment may not be capturing the dynamic changes in the economy that are taking place as knowledge-intensive industries increase in importance. Indeed, the UK's lower productivity growth rate in the period 1995 to 2000 disappears when treating intangible expenditure as investment. It is unclear how the UK's productivity gap with the comparator countries France, Germany and the US would be affected were all countries to treat intangible spending as investment. Of these countries a comparable study only exists for the US and the productivity growth impact of intangibles are of similar magnitude. Future work is planned in conjunction with the authors of the US study to try and produce productivity gap estimates that allow for the treatment of intangibles as investment.

I.8 The UK Government has identified a framework of five 'drivers' that interact to raise productivity growth, with investment and innovation identified as two key drivers, and has implemented major reform programmes under each of these drivers to address underlying failures.[7] The results in this paper highlight the importance of these two drivers and also the importance of focusing on more than just traditional measures of tangible capital.

Methodology **I.9** The methodological approach that this paper takes to addressing this question is as follows.[8] First, we assemble data on knowledge investments for a range of intangible assets.[9] These are wider than the usual R&D and software and include design and 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.

[5] 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.

[6] Strictly speaking market sector gross value added.

[7] See HM Treasury (2006a). The other three drivers are: competition, enterprise, and skills.

[8] For a longer version of this paper see Giorgio Marrano, Haskel and Wallis (2007).

[9] Following the approach of Corrado, Hulten and Sichel (CHS).

1.10 Second, we look at the consequences of including intangibles for overall business investment and market sector gross value added (MGVA).[10] Ignoring intangibles could explain why the traditionally measured (i.e. focussed on tangible capital) nominal business investment to MGVA ratio has remained constant in the UK despite the perception that the underlying conditions for investment have been so favourable in recent years.

1.11 Third, we look at the consequences for market sector labour productivity. The *level* of labour productivity – MGVA per unit of labour input – rises because the level of MGVA rises once intangibles are accounted for but the amount of labour input stays the same. But the labour productivity *growth rate* will only rise if the additional MGVA from intangibles increases over time. So the impact on productivity growth is not clear. The systematic way of answering this question is via growth accounting and so we extend previous UK growth accounting studies by including intangible capital.

Sensitivity analysis

1.12 There are a number of measurement issues in estimating investment in intangible assets. We assess the robustness of our findings to different measurement methods. First, our major findings are robust to changes in the depreciation rates. Second, regarding levels, around 60 per cent of intangible spending comes from official surveys, the rest comes either from assumptions built on official surveys or from wages and salary surveys used to measure wages by occupation. 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. We also look at different time periods, such as cyclical peak-to-peak, to ensure our growth accounting estimates are robust to selecting different time periods.

Previous literature

1.13 This paper builds on previous work by Oulton and Srinivasan (2003), Basu et al (2004) and Oulton and Srinivasan (2005). Oulton and Srinivasan (2003, 2005) examined a number of measurement issues; they incorporate software into output, measure capital as capital services, build the capital data from a disaggregated level, and measure 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 lower productivity growth rate still remained in all these studies and the authors argued that it was likely to be 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.

[10] 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.

1.14 There have been important studies on the impact of intangibles on GDP for the US, particularly CHS (2004, 2006) and Nakamura (1999, 2001, 2003) but there has not been anything similar for the UK. In this paper we follow the central observation in the US papers that in practice, spending on most knowledge assets is, in accounting terms, like spending on other intangible assets, such as software.

Next steps

1.15 The shift of investment towards knowledge assets in developed countries requires consideration of how this shift can be incorporated into the System of National Accounts (SNA).[11] Software investment has already been fully incorporated as investment in the SNA and R&D spending looks set to be treated as investment by 2010. Much work would be needed in order to fully incorporate the broader range of intangible asset covered here but international discussion on these issues is beginning to intensify.[12]

Structure of paper

1.16 The outline of the rest of this paper is as follows. In the next chapter, we set out how intangibles affects MGVA and growth. Chapter 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 MGVA), and Chapter four outlines our growth accounting approach. Chapter five presents our growth accounting results and Chapter six concludes.

[11] The System of National Accounts is a conceptual framework that sets the international statistical standard for the measurement of the market economy. It is based on internationally agreed concepts, definitions, classifications and accounting rules. Together, these principles provide a comprehensive accounting framework within which economic data can be compiled and presented in a format that is designed for purposes of economic analysis, decision-taking and policy-making.

[12] Intangible investment has been a key topic of discussion at recent conferences by the Organisation for Economic Co-operation and Development (OECD) and the National Bureau of Economic Research (NBER).

2 FRAMEWORK FOR ASSESSING THE IMPACT OF INTANGIBLE INVESTMENT

2.1 To incorporate intangible investment into National Accounts statistics we use the output approach to calculating GDP as opposed to the two alternatives; expenditure and income approaches.

2.2 Most spending on "knowledge" or "intangible" assets is treated as intermediate consumption, like the cost of electricity for example. In the aggregate, gross value added (GVA) is equal to the total value of output for all firms in the economy *less* the total value of spending by firms on intermediate consumption. It follows that treating spending on "knowledge" or "intangible" assets as investment rather than as intermediate consumption means that intermediate consumption is reduced and GVA is increased.

2.3 We assess the impact of intangible investment using the growth accounting framework. A formal growth accounting model for the treatment of intangibles is set out below. The growth accounting framework allows us to decompose labour productivity growth into growth in capital deepening, growth in human capital deepening (increased labour quality) and growth in total factor productivity. The treatment of intangibles as investment in this framework is straightforward.

2.4 Essentially treating spending on "knowledge" or "intangible" assets as investment rather than intermediate consumption means that we have more investment, hence more capital stock. We also have more output and more capital income (operating surplus in the National Accounts). The final impact on productivity growth is unknown a *priori* as GVA will increase in all years and capital input, in the form of our new stock of intangible capital, will also increase.

GROWTH ACCOUNTING FRAMEWORK FOR TREATMENT OF INTANGIBLES

2.5 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.

Intangibles treated as intermediates

2.6 Suppose first that the intangible investment good is regarded as an intermediate. The tangible capital stock K_t is assumed to accumulate according to the perpetual inventory method:

$$K_t=I_t+(1-\delta_K)K_{t-I} \quad (2.1)$$

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

(a) Intangible sector: $N_t=F^N(L_{N,t},K_{N,t},t)$; $P_t^N N_t=P_t^L L_{N,t}+P_t^K K_{N,t}$

(b) Tangible sector: $I_t=F^I(L_{I,t},K_{I,t},t)$; $P_t^I I_t=P_t^L L_{I,t}+P_t^K K_{I,t}+P_t^N N_{I,t}$ (2.2)

(c) Consumption sector: $C_t=F^C(L_{C,t},K_{C,t},N_{C,t},t)$; $P_t^C C_t=P_t^L L_{C,t}+P_t^K K_{C,t}+P_t^N N_{C,t}$

where the superscripts N, I and C refer to the three sectors. So, for example, in equation (2.2a), the left hand side production function in the intangible sector says that the output of intangibles is produced by labour in the intangible sector and tangible capital in the intangible 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.

2.7 Since intangibles are assumed to be intermediates, the production functions in (2.2b) and (2.2c) 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[1]

$P_t^{Q'}Q'_t=P_t^C C_t+P_t^I I_t=P_t^L L_t+P_t^K K_t$ (2.3)

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

Intangibles treated as capital

2.8 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

$R_t=N_t+(1-\delta_R)R_{t-I}$ (2.4)

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

(a) Intangible sector: $N_t=F^N(L_{N,t},K_{N,t},R_{N,t},t)$; $P_t^N N_t=P_t^L L_{N,t}+P_t^K K_{N,t}+P_t^R R_{N,t}$

(b) Tangible sector: $I_t=F^I(L_{I,t},K_{I,t},R_{I,t},t)$: $P_t^I I_t=P_t^L L_{I,t}+P_t^K K_{I,t}+P_t^R R_{I,t}$ (2.5)

(c) Consumption sector: $C_t=F^C(L_{C,t},K_{C,t},R_{C,t},t)$; $P_t^C C_t=P_t^L L_{C,t}+P_t^K K_{C,t}+P_t^R R_{C,t}$

2.9 Note that in contrast to (2.2) 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. 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:

$P_t^Q Q_t=P_t^C C_t+P_t^I I_t+P_t^N N_t=P_t^L L_t+P_t^K K_t+P_t^R R_t$ (2.6)

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

2.10 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.

[1] 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, respectively, 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.

2.11 Finally, to understand the implications for total factor productivity growth (TFPG) we may write a growth accounting relation from the production functions above

(a) $\Delta\ln TFP' = \Delta\ln Q'_t - s'^L_t \Delta\ln L_t - s'^K_t \Delta\ln K_t$ (2.7)

(b) $\Delta\ln TFP = \Delta\ln Q_t - s^L_t \Delta\ln L_t - s^K_t \Delta\ln K_t - s^R_t \Delta\ln R_t$

where equation (2.7a) shows the expression for TFPG=$\Delta\ln TFP$ in the case where intangibles are expensed and the lower equation (2.7b) where they are capitalised. The shares of each factor are denoted with an s.[2] 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 $\Delta\ln Q$ is ambiguous. In addition, the capitalisation of intangibles means that (the growth in) an additional input has to be included as a determinant of growth. Thus we have more capital assets accounting for $\Delta\ln Q$ so that TFPG may rise or fall. Note finally that the shares differ between (2.7a) and (2.7b) since both output and the payments to capital differ.

2.12 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.

2.13 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.

COMPARISON WITH TREASURY APPROACH TO TREND GROWTH[3]

2.14 The Treasury macroeconomic framework requires the decomposition of output into trend and cycle components. Trend output growth is the sum of the growth rates of labour productivity and labour input.[4] The analysis in this paper considers the possible importance of intangible investment by decomposing labour productivity growth into growth in capital deepening, growth in human capital deepening (increased labour quality) and growth in total factor productivity.

[2] 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 (2.7a) and (2.7b).

[3] For more detail on the Treasury approach to trend growth see HM Treasury (2005) and (2006b).

[4] Growth in labour input depends on growth in the population of working age, growth in the employment rate and growth in average hours worked.

3 Intangible spending and the investment and labour shares

3.1 This chapter discusses our data on intangible spending, investment and the investment and labour shares. More information can be found in Giorgio Marrano, Haskel and Wallis (2007).

Intangible assets

3.2 We identify three main intangible asset classes:

- computerised information (mainly software);
- innovative property (mainly scientific and non-scientific R&D); and
- firm competencies (company spending on reputation, human and organisational capital).

3.3 Table 3.1 provides more detail on the types of intangibles we consider and their current treatment in the National Account. The first column shows the broad category of intangible investment and the second list the things that are included.

3.4 The final column is important in terms of assessing the impact of treating intangibles as investment rather than as intermediate consumption. This identifies which of these types of investment are currently included in the standard definition of capital i.e. if you download an official investment series which ones would be included. All investment on computer software is included as is mineral exploration and copyright and licence costs.[1] Everything else is treated as intermediate consumption and so will not be included in official investment (or capital stock) series.

Table 3.1: Types of intangible investment and current treatment in the National Accounts

Type of intangible investment	Includes the following intangibles	Current treatment in National Accounts
Computerised information	(1) Computer software (2) Computer databases	Both treated as investment
Innovative property	(1) Scientific R&D (2) Mineral exploration (3) Copyright and license costs (4) New product development costs in the financial industry (5) New architectural and engineering designs (6) R&D in social science and humanities	Only (2) and (3) treated as investment
Economic competencies	(1) Brand equity (2) Firm-specific human capital (3) Organisational structure	None of these treated as investment

Spending on intangible assets

3.5 Table A.1 in the appendix shows our choice of intangible assets, their data sources, the expenditure figures, the proportion of the expenditure assumed to be investment, the percentage of total intangible investment, their deflators and depreciation rates. We limit our attention to the first six columns.

[1] Since the *Blue Book* 2007 revision to own-account software.

3.6 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. Column five shows the proportion of expenditure that is assumed to be investment.[2] Column six shows the percentage of total intangible investment accounted for by each of the separate intangible assets.

3.7 The type of intangibles, column one, and the data sources for the cross section, column two, have been extensively described in Giorgio Marrano and Haskel (2006). There are two minor changes with respect to that paper. All the data are now consistent with the 2006 *Blue Book* and therefore they include any revisions, and in the asset “new architectural and engineering design” we additionally include twice the turnover of the SIC 74782 “Speciality designs activities” (around £4bn in 2004). Below we will mostly focus on the time series estimates.

Computerised information

3.8 This is straightforward. We use ONS data published in Chamberlin et al (2006). The data are available from 1970 (as highlighted in row 1 column 3 of Table A.1).

Innovative property

Scientific R&D

3.9 For Scientific R&D, row 4, we use expenditure on R&D as published in BERD. In row 4 column 3 we show the time series availability. We have BERD data back to 1981. We backcast it to 1970 using the expenditure on R&D in the private sector 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.

3.10 For Mineral exploration and Copyright and license costs, as shown in row 5 and row 6, we use data from the National Accounts. The series go back to 1970.

Product development in finance

3.11 New product development costs in the financial industry, row 8, is estimated, in the absence of better data, as 20 per cent of intermediate consumption by the Financial Services Industry. 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).

Architectural and engineering design

3.12 For new architectural and engineering design, row 9, we use 50 per cent 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 per cent of the sales of this sector was own-account spending). As column 3 shows these data go 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. 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 to 1979 we backcast using the growth rate of the turnover of the total business service sector as published in the Business Monitor. We then backcast the series to 1970 using the growth rate of the turnover of the sector “Banking, finance, insurance, business services, leasing” from the *Blue Book*.

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

R&D in social sciences **3.13** R&D in social science and humanities, row 10, 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 the Business Monitor. For the period 1985-1981 we backcast using the growth rate of R&D from BERD. Finally, we backcast the resulting series to 1970 using the growth rate of R&D in the Annual Abstract of Statistics.

Economic competencies

Advertising and market research **3.14** For advertising expenditure, row 13, we use data from the Advertising Association that goes back to 1956. We estimate market research, row 14, 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.

Firm-specific training **3.15** For firm-specific training 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 per cent yearly increase in the incidence of training.

Organisational capital **3.16** Turning finally to investment in organisational capital/structure we need purchased and own-account. For purchased, see row 17, 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. We estimate own account spending, on organisational structure, row 18, 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).

INVESTMENT IN INTANGIBLE ASSETS

3.17 Column five of Table A.1 shows the fraction of current spending 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 per cent 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 per cent of purchases of management expertise are capital spending, the rest being day to day advising. We shall discuss the sensitivity of our results to varying these parameters below.

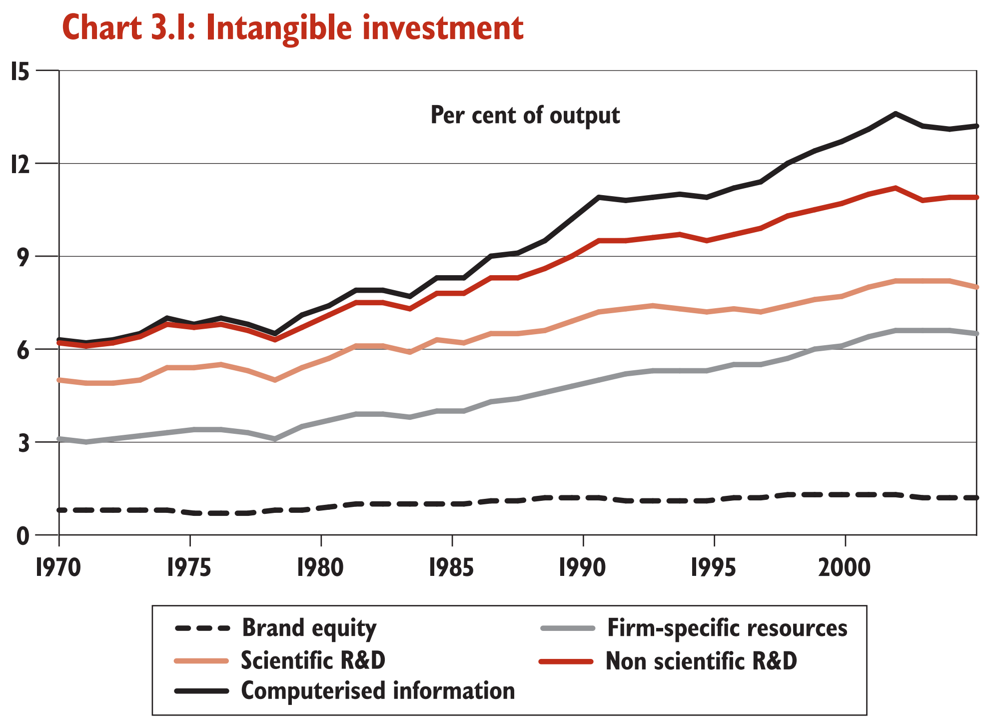
CROSS SECTION RESULTS

3.18 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. In 2004 some £130.8bn was spent on intangibles with an implied figure for intangible investment of £123bn (see row 20).

3.19 The following points are also worth noting. First, around 50 per cent of total intangible investment in 2004 was firm spending on reputation, human and organisational capital (economic competencies). About 35 per cent is on innovative property and 15 per cent 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.[3] Third, the biggest single figure is training investment.

TIME SERIES RESULTS

3.20 Chart 3.1 shows the time series for nominal intangible investment for the aggregated categories as a share of adjusted nominal MGVA. It is a cumulative graph so that the top line shows the share of total intangible investment in intangible-adjusted MGVA.[4] 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.



3.21 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 per cent of MGVA in the 1970s to 13 per cent in 2004 (6 per cent to 15 per cent of unadjusted MGVA, which includes some software i.e. as currently measured in the National Accounts). Second,

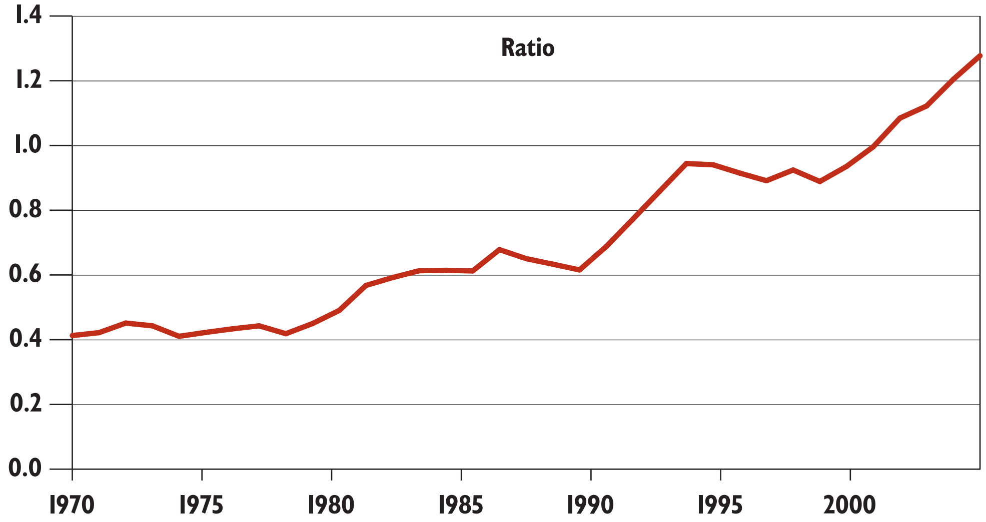
[3] Although the two types of spending might have quite different potential spillovers.

[4] That is, the denominator is gross value added in the market sector, adjusted for the presence of intangible investment.

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 the biggest increases in the share of overall intangible investment.

3.22 Chart 3.2 shows the ratio of intangible investment to tangible investment. The importance of intangible investment can clearly be seen to be growing over time and there is a clear acceleration in the rate of increase after 1990. The ratio moves above 1 in 2001 indicating that intangible investment exceeded tangible investment. By 2004 £123bn was invested in intangibles compared with tangible investment of £96bn.

Chart 3.2: Ratio of intangible to tangible investment



LABOUR SHARES

3.23 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).

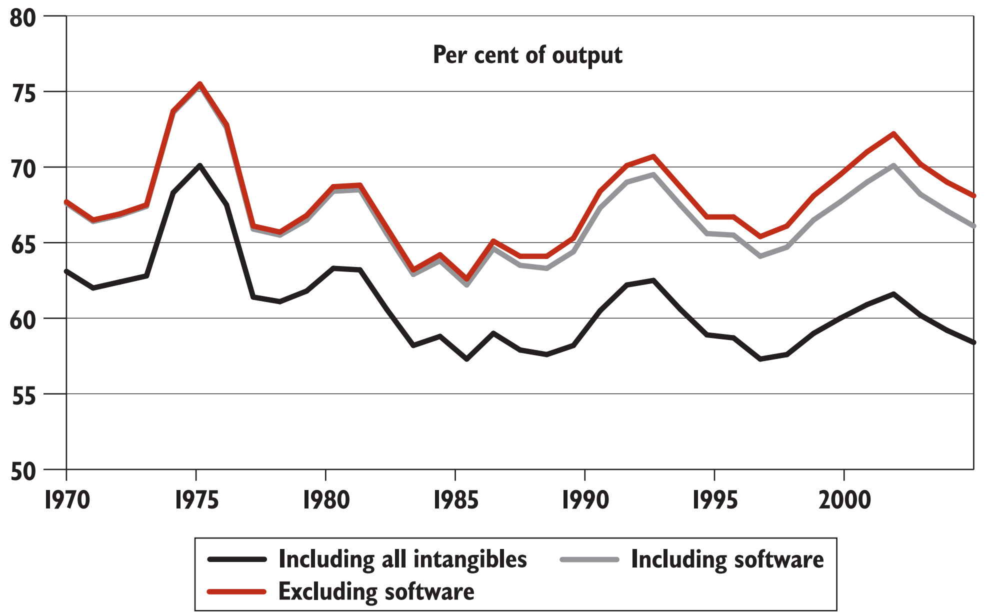
Treatment of mixed income

3.24 One problem in calculating the labour share is the treatment of income of the self-employed. Such 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 and boosts the fraction of MGVA growth that is capital deepening.[5] We split mixed income into labour and capital income. One way of doing this 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 per cent). The other method is to allocate mixed income according to the labour and capital ratio calculated after subtracting the mixed income from 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 operating surplus.

[5] 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.

3.25 Chart 3.3 shows the time series for the labour share in the UK both excluding and including intangibles. It can be seen that the overall trend is flat when excluding intangibles (the excluding software line). When intangibles are included the overall trend for the period is downward, although much of the fall comes in the period up to 1980. Since 1980, the labour share has been flat when including intangibles. In contrast the labour share excluding intangibles has shown a slight upward trend since 1985.

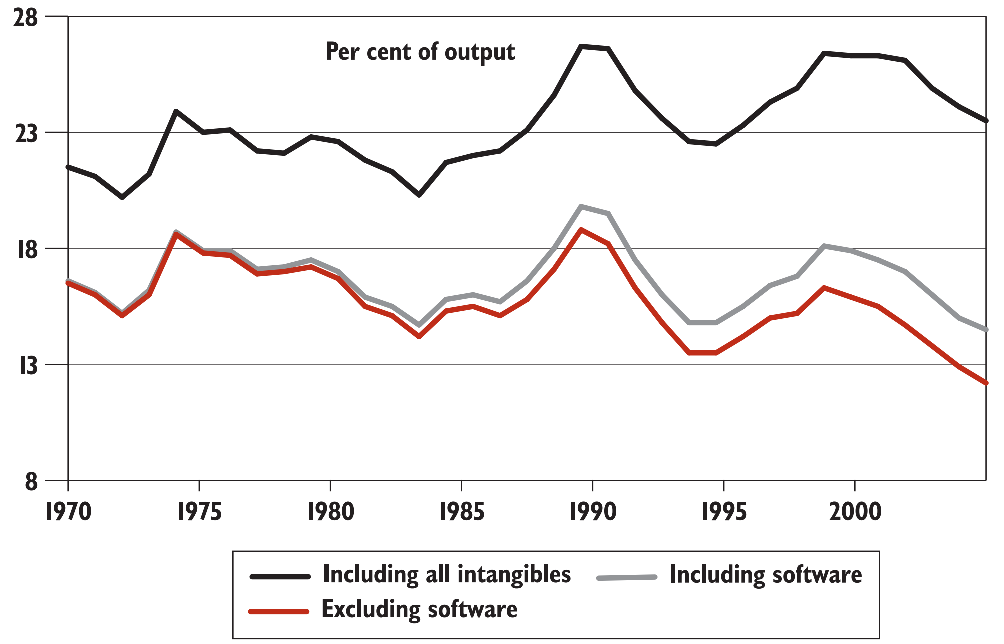
Chart 3.3: Labour share



INVESTMENT SHARES

3.26 Chart 3.4 shows nominal investment shares as a percentage of MGVA for the UK in three cases: traditional National Accounts excluding software, including software and including all intangibles (where the MGVA denominator excludes software, includes software and includes all intangibles respectively). There are two major findings. First, without intangibles, the nominal investment share is flat or a little bit decreasing and is around 15 per cent. Second, once we include intangibles it increases in levels, to around 25 per cent by the end of the period and the trend is upwards.

Chart 3.4: Nominal investment



4 GROWTH ACCOUNTING: METHODS AND DATA

4.1 To implement the growth accounting set out in Chapter 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 is likely to vary and so we distinguish between employee hours, L and quality adjusted employee hours, L^{QA}. Thus our growth accounting expressions are:

$$\begin{aligned}&(a)\ \Delta \ln TFP_t' = \Delta \ln(Q'/L)_t - s'^L \Delta \ln(L^{QA}/L)_t - s'^K \Delta \ln(K/L)_t \\ &(a)\ \Delta \ln TFP_t = \Delta \ln(Q'/L)_t - s^L \Delta \ln(L^{QA}/L)_t - s^K \Delta \ln(K/L)_t - s^R(t) \Delta \ln(R/L)_t\end{aligned} \quad (4.1)$$

4.2 A number of points are worth noting regarding equation (4.1). First, the shares are averages of shares over which the time difference it taken, so that (4.1) 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 $\Delta \ln K$ and $\Delta \ln R$ 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

$$p^B_{it} = T_{it}\left[r_{it} \times p^A_{i,t-1} + \delta_{it} \times p^A_{it} - p^A_{i,t-1})\right],\ B=K,R \quad (4.2)$$

where T is a tax adjustment and r is the rate of return on the asset.[1] This equation holds for each type of capital *i*.

4.3 The relation between equation (4.2) and the $\Delta \ln K$ and $\Delta \ln R$ terms in equation (4.1) 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

$$\pi_t = \sum_{i=1}^{n} p^K_{it} K_{it} + \sum_{i=n+1}^{m} p^R_{it} R_{it} \quad (4.3)$$

where there are n tangible assets and n+1 to m intangible assets.

4.4 Second, the overall volume index of capital services can be shown to be a share-weighted average of all the asset-specific $\Delta \ln K$ and $\Delta \ln R$ terms

$$\begin{aligned}\Delta \ln K_t &= \sum_{i=1}^{n} \left(p^K_{i,t} K_{it} / \pi_t\right) \Delta \ln K_{it} \\ \Delta \ln R_t &= \sum_{i=n+1}^{m} \left(p^R_{i,t} R_{it} / \pi_t\right) \Delta \ln R_{it}\end{aligned} \quad (4.4)$$

where the shares are the flow of rental payment for each asset as a share of total rental payments (π).[2]

[1] The derivation of equation (4.2) is set out in Oulton and Srinivasan (2003).

[2] 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.

4.5 As an empirical matter, we have to take a number of steps. First, we do not have information on time-varying depreciation rates for intangibles assets 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 (4.2) and (4.3) in two unknowns, namely r and p^K which we can solve. 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 (4.4) are the time-averaged weights over which the difference is taken.

4.6 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 (2.1) and (2.4).

2. Re-calculate MGVA to include intangibles, see equation (2.6).

3. Adjust the operating surplus π for MGVA, see equation (4.3)

4. Build Hall/Jorgenson capital services measures of all capital inputs, ensuring the asset rental payments are consistent with the adjusted operating surplus, see equations (4.2) to (4.4).

5. Build a quality adjusted labour index to measure L^{QA} in (4.1).

6. Undertake growth accounting, in (4.1).

The next sections describe how we do this.

COLLECT A TIME SERIES OF NOMINAL INVESTMENT IN INTANGIBLE AND TANGIBLE ASSETS

4.7 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 investment and capital stock data, *Blue Book* 2006 consistent and classified by SIC92 industries. The asset breakdown of the investment and capital stock series is: buildings, plant and machinery, vehicles and computers. The data are aggregated to market sector levels to ensure consistency with the use of MGVA as our measure of output.

DEFLATE TO GET REAL INVESTMENT SERIES

4.8 For tangible assets we use deflators for plant, vehicles, non-IT machinery, and buildings consistent with the UK National Accounts (see Wallis, 2005). 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 data stops in 1984 and so we backcasted using NIESR data. We have explored US deflators and the results are robust to this change.

4.9 The choice of deflators for intangible investment, as CHS discuss, is a difficult one. One possibility is to develop a price index for the particular intangibles 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.[3] A second possibility is to use the output deflator. This is sometimes justified in studies of R&D where a physical unit has little meaning and so it is felt best to deflate by the price of the good that 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.

4.10 Our deflators are set out in more detail in Table A.1. Software deflators are taken as follows. For own-account we use wages of the relevant occupations and then a 2.5 per cent 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 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.

BUILD REAL CAPITAL STOCK USING PERPETUAL INVENTORY METHOD

4.11 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 A.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.

ADJUSTING OPERATING SURPLUS OF MARKET SECTOR

4.12 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 backcast 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 operating surplus. The first version excludes software investment already present in the National Accounts. The second includes this investment and 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 backcast the series using the growth rate of the OECD estimated wage bill.

[3] Consider for example the CRS relation (2.2a). 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 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 TFP growth in the process generating the good.

RE-CALCULATE MARKET SECTOR GVA TO INCLUDE INTANGIBLES

4.13 The ONS publish a time series back to 1992 of MGVA 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.

Adjustment to GVA to include intangibles

4.14 As GVA is calculated as output minus intermediate consumption to adjust GVA to include intangibles as investment rather than as intermediate consumption we simply add the nominal investment in intangibles (note not spending but investment) to nominal MGVA ensuring that we do not double count any intangibles already included (such as some software and mineral exploration).

4.15 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 MGVA and real intangible investment, with the weights being the share of each expenditure category in overall GVA.

4.16 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.

BUILD HALL/JORGENSON MEASURES OF CAPITAL SERVICES

4.17 To do this we use method described above (equations (4.2), (4.3) and (4.4)). 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.

QUALITY ADJUSTED LABOUR INDEX

4.18 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.

5 Growth Accounting: Results

5.1 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 MGVA. 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.[1]

5.2 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 MGVA 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.[2] 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.

GROWTH ACCOUNTING RESULTS, 1990-2004

5.3 Table 5.1 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 the reasons for lower growth in LPG and TFPG in 1995-2000 relative to 1990-95 (in contrast to the US speed up).

5.4 Table 5.1 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 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.

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

[2] 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.

5.5 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).[3] In turn, the BEID is based on the then current National Accounts with an adjustment for software.[4] 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.[5]

Table 5.1: Labour productivity growth accounting[1]

	Labour productivity growth	Capital deepening	Human capital deepening	Total factor productivity growth
Excluding software				
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				
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				
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

[1] *All data are average percentage growth rates per annum.*

5.6 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 5.1). 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.

5.7 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 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.

[3] The Bank of England Industry data set is described in Oulton and Srinivasan (2003b).

[4] And a few other adjustments such as to financial services output, see Oulton and Srinivasan (2005).

[5] 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.

5.8 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 MGVA, 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.

5.9 Second, the addition of intangibles gives a different picture to the 1990s LPG mystery. Looking at the top panel, when software and other intangibles are excluded we see that LPG slowed 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 decline 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 is to changes in our assumptions.

5.10 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.[6]

5.11 Table A.3 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 A.3 shows, if we look at the top and middle panel, the share of capital and the capital services per hours increases in all periods when we include software.

5.12 Returning to Table 5.1, 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 A.3 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.

5.13 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 in the mid90s, but speeds up in 2000-04. The lower panel most interestingly shows that TFPG speeds up in the mid-90s, 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 MGVA 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.

[6] 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.

5.14 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.

THE ROLE OF ICT

5.15 Before turning to the comparison with the US we return to Table A3 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 per cent of total capital deepening while non ICT was 55.4 per cent. In the period 1995-2000 it is reversed: ICT accounts for 74.6 per cent of capital deepening while non-ICT just 25.4 per cent. 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.

COMPARISON WITH US RESULTS

5.16 Giorgio Marrano, Haskel and Wallis (2007) includes a detailed comparison of UK and US results (a comparison of the estimates reported here with those in CHS (2006)). In summary the main results are as follows:

1. The share of intangible investment in output is very similar in both countries;
2. LPG for 1995-2003 (the period where comparable results are available) is slightly higher in the US whether intangibles are included or not;
3. US LPG accelerated sharply after 1995, whereas UK productivity growth did not, although it was growing much faster during that pre-95 period than in the US;
4. Over the period 1995-2003, capital deepening is a higher share of LPG in UK than in US;
5. The contribution of human capital deepening in 1995-2003 is very similar in both countries;
6. The contribution of TFP is less as a share of LPG in the UK than in the US;
7. When we include intangibles in both the US and the UK, LPG and capital deepening rises and TFP falls;
8. The increase in LPG when including intangibles is similar in both countries but with the increase in capital deepening is higher in the US, but the decline in TFP is more;
9. R&D makes more of a contribution to capital deepening in the US, but design and training more of a contribution in the UK.

SENSITIVITY OF RESULTS

5.17 Given the range of assumptions that we have had to make, an obvious question is how robust our results are. Giorgio Marrano, Haskel and Wallis (2007) includes a range of sensitivity and robustness checks.

5.18 In summary, the quantitative results relating to the path of the investment share, the path of the labour share and the difference in LPG, capital deepening and TFPG over the 1990s are robust to large changes in the assumptions we make. The qualitative direction of the effects for LPG and TFPG are robust but the quantitative effect is somewhat sensitive. 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.

5.19 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 Conclusions and next steps

6.1 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 CHS (2004, 2006), 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.

6.2 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 MGVA and business investment. We then look at the consequences for productivity by calculating the new implied labour productivity growth and total factor productivity growth estimates.

6.3 Our main findings are as follows.

1. Nominal intangible investment in 2004 was about equal to nominal tangible investment spending, each around 15 per cent of MGVA. Around 50 per cent of total intangible investment is on economic competencies, 35 per cent on innovative property and 15 per cent on computerised information. Since 1970, nominal investment has grown from about 6 per cent of nominal MGVA to about 15 per cent;

2. Accounting for intangibles raises MGVA (by about 6 per cent in 1970 and 13 per cent in 2004) and also the shares of nominal investment and capital;

3. Accounting for intangibles also affects labour productivity growth and total factor productivity growth;

4. Without intangibles, we confirm previous work that shows a lower growth rate of labour productivity and total factor productivity in 1995-00 compared to 1990-95. We also document slightly lower growth in labour productivity and a speed up in total factor productivity growth in 2000-04;

5. The inclusion of intangibles changes the picture interestingly. First, both labour productivity growth and total factor productivity growth speedup between 1990-95 and 1995-00. Second, the lower 2000-04 labour productivity growth persists but total factor productivity growth speeds up.

6.4 These results suggest that traditional measures of investment may not be capturing the dynamic changes in the economy that are taking place. This is affecting the estimated productivity performance of the UK in important ways. The well-documented lower productivity growth rate in the period 1995 to 2000 disappears when treating knowledge expenditure as investment.

6.5 We compare our estimates to the US study by CHS (2006). Interestingly the share of intangible investment in output is very similar in both countries. Like them, from 1995-03, including intangibles raises labour productivity growth and lowers total factor productivity growth but there are some interesting differences. First, in the UK more of labour productivity growth 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.

Next steps **6.6** It is unclear how the UK's productivity gap with the comparator countries France, Germany and the US would be affected were all countries to treat intangible spending as investment. Of these countries a comparable study only exists for the US and the productivity growth impact of intangibles are of similar magnitude. Future work is planned in conjunction with the authors of the US study to try and produce productivity gap estimates that allow for the treatment of intangibles as investment.

6.7 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 improve our estimates. Perhaps the biggest is that while 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 macroeconomic performance changes quite substantially with different measurement and so these questions are worth pursuing.

6.8 The shift of investment towards knowledge assets in developed countries requires consideration of how this shift can be incorporated into the System of National Accounts (SNA). Software investment has already been fully incorporated as investment in the SNA and R&D spending looks set to be treated as investment by 2010. Much work would be needed in order to fully incorporate the broader range of intangible asset covered here but international discussion on these issues is beginning to intensify.

A Annex tables

Table A.1: Intangibles

	Type of intangible investment	2004 cross section (GH 2006)	Time series	Total spending £bn, 2004	Proportion of spending considered as investment, 2004	% of total intangible investment, 2004	Deflator	Depreciation rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Computerised 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** Backcasted using the growth rate of the turnover of the sector "Banking, finance, insurance business services, leasing"	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 to account for 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- 1970** Backcasted using turnover	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 **1991-1970** Backcast using the growth rate of the turnover	0.3	1	0.28	Implied market sector GVA deflator	0.2
(11)	**Total**			**39.5**		**32.4**		

Table A.1: Intangibles *continued*

	Type of intangible investment	2004 cross section (GH 2006)	Time series	Total spending £bn, 2004	Porportion of spending considered as investment, 2004	% 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.	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.	**2004-1970** 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 MC	**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 **1991-1970** Backcasted using growth rate of turnover	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, £bn**			**130.8**		**123**[1]		

[1] *This is total intangible investment in 2004 calculated as the sum of column (4) times column (5).*

Table A.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)

BEA is Bureau of Economic Analysis. NIESR is National Institute of Economic and Social Research.

Table A.3: Analysis of capital deepening

	Capital deepening: average annual growth rates, % per annum				Proportion of total capital deepening, average % per annum				Income shares, % of market sector GVA				Capital services per hour: growth rates, % per annum			
	ICT capital	Non ICT tangible	Other intangibles	Total	ICT capital	Non ICT tangible	Other intangibles	Total	ICT capital	Non ICT tangible	Other intangibles	Total	ICT capital	Non ICT tangible	Other intangibles	Total
Excluding software																
1990-1995	0.55	0.85	n/a	1.40	38.96	61.04	n/a	100	4.06	28.22	n/a	31.41	16.90	3.17	n/a	4.55
1995-2000	1.32	0.51	n/a	1.82	72.30	27.70	n/a	100	5.47	27.72	n/a	31.99	29.55	1.87	n/a	5.71
2000-2004	0.69	0.49	n/a	1.18	58.31	41.69	n/a	100	5.89	24.66	n/a	30.10	15.51	1.95	n/a	4.03
Including software																
1990-1995	0.69	0.86	n/a	1.55	44.65	55.35	n/a	100	4.34	28.05	n/a	32.57	15.70	3.17	n/a	3.39
1995-2000	1.49	0.51	n/a	2.00	74.61	25.39	n/a	100	5.93	28.03	n/a	33.60	25.04	1.87	n/a	7.03
2000-2004	0.86	0.49	n/a	1.35	63.66	36.34	n/a	100	6.43	25.32	n/a	32.12	13.23	1.96	n/a	4.22
Including all intangibles																
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

For the excluding software estimates ICT capital refers to computer hardware

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