Nesta...

WORKING PAPER SERIES

Nesta Working Paper No. 12/09

UK Innovation Index: Productivity and Growth in UK Industries

Peter Goodridge
Jonathan Haskel
Gavin Wallis

UK Innovation Index: Productivity and Growth in UK Industries

Peter Goodridge
Imperial College Business School

Jonathan Haskel
Imperial College Business School; CEPR and IZA

Gavin Wallis
HM Treasury and University College London

Nesta Working Paper 12/09
July 2012

www.nesta.org.uk/wp12-09

Abstract

This paper provides an update of the NESTA Innovation Index and tries to calculate some facts for the "knowledge economy". Building on the work of Corrado, Hulten and Sichel (CHS, 2005,9), using new data sets and a new micro survey, we (1) document UK intangible investment and (2) see how it contributes to economic growth. Regarding investment in knowledge/intangibles, we find (a) this is now 34% greater than tangible investment, in 2009, £124.2bn and £92.7bn respectively; (b) that scientific R&D is about 11% of total intangible investment, software 18%, design 12%, and training and organizational capital 21% each; (d) the most intangible-intensive industry is manufacturing (intangible investment is 17% of value added) and (e) treating intangible expenditure as investment raises market sector value added growth in the 1990s due to the ICT investment boom, but has less impact on aggregate measures of growth in the 2000s. Regarding the contribution to growth, for 2000-09, (a) intangible capital deepening accounts for 26% of labour productivity growth, against computer hardware and telecommunications equipment combined (16%) and TFP (-0.4%); (b) adding intangibles to growth accounting lowers TFP growth by about 18 percentage points (c) capitalising R&D adds 0.04% to input growth and reduces ΔlnTFP by 0.02% and (d) manufacturing accounts for 47% of intangible capital deepening plus TFP.

JEL Classification: O47, E22, E01

Keywords: innovation, productivity growth

We are very grateful for financial support from NESTA, ESRC (Grant ES/I035781/1) and UKIRC. We thank Jean Acheson and Richard Jones of ONS for kindly running our estimates of labour services and training expenditure respectively; and Nick Oulton and Brian MacAulay for useful comments. New estimates of own-account intangible investment were produced using the Secure Data Service at the UK Data Archive. This work contains statistical data from ONS which is crown copyright and reproduced with the permission of the controller HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data.

Corresponding Author: Jonathan Haskel, Imperial College Business School, Imperial College, London SW7 2AZ, j.haskel@imperial.ac.uk.

1 Executive Summary

This report presents an update of the NESTA Innovation Index for the period 1990 to 2009. The aim is to better understand the contribution of innovation to productivity growth in the UK market sector including the contribution of individual industries to the market sector aggregate. In doing so we apply an approach that is consistent with National Accounts methods of measuring output, income and investment. Innovation is estimated by calculating the contributions of a wider range of assets to growth in GDP in a more complete, but national accounts consistent, framework that avoids double-counting.

The report makes three contributions. First, we set out our approach and results on *innovation accounting*, namely our best estimate of how much firms are spending on knowledge. Second, we set out our approach and present results using a growth-accounting based *innovation index*, namely our best estimate of how much all forms of knowledge contribute to growth. Third, we provide new estimates of growth in the UK economy over the period 1990-2009, restated by adding in to the official National Accounts investments in knowledge assets normally counted as intermediate input purchases by firms. Treating these inputs as investment has the effect of raising GDP levels and changing growth rates over the period. We do this for (a) the whole market sector and (b) for eight disaggregated industries.

Knowledge takes different forms, so quantifying it is not straightforward. In this framework we measure (a) investment in intangible assets to approximate the knowledge stock created by firms (b) consider improvements in the knowledge held by workers in the labour force thanks largely to their qualifications and experience and (c) since knowledge can leak across firms (in the way that tangible capital cannot), we also consider freely-available knowledge.

We define our innovation index as the growth in output – that is, value-added created by new products and services, processes and ways of working – over and above the contributions of physical capital and labour input. Therefore, the widest definition of our index includes the shares of growth which can be attributed to knowledge investment in the market sector, to improvement in human capital due to education, and to Total Factor Productivity (TFP) which measures spillovers and other unmeasured knowledge inputs to firms (as well as measurement error). Other variants of the index include the joint contributions to growth of TFP and knowledge capital.

This report builds on previous work on intangible asset spending and growth. It continues the research programme set out in Corrado, Hulten and Sichel (CHS, 2005, 6) and van Ark and

Hulten (2007) and incorporates some of the previous work for the UK, including Giorgio Marrano, Haskel and Wallis (2007) and the additional industry detail used in previous papers for NESTA (Clayton, Dal Borgo and Haskel, 2008 and Haskel et al, 2009).

Following that approach, the intangible assets that we measure are software, design, product development in financial services and artistic creation, and investment in brands, firm-specific human capital and organisations. Relative to our last report the following is new:

1. improved estimates of intangible spending

Our improved estimates come from the following sources. First, since the interim report we have undertaken two runs of the Investment in Intangible Assets survey, asking firms for data on intangible spending and life lengths of intangible assets. This enables us to cross-check our spending and deprecation results against micro data. We find our deprecation assumptions to be largely in line with micro evidence, as is our spending data for software, R&D, marketing and training. More research is necessary to better measure design and spending on organisational capital.

Second, we have improved our methodology for estimating private investments in knowledge. First, we have incorporated new estimates for UK investment in artistic originals (Goodridge and Haskel, 2011 and Goodridge, Haskel and Mitra-Kahn, 2012). Second we have refined our estimates of purchased assets by eliminating potential double-counting that arises for outsourced or sub-contracted activity.

2. industry-level data to better understand the industry contributions to market sector innovation

Again we provide data at the industry level, consistently aggregated to the market sector, so that we can work out the contributions of each industry to overall growth and innovation. This year we apply a more complete definition of the UK market sector, including the range of consumer, personal and recreational services contained in section ‘O’ of SIC2003.

3. Up-to-date official estimates to build market sector GDP, hours, tangible investment and labour skill composition.

We use Blue Book[1] data for ONS, last published in detail in November 2011 with data up to 2010, and detailed input-output data up to 2009. Due to changes in the Standard Industrial Classification implemented in Blue Book 2011, our data include a mix of Blue Book 2010 and 2011 data, all mapped to SIC2003. We also use the latest ONS data for capital services (VICS) and quality-adjusted labour input (QALI).

Our definition of the UK market sector excludes the public sector, private delivery of public services such as education and health, and dwellings (actual and imputed rents). Dwellings are removed for both conceptual and practical reasons. First, housing services produced by households (imputed rents) do not represent true economic output. Second, dwellings are not a part of productive capital stock and so its associated services are removed from the output data to be consistent with the capital input data. Third, they inhibit international comparability since the proportions of people that choose to own/rent housing varies across countries for social and cultural reasons. This is standard practice in growth accounting exercises.

4. Tax adjustment of rental prices for growth accounting.

Previous work has not tax adjusted the rental prices used for growth accounting. We have constructed a full set of tax-adjustment factors for both tangible and intangible assets. This has meant better estimation of rental prices, capital income shares and the contributions of capital deepening in our dataset. Specifically on intangibles, this adjustment is particularly important for R&D as the R&D tax credit introduced in 2002 had a large impact on the cost of capital which our data now reflects. Appropriate tax adjustment factors for mineral exploration and purchased software are also incorporated.

5. Data from EUKLEMS, up to 2007, to build industry-level estimates of value added, gross output, intermediate inputs, hours, tangible investment and labour skill composition.

ONS do not publish data on real intermediate input use and so we use EUKLEMS data for this to undertake gross output growth accounting at the industry level. We then aggregate this up to the market sector level. EUKLEMS data ends in 2007. We show below that the two

[1] The Blue Book is the annual publication of ONS National Accounts.

series agree mostly with the exception of inputs in financial and business services and labour quality measures.

With this in mind, our major findings are as follows:

1. Investment in knowledge.

UK investment in intangible or knowledge assets has been greater than that for tangible assets since the early 2000's. In 2009 it stood at £124bn, as opposed to £93bn tangible investment. Of that intangible spend training by firms and organisational capital account for £26bn each, design £16bn, software £23bn and scientific R&D £14bn.

The industry that is most intensive in intangible spend is manufacturing, which invests 17% of their value added on intangibles (agriculture is the least at 6%). Financial services was the clear intensity leader in the late 1990s and early 2000s, spending 26% of their value added in intangibles (mostly software) in 2001, but has since fallen back to 15%.

The effect of treating intangible expenditure as capital spending[2] is to raise market sector gross value added (MGVA) growth in the late 1990s, with little change in the 2000s. MGVA growth is raised in the late 1990s due to strong investment in software, training and organisational change which accompanied the rise of the internet and boom in ICT hardware investment

2. Innovation in the market sector

Beginning with some background, if we ignore intangibles, labour productivity growth was steady in the early and late 1990s, at 3.07% p.a. in 1990-95 and 3.06% p.a. in 1995-2000. This is contrary to the slowdown reported in most studies. This difference is not due to intangibles, but the result of the incorporation of FISIM[3], along with a new methodology and data for investment in own-account software and numerous other methodological reviews,

---

[2] In the National Accounts, intangible spending is categorised as intermediate consumption. Since gross value-added is defined as gross output less intermediate consumption, treating such spending as investment results in an increase to the level of MGVA.

[3] Financial Institutions generate revenue in two ways, via direct charges or interest differentials in their lending and borrowing activities. FISIM represents the second, and stands for 'Financial Intermediation Services Indirectly Measured'.

particularly for the service sector, most of which were incorporated in Blue Book 2008. Labour productivity growth slowed down in the 2000s to 1.44%pa.

When we included intangibles, labour productivity also speeds up in the 1990s, from 3.36% p.a., 1990-95 to 3.57% p.a., 1995-00. From 2000-09, it grew at 1.43% p.a.., consisting of 2.45% p.a. between 2000-05 and 2005-09, 0.17% pa. Of the 2000-09 growth in value added per hour of 1.43% p.a., we have the following contributions:

- Intangible capital deepening: 0.38% p.a.
- Total factor productivity, that is, learning from knowledge spillovers (plus other mismeasured factors): -0.01% p.a.
- Improved general worker human capital due to formal qualifications, age and experience changes: 0.27% p.a.

If we define innovation as the contribution of knowledge capital and TFP, then innovation raised growth in output per person-hour in the UK by 0.38%+(-0.01%) = 0.37% in 2000-09, which is 33% (0.37/1.43) of labour productivity growth. On this measure, innovation was responsible for about 64% p.a. of labour productivity growth in the late 1990s, reflecting the boom in investment in software along with the mass take up of the internet and 61% in the early 1990s.

If we define innovation more widely, that is the contribution of knowledge capital, TFP and general human capital[4], we have that innovation raised growth in output per person-hour in the 2000s 0.38% + (-0.01%) +0.27% = 0.64% p.a. in the 2000s, which is 45% (0.64/1.43) of labour productivity growth.

3. Innovation in industries and their contribution to the overall market sector

At the industry level, financial services, manufacturing and business services have the highest industry-level gross output based TFP. Manufacturing, business services and

[4] General human capital or labour services are an adjusted measure of labour input where growth in hours of different worker types are weighted by their share of the total wage-bill. The methodology used is in line with the internationally accepted OECD methodology. Labour services input has grown steadily through the period, reflecting growth in the quality of labour input, while total hours worked have been relatively flat from 1998 until the recent recession when they obviously fell sharply.

distribution/communications have the highest contributions of intangible investment to their gross output based labour productivity, reflecting strong investment in intangibles in these sectors. Thus the most innovative sectors at the industry level (defined as shares of gross output based labour productivity growth accounted for by intangible spend, improvements in labour composition plus TFP growth) are financial services, business services and manufacturing.

The contributions however of each sector to overall innovation depend upon both this and their weights in overall activity. For intangible investment this depends on the sector's intangible contribution weight in the total. For TFP, it depends upon the sector's Domar weight (since an increase in TFP in sector A raises overall TFP, but also TFP in other sectors to the extent that that sector A's output is an intermediate into other sectors). When all this is added consistently, we find that manufacturing is particularly important. Defining innovation as productivity growth accounted for by growth in intangible capital deepening, labour composition and TFP, manufacturing accounts for 46% of the innovation in the UK market sector (its employment share is only 17%). We also find important contributions of distribution/communications, accounting for 29% of innovation, business services contributes 25% and finance 15% (their employment shares are 36%, 20% and 5% respectively).

2 Introduction

What drives growth in increasingly knowledge-intensive economies? The sources of growth are of course an enduring subject of interest for academics and policy-makers alike, and since at least Solow (1956), have been studied in a growth accounting framework. Whilst this gives the proximate sources, namely capital deepening, skills and total factor productivity, and not the ultimate sources (e.g. legal framework) it is, most are agreed, an important first step in marshalling data and uncovering stylized facts that other frameworks might explain.

The productivity consequences of the ICT revolution have been studied in a growth accounting framework by many authors in many countries (see e.g. Timmer, O'Mahony, van Ark and Inklaar 2010, Jorgenson et al, 2007). But hanging over this literature is an early suggestion, (Brynjolfsson and Hitt 2000) for example, that investment in computer hardware needed complementary investments in knowledge assets, such as software and business processes, to reap productivity advantages. This re-awakened interest in the application of the sources of growth framework to information and knowledge-intensive economies. For free knowledge (e.g. from universities or the internet), the framework is quite clear: if competitive assumptions hold, total factor productivity growth (TFPG) measures the growth contribution of knowledge that is costless to obtain and implement.

However, there are two points illustrated nicely by Tufano's (1998) description of a typical financial product innovation. He states it requires

> *"an investment of $50,000 to $5 million, which includes (a) payments for legal, accounting, regulatory, and tax advice, (b) time spent educating issuers, investors, and traders, (c) investments in computer systems for pricing and trading, and (d) capital and personnel commitments to support market-making."*

First, in this example knowledge is not costless to obtain or commercialise and so cannot be relegated to TFPG. Second, a long-established literature adds R&D to the growth accounting framework. But, some industries e.g. finance and retailing, do no (measured) R&D[5]. Thus

[5] The qualification measured is important. In the UK at least, the Business Enterprise R&D survey (BERD) defines R&D to respondents as 'undertaken to resolve scientific and technological uncertainty'. Indeed, up until very recently, no firms in financial intermediation for example were even sent a form. See below for more discussion.

one needs to consider knowledge investment besides R&D: this example suggests training, marketing and organisational investments for example. Thus our objective in this paper is to better measure growth and its sources for the UK economy where: (a) knowledge development and implementation is not costless, and (b) R&D is not the only knowledge investment.

To do this, this paper implements the framework set out in the widely-cited papers by Corrado, Hulten and Sichel (2005, 9, CHS). Whilst CHS builds upon the methods of capitalising tangible assets, and intangible assets such as software which are now capitalised in national accounts, it was the first paper to broaden the approach to a fuller range of intangible or knowledge assets.[6] Thus it fits with the range of innovation investments mentioned above.

More specifically, we seek to do two things in this paper. First, we seek to measure investment in intangible assets at an aggregate and industry level. This part of the paper takes no stand on growth accounting. We believe it of interest for it tries to document knowledge investment in industries where measured R&D is apparently very low, such as finance and retailing. Current data can document the physical, software and human capital deepening in these industries (and also R&D, when capitalised in the National Accounts in 2014). However, this paper tries to ask and answer whether we are missing significant investment in knowledge or ideas in these sectors.[7]

Second, we use these data to perform a sources-of-growth analysis for the UK using the CHS framework. Whilst one might have reservations about the assumptions required for growth accounting, see below, we believe this is also of interest. The main reason is that it enables us to investigate a number of questions that could either not be addressed without these data, or all relegated to the residual. First, as CHS stress, the capitalisation of knowledge changes the measures of both inputs and outputs. Insofar as it changes outputs, it alters the labour productivity picture for an economy. Thus we can ask: what was the productivity performance in the late 1990s when the UK economy was investing very heavily (as we

---

[6] Earlier contributions were made by Nakamura (1999, 2001) and Machlup (1962). For European data see Jona-Lasinio, C., Iommi, M. and Roth, F. (2009) and van Ark, Hao, Corrado, Hulten, (2009).

[7] We also shed light on recent considerable interest in "creative" industries, including the software, design, film/television, literary, music, and other artistic industries. Most papers that study such activity select a number of creative industries, and then document their employment or value added from published sources. This understates the output of creative assets, since much intangible creation is done on own-account in industries not in the usual creative list e.g. software spending in financial services or design in retail. Nor does this approach show how much creative industries contribute to economic growth, as we are able to do (conditional on the assumptions we make).

document below) in intangible assets during the early stages of the internet boom? Second, we can then ask: how was that performance accounted for by contributions of labour, tangible capital, intangible capital and the residual? Here we can describe how sources of growth will differ when R&D is capitalised and how other knowledge contributes and alters TFP. Third, we also ask and try to answer this question at industry level. So we can ask, for example, how much productivity in non-R&D intensive sectors, such as retail and financial services, was accounted for by other intangibles or was it mostly TFPG?

In implementing the CHS framework, we proceed as follows, going, we believe, a bit beyond their work for the US. First, we gather data on the intangible assets that CHS suggest, but by industry (Fukao et al (2009) and van Rooijen-Horsten, van den Bergen and Tanriseven (2008) do this for Japan and Holland, but they do not do growth accounting to derive the contributions of the industries to the total).

Second, we update some of the methods of CHS. For example, much intangible spend, like R&D, is own-account. CHS had no own-account estimates for design or for financial services. We apply the National Accounts software method to estimate such own-account spending, using interviews with design and financial companies to identify occupations and time use and thereby derive intangible spend from wage data.[8] We have also improved estimates of investment in artistic originals (Goodridge and Haskel, 2011) and are currently working with the Office for National Statistics (ONS) and Intellectual Property office (IPO) to incorporate those into the National Accounts. In addition, there is almost no information on the depreciation of intangible assets.[9] Thus, for the previous compilation of the NESTA Innovation Index, we conducted a survey of over 800 companies on the life lengths of their intangible spend, by asset, to gather data on depreciation. For this update we have re-run that survey with additional sample boosts for the devolved UK countries; Scotland, Wales and Northern Ireland, on this occasion giving us 1,180 total responses from firms on intangible spend and the expected life length of those investments. Similarly little work has been done on the price of intangible assets. Corrado, Goodridge and Haskel (2011) estimate an implied price for R&D assets, with significant implications for measurement of real R&D investment and its contribution to growth. We also apply that price index in this work where indicated.

---

[8] Official own-account software investment is estimated by (1) finding software writing occupations, (2) applying a multiple to their wage bills to account for overhead costs and (3) applying a fraction of time such occupations spend on writing long-lived software as opposed to short term bug fixes, maintenance etc. We duplicate this approach for finance and design.

[9] With the honourable exceptions of Soloveichik (2010) who estimates depreciation rates for artistic originals and Peleg (2005) who surveyed a small number of Israeli R&D performers.

Third, we provide (gross output based) growth accounting results by industry aggregated consistently into value-added based growth accounting for the UK market sector, using the approach of Jorgenson, Ho, Samuels, Stiroh (2007). Thus we can examine the contributions of different industries to overall growth. This then speaks to the question of, for example, how much manufacturing versus financial services contributed to overall TFP growth.

On specifically UK data, our work is mostly closely related to the industry-level work (Basu, Fernald, Oulton, Srinivasan et al. 2004). They incorporated software as a productive asset and looked at productivity and TFPG in 28 industries 1990 to 2000. They did not have data however on other intangible assets and so whilst they were able to document software and hardware spending across industries, they were not able to look at other co-investments in innovation. As will be clear however, we rely heavily on their important work on measuring software and also tangible assets, now embodied in official UK data collection. Likewise, our work is also closely related to EUKLEMS (O'Mahony and Timmer, 2009). Their dataset includes software, and we extend their framework with additional intangibles, explicitly setting out the industry/market sector aggregation.

Whilst growth accounting is an internally consistent method for analysing productivity growth there are of course limits to the analysis that caveat our work. First, in the absence of independent measures of the return to capital we are compelled to assume constant returns to scale and perfect competition to measure the output elasticities of capital residually from the cost share of labour. A consistent framework for growth and innovation accounting with these assumptions relaxed is outside the scope of this current paper. But we hope that readers sceptical of the growth accounting assumptions would still find of interest the findings on knowledge investment and how their addition to the growth accounting framework changes the usual findings (which turns out to be quite considerably). We also hope that readers likewise sceptical of capitalising the full range of intangibles will find our work on R&D, which is to be officially capitalised in 2014, of interest.

Second, like other work in this area, we are of course limited in what we can do by data uncertainty. Measures of intangible assets are clearly difficult to obtain, especially for the own-account part of organisational capital. Deflators for intangibles are as yet uncertain. Our industry data covers eight broad industries in the UK market sector since finer detail on intangible spend is very hard to obtain.

We have two sets of findings (a) on knowledge spending and (b) implications for growth. On *knowledge spending*, first, investment in long-lived knowledge, which creates intangible assets, now exceeds tangible investment, at around, in 2009, £124bn and £93bn respectively. R&D is about 11% of such spend. Training, organisational investments and software are the largest categories of intangible investment, and are particularly important in services. The effect on market sector gross value added (MGVA) of treating intangible expenditure as investment is to raise MGVA growth in the 1990s, but very slightly reduce it in the 2000s.

Second, around 70% of this spending is own account. Thus measures of the “creative economy” (ONS, 2006) that assemble data for a list of “creative industries” are missing significant creative activity outside those industries.

On the *implications for growth*, for 2000-09, the most recent period with data available, intangible capital deepening accounts for 26% of labour productivity growth, a larger contribution than computer hardware (15%), telecommunications equipment (2%), and human capital (19%). Other tangibles (buildings, vehicles, non-ICT plant) accounted for 39% of productivity growth. Due to the general slowdown in TFP in the 2000s, followed by the collapse in 2008 and 2009, TFP makes a slight negative contribution at minus 0.4% of LPG. These findings are quite robust to variations in depreciation and assumptions on intangible measures. Capitalized R&D accounts for about 2.5% of LPG and lowers the contribution of TFP by 2 percentage points.

Regarding industries, the main finding here is the importance of manufacturing, which contributes 47% of the total contribution to MGVA growth of intangible investment and TFPG (but with a 17% share of total hours worked). We also find important roles for distribution/communications, (34% of the total contribution), business services (22%) and finance (18%).

The rest of this paper proceeds as follows. Section 2 sets out a formal model, and section 3 our data collection. Section 4 our results and section 5 concludes.

3 A formal model and definitions

In this paper we undertake growth accounting for the UK market sector. But we are also interested in how industries contribute to the overall changes. Thus we follow Jorgenson et al (2007), see also Hulten (1992, 2000). The key point is that at industry level, a value added production function exists under restrictive assumptions and it is therefore preferable to work with TFP computed from gross output. But at the aggregate level, productivity is best defined using value added (to avoid double counting). So what is the relation between the industry components of growth and the whole market sector?

We start with two definitions of TFPG. Supposing there is one capital, labour and intermediate asset (respectively K, L and X) which produce output Y_j in industry j. That capital asset might or might not be intangible capital. Thus for each industry, we have the following gross output defined $\Delta \ln TFP_j$

$$\Delta \ln TFP_j \equiv \Delta \ln Y_j - \bar{v}_{K,j} \Delta \ln K_j - \bar{v}_{L,j} \Delta \ln L_j - \bar{v}_{X,j} \Delta \ln X_j \qquad (1)$$

Where the terms in "v" are shares of factor costs in industry nominal gross output, averaged over two periods. For the economy as a whole, the definition of economy wide $\Delta\Delta \ln TFP$ based on value added is

$$\Delta \ln TFP \equiv \Delta \ln V - \bar{v}_K \Delta \ln K - \bar{v}_L \Delta \ln L \qquad (2)$$

Where the "v" terms here, that are not subscripted by "j", are shares of K and L payments in economy wide nominal value added. Now we write down two definitions. First, define the relation between industry gross output and industry value added as

$$\Delta \ln Y_j \equiv \bar{v}_{V,j} \Delta \ln V_j + \bar{v}_{X,j} \Delta \ln X_j \qquad (3)$$

which says that (changes in real) industry gross output are weighted averages of changes in real value added and intermediates. Second, write changes in aggregate real value added as a weighted sum of changes in industry real value added as follows.

$$\Delta \ln V \equiv \sum_j \bar{w}_j \Delta \ln V_j, \quad w_j = P_{V,j} V_j \Big/ \sum_j (P_{V,j} V_j), \bar{w}_j = 0.5(w_{j,t} + w_{j,t-1}) \qquad (4)$$

We may then write down value added growth in the industry as a weighted average of K, L and (gross output-based) $\Delta\ln TFP_j$

$$\Delta \ln V_j = \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j + \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta \ln L_j + \frac{1}{\bar{v}_{V,j}} \Delta \ln TFP_j \qquad (5)$$

where the weights on K and L are a combination of the shares of K and L in industry gross output and the shares of industry gross output in aggregate value added.

We are now in position to write down our desired relationship, that is the relation between economy-wide real value added growth and its industry contributions

$$\Delta \ln V = \left(\sum_j \bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j \right) + \left(\sum_j \bar{w}_j \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta \ln L_j \right) + \sum_j \frac{\bar{w}_j}{\bar{v}_{V,j}} \Delta \ln TFP_j \qquad (6)$$

Which says that the contributions of K_j and L_j to whole-economy value added growth depend upon the share of V_j in total V (w_j) and the shares of K and L in gross output and value added. The contribution of $\Delta\ln TFP_j$ depends on the share of V_j in total V (w_j) and the share of industry value added in gross output. As Jorgenson et al point out, the weight on TFP is approximately $(P_{Y,j}Y_j / P_V V)$ which is of course the usual interpretation of the Domar (1961) weight. It sums to more than one, since an improvement in industry TFP contributes directly to the average of all TFPs and indirectly if it produces output that is then an intermediate in other industries.[10]

Finally, in reality we do not of course have one capital and labour unit, but many. These are then aggregated across different types: for labour, see below, we use, education, age (experience), and gender; for capital, different types of both tangible assets and intangible assets. Denoting the capital and labour types *k* and *l* we have following industry and aggregate variables for each type where industry is defined as industry *j* and the aggregate variables are unsubscripted:

[10] As JGHS point out, comparing (6) with (2) gives the relation between this industry aggregated input/output relation and that implied by the TFP expression in (2), which involves some additional terms in reallocation of K and L between industries. These terms turn out to be very small in our data.

$$\Delta \ln K = \sum_k \overline{w}_k \Delta \ln K_k, \quad \textit{capital type k}$$
$$\Delta \ln L = \sum_l \overline{w}_l \Delta \ln L_l, \quad \textit{labour type l}$$
$$\overline{w}_k = P_{K,k} K_k / \sum_k (P_{K,k} K_k), \overline{w}_l = P_{l,l} K_l / \sum_l P_{L,l} K_l, K_j = \sum_j K_{k,j} \forall k, L_j = \sum_j L_{l,j} \forall l,$$
$$\overline{w}_t = 0.5(w_t + w_{t-1}) \tag{7}$$

In our results we document the following. First, we set out the gross output growth accounting results for each industry, (1). Second, we take these data and set out the contributions for each industry to the growth of aggregate value added, (6) . Third, we sum up the contributions across industries to the decomposition of aggregate (market sector) value-added, (6). In each case we carry out the decomposition with and without intangibles, and also using a National Accounts model only including intangibles already capitalised in the SNA.

Before proceeding to the data, some further theory remarks on the measurement of capital. As pointed out by e.g. Jorgenson and Grilliches (1967) the conceptually correct measure of capital in this productivity context is the flow of capital services. This raises a number of measurement problems set out, for example, in the OECD productivity handbook (2004). We estimate the now standard measure as follows. First, we build a real capital stock via the perpetual inventory method whereby for any capital asset k, the stock of that assets evolves according to

$$K_{k,t} = I_{k,t} + (1-\delta_{k,t}) K_{k,t-1} \tag{8}$$

Where I is investment over the relevant period and δ the geometric rate of depreciation. Real tangible investment comes from nominal tangible investment deflated by an investment price index. Second, that investment price is converted into a rental price using the Hall-Jorgenson relation, where we assume an economy-wide rate of return such that the capital rental price times the capital stock equals the total economy-wide operating surplus (on all of this, see for example, (Oulton 2007) and Oulton and Srinivasan, (2003).

4 Data

4.1 Time period

For the industry analysis, ONS does not publish real intermediate input data and so we used the EUKLEMS, November 2009 release which gives data up to 2007. For intangibles, our industry level data is available 1992-2009 since this is when Input-Output (IO) tables are consistently available from. Data for the whole market sector is available going back to 1980 up to 2010 (the most recent year National Accounts are available). Thus we work with two data sets: (1) market sector, 1980-2009, consistent with National Accounts 2011, and (2) industry level 1992-2007 (the data turn out to be very close over the overlapping years).

4.2 Industries

The EUKLEMS data includes measures of output, and various categories of employment and capital at the industry level for 71 industries, classified according to the European NACE revision 1 classification. We then aggregate these data to the eight industries described in Table 1. The choice of the eight industries is dictated by the availability of the intangible data: training and management consulting data are only available at these aggregated levels.

Table 1: Definition of eight industries

#	Sectors	SIC(2003) code		NACE1 sections
1	Agriculture, Fishing and Mining (AgrMin)	1-14	A	Agriculture, hunting and forestry
			B	Fishing
			C	Mining and quarrying
2	Manufacturing (Mfr)	15 - 37	D	Total manufacturing
3	Electricity, Gas and Water Supply (Util)	40 - 41	E	Electricity, gas and water supply
4	Construction (Constr)	45	F	Construction
5	Wholesale and Retail Trade, Hotels and Restaurants, Transport and Communications (RtHtTran)	50 - 64	G	Wholesale and retail trade
			H	Hotels and restaurants
			I	Transport and storage and communication
6	Financial Services (FinSvc)	65 – 69	J	Financial services
7	Business Services (BusSvc)	71- 74	K	Business activities (excluding imputed and actual letting of dwellings)
8	Personal Services (PersSvc)	90-97	OP	Other community, social and personal service activities; Private households with employed persons

We measure output for the market sector, defined here as industries A to K and OP as in EUKLEMS, excluding actual and imputed housing rents. Note this differs from the ONS official market sector definition, which includes part of sections O and P, as well as the private delivery of education, health and social care. We also used disaggregated real value added data for this industry definition.

For the years where industry level data is available, the data are bottom-up, that is derived at the industry level and aggregated subsequently. Aggregation of nominal variables is by simple addition. Aggregates of real variables are a share-weighted superlative index for changes, benchmarked in levels to 2005 nominal data. For other years, the intangible data are for the market sector and the other output and input data from ONS, latest National Accounts, aggregated from industry values.

4.3 Outputs and tangible and labour inputs.

EUKLEMS also provides growth accounting data, but since we have expanded the amount of capital and changed value added we do our own growth accounting. In addition, the EUKLEMS labour composition data is slightly different to the ONS data due to differences in the method and compositional breakdown as well as the series on actual hours worked. From the output and intermediate accounts of the EU KLEMS dataset we have used the series of industry Gross Output and Gross Value Added at current basic prices, Intermediate Inputs at current purchasers' prices and their corresponding price and volume indices. Intermediate inputs comprise energy, materials and services.

The tangible capital variables from EUKLEMS that we used are nominal and real gross fixed capital formation, the corresponding price index, real fixed capital stock and capital compensation, all disaggregated by type of assets. Capital compensation equals the sum of the gross operating surplus, which includes the remainder of mixed income, plus taxes on production, after subtracting labour compensation of the self-employed. In practice, it is derived as value added minus labour compensation. We shall of course amend capital compensation to incorporate compensation for intangible capital assets.

The EUKLEMS capital data distinguishes nine asset types, of which we use transport equipment, computing and communications equipment, other machinery and equipment and total non-residential investment. We use ONS estimates for software and mineral exploration, and our own estimates for artistic originals; the latter are expected to be incorporated into ONS estimates in the near future. We excluded residential structures (they are not capital for firm productivity analysis).

Depreciation rates for ICT tangible capital are as in the EUKLEMS, which in turn follows Jorgenson et al. (2005). Depreciation is assumed to be geometric at rates for vehicles, buildings, plant and computer equipment of 0.25, 0.025, 0.13 and 0.40 respectively. As for intangible assets, they are assumed to be the same for all industries. In contrast to the last annual update of this work, we have now incorporated appropriate tax adjustment factors for all assets, tangible and intangible.

4.4 Labour services

The labour services data are for 1992-2007 and are our own estimates based on ONS person-hours by industry. We use these along with LFS microdata to estimate composition-adjusted person hours, where the adjustment uses wage bill shares for composition groups for age, education and gender. Person hours are annual person-hours, with persons including the employed, self-employed and those with two jobs. Data are grossed up using population weights.

4.5 Comparison with ONS data

To form ONS data on value added and capital services, we use industry level ONS value added and capital services data and add up sectors A to K plus OP, subtracting off residential real estate, as described above. How do the KLEMS data compare with the disaggregated ONS data? The real output data are almost exactly the same, as are the capital services data. The labour input data are different. First, the KLEMS data has fewer workers in financial services, but more in business services than the ONS data. We suspect this may be due to the treatment of agency workers of whom there are many in financial services, but employed by agencies in business services and hence their appropriate treatment is a problem. This means that productivity growth in financial services is much higher in KLEMS relative to the ONS, but somewhat less in business services. Second, the KLEMS quality adjusted labour series grows faster than our own and the ONS series, where the latter two are produced using the same data and method but at a slightly different industry breakdown.

4.6 Labour and capital shares

The Compensation of Employees (COE) data are consistent with the labour services data. Mixed income is allocated to labour and capital according to the ratio of labour payments to MGVA excluding mixed income. . Gross operating surplus (GOS) is always computed as MGVA less COE so that GOS +COE =MGVA by construction.

4.7 Details of measurement of intangible Assets

CHS (2006) distinguish three classes of intangible assets:

i) *computerised information*; software and databases

ii) *innovative property;* (scientific & non-scientific) R&D, design (including architectural and engineering design), product development in the financial industry, exploration of minerals and production of artistic originals.

iii) *economic competencies*. firm investment in reputation, human and organisational capital.

Our intangible data update industry-level data reported in Gill and Haskel (2008). Own account investment is allocated to the industry wherein the investment is carried out. Purchased is allocated to industries via the input output tables, with the exception of organisational capital which is allocated using MCA industry information[11]. Particular industry categories (e.g. product development in finance, exploration of minerals, copyright) are allocated to that industry.[12]

4.7.1 Computerised information

Computerised information comprises computer software, both purchased and own-account, and computerized databases. Software is already capitalised and thus we use these data, by industry, as described by Chesson and Chamberlin (2006). Purchased software data are based on company investment surveys and own-account based on the wage bill of employees in computer software occupations, adjusted downwards for the fraction of time spent on creating new software (as opposed to, say routine maintenance) and then upwards for associated overhead costs (a method we use for design below). Software is already included in the EUKLEMS, but for consistency, we subtract it out of all variables and build our own stock and implied service flow using the ONS data.

[11] IO data refers to the product “market research and management consultancy” up to BB2010 and “services of head offices; management consulting services” in BB2011. Due to the implied differences with the MCA data in the i) the industry composition of purchases; ii) the level of those purchases; iii) growth in such purchases and even iv) the direction of growth in recent years, we have chosen to base our industry breakdown on that published by the MCA.

[12] Copyright, or more accurately, investment in artistic originals, is problematic for the correct allocation likely is somewhere between publishers (manufacturing) and artists, since each have some ownership share of the final original. The latter are mostly in the omitted sector “O”, which covers a miscellany of businesses from performing arts to museums. For simplicity we have allocated all investment in artistic and literary originals to O. Overall however, the numbers are small and any error in allocation is likely trivial.

4.7.2 Innovative property

For business *Scientific R&D* we use expenditure data by industry derived from the Business Enterprise R&D survey (BERD). To avoid double counting of R&D and software investment, we subtract R&D spending in "computer and related activities" (SIC 72) from R&D spending since this is already included in the software investment data.[13] Since BERD also includes physical capital investments we convert those investments into a capital compensation term, using the resulting physical capital stocks for the R&D sector and the user cost relation[14].

Like computerised information, *mineral exploration, and production of artistic originals* (copyright for short) are already capitalised in National Accounts. Data for mineral exploration here are simply data for Gross Fixed Capital Formation (GFCF) from the ONS, valued at cost (ONS National Accounts, 2008) and explicitly not included in R&D. Data for copyright are our own estimates produced with the co-operation of ONS and the Intellectual Property Office (Goodridge and Haskel, 2011). The production of artistic originals covers, "original films, sound recordings, manuscripts, tapes, etc, on which musical and drama performances, TV and radio programmes, and literary and artistic output are recorded." .

The measurement methodology for *New product development costs in the financial industry* follows that of own account software above (and therefore replaces the CHS assumption of 20 per cent of intermediate consumption by the financial services industry). This new method reduces this category substantially. Further details are in Haskel and Pesole (2009) but a brief outline is as follows. First, we interviewed a number of financial firms to try to identify the job titles of workers who were responsible for product development. Second, we compared these titles with the available occupational and wage data from the Annual Survey on Hours and Earnings (ASHE). The occupational classification most aligned with the job titles was 'economists, statisticians and researchers'. Third, we asked our interviewees how much time was spent by these occupations on developing new products that would last more than a year. Some firms based their estimates on time sheets that staff filled out. Fourth, we asked firms about the associated overhead costs with such workers. Armed with these estimates, we went to the occupational data in the ASHE and derived a time series of earnings for those particular

[13] The BERD data gives data on own-account spending. Spending is allocated to the industry within which the product upon which firms are spending belongs. That is we assume that R&D on say, pharmaceutical products takes place in the pharmaceutical industry. General R&D spending is allocated to business services. Thus the BERD data differs from that in the supply use tables, which estimates between-unit transactions of R&D.

[14] $PK = PI(\rho+\delta)$, where PK is the rental price of physical capital; PI is the asset price, ρ is the real rate of return and δ is the depreciation rate.

occupations in financial intermediation. Own-account investment in product development is therefore the wage bill, times a mark-up for other costs (capital, overheads etc.), times the fraction of time those occupations spend on building long-term projects. All this comes to around 0.52% of gross output in 2005 (note that reported R&D in BERD is 0.01% of gross output).

For new *architectural and engineering design* we again updated the CHS method (that used output of the design industry). To measure better such spending, we used the software method for own-account, and purchased data, by industry, are taken from the supply-use tables, see details in Galindo-Rueda et al (2011). Our estimates for purchased design as contained in this report are lower than those published in previous years. The reason is that we have chosen to exclude purchases of design by the industry itself (‘Other Business Services’, SIC74), since some of these purchases will certainly include outsourcing and subcontracting arrangements which would be double-counting. The choice of occupations and the time allocation are, as in financial services, taken from interviews with a number of design firms. Interestingly, almost all of the design firms we interviewed have time sheets for their employees which break out their time into administration, design and client interaction/pitching for new business (almost all firms target, for example, that junior designers spend little time on administration and senior more time on pitching). Finally, *R&D in social sciences and humanities* is estimated as twice the turnover of SIC73.2 “Social sciences and humanities”, where the doubling is assumed to capture own-account spending. This is a small number.

4.7.3 Economic competencies

Advertising expenditure is estimated from the IO Tables by summing intermediate consumption on Advertising (product group 113) for each industry. Our estimates for advertising and market research as contained in this report are lower than those published in previous years. The reason is that we have chosen to exclude purchases of marketing services by the industry itself (‘Other Business Services’, SIC74), since some of these purchases will include outsourcing and subcontracting arrangements which would be double-counting.

Firm-specific human capital, that is training provided by firms, was estimated as follows. Whilst there are a number of surveys (such as the Labour Force Survey) who ask binary questions (such as whether the worker received training around the Census date), to the best of our knowledge there is only one survey on company training spending, namely the National Employer Skills Survey (NESS) which we have available for 2004 and 2006-09.[15] We also have summary data for 1988 (from an unpublished paper kindly supplied by John Barber). The key feature of the survey, like the US Survey of Employer-provided Training (SEPT) used in CHS, is that it asks for direct employer spending on training (e.g. in house training centres, courses bought in etc.) and indirect costs via the opportunity cost of the employee's time whilst spend training and therefore not in current production.[16] This opportunity costs turns out to be about equal to the former.

One question is whether all such surveyed training creates a lasting asset or is some of it short-lived. We lack detailed knowledge on this, but the NESS does ask what proportion of training spend is on Health and Safety or Induction Training. In the past we have subtracted spending on Health and Safety training, which was around 10% of total spend. Our new data has a component for both Health and Safety and Induction training, and we note that in the production industries this is between 30 and 40 per cent of the total. Since it seems reasonable that Health and Safety training may have more impact on firm productivity in the production industries compared to say Business Services, and that Induction training in production may be more likely to include training on job-specific skills, we decided to include this component for production but exclude it in the service sector. Whilst this subtraction lowers the level of training spending, it turns out to have little impact on the contribution of training to growth[17]. A second question is the extent to which such training financed by the firm might be incident on the worker, in the sense of reducing worker pay relative to what it might have been without training, unobserved by the data gatherer. O'Mahony and Peng (2010) use the fraction of time that training is reported to be outside working hours, arguing that such a fraction is borne by the worker. Our data is all for training in working hours.

Finally, our data on investment in *organisational structure* relies on purchased management consulting, on which we have consulted the Management Consultancy Association (MCA),

---

[15] For example NESS07 samples 79,000 establishments in England and spending data is collected in a follow-up survey among 7,190 establishments who reported during the main NESS07 survey that they had funded or arranged training in the previous 12 months. Results were grossed-up to the UK population. To obtain a time series, we back cast the industry level series using EU KLEMS wage bill data benchmarking the data to four cross sections.

[16] Firms are asked how many paid hours workers spend away from production whilst training and the hourly wage of such workers.

[17] When excluding Health and Safety and induction training from the service sector, our estimates of the contribution of training capital deepening to growth are: (1990-95) 0.09%; (1995-00) 0.13%; (2000-09) 0.06%. Once we include the omitted expenditure, they change to: (1990-95) 0.12%; (1995-00) 0.16%; (2000-09) 0.08%.

and own-account time-spend, the value of the latter being 20% of managerial wages, where managers are defined via occupational definitions. We test the robustness of the 20% figure below.

4.8 Prices and depreciation

Rates of depreciation and the prices of intangible assets are less well established. The R&D literature appears to have settled on a depreciation rate of around 15-20%, and OECD recommends 33% for software. Solovechik (2010) has a range of 5% to 30% for artistic originals, depending on the particular asset in question. To shed light on this and the deprecation of other assets, in our intangible assets survey we asked for life lengths for various intangibles (Awano, Franklin, Haskel and Kastrinaki, 2009). The responses we obtained were close to the assumed depreciation rates in CHS, depending on the assumptions one makes about declining balance depreciation. Thus we use 33% for software, 60% for advertising and market research, 40% for training and organisational investments, and 20% for R&D. Once again, we shall explore the robustness of our results to depreciation, but note in passing that our assets are assumed to depreciate very fast and so are not very sensitive to depreciation rates, unless one assumes much slower rates, in which case intangibles are even more important than suggested here.

The asset price deflators for software are the official deflators (own-account and purchased), but otherwise the GDP deflator is used for intangible assets. This is an area where almost nothing is known, aside from some very exploratory work by the BEA and Corrado, Goodridge and Haskel (2011). These papers attempt to derive price deflators for knowledge from the price behaviour of knowledge intensive industries and the productivity of knowledge producing industries. Two observations suggest that using the GDP deflator overstates the price deflator for knowledge, and so understates the impact of knowledge on the economy. First, many knowledge-intensive prices have been falling relative to GDP. Second, the advent of the internet and computers would seem to be a potential large rise in the capability of innovators to innovate, which would again suggest a lowering of the price of knowledge, in contrast to the rise in prices implied by the GDP deflator. Thus our use of the GDP deflator almost certainly understates the importance of intangible assets.

4.9 Relation of intangible approach to other approaches

Haskel et al (2009, 2010) discusses how this work relates to the definition of innovation and the Frascati and Oslo manuals. It is clearly consistent with the work on IT and economic growth, see, for example, Jorgenson, Ho and Stiroh (2007), the capitalisation of software and the forthcoming capitalisation of R&D in national accounts, both of which are part of the process of recognizing spending on intangibles as building a (knowledge) capital stock. Van Ark and Hulten (2007) point out that with an expanded view of capital following the CHS argument innovation "*…would appear in several forms in the sources of growth framework: through the explicit breakout of IT capital formation, through the addition of intangible capital to both the input and output sides of the source of growth equation, through the inclusion of human capital formation in the form of changes in labour "quality," and through the "multifactor productivity" (MFP) residual"* For shorthand, we refer to "innovation" contribution as the sum of the intangible contribution and TFP (and sometimes labour composition), but take no stand on this: we provide other components for the reader.

4.10 Accuracy of intangible measures

The following points are worth making. First, data on minerals, copyright, software and R&D are taken from official sources. As mentioned above, official data is an undercount of copyright spending and so we use our own data for that, but we are currently working with ONS to incorporate them into the official data. Second, data on workplace training are taken from successive waves of an official government survey, weighted using ONS sampling weights. Once again one might worry that such data are subject to biases and the like but this does look like the best source currently available.

Third, data on design, finance and investment in organisational capital are calculated using the software method for own-account spending, but the IO tables for bought-in spend in the case of design and finance. The use of the IO tables at least ensures the bought in data are consistent with the Blue Book. The use of the own account software method means that we have to identify the occupations who undertake knowledge investment, the time fraction they spend on it and additional overhead costs in doing so. For design and financial services we have followed the software method by undertaking interviews with firms to try to obtain data on these measures. Such interviews are of course just a start but our estimates are based then on these data points. For own-account organisational change we use an assumed fraction of time spent (20%) by managers on organisational development. We have been unable to improve on this estimate in interviews and so this remains a subject for future work: below we test for robustness to this assumption.

To examine all further, we undertook two further studies. First, we used survey data kindly supplied by Stephen Roper and described in detail in Barnett (2009). These data ask around

1,500 firms about their spending on software, branding, R&D, design and organisational capital. The firms are sampled from service and hi-tech manufacturing industries. Comparison of the proportions of spend on the intangible assets with those proportions in our manufacturing and business services gives similar answers.

Second, we undertook our own survey of firms for a second year. The results of the first survey are fully documented in Awano et al (2009). Results from the second year will be available in the near future. In terms of the spending numbers here, that micro study found spending on R&D, software, marketing and training to be in line with the macro-based numbers in this report. However, the implied spending on design and organisational capital were very much lower in the survey. This again suggests that these investment data require further work.

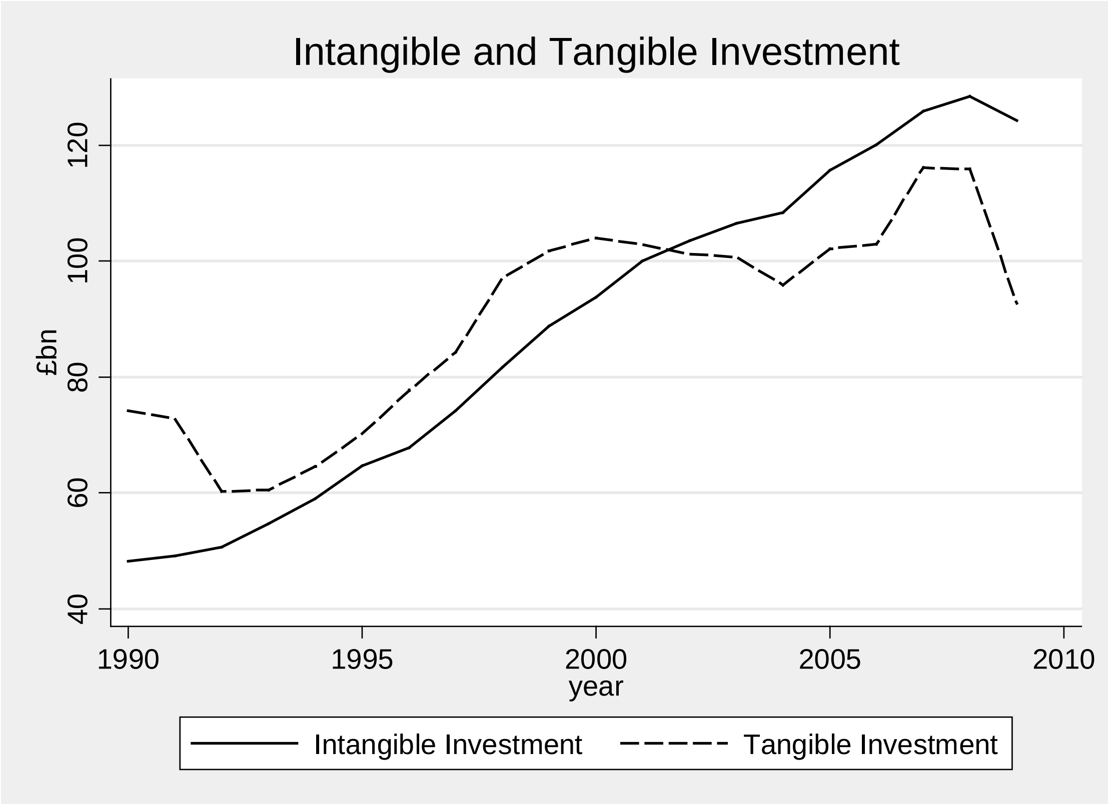
5 Results

5.1 Intangible spending: market sector over time

Figure 1 presents market sector nominal total tangible and intangible investment data. In the 2000s intangible investment has exceeded tangible. Note that in previous years our data have shown intangible investment to be greater than tangible from an earlier point. That feature of the data was due to the coverage of market sector activity, which excluded a large part of the service sector. We have rectified that for this work, with a new definition of the UK market sector that is consistent with that used in EUKLEMS, but note that the new sector ('O') is highly capital intensive particularly in buildings (sports stadia etc.) thus adding much more tangible investment into our dataset. It is also not possible to exclude some of the non-market elements of this industry which are also quite capital intensive.

Note that, intangible investment has fallen less than tangible investment in the recent recession. In 2008-09 tangible investment fell sharply whilst although intangible investment does fall it is nowhere near as steeply. Part of the effect in the case of tangibles may be due to the sharp increase that took place in 2007, part of which may have been an 'Olympic effect' from associated infrastructure investment. However, depreciation rates for intangible assets are significantly faster than those for tangibles. Thus a relatively small slowdown in intangible investment turns out to generate the same fall in capital stock as a steep fall in tangible spend, so the changes in resulting capital services are similar.

Figure 1: **Market sector tangible and intangible investment, £bn, 1990-2009**



Source: ONS data for tangibles, this paper for intangibles. All data in current prices

Table 2 shows investment by intangible asset for 1990, 1995, 2000 2005, 2008 and 2009 with tangible investment for comparison. The intangible category with the highest investment figures is training, growing to over a quarter of tangible investment by 2009 and over double that of ICT tangible (hardware and telecommunications) investment. For information we also report MGVA excluding intangibles.

Table 2: Tangible and Intangible Investment, £bn

Asset	1990	1995	2000	2005	2008	2009
Purchased Software	2.7	5.7	9.2	8.5	10.6	9.1
Own-Account Software	3.5	4.2	7.4	10.2	12.2	13.5
Total Software	***6.2***	***9.9***	***16.5***	***18.7***	***22.8***	***22.6***
R&D	7.3	8.0	10.5	12.2	14.4	14.0
Design	7.1	7.3	10.3	13.5	15.5	15.5
Non-scientific R&D	0.2	0.3	0.4	0.3	0.7	0.8
Mineral Exploration	1.6	1.1	0.3	0.4	0.6	0.6
Financial Innovation	0.3	0.4	0.7	0.9	1.2	1.5
Film Originals	0.0	0.1	0.2	0.2	0.2	0.3
TV (fiction) Originals	0.5	0.9	1.2	1.5	1.6	1.4
TV (non-fiction) Originals	0.2	0.5	0.6	0.7	0.7	0.7
Total TV Originals	0.7	1.4	1.7	2.2	2.2	2.1
Literary Originals	0.8	1.0	1.1	0.8	0.9	1.0
Music Originals	0.9	1.4	1.7	1.7	1.3	1.3
Miscellaneous Art	0.1	0.2	0.4	0.3	0.4	0.4
Total Artistic Originals	*2.6*	*4.1*	*5.0*	*5.2*	*5.0*	*5.1*
Total Innovative Property	***19.1***	***21.2***	***27.2***	***32.5***	***37.4***	***37.3***
Advertising	4.2	6.0	9.4	10.0	10.8	10.8
Market Research	0.9	1.2	1.5	2.4	2.1	2.0
Total Branding	*5.2*	*7.2*	*10.8*	*12.4*	*12.9*	*12.8*
Own-Account Organisational Capital	4.6	9.8	14.5	19.5	23.5	21.8
Purchased Organisational Capital	0.8	1.7	3.3	6.0	4.4	3.9
Total Organisational Capital	*5.4*	*11.4*	*17.8*	*25.5*	*27.9*	*25.7*
Training	12.3	14.9	21.4	26.6	27.4	25.8
Total Economic Competencies	***22.9***	***33.5***	***50.0***	***64.6***	***68.2***	***64.3***
TOTAL INTANGIBLES	**48.2**	**64.7**	**93.7**	**115.7**	**128.4**	**124.2**
Buildings	30.1	21.8	34.5	35.9	50.1	40.7
Plant & Machinery (excl ICT)	25.5	25.8	33.9	34.5	35.6	27.8
Vehicles	9.4	9.8	12.3	14.3	14.5	11.9
IT Hardware	6.2	9.0	15.9	12.4	11.1	8.6
CT	2.9	3.6	7.4	5.1	4.5	3.7
ICT (excluding software)	*9.1*	*12.7*	*23.3*	*17.5*	*15.7*	*12.3*
TOTAL TANGIBLES	**74.1**	**70.1**	**104.0**	**102.1**	**115.9**	**92.7**
MSGVA						
without intangibles	393.8	485.1	642.0	812.4	946.2	900.0
with NA intangibles	404.3	500.2	663.9	836.7	974.7	928.2
with all CHS intangibles	442.0	549.8	735.7	928.1	1074.7	1024.2

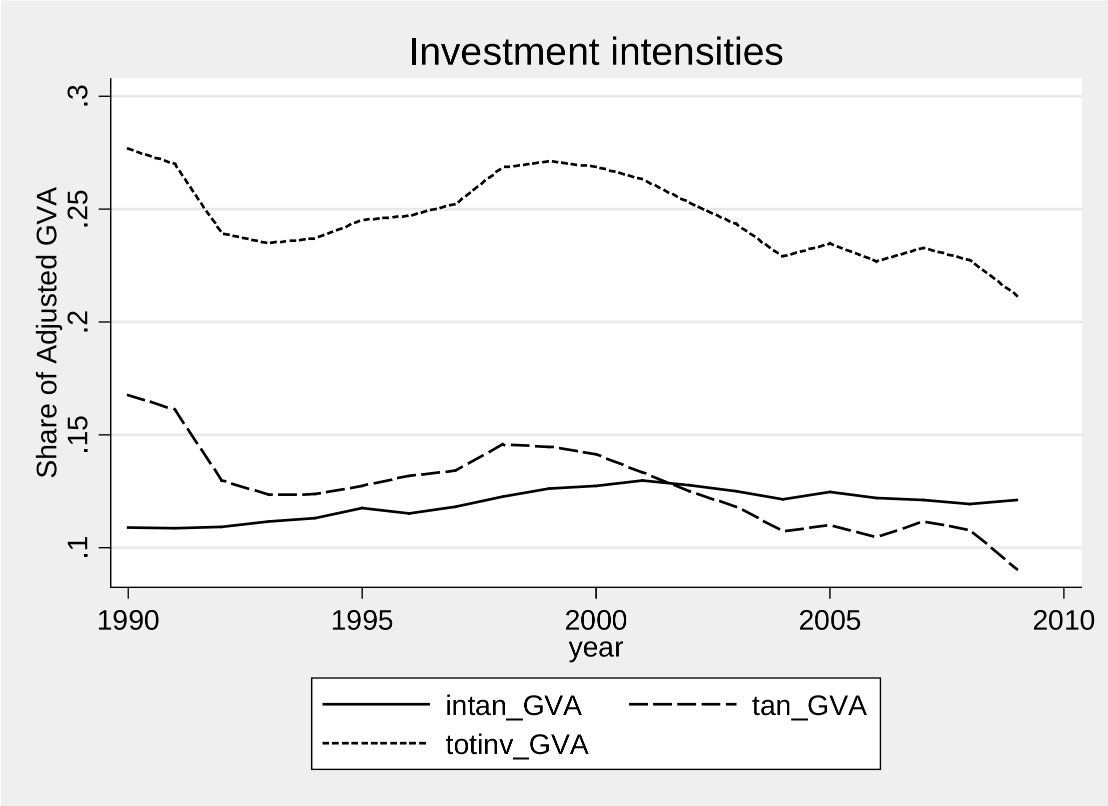
Note to table. Data are investment figures, in £bn, current prices: italicized data are sub-totals for broader asset definitions. ‘Design’ refers to architectural & engineering design. MSGVA is presented with no intangibles capitalized; with only NA intangibles capitalized (software, mineral exploration and artistic originals); and with all CHS intangibles capitalized. Market Sector refers to sectors A to K plus OP, excluding residential real estate. Source: ONS data for tangibles, this paper for intangibles.

In Figure 2 we report tangible and intangible investment as shares of MSGVA, where output has been adjusted for the capitalisation of all intangibles. There are three main points to note.

First note the steady consistent decline in investment across all assets in market sector investment as a share of value-added, falling from approximately 27% in 1999 to 21% in 2009. Looking at data from before the recent recession, the aggregate share stood at 23% in 2007. Second, within total investment, tangible investment as a share of MSGVA has fallen very sharply. After the recession in the early 1990s tangible investment recovered to almost 15% of value-added in 1998, and then declined to around 11% in 2007, and to 9% in 2009. Third, intangible investment as a share of value-added rose steadily throughout the 1990s, peaking at almost 13% in 2001 and declining very slightly since then to 12% in 2009. It is worth noting that although the decline in tangible investment is somewhat compensated by the steady profile of intangible investments, assets in the latter category tend to have much higher depreciation rates than tangible investments, with implications for the level and growth of the UK market sector aggregate stock.

Although not presented here, one point to note on the data within tangibles is that ICT as a share of tangible investment has declined since the ICT investment boom in the late 1990s, as has plant and machinery, with strong growth in investment in buildings as a share of tangible investment even in the most recent years. Note that here buildings refers to commercial property. Residential dwellings are excluded from our data since they do not form part of the productive capital stock.

Figure 3: **Market Sector tangible and intangible investment as a share of (adjusted) MSGVA, 1990-2009**



Note to figure: MSGVA adjusted for a capitalisation of all CHS intangibles for all three series'. Intangible investment data also incorporates all CHS intangibles.

5.2 Industry intangible investment

Table 3 reports tangible and intangible investment by industry in 2007. Finance and manufacturing invest very strongly in intangibles relative to tangibles: in both sectors, intangible investment is three times that in tangibles. It is interesting to note in passing that this raises important questions on how to classify manufacturing since it is undertaking a very good deal of intangible activity (manufacturing own-account intangible investment is 17% of value added by 2007 for example).

Table 4 is based on the same data as that presented in Table 3 but presents a breakdown by both asset and industry for 2007. It shows the prevalence of R&D investment in manufacturing; design and training in construction; software, training and organisational investments in distribution and communications; software and organisational investments in finance; training in business services; and creation of artistic originals in recreational services

.

Table 3: Tangible and Intangible investment, by industry, 2007, Current Prices £bn

	Agriculture and Fishing; Mining		Manufacturing		Utilities		Construction		Retail & Wholesale; Hotels & Restaurants; Transport & Comms		Financial Services		Business Services		Community, Social and Personal Services		Market Sector (A-K & OP)	
Year	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*	*Tangible*	*Intangible*
1997	6.98	2.66	18.11	23.65	4.98	1.50	1.80	3.25	28.43	16.99	4.05	8.85	8.23	9.79	6.42	7.45	79.00	74.14
1998	7.76	2.22	18.47	25.48	5.26	1.65	1.70	3.48	33.14	19.18	6.24	9.97	13.81	11.96	7.24	7.75	93.61	81.68
1999	6.22	2.01	16.54	26.69	5.56	1.74	1.89	3.84	33.94	21.25	5.26	11.10	13.70	13.71	8.85	8.45	91.96	88.79
2000	5.04	1.82	16.18	26.98	5.06	1.80	1.99	4.13	38.60	22.75	5.25	12.41	12.82	15.04	8.22	8.80	93.18	93.73
2001	6.13	1.91	14.67	28.18	5.33	1.87	2.15	4.39	38.13	24.78	4.74	13.37	12.09	16.28	7.08	9.29	90.31	100.06
2002	7.24	2.05	12.26	27.74	4.77	1.80	3.12	5.01	38.11	25.91	4.91	13.97	10.53	17.59	7.06	9.42	87.99	103.49
2003	6.88	2.09	11.93	27.90	4.82	1.72	3.11	5.51	35.08	26.73	4.23	14.13	10.41	18.52	8.10	9.92	84.57	106.51
2004	6.81	2.01	11.78	28.15	2.68	1.79	3.63	5.83	36.65	27.34	3.62	13.97	8.46	19.04	11.13	10.30	84.75	108.43
2005	6.63	2.19	11.57	29.08	3.73	2.03	2.70	6.32	35.58	28.67	5.02	15.30	10.54	21.34	12.05	10.81	87.83	115.73
2006	7.04	2.36	11.16	28.98	5.04	2.34	3.20	6.78	35.81	29.75	4.63	15.53	11.60	22.87	11.66	11.51	90.15	120.14
2007	8.26	2.52	11.98	29.46	6.92	2.46	3.15	7.42	39.81	30.89	5.46	16.62	12.99	24.79	12.44	11.70	101.02	125.85

Source: authors' calculations using EUKLEMS data for tangibles and methods in this paper for intangibles.

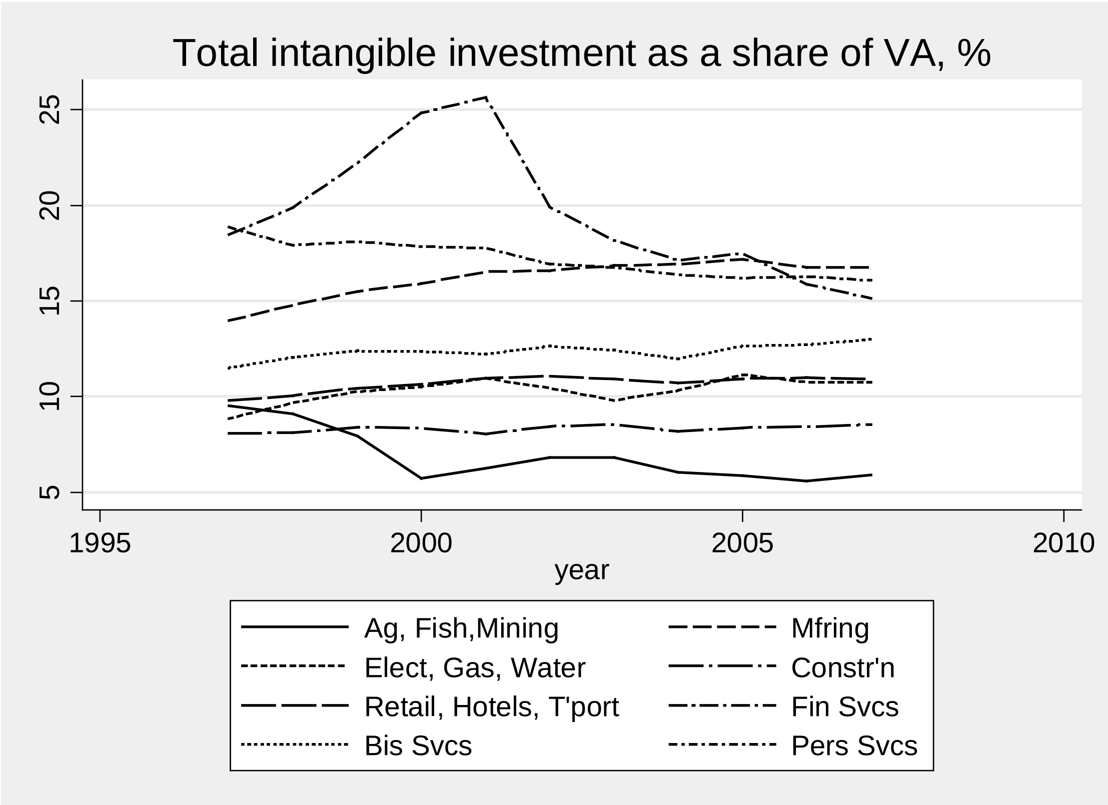
Table 4: **Intangible investment, by asset and industry, 2007, Current Prices £bn**

Industry	Software (purchased & own-account)	Scientific R&D	Arch & Eng Design (purchased & own-account)	Artistic Originals	Mineral Exploration	Financial Product Innovation	Non-scientific R&D	Branding (Advertising and Market Research)	Training	Organisational Capital (purchased & own-account
Agriculture; Mining	0.2	0.1	0.5	0.0	0.6	0.0	0.0	0.1	0.5	0.5
Manufacturing	2.9	11.8	3.8	0.0	0.0	0.0	0.0	2.3	3.8	4.9
Utilities	0.6	0.0	0.4	0.0	0.0	0.0	0.0	0.2	0.6	0.7
Construction	0.4	0.0	2.3	0.0	0.0	0.0	0.0	0.5	2.6	1.6
Distribution; Hotels; Transport	6.1	1.6	3.0	0.0	0.0	0.0	0.0	4.6	8.0	7.6
Finance	4.7	0.0	1.6	0.0	0.0	1.2	0.0	2.4	1.3	5.3
Business Services	5.1	0.0	2.5	0.0	0.0	0.0	0.6	1.4	10.1	5.2
Personal Services	1.3	0.0	1.0	5.1	0.0	0.0	0.0	1.1	2.1	1.0

Source: authors’ calculations.

Figure 2 shows the ratios of total investment in all intangible categories to industry value added (where industry value added equals conventional value added plus additional intangible investment not officially capitalised). Note the initial very high level in financial services due to the software boom in the late 1990s, especially in the run up to Y2K. Since, then it is worth noting that manufacturing and personal services are the most intangible investment intensive, at 17% and 16% of industry-value-added respectively in 2007.

Figure 4: **Ratio of investment to (adjusted) value-added ratios, by industry (1997-2007)**



Note to figure: Industry value-added has been adjusted to account for the capitalisation of intangible assets

Which particular intangible assets are most important in which industries? Table 5shows the asset share of total intangible spending by industry (in 2007, the shares are very stable over time). Starting with manufacturing, the largest share of all intangible spending is innovative property (53%), with software 10%. Compare with financial intermediation, where innovative property accounts for only 17% whereas "ecom" (training, branding and organization building) accounts for 54%, whilst software is 28%. Similarly, in distribution/communications, software and economic competencies are more important than innovative property. In our new industry, Community and Personal Services, innovative property accounts for 52% of intangible investment. Note here that innovative property here includes the creation of new artistic originals in film, television, music, literary and miscellaneous works. Software and economic competencies account for 11% and 36% respectively.

To shed light on the importance of non-R&D spend outside manufacturing, the lower panel sets out some detail on selected individual measures. As the top line shows, R&D accounts, in manufacturing, for 40% of all intangible spend, but 0% in all services with the exception of 5% in distribution & communications. Training, line 2, accounts for 13% in manufacturing, 26% in distribution & communications and 8% in finance, but 41% in business services. Investment in organisational capital, line 3, is 17% in manufacturing, 25% in trade and a considerable 32% in finance. Finally, branding is almost twice as important in distribution and finance as in manufacturing. Thus we can conclude that the "non-R&D" intangible spend, outside manufacturing, is mostly due to software, training, organisational capital and branding.

Table 5: **Shares of total industry intangible investment accounted for by individual intangible asset categories (for 2007)**

	AgrMin	Mfr	Utilities	Constr	RtHtTrs	FinSvc	BusSvc	PersSvc
Shares								
soft	0.08	0.10	0.23	0.06	0.20	0.28	0.20	0.11
innop	0.47	0.53	0.16	0.31	0.15	0.17	0.13	0.52
ecom	0.44	0.37	0.60	0.63	0.65	0.54	0.67	0.36
	100%	100%	100%	100%	100%	100%	100%	100%
Individual Assets:								
R&D	0.04	0.40	0.02	0.00	0.05	0.00	0.00	0.00
Training	0.22	0.13	0.26	0.35	0.26	0.08	0.41	0.18
Organisational	0.20	0.17	0.28	0.22	0.25	0.32	0.21	0.08
Branding	0.03	0.08	0.07	0.06	0.15	0.15	0.06	0.10

Notes to table: "Soft" is Software; "ecom" is economic competencies; "innop" is Innovative Property. Where: economic competencies are advertising & market research, training and organisational investment and innovative property is R&D, mineral exploration and copyright creation, design, financial product development and social science research. All data are shares of total investment: upper panel sums to 100% since categories are exhaustive, lower panel shows a sample of individual assets that are part of the asset groups in the upper panel.

6 Growth accounting results: market sector

6.1 Growth accounting results for the market economy

Our growth accounting results are set out in Table 6 (Panel 1). Consider Table 6 which reads as follows. The first column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times the share of labour in MGVA. Column 3 is growth in computer capital services times the share of payments for computer services in MGVA. Column 4 is growth in telecommunications capital services times share in MGVA. Column 5 is growth in other tangible capital services (buildings, plant, vehicles) times share in MGVA. Column 6 is growth in intangible capital services times share in MGVA. Column 7 is TFP, namely column 1 minus the sum of columns 2 to 5. Column 8 is the share of labour payments in MGVA. Columns 9 to 12 are the shares of particular contributions, shown in the table heading, to form alternative versions of the 'innovation index'.

Consider first the top panel of data, which reports the contributions to growth in a standard framework that *does not* include intangibles. LPG was steady in the 1990s and then fell strongly in the 2000s[18]. Note that were it not for the introduction of a new methodology for FISIM and other methodological changes in the 2008 and 2009 National Accounts, see Haskel et al (2009) labour productivity growth in the late 1990s especially would have been measured as substantially lower[19] The contribution of labour quality, column 2, rose in the late 1990s. Computer capital input grew quickly in the 1990s, but fell in the 2000s. The opposite profile occurs for other tangibles (buildings, plant and vehicles) leaving the overall contribution of tangible capital stable in the 1990s but falling in the 2000s. Therefore the overall contribution of tangible capital as a share of LPG was also stable in the 1990s but grew strongly in the 2000s. Thus the overall TFP record was a small fall in the second half of the 1990s and then a strong fall in the 2000s to a low rate of 0.17% p.a.

Consider now the second set of results in panel 1, where we include intangibles officially capitalized in the SNA, namely software, mineral exploration, and artistic originals, where software is by far the biggest category. Their inclusion raises output growth in the 1990s but

---

[18] In contrast to previous work (Haskel et al, 2010) where LPG rose in the 1990s. The difference is down to the addition of sector O which has very low productivity growth and thus drags down the aggregate, particularly in the late 1990s.

[19] FISIM added around 0.5 ppa to growth in GDP in selected years in the late 1990s, all of which adds to TFPG almost directly since no new inputs are involved. Thus even without intangibles, the productivity picture changes.

has much less impact in the 2000s. Other contributions are also changed due to the changes in factor and asset income shares, and TFP growth is lowered slightly.

The third set of results in panel 1 adds R&D as a capitalized asset, and thus provides a guide as to the impact of the upcoming capitalisation of R&D on the UK productivity picture. As we have previously argued, scientific R&D is actually a small component of the total investment in knowledge undertaken by firms. Therefore the impact of capitalizing R&D is small, adding between -0.04 to +0.01% p.a. to labour productivity growth depending on the period considered. The reduction to TFP growth is in a similar range. We stress however that this result is dependent on the use of a market sector output deflator to estimate real R&D investment. There is no reason to believe that the price of R&D follows general output prices. We discuss this in more detail later, and provide an alternative result using improved estimates of changes in R&D asset prices.

The fourth set of results are for a decomposition that incorporates all intangibles identified by CHS. The inclusion of intangibles raises output growth in the 1990s, with little effect in the 2000s, due to a decline in intangible investment growth in the 2000s following the boom in intangible investment in the preceding years. The impact of labour quality, column 2 falls due to the fall in the labour share. The contribution of tangible capital, columns 3, 4 and 5, falls somewhat relative to the upper panel as the inclusion of intangibles alters the factor income shares of these inputs. In column 6 we see the contribution of the intangible inputs; stronger in the 1990s and weaker – though still important – in the 2000s. Thus the overall TFPG record in column 6 is acceleration in the late 1990s and then virtually zero growth in the 2000s, with the decline in the 2000s even stronger than the “without intangibles” or “national accounts” models.

Table 6: **Growth accounting for market sector with and without intangibles**

	1	2	3	4	5	6	7	8	9	10	11	12
	DlnV/H	**sDln(L/H)**	**sDln(K/L) cmp**	**sDln(K/L) telecom**	**sDln(K/L) othtan**	**sDln(K/L) intan**	**DlnTFP**	***Memo: sLAB***	**InnIndex1**	**InnIndex2**	**InnIndex3**	**InnIndex4**
1) Baseline Results: With and without intangibles												
Without all intangibles									*7/1*	*(6+7)/1*	*(2+6+7)/1*	*(6+7)*
1990-95	3.07%	0.24%	0.33%	0.01%	0.85%	0.00%	1.64%	0.66	0.53	0.53	0.61	1.64%
1995-00	3.06%	0.30%	0.73%	0.08%	0.39%	0.00%	1.57%	0.65	0.51	0.51	0.61	1.57%
2000-09	1.44%	0.31%	0.24%	0.03%	0.68%	0.00%	0.17%	0.68	0.12	0.12	0.34	0.17%
National Acc's Intangibles: just software (ONS); mineral exploration (ONS); artistic originals (GH)												
1990-95	3.26%	0.23%	0.32%	0.01%	0.84%	0.24%	1.63%	0.65	0.50	0.57	0.64	1.86%
1995-00	3.29%	0.29%	0.71%	0.07%	0.37%	0.26%	1.59%	0.63	0.48	0.56	0.65	1.85%
2000-09	1.47%	0.30%	0.23%	0.02%	0.64%	0.11%	0.16%	0.66	0.11	0.18	0.39	0.27%
National Accounts plus R&D												
1990-95	3.22%	0.23%	0.32%	0.01%	0.83%	0.28%	1.56%	0.64	0.48	0.57	0.64	1.84%
1995-00	3.30%	0.28%	0.70%	0.07%	0.36%	0.29%	1.60%	0.62	0.48	0.57	0.66	1.89%
2000-09	1.47%	0.30%	0.23%	0.02%	0.63%	0.15%	0.14%	0.65	0.09	0.19	0.40	0.28%
All CHS Intangibles												
1990-95	3.36%	0.21%	0.29%	0.01%	0.78%	0.68%	1.38%	0.59	0.41	0.61	0.68	2.06%
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	0.73%	1.54%	0.57	0.43	0.64	0.71	2.27%
2000-09	1.43%	0.27%	0.21%	0.02%	0.56%	0.38%	-0.01%	0.59	0.00	0.26	0.45	0.37%
2) Baseline: alternative periods												
Without all intangibles												
1990-95	3.07%	0.24%	0.33%	0.01%	0.85%	0.00%	1.64%	0.66	0.49	0.49	0.59	1.64%
1995-00	3.06%	0.30%	0.73%	0.08%	0.39%	0.00%	1.57%	0.65	0.54	0.54	0.63	1.57%
2000-05	2.36%	0.19%	0.39%	0.04%	0.57%	0.00%	1.17%	0.68	0.45	0.45	0.55	1.17%
2005-09	0.28%	0.47%	0.05%	0.01%	0.82%	0.00%	-1.07%	0.67	1.35	1.35	1.24	-1.07%
All CHS Intangibles												
1990-95	3.36%	0.21%	0.29%	0.01%	0.78%	0.68%	1.38%	0.59	0.41	0.61	0.68	2.06%
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	0.73%	1.54%	0.57	0.43	0.64	0.71	2.27%
2000-05	2.45%	0.16%	0.34%	0.03%	0.48%	0.48%	0.96%	0.60	0.39	0.59	0.65	1.44%
2005-09	0.17%	0.41%	0.04%	0.01%	0.66%	0.25%	-1.21%	0.59	-7.27	-5.76	-3.28	-0.96%
3) Altering Depreciation rates												
All CHS Intangibles: Halve intangible dep rates												
1990-95	3.36%	0.21%	0.30%	0.01%	0.83%	0.66%	1.35%	0.59	0.40	0.60	0.66	2.01%
1995-00	3.57%	0.26%	0.64%	0.07%	0.34%	0.68%	1.57%	0.57	0.44	0.63	0.71	2.25%
2000-09	1.43%	0.27%	0.21%	0.02%	0.55%	0.52%	-0.15%	0.59	-0.10	0.26	0.45	0.37%
All CHS Intangibles: Double intangible dep rates												
1990-95	3.36%	0.21%	0.29%	0.01%	0.75%	0.67%	1.43%	0.59	0.42	0.62	0.69	2.10%
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	0.77%	1.50%	0.57	0.42	0.64	0.71	2.27%
2000-09	1.43%	0.27%	0.21%	0.02%	0.57%	0.23%	0.13%	0.59	0.09	0.25	0.44	0.36%

	1	2	3	4	5	6	7	8	9	10	11	12
	DlnV/H	sDln(L/H)	sDln(K/L) cmp	sDln(K/L) telecom	sDln(K/L) othtan	sDln(K/L) intan	DlnTFP	*Memo: sLAB*	InnIndex1	InnIndex2	InnIndex3	InnIndex4
4) Excluding 75% of Organisational own-account												
All CHS Intangibles: Org own-account conversion factor = 0.25												
1990-95	3.25%	0.22%	0.30%	0.01%	0.79%	0.55%	1.39%	0.60	0.43	0.60	0.66	1.94%
1995-00	3.52%	0.26%	0.65%	0.07%	0.34%	0.63%	1.57%	0.58	0.45	0.63	0.70	2.20%
2000-09	1.42%	0.28%	0.21%	0.02%	0.57%	0.31%	0.02%	0.60	0.02	0.24	0.43	0.34%
5) Without Tax adjustment factors for tangible and intangible capital												
All CHS Intangibles: TAF=1												
1990-95	3.36%	0.21%	0.27%	0.01%	0.77%	0.70%	1.40%	0.59	0.42	0.62	0.69	2.10%
1995-00	3.57%	0.26%	0.59%	0.06%	0.33%	0.74%	1.57%	0.57	0.44	0.65	0.72	2.32%
2000-09	1.43%	0.27%	0.19%	0.02%	0.55%	0.39%	0.00%	0.59	0.00	0.28	0.47	0.40%

Notes to table. Data are average growth rates per year for intervals shown, calculated as changes in natural logs. Contributions are Tornqvist indices. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in MGVA. Column 3 is growth in computer capital services times share in MGVA. Column 4 is growth in telecommunications capital services times share in MGVA Column 5 is growth in other tangible capital services (buildings, plant, vehicles) times share in MGVA. Column 6 is growth in intangible capital services times share in MGVA. Column 7 is TFP, namely column 1 minus the sum of columns 2 to 5. Column 8 is the share of labour payments in MGVA. Columns 9-12 are alternative version of the innovation index

.

Columns 9 to 11 set out the shares of LPG of various components and column 12 presents the total contribution of private intangible capital and TFP combined. What are the main findings? First, the inclusion of intangibles lowers TFPG as a share of LPG. Consider column 9 in the upper panel. TFPG as a share of LPG is around 10-15 percentage points less with intangibles compared to without intangibles. Second, the contribution of the "knowledge economy" to LPG is very significant, whether measured as column 10 or 11. Looking at column 10, TFPG and intangible capital deepening are between 61-64% of LPG in the 1990s and 26% in the 2000s. Column 11 adds the contribution of labour quality taking the figure to around 68-71% and 45% respectively. Note how high this contribution is in the late 1990s when intangible capital deepening was very fast

6.2 Growth accounting: further details and robustness checks

As we have seen, we necessarily make a number of assumptions when implementing the growth accounting exercise. How robust are our findings to key assumptions? This is shown in the rest of the table. The strong fall in labour productivity and TFP in the 2000s are driven partly by a general slowdown throughout the period and also by the collapse that occurred in the recession that followed the financial crisis. Therefore panel 2 breaks the 2000s into two separate periods. As can be seen, the data show a significant slowdown in labour productivity in the early 2000s. Features of the data for the later 2000s include a strong increase in the contribution of labour composition. This is partly driven by the increased labour share as wages have held up in comparison to profits, and partly by the hoarding of experienced workers.

Panel 3 tests the robustness of the results to changes in intangible depreciation rates, where we first halve and then double the geometric rates for intangible capital. Halving the depreciation rates causes the contribution of intangibles to rise in the 2000s as would be expected. In the 1990s this halving causes the contribution to fall, but this difference simply reflects the intangible investment boom that took place in the late 1990s forming much of the stock. Doubling the depreciation rates has a similar impact but in the opposite directions, as would be expected. The changes in the contributions more or less directly affect $\Delta \ln TFP$, so that, if for example, intangibles depreciated half as fast as we have assumed, $\Delta \ln TFP$ falls from -0.01%pa to -0.15%pa in 2000-09.

Since estimation of own account organizational capital is particularly uncertain, panel 4 reduces such spending by 75% (that is, managers are assumed to spend 5% of their time building organizational capital, as opposed to 20% in the baseline estimates). In this case in

2000-09 the contribution of intangible capital falls from 0.38%pa to 0.31% pa and ΔlnTFP rises from -0.01%pa to +0.02%pa.[20]

One way of looking at the robustness of these results is to calculate the fraction of overall ΔlnV/H accounted for by intangibles, ΔlnTFP and ΔlnL/H under the various different scenarios. It is in fact quite robust giving similar results in the models: without intangibles; with national accounts intangibles; with national accounts intangibles plus R&D. With intangibles, the fractions for just TFP (column 9) fall, but once we take account of the intangibles contribution (column 10) the fraction is raised. But the interesting thing to note is that these fractions are almost identical with the experiments on depreciation and organizational capital. Thus the inclusion of the full range of intangibles lowers the share of the contribution of ΔlnTFP, but consistently raises the share of the summed contributions of ΔlnTFP plus intangible capital deepening plus labour composition, such that the latter sum of contributions has accounted for 45% of ΔlnV/H over this century.

In panel 5 we look at the impact of incorporating new tax adjustment factors for all tangible and intangible assets, by excluding those factors and comparing the results with the (fourth set of) baseline estimates in panel 1. Note that our previous work in this area did not include tax adjustment factors for either tangible or intangible assets.

Looking first at the contributions for tangibles, in the case of computers, applying a tax adjustment factor incorporating the impact of capital allowances and corporation tax increases the contribution of capital deepening in that asset by around 8% across all periods. For other tangibles (plant & machinery, buildings and vehicles) the contribution is reduced by 2% in the early 1990s and 2000s, but is unaffected in the late 1990s. As with other tangibles, there is a large impact on the contribution of intangible capital deepening which is reduced by 3% in the early 1990s, 2% in the late 1990s and by 5% in the 2000s. This reduction added to that of other tangibles, is largely offset by the increased contribution for IT equipment. In the 1990s it is also partly offset by an increased estimate for TFP.

[20] We also looked at year by year changes and in particular the impact of the recession. In 2008, there was a decline of -0.69% in adjusted growth in value-added, and smaller contributions from capital deepening than previous years. Measured TFP falls by 1.98% and labour composition makes a strong contribution. It is likely however that in very severe recessions we do not measure the actual fall in capital that likely comes about due to premature scrapping and underutilisation and since TFP is a residual, this renders TFP negative. Thus we should be careful about interpreting year-to-year movements in the innovation index.

The reasoning for these changes is as follows. Incorporation of tax adjustment factors results in better estimation of asset rental prices and the cost of capital since they account for both the rate of corporation tax plus any asset-specific capital depreciation allowances that firms are allowed to expense for tax purposes. The intent of those allowances is to reduce the cost of capital to firms, and their size varies by asset. However, since the impact of corporation tax still outweighs such allowances, the incorporation of adjustment factors increases the rental prices and relative factor incomes for tangible assets compared to our previous work. In the case of intangibles, there is also an allowance for purchased software, the R&D tax credit, and tax relief on mineral exploration and the production of film originals. For all other intangibles no capital allowances are available but firms are able to expense their expenditures leaving the cost of capital unaffected by the presence of corporation tax. In other words, the tax adjustment factors are equal to 1. The result is that tax adjustment factors increase the rental prices, factor income shares and therefore the contributions of capital deepening in tangibles relative to most intangibles. Investment and capital stocks remain as previously measured. So although, ex ante, we would expect changes in the tax adjustment factors to impact the rate of investment, any impact on investment had already been picked up in our previous work. However our incorporation of tax adjustment factors specific to each asset means that our growth accounting decomposition is more accurate than that presented in previous reports.

6.3 Annual Contributions and the impact of recession

All tables above are annual averages. For completeness we also provide a full annual decomposition below. We stress however that annual TFP estimates are inherently volatile, and care should be taken in interpreting annual movements in unsmoothed annual estimates of TFP or the Innovation Index. In particular annual changes in the contributions reflect changes in ex-post rental prices, due to the inability to accurately observe the utilisation of capital.

The data show the collapse in labour productivity that occurred in 2008 and particularly 2009. Rises in the labour share and the wage bill share of experienced and skilled worked resulted in an increase to the contribution of labour composition. This combined with the strong contributions of other tangible capital and intangible capital results in large negative estimates for the TFP residual. The former is driven by revisions to ONS investment deflators and their impact on growth in tangible capital services.

Table 7: **Annual Decomposition, 'National Accounts model' compared to 'All CHS intangibles'**

	1	2	3	4	5	6	7	8	9	10	11	12
	DlnV/H	sDln(L/H)	sDln(K/L) cmp	sDln(K/L) telecom	sDln(K/L) othtan	sDln(K/L) intan	DlnTFP	*Memo: sLAB*	InnIndex1	InnIndex2	InnIndex3	InnIndex4
National Acc's Intangibles: just software (ONS); mineral exploration (ONS); artistic originals (GH)									*7/1*	*(6+7)/1*	*(2+6+7)/1*	*(6+7)*
1996	3.01%	0.08%	0.55%	0.04%	0.25%	0.30%	1.79%	0.62	0.60	0.69	0.72	2.09%
1997	1.79%	0.08%	0.45%	0.02%	-0.14%	0.22%	1.16%	0.61	0.65	0.77	0.82	1.38%
1998	3.57%	0.43%	0.88%	0.06%	0.51%	0.34%	1.35%	0.62	0.38	0.47	0.59	1.69%
1999	3.82%	0.39%	0.84%	0.11%	0.59%	0.25%	1.64%	0.64	0.43	0.49	0.60	1.89%
2000	4.26%	0.45%	0.83%	0.14%	0.63%	0.21%	2.00%	0.66	0.47	0.52	0.62	2.21%
2001	1.59%	0.05%	0.66%	0.07%	0.35%	0.10%	0.36%	0.67	0.23	0.29	0.32	0.46%
2002	2.75%	0.13%	0.47%	0.05%	0.88%	0.10%	1.12%	0.67	0.41	0.44	0.49	1.22%
2003	2.80%	0.57%	0.32%	0.01%	0.60%	0.10%	1.20%	0.66	0.43	0.46	0.67	1.30%
2004	3.20%	-0.20%	0.25%	0.03%	0.48%	0.09%	2.56%	0.65	0.80	0.83	0.76	2.65%
2005	1.66%	0.36%	0.21%	0.02%	0.40%	0.08%	0.59%	0.65	0.35	0.40	0.62	0.66%
2006	2.73%	0.36%	0.04%	0.02%	0.50%	0.11%	1.70%	0.65	0.62	0.67	0.80	1.82%
2007	2.13%	0.42%	0.13%	0.02%	0.49%	0.11%	0.96%	0.65	0.45	0.50	0.70	1.07%
2008	-0.69%	0.38%	0.06%	0.00%	0.62%	0.11%	-1.87%	0.64	2.69	2.53	1.98	-1.76%
2009	-2.90%	0.66%	-0.04%	0.01%	1.47%	0.19%	-5.20%	0.65	1.79	1.73	1.50	-5.02%
All CHS Intangibles												
1996	2.76%	0.08%	0.50%	0.04%	0.22%	0.49%	1.44%	0.56	0.52	0.70	0.73	1.93%
1997	2.22%	0.07%	0.41%	0.02%	-0.13%	0.48%	1.37%	0.56	0.62	0.83	0.87	1.85%
1998	3.95%	0.39%	0.80%	0.05%	0.46%	0.82%	1.43%	0.57	0.36	0.57	0.67	2.25%
1999	4.38%	0.35%	0.76%	0.10%	0.54%	0.94%	1.70%	0.58	0.39	0.60	0.68	2.64%
2000	4.52%	0.40%	0.75%	0.12%	0.57%	0.89%	1.78%	0.59	0.39	0.59	0.68	2.67%
2001	1.99%	0.05%	0.59%	0.06%	0.31%	0.69%	0.28%	0.60	0.14	0.49	0.51	0.97%
2002	2.67%	0.11%	0.42%	0.04%	0.78%	0.68%	0.64%	0.60	0.24	0.49	0.53	1.31%
2003	2.56%	0.51%	0.28%	0.01%	0.53%	0.39%	0.85%	0.60	0.33	0.48	0.68	1.23%
2004	2.94%	-0.18%	0.22%	0.02%	0.42%	0.25%	2.21%	0.59	0.75	0.84	0.77	2.45%
2005	2.09%	0.33%	0.19%	0.02%	0.35%	0.38%	0.82%	0.59	0.39	0.58	0.73	1.20%
2006	2.45%	0.32%	0.04%	0.01%	0.43%	0.31%	1.34%	0.59	0.55	0.67	0.80	1.64%
2007	2.01%	0.38%	0.11%	0.02%	0.42%	0.18%	0.89%	0.59	0.44	0.53	0.72	1.07%
2008	-0.97%	0.35%	0.06%	0.00%	0.53%	0.08%	-1.98%	0.58	2.04	1.96	1.60	-1.90%
2009	-2.82%	0.60%	-0.03%	0.01%	1.26%	0.43%	-5.09%	0.59	1.81	1.65	1.44	-4.66%

The above table is presented as a decomposition of labour productivity, with all terms expressed in terms of per hour worked. Obviously the recent recession has been associated with a strong fall in hours worked. Therefore to better understand how the raw capital services data is behaving, the following table is a decomposition of growth in value-added, unadjusted for hours worked. The contribution of labour therefore includes the volume of hours worked plus the impact of labour quality or composition.

Table 8**: Decomposition of output and the recession**

	1	2	3	4	5	6	7	8	9	10
	DlnV	sDln(L)	sDln(K) cmp	sDln(K) telecom	sDln(K) buildings	sDln(K) plant	sDln(K) vehicles	sDln(K) intan	DlnTFP	*Memo: sLAB*
All CHS Intangibles										
2006	2.83%	0.55%	0.05%	0.02%	0.31%	0.17%	0.04%	0.36%	1.34%	0.59
2007	3.19%	1.07%	0.13%	0.03%	0.39%	0.28%	0.05%	0.35%	0.89%	0.59
2008	-0.69%	0.51%	0.06%	0.00%	0.44%	0.17%	-0.01%	0.12%	-1.98%	0.58
2009	-7.50%	-2.18%	-0.10%	-0.02%	0.30%	-0.07%	-0.13%	-0.23%	-5.09%	0.59

The data show that the UK market sector suffered a massive 7.5% fall in value-added in 2009. Strong falls in market sector investment were enough to cause estimates of growth in capital services to turn negative. The exception is buildings, where the stock continued to grow. This reflects the fact that the rate of depreciation of buildings is lower than for other assets and the existing stock has a higher value. This means that a much sharper fall in investment is needed to generate a fall in the capital stock.

6.4 Contributions of individual intangible assets

Contributions of each tangible and intangible asset are set out in Table 9. Column 8 shows that software is an important driver, with a very strong contribution in the 1990s of between 0.18% and 0.23% p.a., but less so this century, contributing 0.10% p.a. Columns 9 and 10 show a small negative contribution for mineral exploration and a small positive contribution for artistic originals, although the latter are around double those when we use official ONS estimates. Columns 11 and 12 show the contribution of design to be above that of R&D in all periods, at around 0.06%pa with R&D at 0.03% p.a. in 2000-2009 (note R&D in this table includes R&D in financial services and social sciences, as well as scientific R&D). In columns 13 to 15, we show the contributions of advertising and marketing, training and organisational capital. Organisational capital is the most important here, with the contributions from all three declining in the 2000s.

Table 9: **Contributions of individual assets: Detailed breakdown**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	DlnV/H	**sDln(L/H)**	**sDln(K/L) cmp**	**sDln(K/L) telecom**	**sDln(K/L) buildings**	**sDln(K/L) P&M**	**sDln(K/L) vehicles**	**sDln(K/L) software**	**sDln(K/L) min**	**sDln(K/L) cop**	**sDln(K/L) aed**	**sDln(K/L) rd**	**sDln(K/L) brand**	**sDln(K/L) train**	**sDln(K/L) org**	**DlnTFP**	***Memo: sLAB***
1990-95	3.36%	0.21%	0.29%	0.01%	0.41%	0.35%	0.02%	0.18%	0.00%	0.03%	0.07%	0.04%	0.05%	0.09%	0.21%	1.38%	0.59
1995-00	3.57%	0.26%	0.64%	0.07%	0.20%	0.08%	0.06%	0.23%	-0.02%	0.03%	0.06%	0.03%	0.09%	0.13%	0.18%	1.54%	0.57
2000-09	1.43%	0.27%	0.21%	0.02%	0.31%	0.21%	0.04%	0.10%	-0.01%	0.01%	0.06%	0.03%	0.01%	0.06%	0.11%	-0.01%	0.59

Notes to table. Data are average growth rates per year for intervals shown. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in MGVA. Column 3 is growth in computer capital services per hour times share in MGVA. Column 4 is growth in telecommunications capital services per hour times share in MGVA. Column 5 is growth in capital services from buildings per hour times share in MGVA. Column 6 is growth in capital services from plant & machinery (excluding computers and telecoms equipment) per hour times share in MGVA. Column 7 is growth in capital services from vehicles per hour times share in MGVA. Column 8 is growth in software capital services Column 9 is growth in capital services from mineral exploration per hour times share in MGVA. Column 10 is growth in capital services from copyright (artistic originals) per hour times share in MGVA. Column 11 is capital services from design per hour times share in GVA. Column 12 is growth in broadly defined R&D (including non-scientific R&D and financial product development) capital services per hour times share in GVA. Column 13 is capital services from advertising and market research per hour times share in MGVA. Column 14 is capital services from firm-level training per hour times share in MGVA. Column 15 is organisational capital services per hour times share in MGVA. Column 16 is TFP, namely column 1 minus the sum of columns 2 to 15. Column 17 is the share of labour payments in MGVA.

6.5 Impact of alternative deflators for intangible assets

Whilst a great deal has been done to improve estimates of investment in knowledge assets, less has been done on estimation of their prices. Such estimation is difficult as a feature of these assets is that they are rarely acquired via market transactions. Indeed one of the benefits of ownership is the sole right to knowledge unavailable to market competitors. Therefore much investment takes place in-house, and no market price can be recorded. For this reason the standard approach for deflating investment in most intangible assets has been to use a value-added deflator, implicitly assuming that their prices closely follow a weighted average of prices in the rest of the economy.

Corrado, Goodridge and Haskel (CGH, 2011) use industry productivity data to show that the implied price of R&D assets has been falling strongly over time due to technical progress in the upstream, or knowledge production, sector. Their final estimate of a price index for R&D falls at 7.5% p.a. on average between 1985 and 2005. Obviously replacing a value-added deflator which typically rises at a rate of 4-5% p.a. with the CGH R&D deflator has a considerable impact on measures of real R&D investment, the R&D capital stock, and the contribution of R&D capital deepening to growth in labour productivity, as shown below in Table 10. Panel 1, column 8 presents estimates of the contribution of R&D capital deepening where R&D has been deflated using a value-added price index. Panel 2 presents estimates which use the CGH R&D deflator, with contributions as much as six times greater in the early 1990s.

That result is based on estimated strong productivity growth in the creation of R&D assets. It could of course be the case that productivity growth has also been growing strongly in the creation of other knowledge assets. Consider own-account software. The official ONS own-account software deflator is based on the wages of software professionals with a small downward adjustment based on labour productivity growth in the wider service sector. However if productivity in the creation of own-account software has been rising faster than productivity in the wider service sector, then the software asset price index will over-estimate price changes and underestimate growth in real investment and software capital services.

Instead of using an adjusted wage index for software professionals, one option would be to use the same deflator as that for purchased software. After all it would seem reasonable to assume that growth in the productivity of creating own-account software is similar to that in creating software that is sold in the marketplace. That is what we use in Panel 3, resulting in an increase in the contribution of total software of around a quarter.

Another option available is to use the own-account and purchased software deflators produced by the BEA. Doing that produces the estimates presented in Panel 4, with the impact on the total contribution of software capital deepening slightly greater than that in Panel 3.

Table 10: **Alternative deflators for intangible assets**

	1	2	3	4	5	6	7	8	9	10	11
	DlnV/H	**sDln(L/H)**	**sDln(K/L) cmp**	**sDln(K/L) telecom**	**sDln(K/L) othtan**	**sDln(K/L) software**	**sDln(K/L) innov less rd**	**sDln(K/L) rd**	**sDln(K/L) ec comp**	**DlnTFP**	***Memo: sLAB***
1) Baseline											
All CHS Intangibles											
1990-95	3.36%	0.21%	0.29%	0.01%	0.78%	**0.18%**	0.10%	**0.04%**	0.35%	1.38%	0.59
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	**0.23%**	0.06%	**0.03%**	0.40%	1.54%	0.57
2000-09	1.43%	0.27%	0.21%	0.02%	0.56%	**0.10%**	0.07%	**0.03%**	0.17%	-0.01%	0.59
2) CGH R&D deflator											
All CHS Intangibles											
1990-95	3.64%	0.21%	0.29%	0.01%	0.78%	0.18%	0.10%	**0.25%**	0.35%	1.45%	0.59
1995-00	3.63%	0.26%	0.64%	0.07%	0.33%	0.23%	0.07%	**0.15%**	0.40%	1.48%	0.57
2000-09	1.53%	0.27%	0.21%	0.02%	0.56%	0.10%	0.07%	**0.14%**	0.17%	-0.02%	0.59
3) Using UK purchased software deflator for own-account											
All CHS Intangibles											
1990-95	3.36%	0.21%	0.29%	0.01%	0.79%	**0.23%**	0.10%	0.04%	0.35%	1.33%	0.59
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	**0.27%**	0.07%	0.03%	0.40%	1.50%	0.57
2000-09	1.43%	0.27%	0.21%	0.02%	0.56%	**0.12%**	0.07%	0.03%	0.17%	-0.03%	0.59
4) Using US (BEA) software deflators for purchased and own-account											
All CHS Intangibles											
1990-95	3.36%	0.21%	0.29%	0.01%	0.79%	**0.23%**	0.10%	0.04%	0.35%	1.33%	0.59
1995-00	3.57%	0.26%	0.64%	0.07%	0.33%	**0.28%**	0.07%	0.03%	0.40%	1.49%	0.57
2000-09	1.43%	0.27%	0.21%	0.02%	0.56%	**0.14%**	0.07%	0.04%	0.17%	-0.05%	0.59

Note to table. Panel 1 are baseline estimates as presented previously. Panel 2 uses the R&D deflator developed in Corrado, Goodridge and Haskel (2011). Panel 3 uses the deflator for purchased software to also deflate own-account, with the implicit assumption being that productivity in the creation of own-account software is similar to that in the software industry itself. Panel 4 uses official US BEA deflators for purchased and own-account software, where the latter incudes a productivity adjustment based on the purchased software data.

6.6 Comparison with previous estimates

This report is an update on previous work, including estimates of the Innovation Index funded by NESTA. The following table compares the results in this report with those in the previous NESTA Innovation Index (Haskel et al, 2010). The results differ for a number of reasons which are expanded on further in Appendix 2. In short there have been changes to:

- estimated growth in labour services (and underlying hours) and (tangible and intangible) capital deepening, due to the addition of a new industry to our market sector definition[21];

---

[21] Our dataset remains based on SIC03. To maintain compatibility we therefore do not use real output data based on SIC07, as published in BB2011. Whilst this means our data do not reflect the revisions

- estimated growth in tangible capital services due to revisions to ONS asset price deflators and Gross Operating Surplus
- estimated rentals due to updated deflators and the introduction of tax adjustment factors to the estimation, and
- estimated growth in intangible capital deepening due to improved methodologies to remove potential double-counting in purchased investments, and to better estimate investments in artistic originals

As a result of these changes, relative to the last report our data show improved growth in labour productivity in the 1990s but lower growth in the 2000s; stronger growth in labour composition in all periods; stronger growth in tangible capital deepening in tall periods and stronger growth in intangible capital deepening throughout the 1990s, but weaker growth in the 2000s. TFP is also estimated as weaker in the late 1990s and 2000s relative to the previous report. The increase in the contribution of tangible capital deepening is largely a result of incorporating new tax adjustment factors as described above, increasing the factor income shares of tangible assets relative to intangible assets compared to previous results. The reduction in estimated TFP is largely due to the introduction of the personal services (‘O’) industry into our dataset. Estimated TFP in this industry is consistently strongly negative. Since this industry makes up 7% of market sector value-added and 8% of hours worked, and invests relatively heavily in intangible assets, we consider the inclusion of this industry a significant development in our dataset. However, the industry data also suggests there may be significant issues with official measures of prices and quantities which hamper analysis.

Table 11: **Comparison with previous results**

	1	2	3	4	5
	DlnV/H	**sDln(L/H)**	**sDln(K/L) tang**	**sDln(K/L) intang**	**DlnTFP**
NESTA (2012) All CHS Intangibles, (SIC03: A-K & OP)					
1990-95	3.36%	0.21%	1.09%	0.68%	1.38%
1995-00	3.57%	0.26%	1.04%	0.73%	1.54%
2000-08	1.97%	0.23%	0.73%	0.37%	0.63%
NESTA (2010) All CHS Intangibles (SIC03: A-K)					
1990-95	2.94%	0.17%	0.95%	0.64%	1.19%
1995-00	3.53%	0.25%	0.74%	0.67%	1.87%
2000-08	2.69%	0.17%	0.68%	0.55%	1.30%

---

to growth published in BB2011, due to changes in industry output deflators, it also means our data does not suffer from a break in series at the time of the switch between use of retail (RPIs) and consumer (CPIs) price indices in the late 1990s.

Note to table. For comparison, data are based on the same periods. The top panel are our most recent results that incorporate a new industry and tax adjustment factors for all assets. The bottom panel includes neither of these features, hence the differences in productivity growth and the factor contributions.

7 Growth accounting results: industry-level

Our industry growth accounting is feasible between 2000-07.[22] Thus we start with comparing our aggregated market sector results with those using ONS data to check the two are closely comparable. Then we look more closely industry by industry.

7.1 Comparing aggregated KLEMS industry data with ONS data

Table 12 sets out our results**.** The top row shows the use of ONS data, with intangibles, 2000-07. The second row shows the results for 2000-07, with intangibles, using the aggregated ONS industry data. $\Delta \ln V/H$ is 15 percentage points higher with EUKLEMS. There are also bigger differences to some of the contributions compared to our previous work. The reasons are as follows. First, ONS data on tangible capital have been revised, increasing real investment and the contribution of capital deepening for other tangibles. Second, our series on labour composition was only produced using ONS hours and we have not produced a version based on KLEMS hours for the industry decomposition. Third, we have incorporated an additional industry into our decomposition. Fourth we have incorporated tax adjustment factors for all assets.

7.2 Results by industry

To build up the industry contributions to these overall figures we start with the industry-by-industry results in Table 13. These are on a gross output basis: we show how they relate to the whole economy value-added level below.

[22] We have data based on the Supply-Use Tables back to 1992, but due to uncertainty about initial capital stocks we confine ourselves to growth accounting starting in 2000.

Table 12: **Growth accounting: comparison of ONS market sector and Domar-weighted Market Sector Aggregates, 2000-07**

	1	2	3	4	5	6	7
		Capital deepening contributions:					
	ALPG	**Total**	**Computers & Telecoms**	**Other tang**	**Intangibles**	**Labour Composition**	
	DlnV/H	**sDln(K/H)**	**sDln(K/H) cmp**	**sDln(K/H) othtan**	**sDln(K/H) intan**	**sDln(L/H)**	**DlnTFP**
ONS data, with all CHS intangibles	2.39%	1.16%	0.29%	0.46%	0.41%	0.22%	1.00%
KLEMS, with all CHS intangibles	2.54%	1.09%	0.33%	0.35%	0.41%	0.27%	1.18%

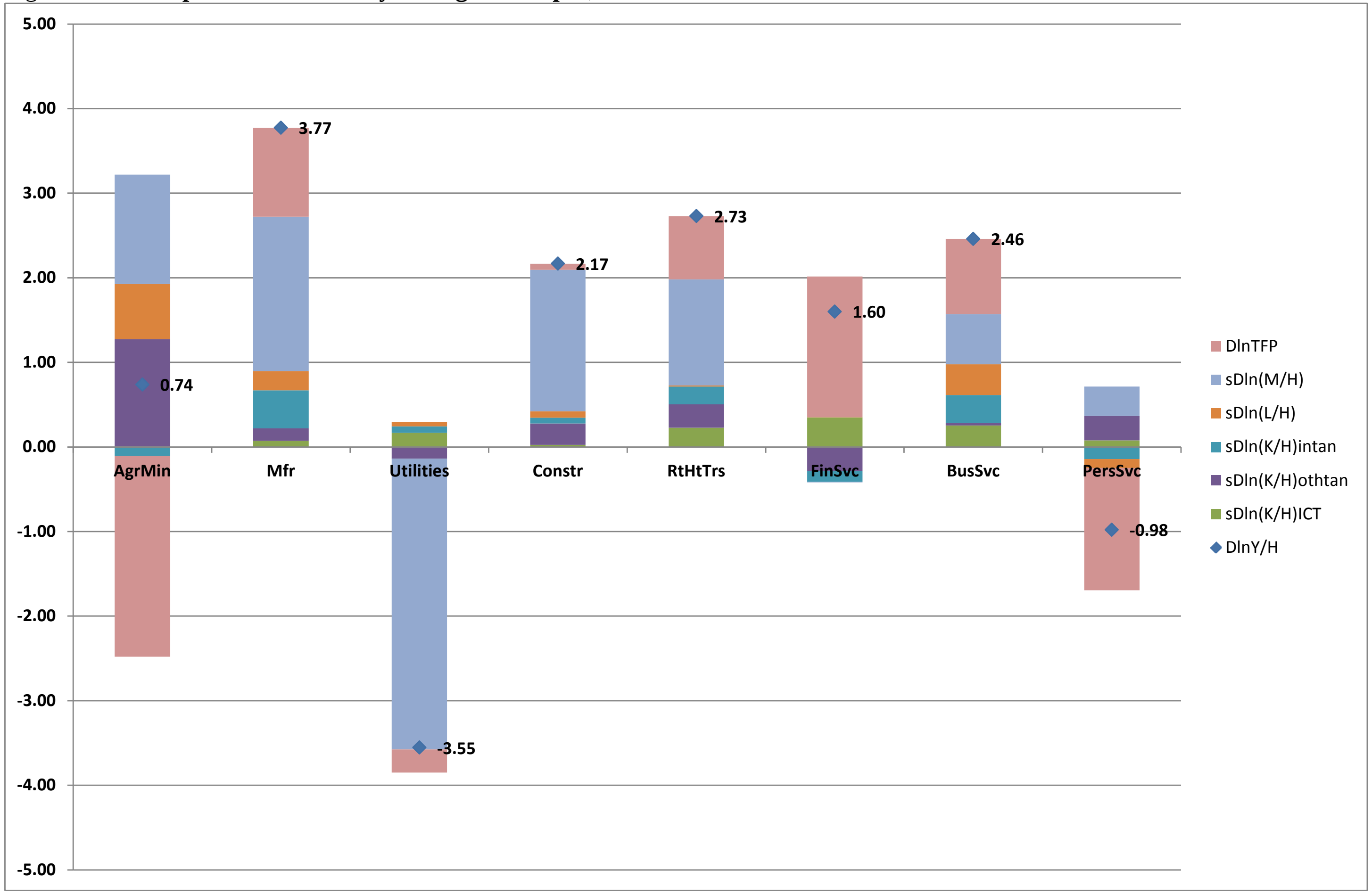
Note: All figures are average annual percentages. The contribution of an output or input is the growth rate weighted by the corresponding average share. Columns are annual average change in natural logs of: column 1, real value added per hour, column 2, contribution of total capital (which is the sum of the next three columns), column 3, contribution of ICT (computer hardware and telecommunications) capital, column 4, contribution of other non-ICT tangible capital, column 5, contribution of intangibles, column 6, contribution of labour quality per person hour, column 7, TFP, being column 1 less the sum of column 2 and column 6. Row 1 is based on ONS data with the capitalisation of intangibles for the market sector. Row 2 is EUKLEMS data, with intangibles, 2000-07, aggregated to the market sector. In each the market sector is defined using our definition of SIC(2003) A-K plus OP excluding dwellings. **Source**: authors' calculations

Table 13: **Industry level gross output growth accounting, 2000-2007, including intangibles**

Industry	**DlnY/H**	**sDln(K/H)**	**sDln(K/H)ICT**	**sDln(K/H)othtan**	**sDln(K/H)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
2000-07								
AgrMin	0.74	1.16	0.01	1.27	-0.11	0.65	1.29	-2.37
Mfr	3.77	0.67	0.07	0.15	0.45	0.23	1.82	1.05
Utilities	-3.55	0.11	0.17	-0.14	0.07	0.05	-3.44	-0.27
Constr	2.17	0.35	0.02	0.25	0.07	0.08	1.67	0.07
RtHtTrs	2.73	0.71	0.23	0.28	0.21	0.01	1.25	0.75
FinSvc	1.60	-0.06	0.35	-0.28	-0.13	0.00	-0.01	1.66
BusSvc	2.46	0.61	0.25	0.03	0.33	0.36	0.59	0.89
PersSvc	-0.98	0.22	0.08	0.29	-0.14	-0.11	0.35	-1.45

Note: All figures are average annual percentages. The contribution of an output or input is the growth rate weighted by the corresponding average share. Columns are annual average change in natural logs of: column 1, real gross output per hour, column 2, contribution of total capital (which is the sum of the next three columns), column 3, contribution of ICT (computer & telecoms) capital, column 4, contribution of other non-ICT tangible capital, column 5, contribution of intangibles, column 6, contribution of labour quality per person hour, column 7, contribution of intermediates, column 8, TFP, being column 1 less the sum of column 2, 6 and 7. Note also that Health & Safety and induction training are excluded from the investment figures used for the above calculation in the case of the service sector but not in the production sector. **Source**: authors' calculations

Figure 5: **Decomposition of industry-level gross output, 2000-07**



Note to figure: Data as presented in Table 13. Data are annual average growth rates for 2000-07. All CHS intangibles capitalised. Labelled data points are growth in real gross output per hour. Stacked bars are contributions from labour composition, capital deepening (for broad asset definitions) and intermediate inputs, all expressed in terms of per hour worked, and TFP.

We just report the results including all intangibles. Column 1 shows ΔlnY/H, growth in *gross* output per employee-hour. It is negative in Electricity, Gas, Water, and Personal Services, otherwise positive particularly in manufacturing, business services, and trade and communications. Column 2 shows total capital deepening per employee-hour, being strongly positive in those same industries, but negative in financial services. Columns 3, 4 and 5 shed some light on this. The contribution of computer hardware is strongest in financial and business services, and note particularly weak in manufacturing. The contribution of other tangibles (buildings, vehicles etc.) is actually negative in financial services, as is the contribution of intangibles in that industry. It is worth nothing that employee-hours are growing very fast in financial services (the second largest growth in the economy behind business services) and that intangible capital is falling after the massive investment in the late 1990s. So capital deepening per hour is falling, thus rendering the contribution of growth in capital per hour negative. However, this also slows down ΔlnY/H, so it turns out that ΔlnTFP still falls in financial services when we add intangibles (see table Appendix 1, without intangibles, ΔlnTFP=1.84%): thus intangibles do help account for the TFP residual.

Looking at Personal Services in the final row we see that growth in labour productivity is negative over the period considered as is TFP and the contribution of intangibles. The contribution of tangibles however is stronger. Measured TFP is higher in the Appendix table, where no intangibles are included. This result is a consequence of the measured falls in labour productivity, forcing a negative contribution from TFP and intangible capital deepening, and suggests potential issues with the measurement of prices and quantities in this sector. There are a number of reasons for this.

First the industry does include a significant amount of non-market activity. It also includes a lot of ‘cultural’ activity which is in fact heavily subsidised, including museums, galleries and theatres. These features raise numerous issues for the measurement of output. Second, it is notoriously difficult to accurately measure prices and quantities in the service sector. Despite suspicions on the accuracy of the real output and TFP measures for this sector, we felt it important to include as it does house some important investors in UK knowledge assets, such as those in film, television, media, artistic creation etc. Given that this is a significant industry in size in terms of both nominal value-added and employment, and includes activity where the UK is considered to have a comparative advantage, improving measurement of its output is a first order issue. In terms of presentation, we expect our future work to benefit from the improved classification of the service sector in SIC2007.

Columns 6 and 7 show the contributions of labour composition and intermediates, and column 8 shows ΔlnTFP. ΔlnTFP grows particularly fast in finance and manufacturing.

So the overall picture of intangibles at the industry level is as follows. In manufacturing, labour productivity is high, particularly with a lot of labour shedding. About 28% of that LPG is due to TFPG, with 12% due to intangible growth and 6% due to labour quality. In financial services, measured labour productivity is lower, in fact less than half the rate of manufacturing, but TFP is growing faster than labour productivity in that sector, with the overall contribution of capital negative but a positive contribution from computers. So manufacturing is very much driven by within-industry intangible investment, whilst finance is very much driven by TFP (would could of course reflect within-industry spillovers of intangible investment). In the distributive trades, together computers and intangibles account for around 16% of LPG and in business services they account for 24%. Figure 4 presents the same data but in graphical form.

Finally, the appendix shows the impact of adding intangibles, which is that ΔlnY/H is higher and ΔlnTFP is lower than without intangibles. Thus for example, without intangibles one would conclude ΔlnTFP=1.62% instead of 1.18% here with.

7.3 Contributions of individual industries overall performance

The contribution of each industry to the overall market economy is a combination of their contributions within each industry and the weight of each industry in the market sector. Thus for example, there may be much innovation in manufacturing but it might be a small sector in the market sector as a whole. Table 14 sets this out.

Table 14: **Industry contributions to growth in aggregate value added, capital deepening, labour quality and TFP (growth rates and contributions are %pa per employee hour, 2000-07)**

	1	2	3		4	5	6	7	8		9	10		11	12	13		*14*	15	16
	Value added				Capital contributions						Labour contrib			TFP						
							of which													
Industry	**VA weight**	**DlnVA/H**	**contrib to agg va/h**		**Cap weight**	**Contrib to agg K/H**	**Contrib to agg ICT dlnK/H**	**Contrib to agg non-ICT dlnK/H**	**Contrib to agg Intan/H**		**Lab weight**	**Contrib to agg lab qual per hr**		**Domar weight**	**DlnTFP**	**Contrib to agg TFP**		***Memo: % total hrs***		
Agriculture; Mining	0.04	-0.80	-0.03		0.03	0.08	0.00	0.09	-0.01		0.01	0.04		0.07	-2.37	-0.16		*3%*		
Manufacturing	0.20	4.81	0.98		0.07	0.35	0.04	0.08	0.23		0.14	0.11		0.51	1.05	0.52		*17%*		
Utilities	0.02	-0.65	-0.01		0.02	0.00	0.01	-0.01	0.00		0.01	0.00		0.07	-0.27	-0.02		*1%*		
Construction	0.08	1.21	0.09		0.02	0.07	0.00	0.05	0.01		0.06	0.01		0.19	0.07	0.01		*10%*		
Distribution; Hotels; Transport	0.30	2.76	0.83		0.10	0.40	0.13	0.15	0.12		0.20	0.01		0.56	0.75	0.42		*36%*		
Finance	0.09	3.37	0.30		0.04	-0.02	0.06	-0.05	-0.03		0.05	0.00		0.19	1.66	0.32		*5%*		
Business Services	0.19	2.92	0.55		0.06	0.18	0.07	0.01	0.10		0.13	0.11		0.29	0.89	0.26		*20%*		
Personal Services	0.07	-2.09	-0.15		0.02	0.03	0.01	0.03	-0.02		0.06	-0.01		0.11	-1.45	-0.17		*8%*		
Sum	***1.00***		***2.54***			***1.09***	***0.33***	***0.35***	***0.41***			***0.27***		***1.99***		***1.18***		***100%***		
%ages of summed contributions																		***Memo: % total hrs***	***(8 + 13)/ (S8+S13)***	***(8+10+13)/ (S8+S13+Σ10)***
Agriculture; Mining			*-1%*			*8%*	*0%*	*26%*	*-2%*			*16%*				*-14%*		*3%*	*-11%*	*-7%*
Manufacturing			*38%*			*32%*	*12%*	*22%*	*56%*			*41%*				*44%*		*17%*	*47%*	*46%*
Utilities			*-1%*			*0%*	*3%*	*-3%*	*1%*			*1%*				*-2%*		*1%*	*-1%*	*-1%*
Construction			*4%*			*6%*	*1%*	*14%*	*3%*			*5%*				*1%*		*10%*	*2%*	*2%*
Distribution; Hotels; Transport			*32%*			*37%*	*39%*	*44%*	*29%*			*3%*				*35%*		*36%*	*34%*	*29%*
Finance			*12%*			*-2%*	*20%*	*-15%*	*-7%*			*0%*				*27%*		*5%*	*18%*	*15%*
Business Services			*22%*			*16%*	*22%*	*3%*	*24%*			*40%*				*22%*		*20%*	*22%*	*25%*
Personal Services			*-6%*			*2%*	*3%*	*10%*	*-4%*			*-5%*				*-14%*		*8%*	*-12%*	*-11%*
Sum			***100%***			***100%***	***100%***	***100%***	***100%***			***100%***				***100%***		***100%***	***100%***	***100%***

Note: All figures are annual averages. Weights depend on the industry share in aggregate value-added, the input share in gross output and the share of value-added in gross output. Contributions are the product of the weights and the input growth averaged over years. Employment is the share of the industry's hours worked over total hours worked by persons engaged. Column 5 is the sum of columns 6, 7, 8. Column 13= column 11 times 12.

Source: authors' calculations

In the left panel columns 1, 2 and 3 show respectively the industry weights in market sector value added, average ΔlnV/H and the contribution to aggregate value added (which is not quite the product of columns 1 and 2, since the average of a product is not the product of two averages). In the final row, the weights on value added sum to unity and the sum of contributions is the market-sector total as shown in row 2 of table 12 above. The middle panels show the capital and labour contributions which again sum to the market sector total. The right panel shows industry ΔlnTFP and its Domar weight, each industries contribution and confirms the weighted sum duplicates the aggregate. Finally, as a memo item, column 14 shows actual hours worked as a fraction of the total. The lower panel shows the contributions as a proportion of the total.

What do we learn about the economy from this table? Let us start by considering manufacturing. As the top panel shows, column 1, its value added weight in the market sector is 20%, although column 14 shows the employment share is 17% (note these are higher than the shares in the whole economy which are the weights usually quoted). Column 5 shows that the contribution of manufacturing capital deepening to aggregate capital deepening is 0.35%pa, which is, lower panel, 32% of the total. Column 8 shows that the contribution of intangibles in manufacturing is significant: 56% (see lower panel) of the total intangible contribution. Columns 10 and 13 show the contribution of labour quality and ΔlnTFP, 41% and 44% respectively of the total. Finally, Column 15 (lower panel), shows that manufacturing contributes 47% of the total contribution of intangible capital deepening and ΔlnTFP. Thus manufacturing, accounting for 20% of value added and 17% of employment, accounts for 56% of total intangible capital deepening and 44% of ΔlnTFP. The importance of intangible investment in manufacturing of course suggests that a significant component of the activity of firms allocated to manufacturing in the SIC is the production of knowledge assets, which might be regarded as producing a service.

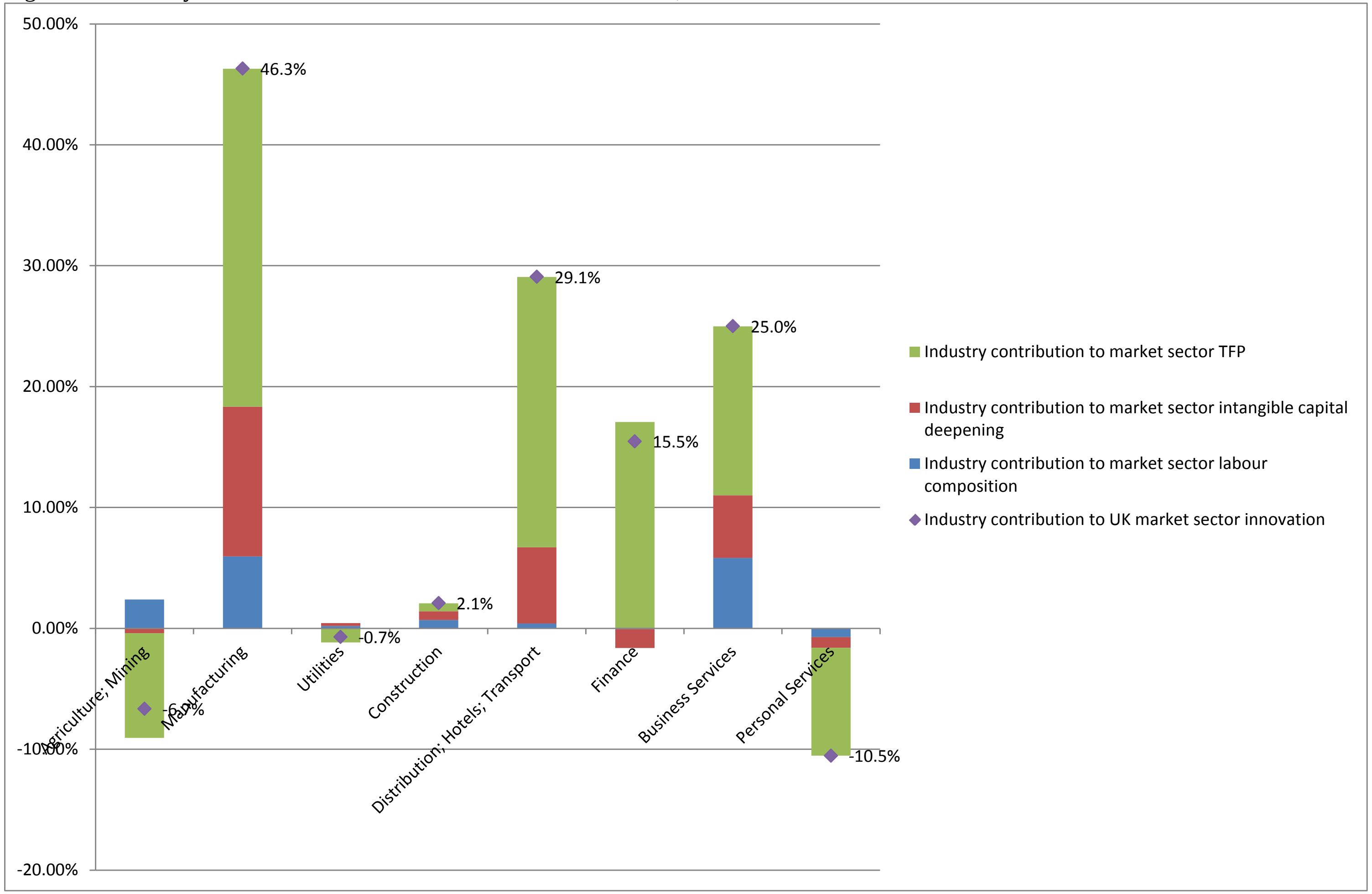
What of other industries? The other large contributions of capital deepening are from the distributive trades which are also grouped with communications, and business services. Within these, ICT capital deepening is very important in distribution and communications, whose ICT capital deepening accounts for 39% of the total. Intangible capital deepening in business services and distribution/communications account for 24% and 29% of the total as well.

Turning to labour composition, manufacturing and business services alone account for 81% of it. Finally, on ΔlnTFP, after manufacturing, trade and communications account for 35%, so that just these two sectors combined account for 79% of market sector ΔlnTFP. Finance and business services account for 49%. Note that whilst the ΔlnTFP of finance exceeds that of for all other industries including manufacturing, the Domar weight for finance is smaller than that for manufacturing, business services, and distribution/communications, so the contribution to total ΔlnTFP is smaller too.

Finally, one might summarise these results by asking what industries account for the contribution of knowledge investment to ΔlnV/H? If we define knowledge investment as the contributions of ΔlnTFP+sΔlnK/H(intang) to the total, we see that manufacturing accounts for 47%, trade, transport & communications 34%, business services 22% and financial services 18% (the numbers are very similar if we add sΔlnL/H, namely 46%, 29%, 25% and 15%).

This same data is also presented in graphical form below which highlights the contribution of manufacturing to total UK market sector innovation.

Figure 6: **Industry contributions to UK market sector innovation, 2000-2007**



Note to figure: data as presented in Table 14. All figures are weighted annual averages, where domar weights depend on the industry gross output as a share in aggregate value-added. Contributions are the product of the weights and the input growth averaged over years.

One important question, we believe, is to ask how these results compare to those without intangibles? The results without intangibles are set out in the appendix, but the main results are as follows. First, without intangibles, ΔlnTFP is 1.62 (against 1.18 above). But note that the contribution above of ΔlnTFP and intangible capital deepening is 1.18+0.41 = 1.59, very close to ΔlnTFP without intangibles, which accounts for 1.59/2.54= 63% of economic growth against 1.62/2.70=60% without intangibles. So in this calculation the total "innovation" contribution turns out to about the same, but intangibles accounts for a quarter of the residual. Second, the industry contributions are different. As we have seen here with intangibles, manufacturing and financial services account for 47% and 18% of final innovation. Without intangibles, manufacturing and financial services ΔlnTFP account for 40% and 25% of ΔlnV/H. So without intangibles financial services ΔlnTFP is overstated.

8 Conclusions

This paper provides an update of the NESTA Innovation Index, combining a number of threads of recent work on the rise of the knowledge economy. First, analysis of ICT suggested that computers need complementary investment in organizations, human capital and reputation. Second, a growing perception that the knowledge economy is becoming increasingly important has led to the treating of software and R&D (upcoming) in the national accounts as investment. To study the questions that arise we have used the CHS framework, extended its measurement method somewhat using new data sets and a new micro survey, and implemented it on UK data for all intangibles in addition to R&D and software. We have documented intangible investment in the UK and tried to see how it contributes to economic growth. We find the following.

1. Investment in knowledge.
    a. Investment in knowledge, which we call intangible assets, is now greater than investment in tangible assets, at around, in 2009, £124bn and £93bn respectively, 12% and 9% of (adjusted) MSGVA, quantifying the UK move to a knowledge-based economy.
    b. In 2009, R&D was about 11% of total intangible investment, software 18%, design 12%, and the largest categories (21%) training and organizational capital. Approximately 70% of intangible investment is own account.
    c. The most intangible-intensive industry is manufacturing (intangible investment as a proportion of value added =17%), closely followed by personal services (=16%), a new addition to our dataset. Manufacturing,

financial services, construction and business services invest between 2 and 3 times more in intangibles than in tangibles. In personal services the ratio is around 1:1 in what is a capital intensive sector.

d. The effect of treating intangible expenditure as investment is to raise growth in market sector value added in the late 1990s (the internet investment boom), but have little impact in the 2000s.

2. Contribution to growth, 2000-09.

a. For the most recent period of 2000-2009, intangible capital deepening accounts for 26% of growth in market sector value added per hour ($\Delta \ln V/H$), a larger contribution than ICT tangibles (computer hardware and telecommunications) (16%) and labour quality (19%), . The 2000s have seen a close to zero contribution from $\Delta \ln TFP$, driven by large declines in the last two years.

b. With (without) intangibles $\Delta \ln V/H$ 1.43%pa (1.44%pa) and $\Delta \ln TFP$ is -0.01%pa (0.17%pa). Thus adding intangibles to growth accounting lowers $\Delta \ln TFP$ and $\Delta \ln V/H$ is unaffected.

c. Capitalising R&D relative to the current practice of capitalizing software (plus mineral exploration and artistic originals) adds 0.04% to input growth and reduces $\Delta \ln TFP$ by 0.02%., with $\Delta \ln V/H$ unaffected.

d. If innovation is measured as $\Delta \ln TFP$ plus the contribution of intangible capital deepening, then innovation has contributed 26% of growth in labour productivity with intangibles and 12% without. Adding the contribution of labour composition gives 45% of $\Delta \ln V/H$ with intangibles and 34% without.

3. *Contribution by industries to growth*. The main finding here is the importance of manufacturing, which accounts for around half of innovation (measured either as intangible capital deepening plus TFP, or intangible capital deepening plus TFP plus labour quality) in the UK market sector. This is due to a combination of its high intangible investment (56% of total intangible contribution) and TFP (44% of total contribution), even though manufacturing is a comparatively small sector in terms of employment share (17% of market sector hours worked). We also find important contributions of retail/hotels/transport/communications, accounting for 34% of innovation, business services contributes 22% and finance 18%.

In future work, we hope to improve the measures of all variables. We also wish to explore policy and the total contributions of various assets by looking for spillovers. So, for example, it is quite conceivable that R&D spillovers will greatly amplify the contribution of R&D.

References

Acheson, J (2011), “Quality-adjusted labour input: new quarterly estimates for 1993 to 2009 and annual estimates from 1970”, Economic and Labour Market Review, Palgrave Macmillan Journals, vol. 5(4), pages 22-46, April

Awano, G., Franklin, M., Haskel, J., and Kastrinaki, Z, (2010). "Measuring investment in intangible assets in the UK: results from a new survey," Economic and Labour Market Review, Palgrave Macmillan Journals, vol. 4(7), pages 66-71, July.

Barnett (2009), UK Intangible Investment: Evidence from the Innovation Index Survey

Basu, S., J. G. Fernald, et al. (2004). "The case of the missing productivity growth, or does information technology explain why productivity accelerated in the United States but not in the United Kingdom?" NBER Macroeconomics Annual 2003 18: 9-+.

Brynjolfsson, E. and L. M. Hitt (2000). "Beyond computation: Information technology, organizational transformation and business performance." Journal of Economic Perspectives 14(4): 23-48.

Clayton, T., Dal Borgo, M. and Haskel, J. (2008), An Innovation Index Based on Knowledge Capital Investment: Definition and Results for the UK Market Sector, Draft Report for NESTA Innovation Index 2008 Summer Project.

Clayton, T., Dal Borgo, M., and Haskel, J., (2008), “An Innovation Index Based on Knowledge Capital Investment: Definition and Results for the UK Market Sector”, Report for NESTA, http://www.coinvest.org.uk/bin/view/CoInvest/CoinvestInnovIndex

Corrado, C. A., Hulten, C. R. and Sichel, D. E. (2005). Measuring Capital and Technology: An Expanded Framework. In Measuring Capital in the New Economy, Vol. 65 (Eds, Corrado, C. A., Haltiwanger, J. C. and Sichel, D. E.). Chicago: The University of Chicago Press

Corrado, C., Hulten, C. and Sichel, D. (2009). “Intangible Capital and US Economic Growth”. The Review of Income and Wealth, (55:3), pp. 661-685.

Domar, E. D. (1961). On the Measurement of Technological Change. The Economic Journal 71, 709-729.

EU KLEMS Database, March 2008, see Marcel Timmer, Mary O'Mahony & Bart van Ark, The EU KLEMS Growth and Productivity Accounts: An Overview, University of Groningen & University of Birmingham; downloadable at www.euklems.net

Fukao, K., T. Miyagawa, et al. (2009). "Intangible Investment in Japan: Measurement and Contribution to Economic Growth." Review of Income and Wealth 55(3): 717-736.

Galindo Rueda, F., Haskel, J., and Pesole, A., (2008), "How much does the UK spend on Design", working paper, www.ceriba.org.uk.

Jorgenson, D,. Ho, M, Samuels, J. Stiroh, K., (2007), "Industry Origins of the American Productivity Resurgence, Economic Systems Research, Vol. 19, No. 3, September 2007, pp. 229-252.

Gill, V, and Haskel, J, (2008), "Industry-level Expenditure on Intangible Assets in the UK", working paper, http://www.coinvest.org.uk/bin/view/CoInvest/CoinvestGilHaspaper

Goodridge, P., and J., Haskel (2011), "Film, Television & Radio, Books, Music and Art: UK Investment in Artistic Originals", working paper, http://www.ceriba.org.uk/bin/view/CERIBA/IPOArtisticOriginals

Goodridge, P., Haskel, J. and Wallis, G. (2012). "The Contribution of the Internet and Telecommunications Capital to UK Market Sector Growth", available on request.

Hulten, C.R. (1978), "Growth Accounting with Intermediate Inputs," Review of Economic Studies,. 45, October 1978, 511-518.

Hulten, C R. (2001). "Total Factor Productivity: A Short Biography." In Studies in Income and Wealth Volume 65, New Developments in Productivity Analysis, Chicago: The University of Chicago Press.

Jorgenson, D. W., (2007). Productivity. Cambridge, Mass.: MIT Press.

Jona-Lasinio, C., Iommi, M. and Roth, F. (2009). "Intangible Capital and Innovations: Drivers of Growth and Location in the EU". INNODRIVE, Deliverable No. 15, WP9.

Jorgenson, Dale W. and Zvi Griliches, "The Explanation of Productivity Change," Review of Economic Studies, 34, July 1967, 349-83.

Jorgenson, D. W., Ho, M. S., Samuels, J. D. and Stiroh, K. J. (2007). Industry Origins of the American Productivity Resurgence. Economic Systems Research, Taylor and Francis Journals 19, 229-252.

Marrano, M. G., Haskel, J. and Wallis, G. (2009). What Happened to the Knowledge Economy? ICT, Intangible Investment and Britain's Productivity Record Revisited. The Review of Income and Wealth Series 55, Number 3, September.

O'Mahony, M. and M.P. Timmer (2009), "Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database", Economic Journal, 119(538), pp. F374-F403

O'Mahony, M., and Peng, L, (2010), Workforce Training, Intangible Investments and Productivity in Europe: Evidence from EU KLEMS and the EU LFS", Working Paper.

OECD (2002), Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition, http://www.oecd.org/document/23/0,3343,en_2649_34273_35595607_1_1_1_37417,00.html

Oulton, N. (2007). "Ex post versus ex ante measures of the user cost of capital." Review of Income and Wealth(2): 295-317.

Oulton, N and Srinivasan. S., (2003), "Capital Stocks, Capital Services, and Depreciation: An Integrated Framework," Bank of England Working Paper, No. 192.

Timmer, M.P., M. O'Mahony, B. van Ark and R. Inklaar (2010), Economic Growth in Europe, Cambridge University Press.

Tufan,o, P., (1998), “"Financial Innovation and First-Mover Advantages," Journal of Financial Economics 25 (1989), 213-240

van Ark, B. and Hulten, C. (2007). "Innovation, Intangibles and Economic Growth: Towards a Comprehensive Accounting of the Knowledge Economy". Yearbook on Productivity 2007, Statistics Sweden, pp. 127-146.

van Rooijen-Horsten, M., van den Bergen, D. and Tanriseven, M. (2008). Intangible Capital in the Netherlands: A Benchmark. Available at http://www.cbs.nl/NR/rdonlyres/DE0167DE-BFB8-4EA1-A55C-FF0A5AFCBA32/0/200801x10pub.pdf

van Ark, B, Hao, J. X. & Corrado, C & Hulten, C., (2009), "Measuring intangible capital and its contribution to economic growth in Europe," EIB Papers 3/2009, European Investment Bank, Economic and Financial Studies.

Appendix 1: Excluding intangibles, industry contributions to growth in aggregate value added, capital deepening, labour quality and TFP (growth rates and contributions are %pa per employee hour)

	1	2	3		4	5	6	7	8		9	10		11	12	13		*14*	15	16
	Value added				**Capital contributions**						**Labour contrib**			**TFP**						
							of which													
Industry	**VA weight**	**DlnVA/H**	**contrib to agg va/h**		**Cap weight**	**Contrib to agg K/H**	**Contrib to agg ICT dlnK/H**	**Contrib to agg non-ICT dlnK/H**	**Contrib to agg Intan/H**		**Lab weight**	**Contrib to agg lab qual per hr**		**Domar weight**	**DlnTFP**	**Contrib to agg TFP**		***Memo: % total hrs***		
Agriculture; Mining	0.04	-0.93	-0.04		0.03	0.11	0.00	0.11			0.01	0.05		0.08	-2.59	-0.20		*3%*		
Manufacturing	0.20	4.70	0.91		0.04	0.13	0.04	0.09			0.16	0.13		0.58	1.14	0.65		*17%*		
Utilities	0.02	-0.52	-0.01		0.02	0.00	0.01	-0.01			0.01	0.00		0.08	-0.15	-0.02		*1%*		
Construction	0.09	1.28	0.10		0.01	0.08	0.01	0.07			0.07	0.02		0.22	0.06	0.01		*10%*		
Distribution; Hotels; Transport	0.31	2.84	0.87		0.07	0.31	0.14	0.16			0.23	0.01		0.64	0.87	0.56		*36%*		
Finance	0.09	4.92	0.40		0.03	0.01	0.08	-0.08			0.06	0.00		0.22	1.84	0.40		*5%*		
Business Services	0.19	2.93	0.55		0.04	0.10	0.09	0.01			0.15	0.12		0.34	0.99	0.33		*20%*		
Personal Services	0.07	-1.34	-0.10		0.00	0.03	0.01	0.02			0.07	-0.02		0.13	-0.83	-0.11		*8%*		
Sum	***1.00***		***2.70***			***0.76***	***0.38***	***0.37***				***0.32***		***2.29***		***1.62***		***100%***		
%ages of summed contributions																		***Memo: % total hrs***	***(8 + 13)/ (S8+S13)***	***(8+10+13)/ (S8+S13+Σ10)***
Agriculture; Mining			*-2%*			*15%*	*0%*	*30%*				*16%*				*-13%*		*3%*	*-13%*	*-8%*
Manufacturing			*34%*			*17%*	*11%*	*23%*				*41%*				*40%*		*17%*	*40%*	*40%*
Utilities			*0%*			*0%*	*3%*	*-3%*				*1%*				*-1%*		*1%*	*-1%*	*-1%*
Construction			*4%*			*10%*	*2%*	*19%*				*5%*				*1%*		*10%*	*1%*	*1%*
Distribution; Hotels; Transport			*32%*			*40%*	*37%*	*44%*				*3%*				*34%*		*36%*	*34%*	*29%*
Finance			*15%*			*1%*	*22%*	*-21%*				*0%*				*25%*		*5%*	*25%*	*21%*
Business Services			*21%*			*13%*	*23%*	*3%*				*40%*				*20%*		*20%*	*20%*	*24%*
Personal Services			*-4%*			*4%*	*2%*	*7%*				*-5%*				*-7%*		*8%*	*-7%*	*-6%*
Sum			***100%***			***100%***	***100%***	***100%***				***100%***				***100%***		***100%***	***100%***	***100%***

Note: See notes to Table 8. All figures are annual averages. Weights depend on the industry share in aggregate value-added, the input share in gross output and the share of value-added in gross output. Contributions are the product of the weights and the input growth averaged over years. Employment is the share of the industry's hours worked over total hours worked by persons engaged. Column 5 is the sum of columns 6 and 7 . Column 8 blank since no intangibles are included . Column 13= column 11 times 12.
Source: authors' calculations

Appendix 2: A note on changes since previous report

The main changes are as follows.

1. Improved Industry Breakdown

We now have a more complete definition of the market sector, in line with that used in EUKLEMS, and a dataset more representative of the UK economy. The new industry is labelled 'OP', defined as "Other Community, Social and Personal Service Activities"; "Private households employing staff" in the 2003 Standard Industrial Classification. In the body of this work, for simplicity, we sometimes refer to this sector as personal services. Actually the coverage is much wider than that. The following table provides a more complete overview of industry activity.

Table Appendix 2.1: Personal Services: Industry Description

SIC(03) Section	Subsections (two digit)	Divisions (three digit)	Industry Description	*Including:*
O			OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICE ACTIVITIES	
	90	900	Sewage and Refuse Disposal, Sanitation and Similar Activities	*collection / treatment of household / industrial waste; street cleaning*
	91		Activities of Membership Organisations Not Elsewhere Classified	
		911	Activities of business, employers and professional organisations	*trade / business / professional associations; guilds and similar*
		912	Activities of trade unions	
		913	Activities of other membership organisations	*religious; political and other membership organisations*
	92		Recreational, Cultural and Sporting Activities	
		921	Motion picture and video activities	*production; distribution and projection of film / video*
		922	Radio and television activities	
		923	Other entertainment activities	*artistic and literary creation and interpretation; live theatrical presentation; arts facilities; amusment parks; dance halls/instruction*
		924	News agency activities	
		925	Library, archives, museums and other cultural activities	*prervation and reconstruction; botanical and zoological gardens*
		926	Sporting activities	*arenas/stadia; ice rinks; racehorse owners; leisure centres; marinas*
		927	Other recreational activities	*gambling; lottery; coin operated video games*
	930	930	Other Service Activities	*washing and dry cleaning; hairdressing; funeral and related activities; physical well-being activities; pet care*
P			PRIVATE HOUSEHOLDS EMPLOYING STAFF AND UNDIFFERENTIATED PRODUCTION ACTIVITIES	
	95	950	Activities of Households as Employers of Domestic Staff	*domestic personnel such as maids, cooks, grdeners, babysitters, etc.*
	96	960	Undifferentiated Goods Producing Activities of Private Households for Own Use	
	97	970	Undifferentiated Services Producing Activities of Private Households for Own Use	

As can be seen, although this addition gives us better coverage of market activity, it also means we include some non-market activity which we may prefer to exclude. For instance, although some activities have been outsourced, local authorities still provide many of the above services for sewage and refuse; sporting activities (leisure centres etc.). We also end up including some activity on the boundaries of market and non-market provision by organisations such as the BBC and museums. Although the former is officially defined as a public corporation outside the market sector, it is a significant investor in knowledge assets in an industry that we consider important to include in our dataset. It is also worth noting that our definition of the market sector as used in this paper does not include private provision of health and education services, with sections L (Public Administration and Defence), M (Education) and N (Health and social work) entirely excluded from our estimation.

We consider this addition a step forward. As well as capturing additional investments in assets such as software, design, training, business process improvement, as outlined above this industry includes film production; television and radio activities; and artistic and literary creation so including the creators of artistic originals which we now properly account for at the industry level.

2. Measurement of Tangible capital.

Data on tangible investment have been revised, see Appleton and Wallis (2011). Broadly the revisions are due to: revisions to estimates of real investment; the use of updated data to separate computers from plant and machinery; and downward revisions to Gross Operating Surplus in 2006 and 2008. Overall this has raised both nominal investment and the growth in volume of capital services by around a percentage point on average in the 2000's, quite a substantial revision. The overall effect in our work, relative to previous data, has been

   a. To raise the contribution of computers in the early 2000s, and lower it in the late 2000s
   b. To raise the contribution of buildings throughout. Buildings and non-computer plant had a roughly equal income share of value added (13-15% each in the early 1990s). The share of non-computer plant then rose sharply and fell back from 1996, whereas buildings did the opposite, rising very strongly from 2001, so that they both converged again around 2008. The building share remains just above that of plant and machinery.

3. Measurement of Intangible investment

   We have updated our estimates using official sources as much as possible e.g. for software, mineral exploration and R&D. These numbers look very similar to before. The main changes are:

   a. Design. As before, we have used the IO tables for purchased design and occupational methods for own account. In the data, in 2008, total (market sector) design purchases from are around £32.3bn. Business services (excluding dwellings), was by far the largest purchaser, at £13.6bn. Of that £13.6bn, £10.1bn were purchased by SIC74, a subdivision of business services, “other business activities”. This is the industry where design firms are located, and hence is it plausible that at least part of this £10.1bn is the purchase of design services by design companies i.e. the outsourcing of design by design companies to, for example, independents. To be conservative therefore, we excluded all of this £10.1bn to avoid double-counting. This is why the design total investment is about £8bn less than before (the 2008 figure last time was £23bn, now it is £15.5bn). The additional £2bn is due to the addition of consumer and personal services (section O) to our dataset.

b. Advertising and Market Research. Here we have applied the same adjustment as that for purchased design, to avoid the double-counting of sub-contracted or outsourced activity, which has reduced branding spending from around £15bn to £13bn, after accounting for the inclusion of an additional industry in our dataset.

c. Artistic originals. We have conducted a major revision of this whole asset class using industry data on film production, TV, books, music, art and other spending. This has raised investment by about £2bn relative to previous numbers. We are currently working with the ONS to incorporate our new estimates into the National Accounts.

d. Training. In previous data we subtracted spending on health and safety training. In the latest version of the NESS firms are asked to provide the proportion of training expenditure that is either health and safety or induction training. In this run, we noted that health and safety and induction is above 30% of training spending for the production industries (agriculture and mining; utilities; and manufacturing). Thus we added this back in for these industries, since one would imagine that such spending in oil and gas mining builds long term knowledge more than in, say, health and safety and induction in accounting and other service industries.

e. Organisational capital. Last year, purchased organizational capital was based on interpolated numbers based on a 2005 benchmark from the Management Consultancies Association (MCA). We have now obtained actual MCA data for the latest years, which shows a fall in spend rather than a rise, reducing overall organisational spend from 31bn in 2008 to 27bn, after accounting for the inclusion of an additional industry in our dataset.

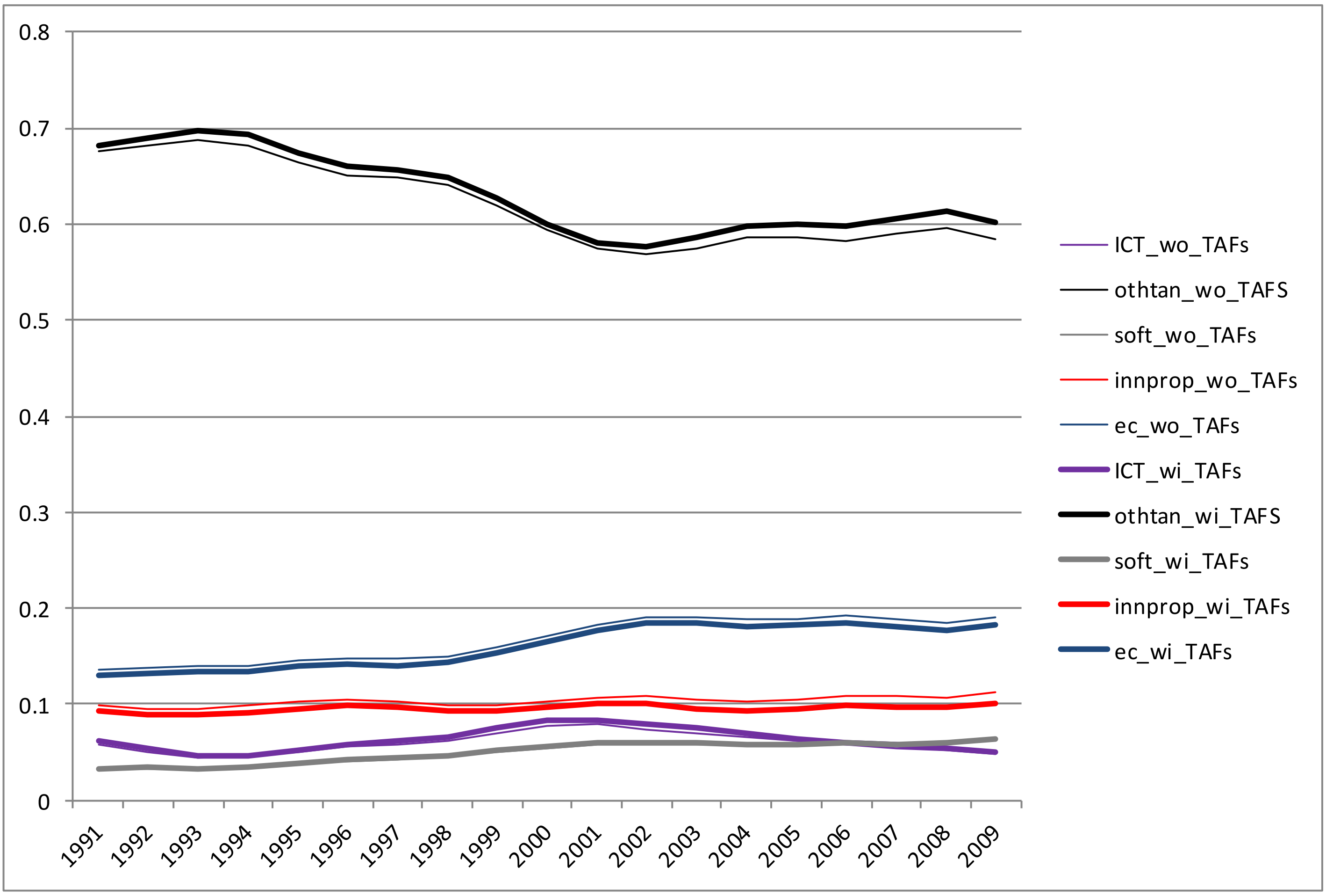
It is worth re-iterating that our dataset is still classified using SIC 2003. Blue Book 2011 was the first to be produced using SIC 2007. As a result much of our data remains based on either Blue Book 2010 or National Accounts publications in the year 2011 prior to the release of Blue Book 2011. Some Blue Book 2011 data has been mapped back to SIC 2003, to ensure consistency. We aim to fully update our dataset in accordance with SIC 2007 in future work. Improved classification of the service sector in the new SIC will aid the measurement and analysis of knowledge-intensive activity.

4. Tax-adjustment factors

We have adjusted our estimation to properly account for appropriate tax adjustment factors in the calculation of capital compensation and rentals, by asset type. In the case of tangibles assets, this also includes the relevant capital depreciation allowances. Most intangible assets do not receive such allowances but the expenditure to generate the intangible asset can be expensed leaving the cost of capital unaffected by the presence of corporation tax. The exceptions are scientific R&D, purchased software, mineral exploration and some types of artistic originals. Purchased software cannot be expensed in most cases but qualifies for the plant and machinery capital allowance. Scientific Research Allowances (SRA), called Research & Development Allowances since 2000, were introduced after the Second World War and are a 100 per cent first-year allowance on capital expenditure for R&D purposes (expensing treatment). Following Bloom et al (2000) we assume that prior to 2000 the relevant capital allowance for firms was the general plant and machinery allowance due to the narrow coverage of the SRA. The R&D Corporate Tax Relief, which most people call the R&D Tax Credit, was introduced in 2002 to provide an allowance for 'revenue expenditure'. In essence this tax relief is a 125 per cent first-year allowance (130 per cent from April 2008 onwards) on revenue expenditure for R&D purposes. The net present value of depreciation allowances for R&D is then a weighted average of the present value of these two different allowances where the weights are given by the shares of capital and revenue expenditure in total R&D spending.

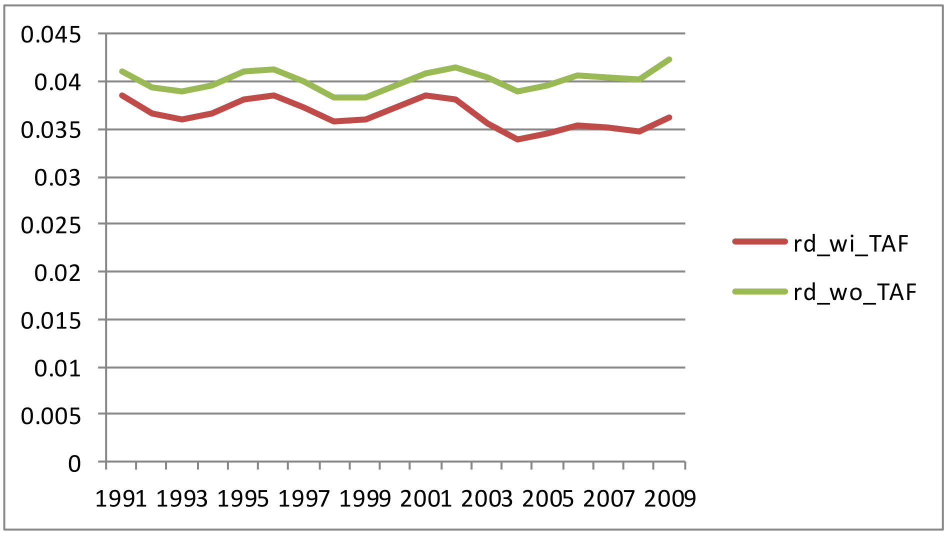
As explained in the main text, the impact of incorporating new tax adjustment factors has been to raise the estimated rental prices and factor income shares for tangible assets relative to intangible assets. The following chart presents income shares for broad asset categories with and without tax adjustment factors. As can be seen the main impact is to the group "other tangibles" where the factor income share rises. Since aggregate capital compensation remains the same, this rise is compensated for by a fall in the factor income share for intangibles. . We also present the income share for R&D which clearly shows the impact of the tax credit subsidising the cost of R&D capital, especially post-2002 when the R&D tax credit was introduced.

Figure Appendix 2.4a: Shares of total capital compensation, by asset



Note to figure: All CHS intangibles treated as capital assets. Labels "wi" and "wo" refer to the incorporation and absence of tax adjustment factors respectively. For asset categories: "ICT" refers to computer hardware plus telecommunications equipment; "othtan" refers to buildings, plant & machinery and vehicles; "soft" refers to software; "innprop" refers to innovative property, that is R&D, mineral exploration, artistic originals, design, non-scientific research and financial product innovation; and "ec" refers to economic competencies, that is branding, organisational capital and training.

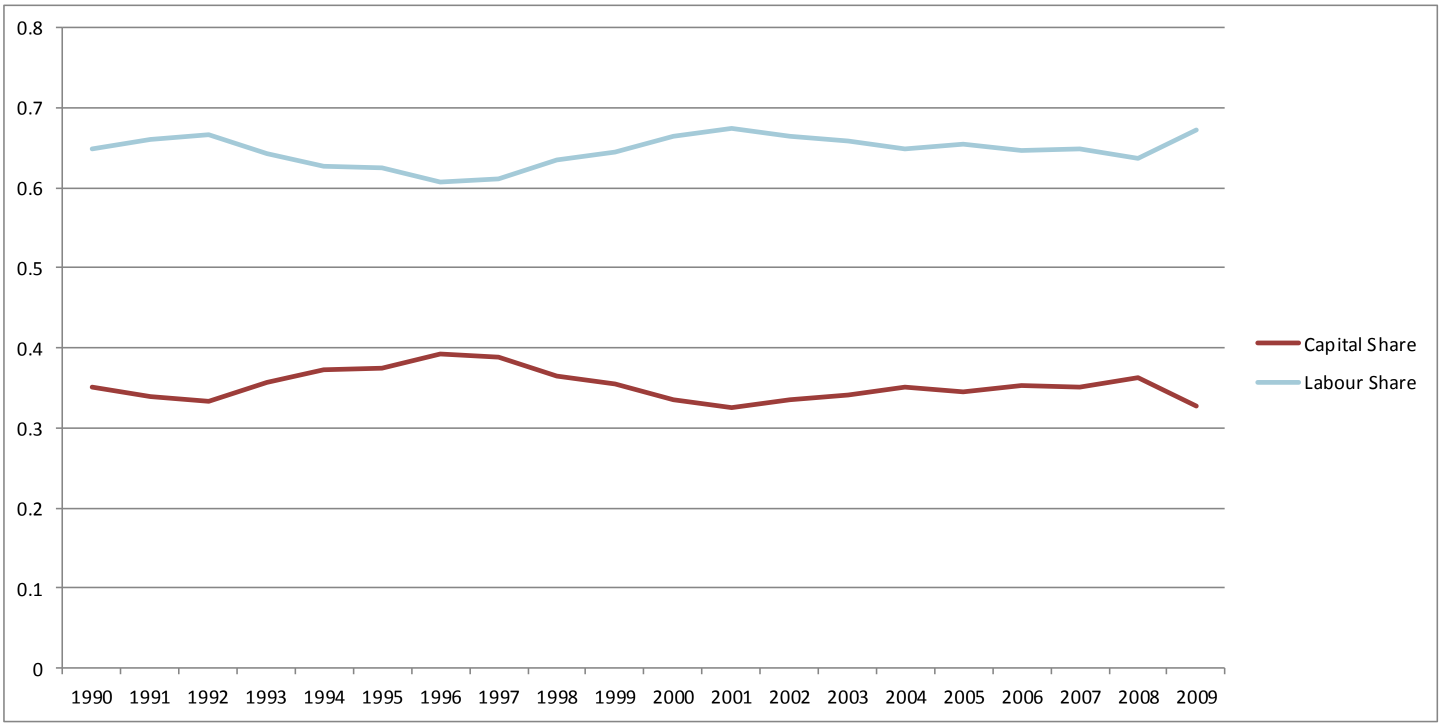
Figure Appendix 2.4b: Share of total capital compensation, R&D



Appendix 3: Comparisons of income shares, by asset: Tangible and Intangible

Estimated growth-accounting contributions are derived using a) estimates of growth in capital deepening and b) the asset share of compensation in aggregate income. The following charts present data for the total factor income shares in 3a, and the asset shares in 3b.

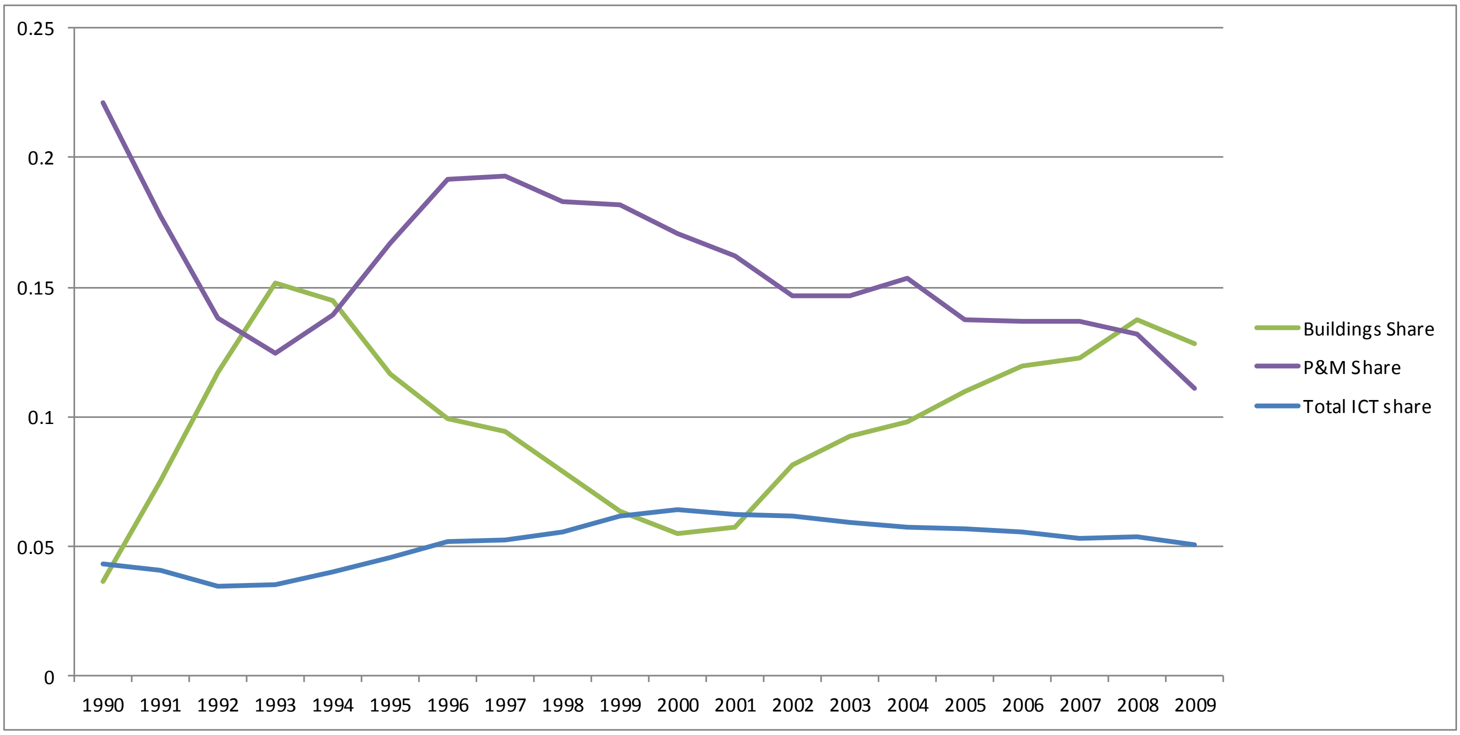
Figure Appendix 3a: Labour and Capital (standard NA capital definition) income shares



Note to figure: Capital defined as in the National Accounts i.e. buildings, plant and machinery, vehicles, ICT tangible capital, software, mineral exploration and artistic originals.

The above chart shows that since the mid-90s the labour share as typically defined in the National Accounts has risen. The final two data points show a sharp rise in the labour share in 2009, helping explain the increase in the contribution of labour composition, and decrease in the contribution of capital deepening, as a share of LPG toward the end of our study. This feature is driven by a relatively smaller fall in labour compensation than value-added due to the stickiness of nominal wages and firms hoarding labour.

Figure Appendix 3b: Capital (standard NA capital definition) income shares for selected assets



Note to figure: Total ICT share is defined as Computer Hardware: Telecommunications Equipment; Software (own-account and purchased)

Figure Appendix 3b looks more closely at some of the individual asset shares within the capital share. The respective shares for 'buildings' and 'plant and machinery' are striking. The income share for buildings declined strongly throughout the 1990s before rising sharply in the 2000s and then falling again in 2009. We conjecture that this profile may be at least partly be explained by infrastructure investments prior to the 2012 Olympics. The pattern is mirrored by the series for plant and machinery, where the income share rose in the 1990s before exhibiting a steady decline. The share for total ICT capital (defined here as computer hardware, telecommunications equipment and software) tended to gradually rise in the 1990s before declining slightly following the late 1990s ICT investment boom. The total ICT share has tended to be relatively stable throughout the 2000s.

Appendix 4: Discussion of depreciation and discard, and the conversion from expenditure to investment

The following table presents the depreciation rates applied to each asset. In the case of intangible assets we also present the conversion factors used to move from expenditure to investment. The two concepts are related. The purpose of the conversion factor is eliminate expenditure which creates a good that lasts for less than twelve months. The remaining expenditure is therefore counted as building an asset which provides services for a period beyond one year.

As mentioned in the main text, geometric rates may not be appropriate for knowledge assets. Data on the revenues earned by artistic originals show that on average such assets depreciate quickly in first few years of life and much slower thereafter. Application of a conversion factor helps accounts for this fast depreciation rate in early years by effectively applying a very fast depreciation rate to the first year after nay expenditures are made. If conversions factors were not applied, it is likely that the appropriate depreciation rates for most knowledge assets would be greater than those presented below.

Table Appendix 4: Geometric depreciation rates and conversion factors, by asset

Asset	Conversion Factor (Exp --> Inv)	Depreciation rate
Computerised Information		
Purchased Software	1	0.33
Own-Account Software	1	0.33
Innovative property		
R&D	1	0.2
Design	*0.5*	*0.2*
Non-scientific R&D	1	0.2
Mineral Exploration	1	0.2
Financial Innovation	1	0.2
Film Originals	1	0.075
TV (fiction) Originals	1	0.1
TV (non-fiction) Originals	1	0.41
Literary Originals	1	0.2
Music Originals	1	0.1333
Miscellaneous Art	1	0.1
Economic Competencies		
Advertising	*0.6*	*0.6*
Market Research	*0.6*	*0.6*
Own-Account Organisational Capital	1	0.4
Purchased Organisational Capital	*0.8*	*0.4*
Training	1	0.4
Tangibles		
Buildings	-	0.025
Plant & Machinery	-	0.13
Vehicles	-	0.25
Computer Hardware	-	0.4
Telecommunications Equipment	-	0.115

Appendix 5: Annual growth-accounting results by industry

For completeness the following table presents annual growth-accounting results by industry. We stress that care should be taken in interpreting annual changes in contributions and the innovation index, but feel such data are useful for understanding the period averages presented in the main text.

Table Appendix 5: Annual growth-accounting results by industry

Industry	Year	DlnY/H	sDln(K/H)	sDln(K/L)ICT	sDln(K/L)othtan	sDln(K/L)intan	sDln(L/H)	sDln(M/H)	DlnTFP
AgrMin	2001	2.66	3.51	0.01	3.45	0.04	0.49	1.15	-2.48
	2002	10.07	4.13	0.01	3.87	0.25	1.63	1.90	2.40
	2003	-0.64	0.74	0.01	0.82	-0.08	0.67	0.97	-3.01
	2004	1.21	0.03	0.00	0.23	-0.20	0.70	4.58	-4.09
	2005	-5.98	-1.51	0.00	-1.16	-0.35	1.25	-1.08	-4.64
	2006	-2.13	0.95	0.00	1.10	-0.16	0.23	0.21	-3.51
	2007	-0.03	0.31	0.00	0.58	-0.27	-0.41	1.33	-1.25
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
Mfr	2001	2.40	0.92	0.15	0.22	0.54	-0.23	0.86	0.86
	2002	3.39	0.94	0.08	0.26	0.60	0.30	1.92	0.22
	2003	3.75	0.73	0.06	0.18	0.49	0.40	1.71	0.90
	2004	7.11	0.66	0.06	0.13	0.47	0.24	4.42	1.79
	2005	2.85	0.76	0.06	0.18	0.52	0.53	0.12	1.45
	2006	3.39	0.37	0.04	0.02	0.31	0.29	1.72	1.02
	2007	3.51	0.31	0.04	0.03	0.24	0.06	2.01	1.12
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
Utilities	2001	0.70	2.45	0.45	1.55	0.45	0.61	-1.99	-0.37
	2002	-4.28	-0.41	0.15	-0.61	0.04	-0.54	-3.13	-0.19
	2003	12.53	3.64	0.36	2.78	0.49	1.10	7.69	0.11
	2004	-5.60	-2.53	0.01	-2.28	-0.26	-1.13	-3.06	1.13
	2005	-10.29	0.61	0.16	0.26	0.18	0.27	-11.13	-0.04
	2006	-10.96	-1.32	0.07	-1.27	-0.12	0.08	-8.54	-1.17
	2007	-6.98	-1.69	-0.03	-1.40	-0.26	-0.02	-3.90	-1.38
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
Constr	2001	1.83	0.28	0.03	0.17	0.08	0.59	1.07	-0.11
	2002	4.62	0.71	0.05	0.53	0.12	0.18	3.09	0.65
	2003	3.27	0.41	0.02	0.29	0.10	0.01	2.13	0.72
	2004	0.33	0.24	0.02	0.29	-0.07	-0.53	1.18	-0.56
	2005	5.46	0.52	0.02	0.26	0.23	1.31	3.96	-0.34
	2006	-3.51	0.15	0.02	0.14	-0.01	-0.76	-2.84	-0.06
	2007	3.17	0.13	0.01	0.09	0.02	-0.26	3.10	0.20

Industry	Year	DlnY/H	sDln(K/H)	sDln(K/L)ICT	sDln(K/L)othtan	sDln(K/L)intan	sDln(L/H)	sDln(M/H)	DlnTFP
RtHtTrs	2001	1.05	1.05	0.61	0.17	0.26	0.05	0.18	-0.22
	2002	1.77	1.11	0.36	0.42	0.33	0.04	0.21	0.42
	2003	1.94	0.56	0.11	0.25	0.20	-0.35	0.90	0.82
	2004	5.76	0.71	0.15	0.37	0.19	0.36	3.06	1.63
	2005	3.04	0.41	0.11	0.17	0.13	-0.37	2.26	0.74
	2006	2.00	0.53	0.11	0.23	0.18	-0.27	0.42	1.32
	2007	3.53	0.63	0.13	0.33	0.18	0.64	1.74	0.52
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
FinSvc	2001	4.22	1.48	0.62	-0.11	0.97	0.31	2.54	-0.10
	2002	1.86	1.70	0.74	0.24	0.72	1.36	-1.79	0.59
	2003	0.45	-0.69	0.21	-0.34	-0.56	0.07	-1.64	2.71
	2004	0.93	-1.12	0.16	-0.61	-0.67	-1.46	0.52	3.00
	2005	1.78	-0.88	0.20	-0.47	-0.61	-0.50	1.72	1.45
	2006	0.05	-0.76	0.23	-0.55	-0.44	-0.85	-0.90	2.55
	2007	1.91	-0.16	0.29	-0.13	-0.32	1.10	-0.49	1.46
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
BusSvc	2001	1.49	0.83	0.30	0.23	0.30	-0.41	0.34	0.73
	2002	1.11	1.15	0.41	0.24	0.51	-0.73	0.35	0.34
	2003	-1.32	-0.05	0.15	-0.22	0.02	-0.05	-1.08	-0.14
	2004	4.15	0.36	0.29	-0.22	0.29	0.49	1.16	2.14
	2005	2.80	0.12	0.23	-0.20	0.10	1.10	0.94	0.63
	2006	6.08	1.31	0.25	0.30	0.76	2.34	1.24	1.20
	2007	2.90	0.57	0.15	0.08	0.34	-0.20	1.20	1.32
Industry	**Year**	**DlnY/H**	**sDln(K/H)**	**sDln(K/L)ICT**	**sDln(K/L)othtan**	**sDln(K/L)intan**	**sDln(L/H)**	**sDln(M/H)**	**DlnTFP**
PersSvc	2001	1.52	0.20	0.20	0.00	-0.01	1.85	0.62	-1.14
	2002	-1.34	-0.25	0.09	-0.14	-0.20	-0.71	0.90	-1.28
	2003	-4.71	-0.33	0.04	-0.04	-0.33	-2.62	-1.63	-0.13
	2004	-0.65	0.49	0.06	0.63	-0.20	-0.31	1.81	-2.64
	2005	1.21	0.79	0.07	0.74	-0.02	0.59	0.80	-0.96
	2006	-3.14	0.11	0.02	0.36	-0.27	-0.52	-0.64	-2.08
	2007	0.25	0.57	0.06	0.48	0.03	0.98	0.57	-1.87