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# UK Intangible Investment and Growth:
## New measures of UK investment in knowledge assets and intellectual property rights

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## Abstract

This paper provides an update on UK intangible investment and growth, and tries to calculate some facts for the “knowledge economy”. Building on previous work and using new data sets, 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 9% greater than tangible investment, in 2014, at £133bn and £121bn respectively; (b) R&D is about 14% of total intangible investment, software 21%, design 11%, training 20% and organisational capital 16%; (d) the most intangible-intensive industry is the information and communications industry, where intangible investment is 18% of value added and (e) compared to the National Accounts, treating additional intangible expenditures as investment raises market sector value added growth in the 1990s and the early 2000s, but lowers growth in the late 2000s. Regarding the contribution to growth, for 2010-14, (a) intangible capital deepening makes a negative contribution to labour productivity growth of -0.16% pa, compared to 0.05% pa for non-ICT tangible capital and 0.02% pa for tangible ICT equipment; (b) TFP over the period was negative at -0.16% pa. On industries, in 2000-14, manufacturing accounts for 35% of intangible capital deepening in the UK market sector, financial services accounts for 24% and wholesale/retail for 19%.

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# Contents

# 1. Executive Summary

This report presents an update on UK intangible investment and growth for the period 1990 to 2014 to better understand the contribution of innovation to productivity growth in the UK market sector.[1]

To meet this aim the report makes three contributions:

1. Estimates UK investment in knowledge and Intellectual Property Rights (IPRs) – the report sets out the approach and best estimate of how much firms are spending on knowledge. This is achieved by the calculation of investment in intangible assets[2] (building on the previous work by Goodridge, Haskel and Wallis (2014a)) and estimating how much of the UK investment in intangible assets is protected by formal IPRs.

2. Estimates how much all forms of knowledge contribute to growth. The approach used is set out and the results are presented using a growth-accounting based innovation index.[3]

3. Provide new estimates of growth in the UK economy over the period 1990-2014 and estimate the contribution of growth from nine disaggregated industries.[4]

Key findings are:

## 1.1 UK Investment in knowledge and intellectual property rights (IPRs)

UK investment in intangible or knowledge assets has been greater than that for tangible assets since the early 2000s. In 2014 it stood at £133bn, as opposed to £121bn tangible investment. Of that intangible spend training by firms accounts for £26bn, organisational capital for £22bn, design £14bn, software £28bn, branding £15bn and scientific R&D £19bn.

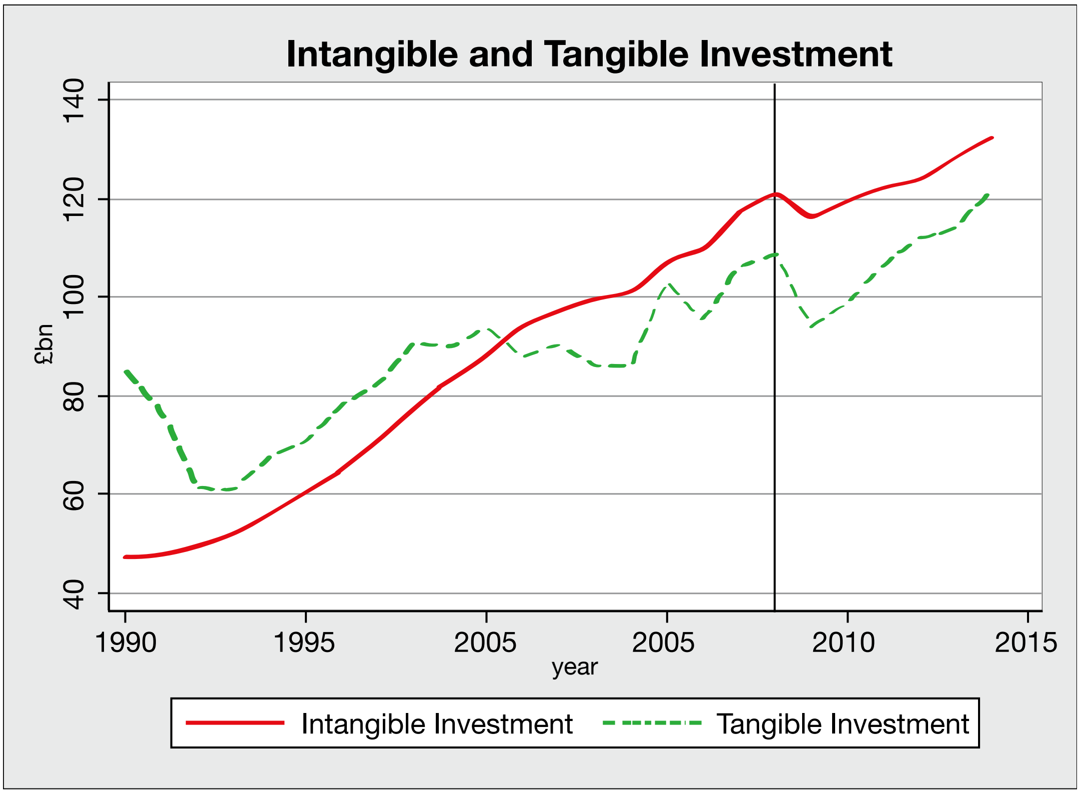
1 The report updates previous work Goodridge, Haskel and Wallis (2014a) and (2014b)

2 The intangible assets measured are software, R&D, design, product development in financial services and artistic creation, and investment in brands, firm-specific human capital and organisations.

3 The innovation index is defined as the growth in output over and above the contributions of physical capital and labour input. The widest definition of the index includes growth which can be attributed to investment in knowledge, to improvement in the workforce due to education and the building of experience, and to Total Factor Productivity (TFP) which measures spillovers of knowledge between firms and other unmeasured knowledge.

4 The nine disaggregated industries are 1) Agriculture, Mining and Utilities 2) Manufacturing 3) Construction 4) Wholesale and Retail Trade, Accommodation and Food 5) Transportation and Storage 6) Information and Communication 7) Financial Services 8) Professional and Administrative Services 9) Recreational and Personal Services

**Market sector tangible and intangible investment, £bn, 1990-2014**




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

The industry that is most intensive in intangible spend is information and communication, which invests 18% of its value added on intangibles. The least intangible-intensive industries in our dataset are agriculture; mining and utilities and construction, where intangible investments are around 6-7% of industry value-added.

In 2014, we estimate that UK market sector investment in assets protected by IPRs reached £70.4bn, approximately 53% of UK market sector intangible investment. Of that £70.4bn, we estimate that: £33.3bn (47%) was in assets protected by copyright; £15.1bn (21%) was in assets protected by trademarks; £7.5bn (11%) was in assets protected by patents; £2.1bn (3%) was in assets protected by design registration; and £12.3bn (17%) in assets protected by unregistered design rights.

Including intangible investment in our growth estimates[5] increases output growth in the 1990s and early 2000s, but reduces growth in the late 2000s relative to ONS official estimates. This is because intangible investment grew at a faster rate than output in the 1990s and early 2000s but at a slower rate in the late 2000s.

5 In the National Accounts, most intangible spending (with the exception of software, mineral exploration, artistic originals, and R&D), is categorised as either intermediate consumption or unmeasured gross output. 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.

## 1.2 Innovation in the market sector

Examining labour productivity growth, including intangibles, shows a slowdown during the 1990s and throughout the 2000s. Labour productivity growth was 3.2% p.a. in 1990-95, slowing to 2.5% p.a. in 1995-2000, to 2.1% p.a. in 2000-05, to 0.5% p.a. in 2005-10, and to just 0.1% p.a. in 2010-14. The profile of growth is similar (although higher) if labour productivity had been calculated excluding intangibles.

For the period 2010-14, innovation had a negative impact on output growth. This is partly explained by decreasing levels of intangible capital per worker and negative Total Factor Productivity growth[6].

## 1.3 Innovation in industries and their contribution to the overall market sector

Industries which had positive Total Factor Productivity (TFP) over the period 2000 to 2014 were information & communication (1.3% pa), manufacturing (1.2% pa), professional & administrative services (1.2% pa) and wholesale & retail; food and accommodation (0.4% pa). Total Factor Productivity in all other industries was negative on average during the period studied.

The contribution of innovation is largely accounted for by a few industries. Manufacturing accounts for 70% of innovation in the UK market sector, whilst there are other significant contributions from professional & administrative services (59%), wholesale & retail; food and accommodation (38%) and information & communication (33%). Clearly these contributions sum to more than 100% as other industries make negative contributions, particularly agriculture, mining and utilities which contributes -85% of innovation.

6 Total Factor Productivity includes measurements of spillovers of knowledge between firms and other unmeasured knowledge. It also includes measurement error.

# 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 (for example: 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 (for example: 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 for example finance and retailing, do no (measured) R&D.[7] Thus 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.

7 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.

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.[8] 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. 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, now it has been officially capitalised in the National Accounts). However, this paper asks whether we are missing other significant investment in knowledge or ideas in these sectors.[9]

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, 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 heavily 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 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.

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 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).

8 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).

9 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).

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.[10] We have also improved estimates of investment in artistic originals (Goodridge, 2014) and those new estimates have been incorporated into the National Accounts. In addition, there is almost no information on the depreciation of intangible assets.[11] Thus, for previous compilations of the Innovation Index, we have conducted two runs of a survey, of each around 1,000 companies, on intangible spend and the life lengths of that spend, by asset, to gather data on depreciation. We also test the robustness of our results to other estimates of the price of intangible assets.

Third, we provide (value-added based) growth accounting results by industry aggregated consistently to the UK market sector. 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 or UK innovation, as well as providing information on the contribution of the UK creative industries.

On specifically UK data, our work is mostly closely related to the industry-level work (Basu, Fernald et al. 2004). They incorporated software as a productive asset and looked at productivity and TFPG in 28 industries between 1990 and 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. 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 based on National Accounts definitions of capital of interest.

10 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.

11 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.

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 2014, £133bn and £121bn respectively. R&D is about 14% of such spend. Organisational investments, training 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 additional intangible expenditure (not already recorded in the National Accounts) as investment is to raise MGVA growth in the 1990s and the early 2000s, but reduce it in the late 2000s.

On the *implications for growth,* for 2010-14, intangible capital deepening makes a negative contribution to growth in labour productivity, at -0.16% pa, due to falls in intangible capital services. Contributions from tangible capital deepening are positive but small, at 0.02% pa (33% of labour productivity growth (LPG), which was just 0.06% pa) for ICT equipment (computer hardware and telecommunications equipment combined but not including software) and 0.05% pa (90% of LPG) for other tangible capital (buildings, plant & machinery and vehicles). Due to the general slowdown in TFP in the 2000s, followed by the collapse in 2008 and 2009, and the lack of recovery in TFP since, TFP makes a negative contribution at -0.16% pa.12 These findings are quite robust to variations in depreciation and assumptions on intangible measures.

Regarding industries, the main finding here is the importance of manufacturing and financial services. In terms of intangible capital deepening, these two industries alone, which together account for just 20% of hours worked, account for 58% of aggregate intangible capital deepening. In terms of TFP, the strongest performers over 2000-14 were information and communications (home too much of what are usually termed the “creative industries”) at 1.3% pa, and manufacturing and professional and administrative services, each at 1.2% pa. Average TFP in financial services was negative over the period, at -0.1% pa, due to negative TFP during and since the financial crisis. TFP was also positive in wholesale and retail, accommodation and food at 0.4% pa but was negative in all other industries over the period.

Unfortunately, since aggregate market sector TFP was negative over the period, we are unable to present the industry TFP contributions as a share of the market sector total. But, in terms of industry contributions to overall market sector innovation (defined as the contributions from intangible capital deepening, labour composition and TFP), our results emphasise the importance of manufacturing and professional and administrative services, which together account for 129% of UK market sector innovation. Other strong contributions come from wholesale/retail (38%) and information and communication (33%).

The rest of this paper proceeds as follows. Section 3 sets out a formal model, section 4 our data collection, section 5 our results on innovation accounting, section 6 our market sector growth accounting, section 7 our industry-level growth accounting and section 8 concludes.

12 Note that some of this negative contribution is almost certainly mismeasurement. Whilst we can observe or estimate capital stocks, we are not able to observe the intensity to which capital (and to a lesser extent labour where we can observe actual hours but not effort) are utilised. If we could measure utilisation perfectly, then during the recession TFP would probably be estimated as higher and the contributions of capital (and labour) lower.

# 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. In past work we have conducted our industry work on a gross output basis. Due to problems of data availability, in this report we work on a value-added basis at the industry-level. At industry level, a value added production function exists under restrictive assumptions. What is the relation between the industry components of growth and the whole market sector?

Using value-added, the output of intermediate goods, and their use as an input, drops out of the output identity. Or put another way, intermediate inputs are not included in a value-added production function. Suppose there is one unit of capital and labour (respectively K and L) which produce (value-added) output $V_j$ in industry j. That capital asset might or might not be intangible capital. Thus for each industry, we have the following value-added defined $\Delta \ln TFP_j$

$$\Delta \ln TFP_j \equiv \Delta \ln V_j - \bar{v}_{K,j} \Delta \ln K_j - \bar{v}_{L,j} \Delta \ln L_j \quad (1)$$

Where the terms in "v" are shares of factor costs in industry nominal value-added, averaged over two periods. For the economy as a whole, the definition of economy wide ΔlnTFP based on value added is the same, that is:

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

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 define the relation between industry value-added and market sector value-added, which is that changes in aggregate real value added are a weighted sum of changes in industry real value added:

$$\Delta \ln V \equiv \sum_j \bar{w}_j \Delta \ln V_j, \quad w_j = P_{V,j} V_j \Big/ \sum_j (P_{V,j} V_j), \bar{w}_j = 0.5(w_{j,t} + w_{j,t-1}) \quad (3)$$

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:

$$\Delta \ln V = \left( \sum_j \bar{w}_j \bar{v}_{K,j} \Delta \ln K_j \right) + \left( \sum_j \bar{w}_j \bar{v}_{L,j} \Delta \ln L_j \right) + \sum_j \bar{w}_j \Delta \ln TFP_j \quad (4)$$

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 industry value-added. Which is equivalent to saying that the contributions of $K_j$ and $L_j$ depend on their share in aggregate value-added. The contribution of $\Delta \ln TFP_j$ also depends on the share of $V_j$ in total V ($w_j$).

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 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:

$$\Delta \ln K = \sum_k \overline{w}_k \Delta \ln K_k, \quad \textit{capital type k}$$

$$\Delta \ln L = \sum_l \overline{w}_l \Delta \ln L_l, \quad \textit{labour type l}$$

$$\overline{w}_k = P_{K,k} K_k / \sum_k (P_{K,k} K_k), \quad \overline{w}_l = P_{L,l} L_l / \sum_l P_{L,l} L_l, \quad K_j = \sum_j K_{k,j} \forall k, \quad L_j = \sum_j L_{l,j} \forall l,$$

$$\overline{w}_t = 0.5(w_t + w_{t-1}) \qquad (5)$$

In our results we document the following. First, we set out the value-added growth accounting results for each industry. Second, we take these data and set out the contributions for each industry to the growth of aggregate value added, (4). Third, we sum up the contributions across industries to the decomposition of aggregate (market sector) value-added, (2). In each case we carry out the decomposition with and without intangibles, and for the market sector 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 Griliches (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:

$$K_{k,t} = I_{k,t} + (1 - \delta_{k,t}) K_{k,t-1} \qquad (6)$$

Where I is real investment in that asset over the relevant period and $\delta$ 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 net 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 and Wallis (2016) and Oulton and Srinivasan, (2003).

# 4. Data

## 4.1 Time period

For the industry analysis, since we work with value-added we use the official ONS data up to 2014. For intangibles, our industry level data is available 1997-2014 since this is when Input-Output (IO) tables are consistently available from.[13] Data for the whole market sector is available going back to 1980 up to 2014. Thus we work with two data sets: (1) market sector, 1980-2014, consistent with Blue Book 2015, and (2) industry level 1997-2014, based on the same data.

## 4.2 Industries

For our industry work, we aggregate to nine broad industries described in Table 1. The choice of the nine industries is dictated by the availability of the intangible data, some of which are only available at these aggregated levels.

### Table 1: Definition of nine industries

| # | Sectors | SIC(2007) Code | | NACE1 section |
|---|---|---|---|---|
| 1 | Agriculture, Mining and Utilities (AgMinUtil) | 1-9 & 35-39 | A | Agriculture, Forestry and Fishing |
| | | | B | Mining and Quarrying |
| | | | D | Electricity, Gas, Steam and Air Conditioning Supply |
| | | | E | Water Supply, Sewerage, Waste Management and Re-mediation Activities |
| 2 | Manufacturing (Mfr) | 10-33 | C | Manufacturing |
| 3 | Construction (Constr) | 41-43 | F | Construction |
| 4 | Wholesale and Retail Trade, Accommodation and Food (RtAcc) | 45-47 & 55-56 | G | Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles |
| | | | I | Accommodation and Food Service Activities |
| 5 | Transportation and Storage (Tran) | 49-53 | H | Transportation and Storage |
| 6 | Information and Communication (InfoCom) | 58-63 | J | Information and Communication |
| 7 | Financial Services (FinSvc) | 64-66 | K | Financial and Insurance Activities |
| 8 | Professional and Administrative Services (ProfAdmin) | 69-82 | M | Professional, Scientific and Technical Activities |
| | | | N | Administrative and Support Service Activities |
| 9 | Recreational and Personal Services (PersSvc) | 90-98 | R | Arts, Entertainment and Recreation |
| | | | S | Other service Activities |
| | | | T | Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use |

Note to table: We break the market sector down into 9 broad industries based on SIC07, as reported above.

13 Our market sector data can be extended back further using data from previous compilations of the Innovation Index, classified under SIC 03. But Input-Output tables and industry GFCF based on SIC07 are only available from 1997.

We measure output for the market sector, defined here as industries A to K, MN and R to T, which is consistent with EUKLEMS, that is excluding real estate, public administration & defence, education and health. Note this differs from the ONS official market sector definition, which excludes some of the publicly-provided services in R (galleries and libraries for instance), and includes the private delivery of education, health and social care. We also use disaggregated real value added data for this industry definition.

For the years where industry level data is available (from 1997), 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 2012 nominal data. For market sector variables, data are back cast further using data from previous compilations of the Innovation Index (e.g. Goodridge, Haskel and Wallis, 2012), which were similarly aggregated from industry values but based on SIC03.

## 4.3 Outputs and tangible and labour inputs.

For labour composition and hours worked we use the ONS Quality-adjusted labour input (QALI) data. We also use ONS data for industry Gross Value Added at current basic prices and the corresponding price and volume indices. Data on labour income, that is compensation of employees plus a proportion of mixed (self-employed) income, are from the ONS. Capital compensation is estimated residually as nominal gross value-added less total labour compensation. We shall of course amend capital compensation to incorporate compensation for intangible capital assets.

ONS GFCF data has been subject to substantive revisions in the last few years as the ONS have been moving to an improved production system. The tangible capital variables we use are based on Oulton and Wallis (2016) but with the underlying GFCF data for the post-1997 period updated to be consistent with ONS Blue Book 2015. The tangible capital data distinguishes five asset types, which are: buildings, computer hardware, telecoms equipment, (non-ICT) plant & machinery, and vehicles. We excluded dwellings (they are not capital for firm productivity analysis). The separation of telecoms equipment from general plant and machinery is an extension from Oulton and Wallis (2016). We also incorporate appropriate tax adjustment factors for all assets, tangible and intangible, based on Wallis (2016).

## 4.4 Labour services

The labour services data are for 1997-2014 and are based on ONS person-hours by industry. The ONS use this data 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. The market sector series is aggregated from industry data using industry shares of labour compensation. Since the labour income data begin in 1997, we back cast our labour input data using EUKLEMS.

## 4.5 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 industry ratio of labour payments to GVA excluding mixed income, as used in the ONS publication of QALI. Gross operating surplus (GOS) is always computed as MGVA less COE so that GOS +COE =MGVA by construction.

## 4.6 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. Particular industry categories (e.g. product development in finance, exploration of minerals, copyright) are allocated to that industry.[14]

14 Copyright, or more accurately, investment in artistic originals, is partly allocated to publishers (information and communication) and artists (arts, entertainment and recreation), as in the official ONS data, since each have some ownership share of the final original.

### 4.6.1 Computerised information

Computerised information comprises computer software, both purchased and own-account, and computerized databases.[15] This category 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).

### 4.6.2 Innovative property

For business *Scientific R&D,* since this category is already capitalised in the national accounts, we use R&D GFCF from the ONS. To avoid double counting of R&D and software investment, some R&D spending in "computer and related activities" (SIC 62) is subtracted since this is already included in the software investment data.

Like computerised information and R&D, *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 and explicitly not included in R&D. Data for copyright are those included in the national accounts, based on our own estimates produced with the co-operation of ONS and the Intellectual Property Office. 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 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.

15 For estimates of UK investments in data and knowledge gleaned from data analytics, see Goodridge and Haskel (2015a; 2015b). Note, investments in data (bases) are to some extent already included in the official National Accounts data.

Armed with these estimates, we went to the occupational data in the ASHE and derived a time series of earnings for those particular 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 exclude purchases of design by the industry itself ('Professional, Scientific and Technical Services', SIC69t74), 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 SIC72.2 "Research and experimental development on social sciences and humanities", where the doubling is assumed to capture own-account spending. This is a small number.

### 4.6.3 Economic competencies

*Advertising expenditure* and *market research* is estimated from the IO Tables by summing intermediate consumption on "Advertising and market research services" (product group 73) for each industry. We again exclude purchases of services by the industry itself ('Professional, Scientific and Technical Services', SIC69t74), since some of these purchases will include outsourcing and subcontracting arrangements which would be double-counting. These estimates are then separated into their respective components using data from the Annual Business Survey (ABS) and the Annual Business Inquiry (ABI) for preceding years. Estimates for market research are then doubled to capture own-account spend.

*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), from which we use the microdata stored at the UK Data Archive available for 2007 and 2009.[16] We also have aggregate expenditure data published by the UK

16 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 backcast the industry level series using EUKLEMS wage bill data benchmarking the data to the NESS cross sections.

Commission for Employment and Skills (UKCES)[17] for 2005, 2010. 2011. 2013 and 2015, as well as for 1986 (from an unpublished paper kindly supplied by John Barber).[18] 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.[19] This opportunity cost 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. This data have 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[20]. 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 and own-account time-spend. On purchased, we have consulted the Management Consultancy Association (MCA), who provide a series that covers around 70% of the industry. We therefore apply an adjustment to account for the rest of the industry, and apportion total purchases to industries according to shares of purchases of product 70 (services of head offices; management consulting services) as recorded in the IO tables. On own-account, we estimate investment as 20% of managerial wages, where managers are defined via occupational definitions. We test the robustness of the 20% figure below. As noted above, new occupational definitions mean that less managers are identified from the UK workforce compared to previous definitions. To maintain consistency with the back-series, we therefore take the level of managers and their wagebill in

17 http://www.ukces.org.uk/ourwork/employer-skills-survey

18 Note that the NESS data refers to England and the UKCESS data to the UK. Therefore for years where the data only apply to England, we adjust using the labour force ratio for England and the UK.

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

20 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) 0.10%; (1995-00) 0.06%; (2000-05) 0.1%; (2005-10) -0.03%; and (2010-14) -0.12%. Once we include the omitted expenditure, they change to: (1990-95) 0.12%; (1995-00) 0.08%; (2000-05) 0.1%; (2005-11) -0.03%; and (2010-14) -0.14%.

the latest data, and use the growth rates from previous data and definitions to backcast the series.

## 4.7 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 recommend 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 deprecation rates, unless one assumes much slower rates, in which case intangibles are even more important than suggested here.

On prices, in past work we have made extensive use of the implied GDP deflator. The price of intangibles is an area where very little 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 use of the GDP deflator could understate the importance of intangible assets.

Therefore in this work we use asset price deflators for software, R&D, mineral exploration and artistic originals from the ONS. For other intangibles use the Services Producer Price Indices (SPPIs) produced by the ONS. Specifically, for architectural and engineering design we use the SPPI for the related industry, "Technical testing and analysis", for advertising we use the SPPI for "Advertising Placement", for market research we use the SPPI for "Market Research", for organisational capital we use the SPPI for "Business and Management Services", and for training we use the SPPI for "Adult Education". These deflators typically rise less quickly than an implied GDP deflator. However, they typically only extend back to the mid-2000s and so only effect the measurement of real investment and capital services in later years. Data for earlier years remain based on the implied value-added deflator. The only remaining assets for which we do not have a specific deflator are financial product innovation and non-scientific R&D, and we deflate each with the implied UK value-added deflator.

## 4.8 Relation of intangible approach to other approaches

Haskel et al (2009, 2010) discusses how this work relates to the definition of innovation in 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 recent capitalisation of R&D in National Accounts, both of which are part of the process of recognising 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 labor "quality," and through the "multifactor productivity" (MFP) residual"* For shorthand, we refer to the "innovation" contribution as the sum of the intangible contribution, TFP and labour composition, but take no stand on this: we provide other components for the reader.

## 4.9 Accuracy of intangible measures

The following points are worth making. First, data on minerals, copyright, software and R&D are taken from official sources. 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. 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 (professional and administrative) services gives similar answers.

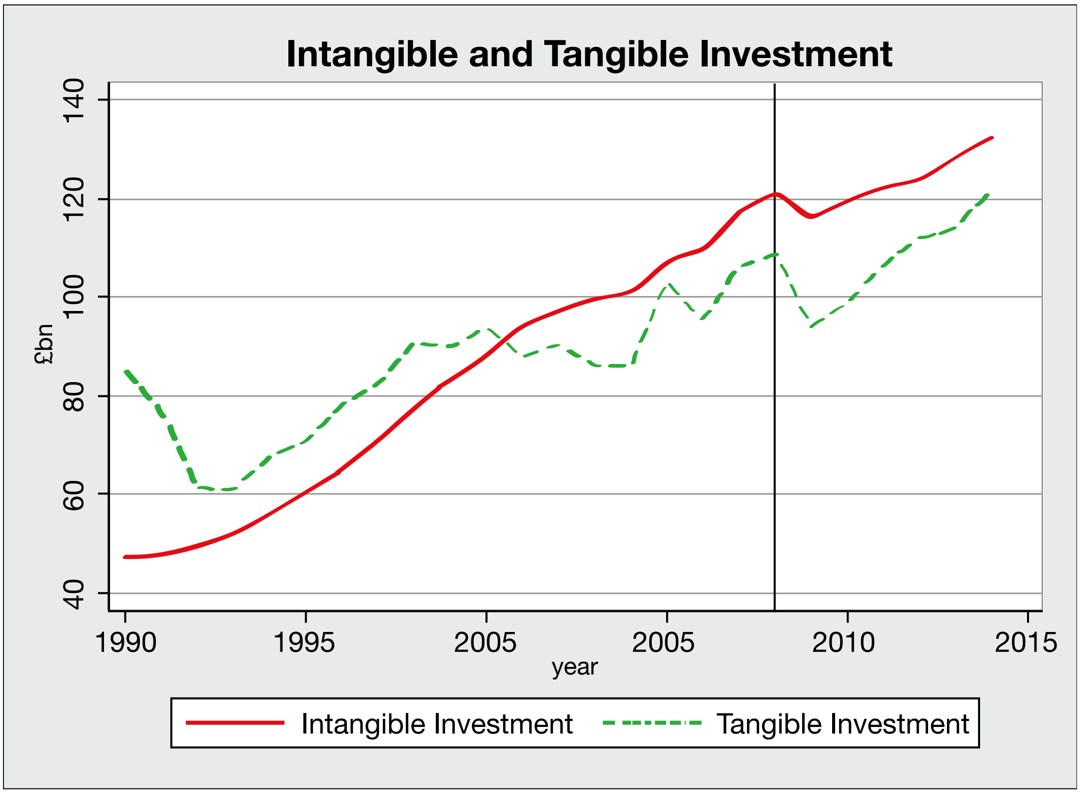
Second, we have undertaken two waves of our own survey of firms. The results of the first survey are fully documented in Awano et al (2009). In terms of the spending numbers here, that micro study found spending on R&D, software, marketing and training to be in line with the macro-based numbers in this 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 Market sector investment over time: tangible and intangible

Figure 1 presents market sector nominal total tangible and intangible investment data. Since 2001, intangible investment has exceeded tangible. The 2008 recession is marked with a vertical line. Note that during and after the recession, intangible investment fell by less than tangible investment. 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 from around 2004-05, 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 a similar fall in capital stock as a steep fall in tangible spend, so the changes in resulting capital services are similar. Since the recession, both tangible and intangible investment have grown, but the former more so, with the latest revised ONS data for GFCF showing a strong recovery in tangible investment post-recession.

**Figure 1: Market sector tangible and intangible investment, £bn, 1990-2014**




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, 2010 and 2014 with tangible investment also included for comparison. The intangible categories with the highest investment figures are organisational capital, training and software, with each category making up 16%, 20% and 21% respectively of intangible investment in 2014. In the range of £21-28bn, investment in each of these three asset categories is around two-thirds of total investment in plant and machinery, and almost 4 times higher than investment in IT hardware. For information we also report MGVA excluding intangibles, with National Accounts intangibles and with all CHS intangibles.

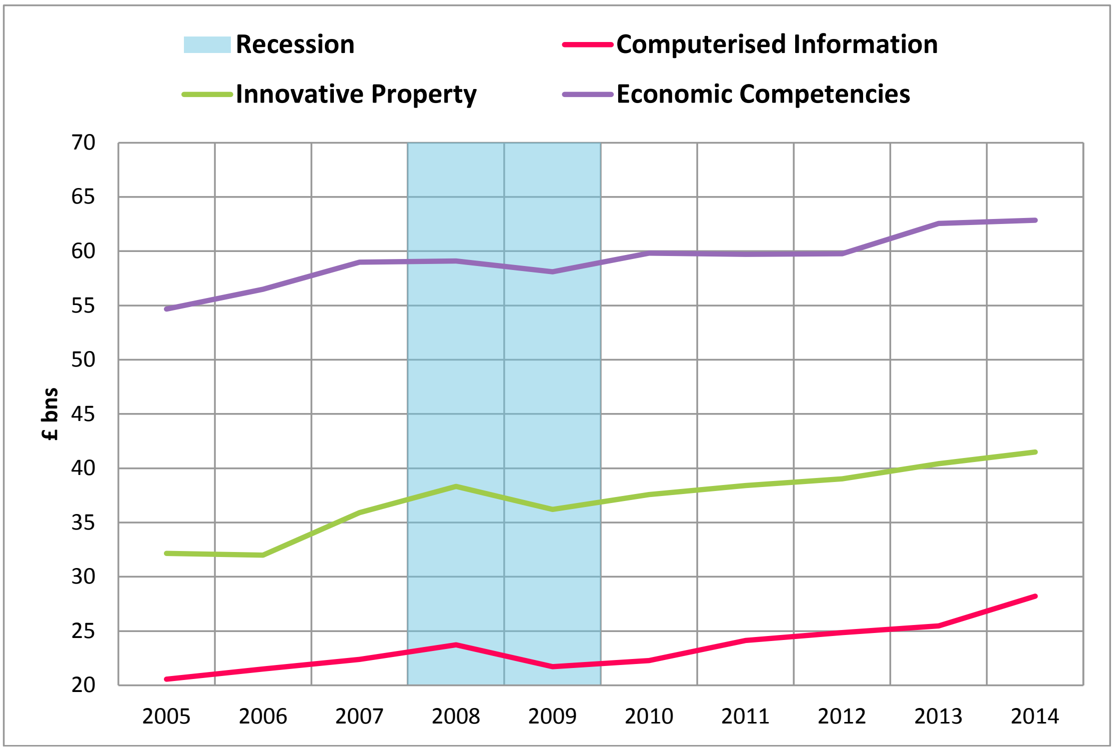
### Table 2: Tangible and Intangible Investment, £bns

| Asset | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---|---|---|---|---|---|---|
| Purchased Software | 2.6 | 5.3 | 7.3 | 9.6 | 10.0 | 15.5 |
| Own-Account Software | 4.9 | 5.9 | 9.8 | 10.9 | 12.3 | 12.7 |
| Total Software | 7.4 | 11.3 | 17.2 | 20.6 | 22.3 | 28.2 |
| | | | | | | |
| R&D | 8.2 | 9.2 | 11.8 | 13.4 | 16.3 | 19.0 |
| Design | 6.4 | 6.6 | 9.2 | 11.9 | 13.0 | 14.2 |
| Non-scientific R&D | 0.2 | 0.3 | 0.4 | 0.3 | 0.9 | 0.4 |
| Mineral Exploration | 1.7 | 1.1 | 0.4 | 0.4 | 1.0 | 1.1 |
| Financial Innovation | 0.3 | 0.4 | 0.6 | 0.8 | 1.3 | 1.7 |
| Artistic Originals | 2.7 | 4.2 | 5.4 | 5.4 | 5.1 | 5.2 |
| Total Innovative Property | 19.4 | 21.8 | 27.8 | 32.2 | 37.6 | 41.5 |
| | | | | | | |
| Advertising | 3.8 | 5.4 | 8.6 | 8.9 | 10.3 | 11.1 |
| Market Research | 1.0 | 1.3 | 1.7 | 2.9 | 3.2 | 4.0 |
| **Total Branding** | **4.8** | **6.7** | **10.3** | **11.7** | **13.6** | **15.1** |
| Own-Account Organisational Capital | 2.9 | 4.9 | 8.9 | 11.8 | 14.6 | 16.2 |
| Purchased Organisational Capital | 1.0 | 1.6 | 4.1 | 6.0 | 4.3 | 5.4 |
| **Total Organisational Captial** | **3.9** | **6.6** | **13.0** | **17.7** | **18.9** | **21.6** |
| Training | 11.8 | 14.4 | 19.9 | 25.2 | 27.4 | 26.2 |
| Total Economic Competencies | 20.5 | 27.7 | 43.1 | 54.7 | 59.8 | 62.9 |
| | | | | | | |
| TOTAL INTANGIBLES | 47.4 | 60.8 | 88.0 | 107.4 | 119.7 | 132.6 |
| Buildings | 41.2 | 22.3 | 36.7 | 39.7 | 49.6 | 67.0 |
| Plant & Machinery (excl IT) | 29.0 | 30.0 | 38.7 | 46.2 | 30.1 | 38.2 |
| Vehicles | 8.7 | 9.9 | 9.7 | 10.4 | 13.0 | 8.9 |
| IT Hardware | 4.7 | 5.7 | 7.2 | 5.7 | 5.1 | 6.9 |
| Telecom | 1.4 | 2.9 | 1.7 | 1.0 | 0.9 | 0.3 |
| | | | | | | |
| TOTAL TANGIBLES | 85.0 | 70.7 | 93.9 | 103.1 | 98.8 | 121.3 |
| **MSGVA** | | | | | | |
| Without Intangibles | 401.9 | 500.4 | 646.6 | 824.4 | 931.2 | 954.8 |
| With NA Intangibles | 422.0 | 526.2 | 681.4 | 864.1 | 975.9 | 1002.1 |
| With all CHS Intangibles | 449.4 | 561.2 | 734.7 | 931.8 | 1050.9 | 1077.0 |

Note to table. Data are investment figures, in £bns, current prices: italicized data are sub-totals for broader asset definitions. MSGVA is presented with no intangibles capitalized; with only NA intangibles capitalized (software, mineral exploration, R&D and artistic originals); and with all CHS intangibles capitalized. Market Sector refers to sectors A to K, MN, R to U, thus excluding real estate. Source: ONS data for tangibles, this paper for intangibles.

Above it was pointed out that intangible and tangible investment have behaved differently since the recession. Table 2 also shows that within intangible investment, different assets have behaved differently. The following chart looks more closely at investment in the three broad categories of computerised information, innovative property and economic competencies, in the 2000s and since the recession.

**Figure 2: Nominal Intangible Investment, by asset category, £bns, 2005-2014**




Note to figure: all data in current prices. Blue bars mark recession.

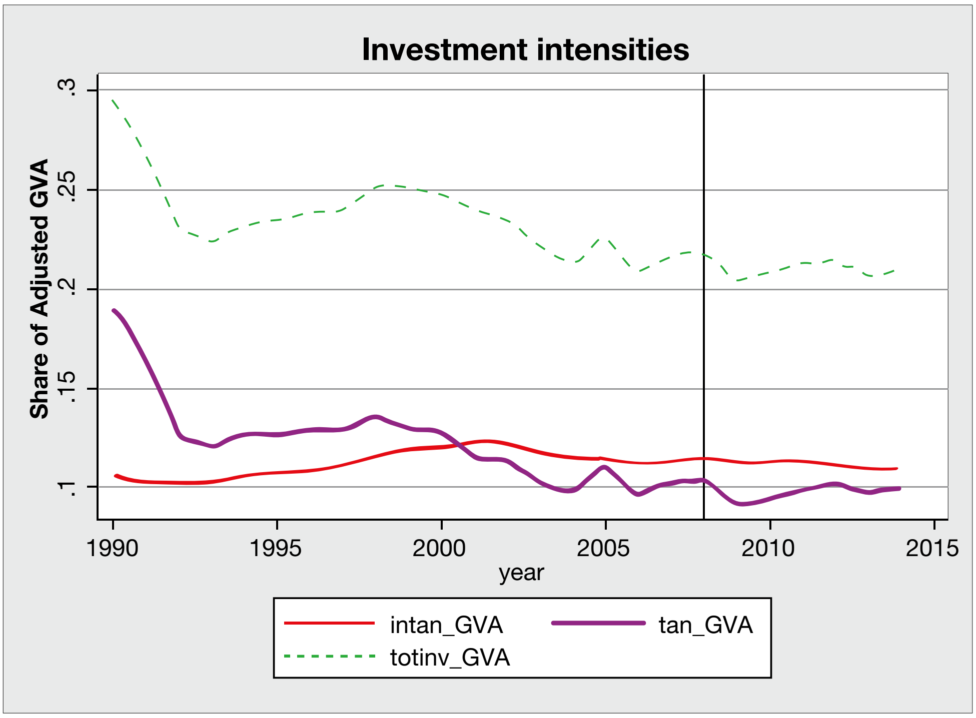
The figure shows that in the depths of the recession in 2009, investment in all three categories fell, but recovered quickly. The fall was strongest in computerised information, which fell by 8.6%, from £23.7bn in 2008, to £21.7bn in 2009. In the same years, investment in innovative property fell 5.5%, from £38.3bn to £36.2bn, and investment in economic competencies fell by 1.7%, from £59.1bn to £58.1bn. As the chart shows, since the recession, investment in all three categories has risen, but with the strongest growth being in computerised information, which since 2009 has grown at an average annual rate of 5.4% pa, compared to 2.8% pa for innovative property, and 1.6% pa for economic competencies.

In Figure 3 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 30% in 1989, to 25% in 2000, and to 21% in 2014.

Second, within total investment, tangible investment as a share of MSGVA has fallen. In 1990, tangible investment accounted for 19% of MSGVA, declining to around 13% in the late 1990s, and to around 10% by the late 2000s.

Third, intangible investment as a share of value-added rose steadily throughout the 1990s, peaking at 12% in 2001, before gradually declining to around 11% by 2014. It is worth noting that although the decline in tangible investment as a share of GVA 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.

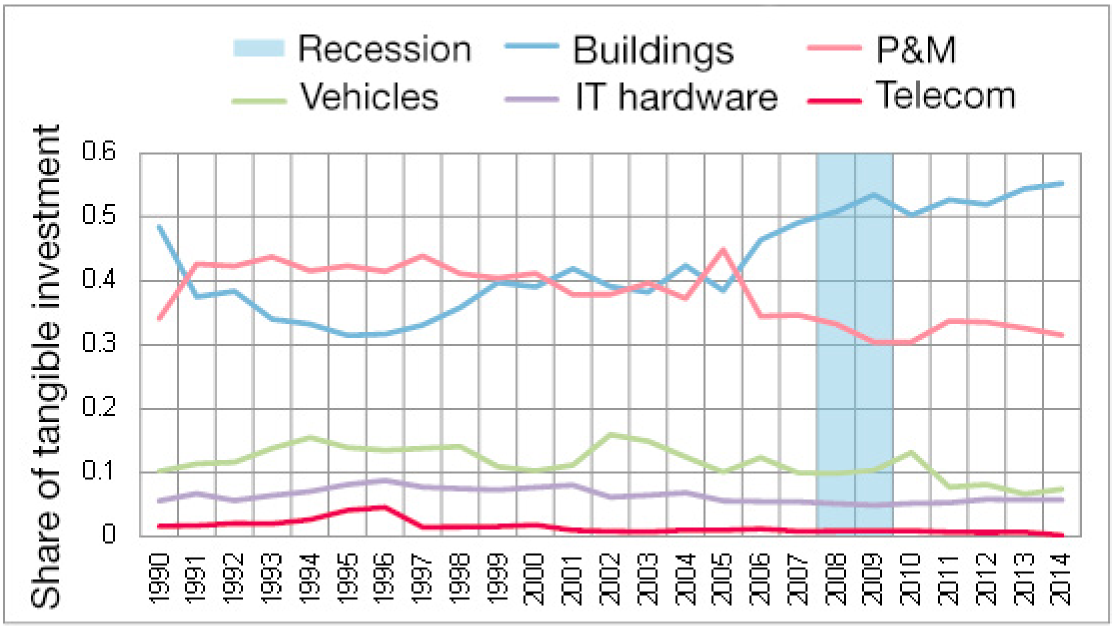
**Figure 3: Market Sector tangible and intangible investment as a share of (adjusted) MSGVA, 1990-2014**




Note to figure: MSGVA adjusted for a capitalisation of all CHS intangibles for all three series'. Intangible investment data also incorporates all CHS intangibles. The start of the recession in 2008 is marked with a vertical line.

The 1990s and 2000s have also seen significant changes to the composition of tangible investment. Figure 4 presents the share of nominal tangible investment accounted for by each asset. Most tangible investment is made up of investments in buildings and plant & machinery. Having been quite similar in the late 1990s and early 2000s, from the mid-2000s the shares for each asset diverge, with a huge run-up in investment in buildings during the commercial property boom. Buildings went from 32% of tangible investment in 1996, to 50% in 2007, 53% in 2009, and the share remains at 55% in 2014. In contrast, the share of investment devoted to plant & machinery declined, from 38% of tangible investment in 1996, to 30% in 2000.

**Figure 4: Shares of (nominal) tangible investment, by asset, 1990-2014**




Note to figure: Share of total nominal tangible investment for each asset. Only tangible assets, therefore software excluded. Investment shares sum to 100%. Recession marked by blue bar. Source: ONS data.

## 5.2 Industry intangible investment

Table 3 reports tangible and intangible investment by industry for 1997-2014. In the UK market sector, the ratio of intangible to tangible investment is 1.1:1 in 2014. Industries where the ratio is higher are, in the following order: financial services (3.3:1); information and communication (2.7:1); professional and administrative services (2.6:1); manufacturing (2:1); wholesale & retail/accommodation & food (1.4:1); and recreational & personal services (1.4:1). In particular, finance, information & communication, business services and manufacturing all invest very strongly in intangibles relative to 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 intangible investment is 13% of value added in 2014 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 2014. It shows the prevalence of R&D investment in manufacturing; design and training in construction; software, training and organisational investments in distribution; software and artistic originals in information & communication; software, branding and organisational investments in finance; and training in professional & administrative services.

### Table 3: Tangible and Intangible investment, by industry, Current Prices £bns

| | Agriculture Mining and Utilities | | Manufacturing | | Construction | | Wholesale & Retail Trade; Accommodation & Food Service Activities | | Transportation and Storage | | Information and Communication | | Financial Services | | Professional and Administrative Services | | Reecreational and Personal Services | | Market Sector (A-K, MN & R-T) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible |
| 1997 | 11.6 | 3.7 | 18.9 | 18.2 | 8.1 | 3.0 | 12.9 | 11.0 | 8.9 | 2.9 | 8.3 | 10.5 | 3.8 | 6.9 | 6.9 | 12.3 | 3.0 | 2.5 | 82.3 | 71.0 |
| 1998 | 11.8 | 3.3 | 19.4 | 19.6 | 9.9 | 3.2 | 14.8 | 12.5 | 9.7 | 2.9 | 8.7 | 11.4 | 4.8 | 7.8 | 8.7 | 14.0 | 2.9 | 2.8 | 90.7 | 77.4 |
| 1999 | 12.0 | 3.0 | 17.8 | 20.3 | 7.5 | 3.5 | 15.3 | 14.0 | 10.2 | 3.2 | 11.2 | 12.6 | 4.2 | 8.5 | 7.9 | 15.3 | 3.5 | 3.1 | 89.7 | 83.4 |
| 2000 | 11.2 | 2.9 | 16.7 | 20.2 | 9.1 | 3.7 | 14.1 | 14.2 | 11.8 | 3.3 | 13.4 | 14.2 | 4.4 | 9.9 | 9.3 | 16.4 | 3.9 | 3.3 | 93.9 | 88.0 |
| 2001 | 11.0 | 3.2 | 14.5 | 20.6 | 9.3 | 4.1 | 12.4 | 15.6 | 12.3 | 3.6 | 10.4 | 15.2 | 4.8 | 10.8 | 10.2 | 17.4 | 3.2 | 3.7 | 88.0 | 94.2 |
| 2002 | 14.8 | 3.7 | 11.9 | 20.3 | 11.6 | 4.4 | 12.4 | 16.3 | 15.4 | 3.8 | 8.5 | 15.5 | 4.3 | 10.6 | 8.4 | 18.3 | 3.1 | 3.8 | 90.3 | 96.8 |
| 2003 | 14.8 | 4.0 | 11.2 | 20.0 | 10.0 | 4.8 | 12.0 | 17.3 | 16.8 | 4.1 | 6.6 | 15.7 | 3.3 | 10.8 | 8.3 | 19.2 | 2.9 | 3.9 | 86.1 | 99.7 |
| 2004 | 14.5 | 3.7 | 10.0 | 20.3 | 12.6 | 5.2 | 11.9 | 17.8 | 15.5 | 4.0 | 7.7 | 16.2 | 3.2 | 10.6 | 7.2 | 18.8 | 3.3 | 4.0 | 85.9 | 100.7 |
| 2005 | 16.9 | 4.1 | 25.0 | 21.8 | 13.3 | 5.6 | 11.4 | 18.2 | 12.8 | 4.2 | 7.5 | 16.8 | 4.7 | 11.7 | 8.1 | 20.8 | 3.3 | 4.3 | 103.1 | 107.4 |
| 2006 | 19.6 | 4.3 | 9.3 | 21.5 | 15.5 | 6.0 | 11.6 | 18.9 | 14.7 | 4.5 | 8.5 | 17.3 | 3.7 | 11.8 | 9.3 | 21.1 | 3.0 | 4.7 | 95.1 | 110.0 |
| 2007 | 22.9 | 4.7 | 10.2 | 22.3 | 18.5 | 6.6 | 13.7 | 20.2 | 15.3 | 4.6 | 7.8 | 17.7 | 4.1 | 13.5 | 10.1 | 23.0 | 3.7 | 4.7 | 106.1 | 117.3 |
| 2008 | 23.4 | 4.4 | 10.9 | 22.8 | 20.6 | 6.7 | 13.8 | 20.7 | 17.5 | 5.0 | 7.6 | 18.3 | 4.6 | 13.5 | 6.5 | 24.7 | 3.8 | 5.0 | 108.6 | 121.2 |
| 2009 | 22.0 | 4.2 | 8.2 | 20.8 | 19.0 | 6.2 | 10.8 | 20.6 | 15.9 | 5.0 | 6.2 | 17.3 | 2.8 | 13.0 | 5.2 | 23.8 | 3.9 | 5.2 | 94.0 | 116.0 |
| 2010 | 20.7 | 5.2 | 8.6 | 21.1 | 19.6 | 6.2 | 10.9 | 20.9 | 19.0 | 5.1 | 6.7 | 17.1 | 3.6 | 13.8 | 6.0 | 24.9 | 3.8 | 5.5 | 98.8 | 119.7 |
| 2011 | 27.4 | 5.6 | 10.5 | 21.4 | 18.7 | 5.9 | 13.4 | 21.2 | 12.3 | 5.1 | 6.9 | 17.4 | 4.4 | 15.1 | 8.8 | 25.0 | 3.9 | 5.5 | 106.3 | 122.3 |
| 2012 | 31.2 | 6.2 | 11.4 | 22.1 | 19.1 | 6.0 | 13.0 | 21.6 | 11.2 | 5.1 | 6.6 | 17.4 | 5.7 | 15.6 | 9.5 | 24.1 | 4.1 | 5.6 | 111.9 | 123.6 |
| 2013 | 33.0 | 6.2 | 11.7 | 23.2 | 17.2 | 6.1 | 14.4 | 22.7 | 12.8 | 5.5 | 6.9 | 18.1 | 4.2 | 15.6 | 9.4 | 25.1 | 4.1 | 6.0 | 113.8 | 128.5 |
| 2014 | 33.6 | 6.0 | 12.1 | 23.7 | 18.4 | 6.3 | 16.5 | 23.7 | 14.2 | 5.8 | 7.0 | 18.8 | 4.9 | 16.2 | 10.3 | 26.3 | 4.2 | 5.9 | 121.3 | 132.6 |

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

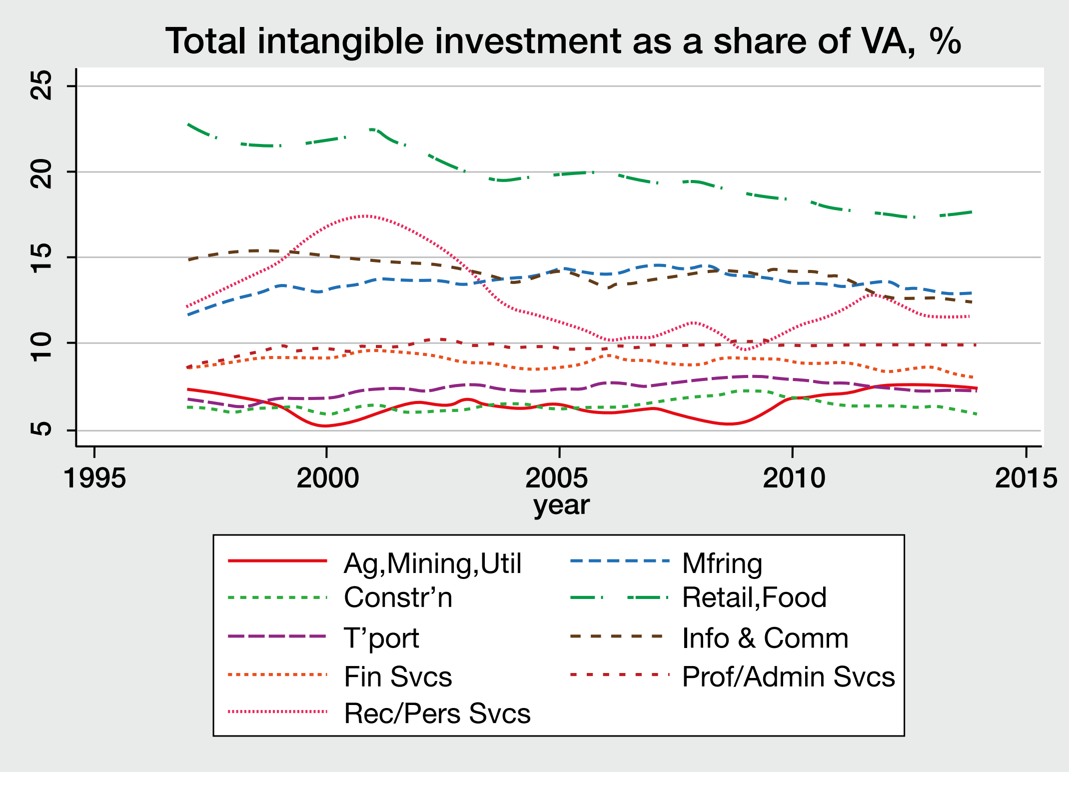
### Table 4: Intangible investment, by asset and industry, 2014, Current Prices £bns

| Industry | Software (purchased & own-account) | Scientific R&D | Arch & Ehg 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 and Utilities | 1.8 | 0.2 | 1.0 | 0.0 | 1.1 | 0.0 | 0.0 | 0.4 | 1.0 | 0.5 |
| Manufacturing | 3.8 | 8.3 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 2.3 | 3.2 | 2.7 |
| Construction | 0.5 | 0.1 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 2.3 | 1.1 |
| Wholesale and Retail Trade, Accommodation and Food | 5.6 | 0.9 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 7.5 | 4.9 |
| Transportation and Storage | 1.6 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 1.3 | 0.8 |
| Information and Communication | 5.3 | 1.8 | 1.7 | 4.8 | 0.0 | 0.0 | 0.0 | 2.2 | 1.3 | 1.6 |
| Financial Services | 3.8 | 0.5 | 1.4 | 0.0 | 0.0 | 1.7 | 0.0 | 3.6 | 0.7 | 4.5 |
| Professional and Administrative Servies | 4.8 | 6.9 | 1.9 | 0.0 | 0.0 | 0.0 | 0.4 | 1.0 | 6.7 | 4.6 |
| Recreational and Personal Services | 1.0 | 0.3 | 0.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.8 | 2.3 | 0.8 |

Source: authors' calculations.

Figure 5 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 consistently very high level in information and communication, and also the rise in the share for financial services due to the software boom in the late 1990s/early 2000s. In 2014, as a share of value-added, the most intangible-intensive sectors were information and communication (18%), manufacturing (13%), professional & administrative services (12%) and financial services (12%).

**Figure 5: Ratio of investment to (adjusted) value-added ratios, by industry (1997-2014)**




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 5 shows the asset share of total intangible spending by industry (in 2014, the shares are very stable over time). Starting with manufacturing, the largest share of all intangible spending is innovative property (49%), with software 16%. Innovative property is also important in information and communication, where it accounts for 44% of intangible spending, and software 28%. Note that innovative property in this industry includes the creation of new artistic originals in film, television, music, literary and miscellaneous works. Compare with professional & administrative services, where software accounts for only 18% whereas "ecom" (training, branding and organization building) accounts for 47%. Similarly, in trade & accommodation, software and, in particular, economic competencies are much more important than innovative property. Economic competencies are also shown to be very important in construction and also recreational and personal services.

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 35% of all intangible spend, but a trivial in most services with the exceptions of professional & administrative services (26%) and information & communications (10%). Training, line 2, accounts for 13% in manufacturing, 32% in distribution & food, 36% in construction, but only 4% in finance, but 33% in professional & administrative services. Investment in organisational capital, line 3, is 11% in manufacturing, 21% in distribution and a considerable 28% in finance. Finally, branding is around 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 2014)**

| | AgMinUtil | Mfr | Constr | RtAcc | Tran | InfoCom | FinSvc | Prof Admin | PersSvc |
|---|---|---|---|---|---|---|---|---|---|
| **Shares** | | | | | | | | | |
| Soft | 0.31 | 0.16 | 0.09 | 0.24 | 0.27 | 0.28 | 0.23 | 0.18 | 0.16 |
| innop | 0.37 | 0.49 | 0.32 | 0.11 | 0.12 | 0.44 | 0.22 | 0.35 | 0.19 |
| ecom | 0.32 | 0.34 | 0.60 | 0.65 | 0.61 | 0.28 | 0.54 | 0.47 | 0.65 |
| | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Individual Assets** | | | | | | | | | |
| R&D | 0.03 | 0.35 | 0.01 | 0.04 | 0.01 | 0.10 | 0.03 | 0.26 | 0.05 |
| Training | 0.17 | 0.13 | 0.36 | 0.32 | 0.22 | 0.07 | 0.04 | 0.25 | 0.38 |
| Organisational | 0.08 | 0.11 | 0.17 | 0.21 | 0.14 | 0.09 | 0.28 | 0.18 | 0.14 |
| Branding | 0.07 | 0.10 | 0.06 | 0.13 | 0.24 | 0.12 | 0.22 | 0.04 | 0.13 |

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.

## 5.3 Investment in intellectual property rights (IPRs)

As well as providing estimates of investment in intangibles disaggregated by asset and industry, in this report we also provide estimates of investment in intangibles that is formally protected by intellectual property rights (IPRs). Not all investment in intangibles is protected by IPRs such as copyright and patents. For instance, investments in software are protected (by copyright) but investments in workforce training are not. In the case of R&D and design, some parts of investment are protected by patents or design registration whilst other parts are protected by other means such as secrecy, confidentiality or complexity. Using an econometric method also described fully in Farooqui, Goodridge and Haskel (2011), Goodridge, Haskel and Wallis (2014a) estimate the proportions of UK intangible investment formally protected by the various types of IPRs, that is, by copyright, trademark, patent, design registration or unregistered design rights. We apply those proportions to measures of intangible investment presented in this report to estimates UK market sector investment in knowledge assets protected by formal IPRs.

Note, that the measures presented here are estimates of IPR-protected investment and not measures of all UK spend on IPRs. Rather they are measures of all long-lived spending on creating knowledge assets, which contribute to the production of output over a period of greater than one year, and which is protected by formal IP mechanisms. Thus, UK IPR investment can be considered a subset of UK IP production that creates assets to be employed in UK final production.

IPRs can be split into two broad groups: registered and unregistered rights. The first requires formal application from innovators, the second are automatic and invoked by the innovator when necessary. Table 6 summarises the IP rights considered in this report, how they fit into each of these groups and summarises the proportion of investment estimated to be protected by IPRs (by asset type).

### Table 6: Registered and Unregistered Rights; % of investment protected by IPRs

| | Registered | | | Unregistered | | |
|---|---|---|---|---|---|---|
| Asset \ IPR | Patents | Trade marks | Design Registration | Copyright | Unregistered Design rights | % of investment protected by IPRs |
| **Artistic Originals** | 0% | 0% | 0% | 100% | 0% | 100% |
| **Software** | 0% | 0% | 0% | 100% | 0% | 100% |
| **Branding** | 0% | 100% | 0% | 0% | 0% | 100% |
| **Scientific R&D** | 38% | 0% | 3% | 0% | 0% | 41% |
| **Design** | 2% | 0% | 11% | 0% | 87% | 100% |

Note to table: estimates for percentage protected by IPRs based on this report. Note that shares of investment protected do not equate to shares of expenditure protected.

First consider 'Artistic Originals'. One of the criteria set out by Eurostat for classification as an artistic original is that it must be covered by copyright. Therefore we consider our estimates of investment in these assets to all fall within the category of 'investment in copyrights'. Regarding software, since all copyrighted works are recognised automatically when asserted by the owner, we classify all investment in software (own-account and purchased) as 'investment in copyrights', alongside investment in artistic originals.

For Branding, we also estimate that 100% of our measure of investment is protected by Trademarks. Our reasoning is as follows. We recognise that not all expenditure on advertising and market research constitutes investment. Based on industry discussions we estimate investment in brands as 60% of expenditure on advertising and market research. In doing so, we effectively remove all short-lived expenditure. Since the remaining investment is by definition long-lived, we allocate all of that to our category 'investment in trademarks'.

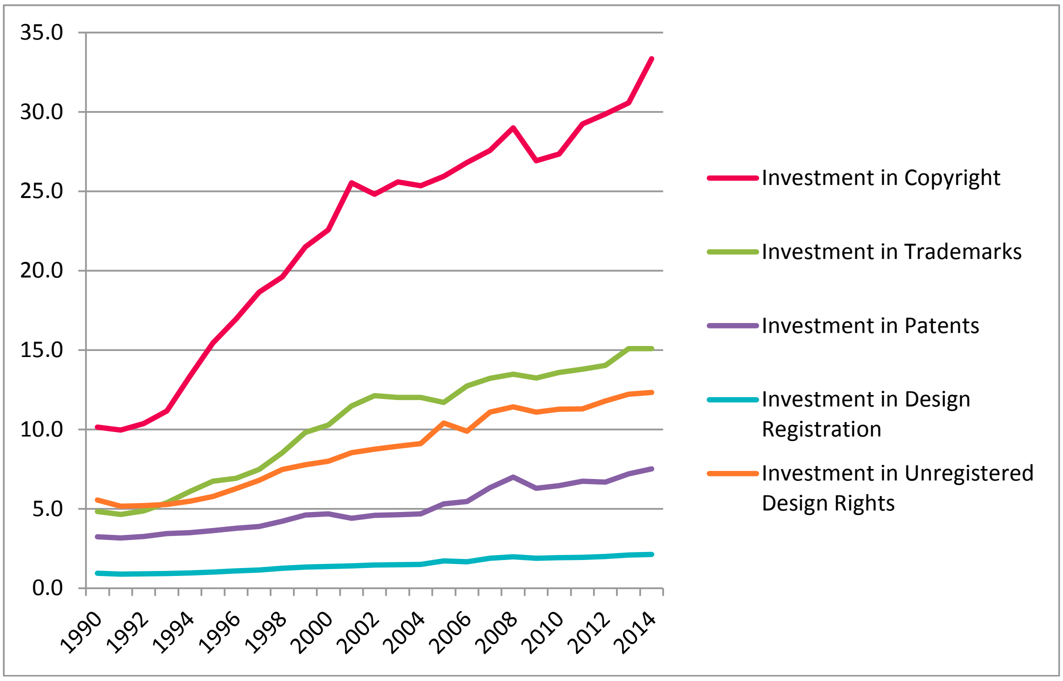
The remaining forms of intangible investment that can be protected by formal IPRs are Scientific R&D and Design, each of which can be protected by either patents or design registration. Using data from the UK Community Innovation Survey (CIS), Goodridge, Haskel and Wallis (2014a) estimate that 38% of R&D is protected by patents and 3% by design registration. Similarly they estimate that 11% of investments in architectural and engineering design (AED) are protected by design registration and 2% by patents. The remaining 87% of AED investment is allocated to unregistered design rights. Of other intangibles, we assume none are protected by formal IPRs. Of course certain licensing rights apply to activities such as Mineral Exploration, but not IPRs which are our interest in this report.

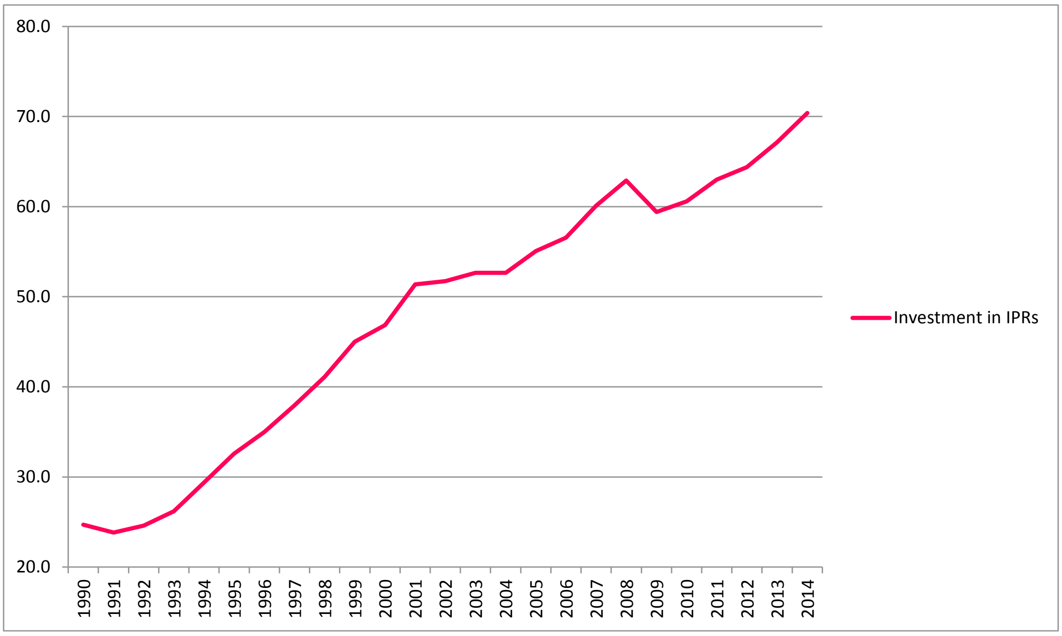
Applying these parameters, we estimate that in 2014 approximately 53% of UK market sector intangible investment (£70.4bn) was protected by formal IPRs. Of that, £33.3bn (47%) was in assets protected by copyright, £15.1bn (21%) was in assets protected by trademark, £12.3bn (18%) was in assets protected by unregistered design rights, £7.5bn (11%) was in assets protected by patent, and £2.1bn (3%) was in assets protected by design registration. Investment in each type of IPR is summarised in the figure 6.

We emphasise that this work estimates investment in knowledge assets and the proportions of that investment protected by formal IPRs. We take no stand on whether investment in knowledge assets is higher or lower than it would have been were those assets not protected by IPRs. That area requires further work. Whilst some evidence suggests that the ability to use IPRs increases investment in innovation through the incentive of monopolist revenues, others suggest that the same mechanism reduces innovation by removing the incentive to continually innovate.

Nevertheless, the scale of investment in IPR-protected assets is not fully appreciated. Investment in IPRs is higher than that in commercial buildings and also higher than plant and machinery (including ICT) and vehicles combined. The role of assets protected by IPRs, as drivers of growth, deserve greater consideration in both measurement and policy.

## Figure 6: UK investment in IPR-protected assets by IPR type, nominal, £bns




Note to figure: Estimated UK investment in intangible assets protected by IPRs. Investment in copyright estimated as 100% of investment in artistic originals and software. Investment in trademarks estimated as 100% of investment in advertising and market research. Investment in patents estimated as 38% of investment in scientific R&D plus 2% of investment in design. Investment in registered design estimated as 11% of investment in design plus 3% of investment in scientific R&D. Investment in unregistered design estimated at 87% of investment in design, that is, the remainder of design investment not allocated to patents or registered design.

# 6. Growth accounting results: market sector

## 6.1 Growth accounting results for the market economy

Our growth accounting results are set out in Table 7 (Panel 1). Consider Table 7 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 (i.e. labour composition) 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 the share of payments 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 growth in TFP, namely column 1 minus the sum of columns 2 to 6. 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 framework that *does not* include intangibles. LPG steadily declined over the first three periods (1990 to 2005) before collapsing in the penultimate period (2005 to 2010) which includes the financial crisis, and remaining very low in the final 2010-14 post-recession period.[21] The contribution of labour quality, column 2, rose in the late 1990s, fell back in the early 2000s, before showing a dramatic rise to 0.6% pa in 2005-10, and then falling back to a still strong 0.34% pa in the latest period. As noted in Franklin and Mistry (2013), labour composition has improved quite dramatically since the recession, with firm's upskilling, that is increasing the hours of their more skilled and/or experienced workers, and reducing the hours of the less skilled/experienced. In particular, there has been strong growth in the hours worked, and the share of hours worked, by workers with higher education qualifications over the period 2007 to 2012. At the same time, hours worked by workers with low levels of education has fallen (Franklin and Mistry, 2013).[22] Since it is education that predominantly drives the QALI data, labour composition during and since the recession has risen strongly.

Computer capital input grew quickly in the late 1990s, but fell considerably in the 2000s, and more so in the late 2000s so that it stood at just 0.03% pa in 2010-14. The opposite profile occurs for other tangibles (buildings, plant and vehicles). That contribution declined in the late 1990s, then rose in the early 2000s and again in 2005-10, before dropping to a very low 0.08% pa in the latest period. Overall, the total contribution of tangible capital fell in the 1990s (1.37% pa in 1990-95 and 0.85% pa in 1995-2000), and fell further to 0.77% pa in 2000-05, before rising to 0.95% pa

21 This is in contrast to previous work (Goodridge, Haskel and Wallis, 2012) where LPG was steady in the 1990s. Growth in real value-added in the late 1990s has been revised down since that previous report.

22 Similarly, since the recession, the hours of younger (less experienced) workers have also declined by more than the middle, and older, cohorts.

in 2005-10, and then falling to a low 0.1% pa in 2010-14. Thus the overall TFP record was one of strong growth in the early 1990s (1.73% pa), falling back in the late 1990s and early 2000s (1.44% pa and 1.41% pa respectively), and collapsing to -0.96% pa in the 2005-10 period. In the latest period since the recession, TFP growth remains weak at 0% pa.

Consider now the second set of results in panel 1, where we include intangibles officially capitalized in the SNA, namely software, mineral exploration, R&D and artistic originals, where software is the biggest category, followed by R&D. Their inclusion reduces output growth in the 1990s and early 2000s, has little impact in the 2005-10 period, but reduces growth in the latest 2010-14 period. Other contributions are also changed due to the changes in factor and asset income shares, and TFP growth is lowered substantially (especially in the late 1990s) for all except the 2005-10 period.

The third set of results are for a decomposition that incorporates all intangibles identified by CHS. Relative to the national accounts model, their inclusion raises output growth in the 1990s and the early 2000s, more so in the late 1990s, but reduces it in the late 2000s. The reason is that real intangible investment grew at a faster rate than measured output in the earlier periods, but at a slower rate than measured output in the more recent periods. The contribution of labour quality, column 2, falls due to the fall in the labour share, since we have expanded the amount of measured capital. The contribution of tangible capital, columns 3 to 5, also falls as the inclusion of intangibles lowers the factor income shares of these inputs. In column 6 we see the contribution of the intangible inputs; stronger in the 1990s and early 2000s, but low in 2005-10 and negative in the latest period when growth in intangible capital deepening has turned negative. Thus the overall TFPG record in column 7 is strong growth in the early 1990s, weakening somewhat in the late 1990s, strengthening in the early 2000s, followed by a collapse and consistently negative growth later in the 2000s.

## Table 7: 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/H) cmp | sDln(K/H) telecom | sDln(K/H) ohtan | sDln(K/H) 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 | 3.46% | 0.36% | 0.19% | 0.04% | 1.14% | | 1.73% | 0.64 | 0.50 | 0.50 | 0.61 | 1.73% |
| 1995-00 | 2.82% | 0.53% | 0.26% | 0.03% | 0.56% | | 1.44% | 0.64 | 0.51 | 0.51 | 0.70 | 1.44% |
| 2000-05 | 2.33% | 0.14% | 0.07% | 0.00% | 0.70% | | 1.14% | 0.68 | 0.61 | 0.61 | 0.67 | 1.41% |
| 2005-10 | 0.59% | 0.60% | 0.05% | 0.01% | 0.89% | | -0.96% | 0.67 | -1.63 | -1.63 | -0.61 | -0.96% |
| 2010-14 | 0.44% | 0.34% | 0.03% | -0.01% | 0.08% | | 0.00% | 0.67 | 0.00 | 0.00 | 0.76 | 0.00% |
| With National Accounts Intangibles: software, mineral exploration, artistic originals and R&D | | | | | | | | | | | | |
| 1990-95 | 3.16% | 0.35% | 0.18% | 0.04% | 1.10% | 0.22% | 1.28% | 0.61 | 0.41 | 0.47 | 0.58 | 1.50% |
| 1995-00 | 2.31% | 0.50% | 0.24% | 0.03% | 0.53% | 0.22% | 0.79% | 0.61 | 0.37 | 0.44 | 0.65 | 1.01% |
| 2000-05 | 2.09% | 0.13% | 0.07% | 0.00% | 0.65% | 0.17% | 1.07% | 0.65 | 0.51 | 0.59 | 0.66 | 1.24% |
| 2005-10 | 0.58% | 0.57% | 0.04% | 0.01% | 0.81% | 0.08% | -0.94% | 0.64 | -1.62 | -1.47 | -0.49 | -0.86% |
| 2010-14 | 0.18% | 0.32% | 0.03% | -0.01% | 0.07% | 0.03% | -0.26% | 0.64 | -1.46 | -1.30 | 0.50 | -0.23% |
| With All CHS Intangibles | | | | | | | | | | | | |
| 1990-95 | 3.20% | 0.33% | 0.17% | 0.03% | 1.05% | 0.59 | 1.03% | 0.57 | 0.32 | 0.51 | 0.61 | 1.62% |
| 1995-00 | 2.51% | 0.47% | 0.23% | 0.03% | 0.50% | 0.54 | 0.75% | 0.56 | 0.30 | 0.51 | 0.70 | 1.29% |
| 2000-05 | 2.13% | 0.12% | 0.06% | 0.00% | 0.59% | 0.41 | 0.94% | 0.60 | 0.44 | 0.64 | 0.69 | 1.35% |
| 2005-10 | 0.49% | 0.53% | 0.04% | 0.01% | 0.72% | 0.18 | -0.99% | 0.60 | -2.01 | -1.65 | -0.57 | -0.81% |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.05% | -0.16 | -0.16% | 0.60 | -2.70 | -5.35 | -0.23 | -0.31% |
| **2) Altering Depreciation rates** | | | | | | | | | | | | |
| With All CHS Intangibles: Halve intangible depreciation rates | | | | | | | | | | | | |
| 1990-95 | 3.20% | 0.33% | 0.17% | 0.04% | 1.10% | 0.60% | 0.97% | 0.57 | 0.30 | 0.49 | 0.59 | 1.57% |
| 1995-00 | 2.51% | 0.47% | 0.23% | 0.03% | 0.51% | 0.53% | 0.75% | 0.56 | 0.30 | 0.51 | 0.69 | 1.27% |
| 2000-05 | 2.13% | 0.12% | 0.06% | 0.00% | 0.59% | 0.53% | 0.82% | 0.60 | 0.39 | 0.63 | 0.69 | 1.35% |
| 2005-10 | 0.49% | 0.53% | 0.04% | 0.01% | 0.70% | 0.34% | -1.13% | 0.60 | -2.29 | -1.60 | -0.52 | -0.79% |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.04% | -0.15% | -0.16% | 0.60 | -2.68 | -5.19 | -0.07 | -0.30% |
| With All CHS Intangibles: Double intangible depreciation rates | | | | | | | | | | | | |
| 1990-95 | 3.20% | 0.33% | 0.17% | 0.03% | 1.01% | 0.54% | 1.12% | 0.57 | 0.35 | 0.52 | 0.62 | 1.66% |
| 1995-00 | 2.51% | 0.47% | 0.23% | 0.03% | 0.49% | 0.57% | 0.73% | 0.56 | 0.29 | 0.52 | 0.70 | 1.30% |
| 2000-05 | 2.13% | 0.12% | 0.06% | 0.00% | 0.59% | 0.32% | 1.03% | 0.60 | 0.48 | 0.63 | 0.69 | 1.35% |
| 2005-10 | 0.49% | 0.53% | 0.04% | 0.01% | 0.74% | 0.08% | -0.91% | 0.60 | -1.85 | -1.70 | -0.62 | -0.84% |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.06% | -0.08% | -0.24% | 0.60 | -4.14 | -5.49 | -0.37 | -0.32% |
| **3) Excluding 75% of Organisational own-account** | | | | | | | | | | | | |
| With All CHS Intangibles: Converstion factor for own-account organisational capital = 0.25 | | | | | | | | | | | | |
| 1990-95 | 3.17% | 0.33% | 0.17% | 0.03% | 1.05% | 0.54% | 1.05% | 0.58 | 0.33 | 0.50 | 0.60 | 1.58% |
| 1995-00 | 2.46% | 0.47% | 0.23% | 0.03% | 0.50% | 0.48% | 0.74% | 0.57 | 0.30 | 0.50 | 0.69 | 1.23% |
| 2000-05 | 2.11% | 0.13% | 0.06% | 0.00% | 0.59% | 0.37% | 0.96% | 0.61 | 0.45 | 0.63 | 0.69 | 1.33% |
| 2005-10 | 0.47% | 0.54% | 0.04% | 0.01% | 0.73% | 0.15% | -0.99% | 0.60 | -2.09 | -1.78 | -0.65 | -0.85% |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.05% | -0.15% | 0.17% | 0.61 | -2.65 | -4.99 | 0.17 | -0.31% |

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 telecoms 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 6. Column 8 is the share of labour payments in MGVA. Columns 9-12 are alternative versions of the innovation index.

Our Innovation Index is shown in columns 9 to 12. 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 all other CHS intangibles lowers TFPG as a share of LPG. Consider column 9 in the upper panel. TFPG as a share of LPG is over 17 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 of the lower panel, TFPG and intangible capital deepening are between 51-64% of LPG in the 1990s and early 2000s. Column 11 adds the contribution of labour quality taking the figure to around 61-70% in the 1990s and early 2000s.

In the late 2000s, the large negative contribution from TFP makes the Innovation Index more difficult to interpret. In those periods, the large negative contribution from TFP and, in the latest period a negative contribution from intangible capital deepening, results in a negative contribution from innovation, which is far larger in absolute terms than LPG.[23]

## 6.2 Measurement of growth

Before going on to discuss some robustness checks on our growth-accounting, it is worth saying a little more on the measurement of growth. As Table 7 shows, whether or not intangibles are capitalised can have a significant impact on measured growth in output and labour productivity. In particular, relative to the national accounts, including the additional CHS intangibles raises output growth in the 1990s and early 2000s, particularly in the late 1990s, and reduces it in the late 2000s. To explain why this is so, consider two measures of output: V (as measured in the national accounts); and Q where all additional CHS intangibles are capitalised.

$$
\begin{aligned}
V_t &= A_t F(L_t, K_t) \\
Q_t &= A_t F(L_t, K_t, R_t) \\
V &= C + I \\
Q &= C + I + N \qquad (7)
\end{aligned}
$$

Measured output (V) is thus a function of services from labour (L) and measured capital (K)[24] with the technological shift parameter, A. In a model where all intangibles are capitalised, adjusted output (Q) is a function of services from labour, measured capital and additional intangible capital (R).

23 Some part of this is almost certainly mis-measurement, with capital (and possibly labour) services during and since the recessions overestimated (and thus TFP under-estimated) due to inability to measure factor utilisation.

24 Where measured capital in the national accounts does include some forms of intangible capital, namely software, mineral exploration, R&D and artistic originals.

Measured output is the sum of final consumption expenditure (C) and measured investment (I). Adjusted output includes additional intangible investment (N). Therefore we can write the relation between measured output growth and adjusted output growth as:

$$\Delta \ln Q_t = \left(1 - s_t^{Q,N}\right)\Delta \ln V_t + s_t^{Q,N} \Delta \ln N_t$$

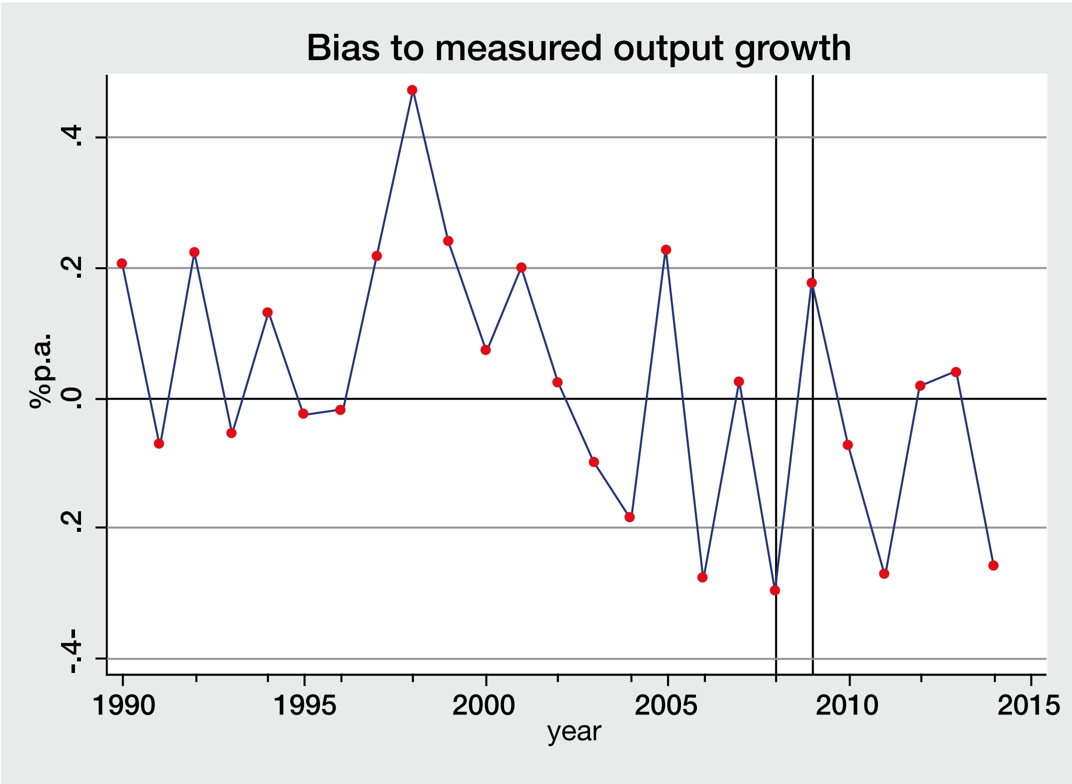
$$\Delta \ln Q_t = \Delta \ln V_t + s_t^{Q,N} \left(\Delta \ln N_t - \Delta \ln V_t\right) \qquad (8)$$

Therefore if $\Delta \ln N_t > \Delta \ln V_t$, measured growth will understate true output growth, $\Delta \ln Q_t$, and vice versa. The term $s_t^{Q,N} \left(\Delta \ln N_t - \Delta \ln V_t\right)$ is therefore an estimate of the bias to measured output if intangibles are not treated as capital. The following chart presents a time-series for this term.

As can be seen, the bias term tended to be positive through the 1990s and early 2000s, meaning that measured growth in GDP understated true growth. This mismeasurement was as much as 0.47% in 1998. In general, post-2003 and in the years leading up to and during the recession, output growth was overestimated, by 0.28% in 2006 and by 0.3% in 2008, the first year of the recession. Since the recession, output growth has generally been overestimated, by 0.27% in 2010 and by 0.26% in 2014, because although real intangible investment has grown, it has grown slowly and even slower than measured output.[25]

25 Note that this goes against what was reported in Goodridge, Haskel and Wallis (2013). In that paper we assumed that after the recession all intangible investment grew at the same rate as scientific R&D. As shown in Figure 2, while investment in innovative property grew (largely made up of scientific R&D), investment in other intangibles grew less quickly than R&D. Our assumption therefore turned out to be incorrect.

**Figure 7: Bias to measured output growth**




Note to figure: Bias to measured output growth when additional CHS intangibles are not capitalised. If the term is positive, measured growth is underestimated due to the omission of intangibles not currently capitalised in the national accounts. If it is negative, measured growth is overestimated. Recession marked with vertical lines.

## 6.3 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 Table 7. Panel 2 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 has little impact in the 1990s, but causes the contribution of intangibles to rise in the 2000s as would be expected, with the exception of the latest period where again there is little impact. The difference simply reflects the intangible investment boom that took place in the late 1990s forming much of the stock. The effect in the 1990s is therefore small as the intangible stock itself is small. The changes in the contributions more or less directly affect ΔlnTFP, so that, if for example, intangibles depreciated half as fast as we have assumed, ΔlnTFP falls from -0.99%pa to -1.13%pa in 2005-10. Doubling the depreciation rates reduces the contribution of intangibles in the early 1990s and most of the 2000s (except for the latest period) and similarly increases the contribution of ΔlnTFP in most periods.

Since estimation of own account organisational capital is particularly uncertain, panel 3 reduces such spending by 75% (that is, managers are assumed to spend 5% of their time building organisational capital, as opposed to 20% in the baseline estimates). In this case the contribution of intangible capital is reduced by 0.03-0.05% pa, with the exception of the final period where the contribution is raised very slightly, and the contribution of ΔlnTFP is generally raised slightly, though not in all periods.

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 each of the models. 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.

## 6.4 Annual Contributions and the impact of recession

All tables above are based on 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. Also note that in years when TFP and/or LPG are negative, care should be taken in interpreting estimates of the Innovation Index. Also note that annual changes in the contributions reflect changes in ex-post rental prices, due to the inability to accurately observe the utilisation of capital.[26]

The data show the fall in labour productivity that occurred in 2008 and the collapse in 2009, as well as the double dip in 2012, and also ongoing weakness in productivity (LPG, driven by weakness in TFP), usually termed the "productivity puzzle". A small rise in the labour income share since the recession (column 8), combined with rises in the wagebill share of experienced and skilled worked resulted in a strong contribution from labour composition (column 2) during and after the recession. The rise in composition during the recession, combined with the strong contribution of other tangible capital, results in large negative estimates for the TFP residual in 2008 and 2009.

26 We also looked at year by year changes and in particular the impact of the recession. In 2009, there was a decline of -7% in adjusted growth in value-added, and smaller contributions from capital services than the previous year (0.07% pa in 2009 compared to 0.89% pa in 2008). Measured TFP falls by -5.57% pa in 2009. 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.

## Table 8: Annual Decomposition, 'National Accounts model' vs 'All CHS intangibles'

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DlnV/H | sDln (L/H) | sDln (K/H) cmp | sDln (K/H) telecom | sDln (K/H) othtan | sDln (K/H) intan | DlnTFP | Memo: sLAB | InnIndex1 | InnIndex2 | InnIndex3 | InnIndex4 |
| National Acc's Intangibles: software; mineral exploration; artistic originals; and R&D | | | | | | | | | 7/1 | (6+7)/1 | (2+6+7)/1 | (6+7) |
| 1991 | 3.11% | -0.03% | 0.27% | 0.04% | 2.70% | 0.33% | -0.20% | 0.62 | -0.07 | 0.04 | 0.03 | 0.13% |
| 1992 | 4.64% | 0.54% | 0.06% | 0.03% | 1.85% | 0.23% | 1.93% | 0.62 | 0.42 | 0.47 | 0.58 | 2.17% |
| 1993 | 4.39% | 0.01% | 0.13% | 0.02% | 0.95% | 0.12% | 3.16% | 0.61 | 0.72 | 0.75 | 0.75 | 3.28% |
| 1994 | 2.72% | 0.60% | 0.17% | 0.03% | 0.03% | 0.16% | 1.73% | 0.60 | 0.64 | 0.70 | 0.92 | 1.89% |
| 1995 | 0.95% | 0.61% | 0.27% | 0.07% | -0.04% | 0.24% | -0.22% | 0.59 | -0.23 | 0.03 | 0.68 | 0.03% |
| 1996 | 2.40% | 0.11% | 0.32% | 0.10% | 0.37% | 0.26% | 1.24% | 0.59 | 0.52 | 0.62 | 0.67 | 1.50% |
| 1997 | 0.61% | 0.54% | 0.26% | -0.01% | 0.17% | 0.22% | -0.57% | 0.58 | -0.93 | -0.57 | 0.32 | -0.35% |
| 1998 | 2.34% | 1.04% | 0.29% | 0.01% | 0.78% | 0.20% | 0.02% | 0.60 | 0.01 | 0.09 | 0.54 | 0.21% |
| 1999 | 2.50% | 0.39% | 0.19% | 0.02% | 0.64% | 0.21% | 1.05% | 0.62 | 0.42 | 0.50 | 0.66 | 1.25% |
| 2000 | 3.71% | 0.42% | 0.15% | 0.03% | 0.70% | 0.21% | 2.20% | 0.64 | 0.59 | 0.65 | 0.76 | 2.41% |
| 2001 | 1.74% | -0.08% | 0.06% | -0.01% | 0.25% | 0.29% | 1.23% | 0.66 | 0.71 | 0.87 | 0.83 | 1.52% |
| 2002 | 2.80% | 0.29% | 0.01% | 0.00% | 1.07% | 0.21% | 1.21% | 0.66 | 0.43 | 0.51 | 0.61 | 1.42% |
| 2003 | 2.72% | 0.38% | 0.07% | 0.00% | 0.72% | 0.17% | 1.38% | 0.65 | 0.51 | 0.57 | 0.71 | 1.55% |
| 2004 | 1.86% | -0.60% | 0.09% | 0.01% | 0.44% | 0.11% | 1.81% | 0.64 | 0.97 | 1.03 | 0.71 | 1.92% |
| 2005 | 1.35% | 0.69% | 0.11% | 0.02% | 0.74% | 0.08% | -0.27% | 0.64 | -0.20 | -0.15 | 0.36 | -0.20% |
| 2006 | 2.87% | 0.62% | 0.06% | 0.02% | 0.63% | 0.11% | 1.42% | 0.63 | 0.49 | 0.53 | 0.75 | 1.53% |
| 2007 | 1.78% | 0.44% | 0.11% | 0.01% | 0.46% | 0.04% | 0.72% | 0.64 | 0.41 | 0.43 | 0.68 | 0.77% |
| 2008 | -1.19% | -0.28% | 0.07% | 0.01% | 0.67% | 0.10% | -1.77% | 0.64 | 1.49 | 1.40 | 1.63 | -1.67% |
| 2009 | -2.42% | 1.46% | -0.01% | 0.01% | 1.72% | 0.15% | -5.75% | 0.65 | 2.37 | 2.31 | 1.71 | -5.59% |
| 2010 | 1.88% | 0.63% | -0.01% | 0.01% | 0.58% | 0.01% | 0.65% | 0.65 | 0.35 | 0.36 | 0.69 | 0.67% |
| 2011 | 1.12% | 0.59% | 0.02% | 0.00% | 0.35% | 0.06% | 0.10% | 0.65 | 0.09 | 0.14 | 0.67 | 0.16% |
| 2012 | -1.64% | 0.66% | 0.04% | 0.00% | 0.10% | 0.02% | -2.47% | 0.65 | 1.51 | 1.49 | 1.09 | -2.45% |
| 2013 | 0.46% | 0.19% | 0.03% | 0.00% | 0.04% | 0.00% | 0.20% | 0.65 | 0.45 | 0.45 | 0.85 | 0.21% |
| 2014 | 0.78% | -0.15% | 0.01% | -0.02% | -0.22% | 0.03% | 1.13% | 0.63 | 1.44 | 1.48 | 1.29 | 1.16% |
| | | | | | | | | | | | | |
| All CHS Intangibles | | | | | | | | | | | | |
| 1991 | 3.04% | -0.03% | 0.26% | 0.04% | 2.57% | 0.94% | -0.74% | 0.58 | -0.24 | 0.07 | 0.06 | 0.20% |
| 1992 | 4.87% | 0.51% | 0.05% | 0.03% | 1.77% | 0.82% | 1.69% | 0.58 | 0.35 | 0.52 | 0.62 | 2.51% |
| 1993 | 4.34% | 0.01% | 0.13% | 0.01% | 0.90% | 0.48% | 2.80% | 0.58 | 0.65 | 0.76 | 0.76 | 3.28% |
| 1994 | 2.85% | 0.56% | 0.16% | 0.02% | 0.03% | 0.37% | 1.70% | 0.56 | 0.60 | 0.73 | 0.92 | 2.07% |
| 1995 | 0.92% | 0.57% | 0.25% | 0.07% | -0.03% | 0.36% | -0.30% | 0.56 | -0.32 | 0.07 | 0.69 | 0.06% |
| 1996 | 2.38% | 0.10% | 0.30% | 0.10% | 0.34% | 0.41% | 1.13% | 0.55 | 0.48 | 0.65 | 0.69 | 1.54% |
| 1997 | 0.82% | 0.51% | 0.24% | -0.01% | 0.16% | 0.33% | -0.40% | 0.54 | -0.48 | -0.09 | 0.53 | -0.07% |
| 1998 | 2.81% | 0.97% | 0.27% | 0.01% | 0.73% | 0.61% | 0.21% | 0.56 | 0.07 | 0.29 | 0.64 | 0.82% |
| 1999 | 2.74% | 0.36% | 0.18% | 0.02% | 0.60% | 0.71% | 0.86% | 0.58 | 0.31 | 0.57 | 0.71 | 1.57% |
| 2000 | 3.78% | 0.39% | 0.14% | 0.03% | 0.65% | 0.65% | 1.92% | 0.59 | 0.51 | 0.68 | 0.78 | 2.57% |
| 2001 | 1.94% | -0.08% | 0.06% | -0.01% | 0.23% | 0.64% | 1.10% | 0.61 | 0.57 | 0.90 | 0.86 | 1.74% |
| 2002 | 2.82% | 0.27% | 0.01% | 0.00% | 0.98% | 0.62% | 0.94% | 0.61 | 0.33 | 0.55 | 0.65 | 1.56% |
| 2003 | 2.62% | 0.35% | 0.07% | 0.00% | 0.66% | 0.40% | 1.15% | 0.60 | 0.44 | 0.59 | 0.73 | 1.55% |
| 2004 | 1.67% | -0.55% | 0.08% | 0.01% | 0.39% | 0.20% | 1.54% | 0.59 | 0.92 | 1.04 | 0.71 | 1.74% |
| 2005 | 1.58% | 0.64% | 0.10% | 0.01% | 0.67% | 0.21% | -0.05% | 0.59 | -0.03 | 0.10 | 0.51 | 0.16% |
| 2006 | 2.59% | 0.57% | 0.06% | 0.02% | 0.56% | 0.27% | 1.10% | 0.59 | 0.43 | 0.53 | 0.75 | 1.38% |
| 2007 | 1.80% | 0.41% | 0.10% | 0.01% | 0.40% | 0.15% | 0.74% | 0.59 | 0.41 | 0.49 | 0.72 | 0.88% |
| 2008 | -1.49% | -0.26% | 0.06% | 0.01% | 0.59% | 0.08% | -1.98% | 0.60 | 1.33 | 1.28 | 1.45 | -1.90% |
| 2009 | -2.25% | 1.35% | -0.01% | 0.01% | 1.52% | 0.46% | -5.57% | 0.60 | 2.48 | 2.28 | 1.68 | -5.12% |
| 2010 | 1.81% | 0.59% | -0.01% | 0.00% | 0.51% | -0.06% | 0.77% | 0.61 | 0.43 | 0.39 | 0.72 | 0.71% |
| 2011 | 0.84% | 0.55% | 0.02% | 0.00% | 0.31% | -0.12% | 0.09% | 0.60 | 0.11 | -0.03 | 0.62 | -0.03% |
| 2012 | -1.63% | 0.62% | 0.04% | 0.00% | 0.09% | -0.19% | -2.17% | 0.61 | 1.34 | 1.45 | 1.08 | -2.37% |
| 2013 | 0.50% | 0.17% | 0.03% | 0.00% | 0.02% | -0.07% | 0.34% | 0.60 | 0.69 | 0.55 | 0.90 | 0.27% |
| 2014 | 0.52% | -0.14% | 0.01% | -0.01% | -0.20% | -0.24% | 1.11% | 0.59 | 2.13 | 1.67 | 1.41 | 0.87% |

The above table is presented as a decomposition of labour productivity, with all terms expressed in terms of per hour worked. 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 (column 2) therefore includes the volume of hours worked plus the impact of labour quality or composition.

### Table 9: 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 | 2.63% | 0.59% | 0.06% | 0.02% | 0.42% | 0.14% | 0.01% | 0.28% | 1.10% | 0.59 |
| 2007 | 3.01% | 1.12% | 0.11% | 0.01% | 0.52% | 0.24% | -0.04% | 0.31% | 0.74% | 0.59 |
| 2008 | -1.15% | -0.05% | 0.06% | 0.01% | 0.55% | 0.18% | -0.04% | 0.13% | -1.98% | 0.60 |
| 2009 | -7.00% | -1.50% | -0.05% | 0.00% | 0.46% | -0.05% | -0.10% | -0.19% | -5.57% | 0.60 |
| 2010 | 1.74% | 0.54% | -0.01% | 0.00% | 0.47% | 0.00% | 0.03% | -0.07% | 0.77% | 0.61 |
| 2011 | 1.62% | 1.02% | 0.02% | 0.00% | 0.56% | 0.09% | -0.14% | -0.01% | 0.09% | 0.60 |
| 2012 | 0.20% | 1.72% | 0.05% | 0.00% | 0.53% | 0.11% | -0.09% | 0.05% | -2.17% | 0.61 |
| 2013 | 2.32% | 1.27% | 0.04% | 0.00% | 0.51% | 0.09% | -0.12% | 0.18% | 0.34% | 0.60 |
| 2014 | 3.69% | 1.72% | 0.03% | -0.01% | 0.54% | 0.13% | -0.04% | 0.21% | 1.11% | 0.59 |

Note to table: annual decomposition of growth in market sector value-added not in per hour terms.

The data show that the UK market sector suffered a massive 7% fall in value-added in 2009.[27] Strong falls in market sector investment were enough to cause estimates of growth in capital services from computers to turn negative in 2009 and 2010, whilst that from vehicles has been negative in all years since 2006 except 2010. The contribution from plant and machinery is also much lower from 2009. The exception to this pattern is buildings. Whilst the contribution for buildings does drop in 2009, it remains positive and substantial, and has since grown, reflecting their slower rate of depreciation and the size of the existing stock. This means that a much sharper and more sustained fall in investment is required to generate a fall in the capital stock. On intangibles, Table 9 shows that the contribution from intangible capital services turned negative in 2009 before returning to positive values from 2012.

27 Note that this is more than the estimates usually quoted as we exclude all government spending, which held up estimates of growth in wider GDP.

## 6.5 Contributions of individual intangible assets

Contributions of each tangible and intangible asset are set out in Table 10. The table shows that, in the most recent period, much of the contribution of capital deepening was in buildings, reflecting the slow depreciation rate of this asset so that the collapse in investment has not had so much impact on growth in the stock. The depreciation rates for other assets, particularly intangibles but also computers and plant for instance, are much higher. The contribution of those assets in the most recent period has therefore been much reduced compared to earlier years, with the contribution of plant, vehicles being negative in the 2010-14 period.

Of the intangibles, data for the most recent period show the contributions to have been relatively weak and in most cases negative. In particular we note a large negative contribution from workforce training. There were positive contributions however from software and mineral exploration. Looking at earlier periods, column 8 shows that software has been an important driver of growth, with a contribution of 0.21% pa in the late 1990s, but of just 0.05% pa in 2010-14. We also note that the contribution of R&D[28] capital deepening is negative in the latest period.[29]

28 Note, R&D in this table is a broad definition that includes R&D in financial services and social sciences, as well as scientific R&D.

29 Note, growth in R&D capital services remains positive but growth in R&D capital deepening (that is growth in capital services *per hour* i.e. DlnK(rd) – DlnH) is negative.

## Table 10: Contributions of individual assets: Detailed breakdown

| | | 1990-95 | 1995-00 | 2000-05 | 2005-10 | 2010-14 |
|---|---|---|---|---|---|---|
| 1 | Dln V/H | 3.20% | 2.51% | 2.13% | 0.49% | 0.06% |
| 2 | sDln (L/H) | 0.33% | 0.47% | 0.12% | 0.53% | 0.30% |
| 3 | sDln (K/H) cm p | 0.17% | 0.23% | 0.06% | 0.04% | 0.02% |
| 4 | sDln (K/H) telecom | 0.03% | 0.03% | 0.00% | 0.01% | 0.00% |
| 5 | sDln (K/H) buildings | 0.40% | 0.20% | 0.24% | 0.57% | 0.27% |
| 6 | sDln (K/H) P&M | 0.62% | 0.29% | 0.33% | 0.16% | -0.08% |
| 7 | sDln (K/H) vehicles | 0.03% | 0.01% | 0.03% | -0.01% | -0.13% |
| 8 | sDln (K/H) software | 0.18% | 0.21% | 0.17% | 0.09% | 0.05% |
| 9 | sDln (K/H) m in | 0.00% | -0.03% | -0.02% | 0.00% | 0.01% |
| 10 | sDln (K/H) cop | 0.03% | 0.02% | 0.01% | -0.01% | -0.03% |
| 11 | sDln (K/H) aed | 0.06% | 0.04% | 0.03% | 0.03% | -0.02% |
| 12 | sDln (K/H) rd | 0.07% | 0.03% | 0.01% | 0.05% | -0.02% |
| 13 | sDln (K/H) brand | 0.05% | 0.07% | 0.03% | 0.02% | -0.01% |
| 14 | sDln (K/H) train | 0.10% | 0.06% | 0.08% | -0.03% | -0.12% |
| 15 | sDln (K/H) org | 0.10% | 0.13% | 0.10% | 0.02% | -0.01% |
| 16 | DlnTFP | 1.03% | 0.75% | 0.94% | -0.99% | -0.16% |
| 17 | Memo: sLAB | 0.57 | 0.56 | 0.60 | 0.60 | 0.60 |

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 telecoms 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 IT hardware) 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 per hour times share in MGVA. 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 MGVA. 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 MGVA. Column 13 is capital services from branding (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.

## 6.6 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 or access 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.

In this report we make use of Experimental Service Producer Price Indices (SPPIs) produced by the ONS to estimate changes in the price of intangibles, which we believe is an improvement on past compilations of the Innovation Index. Specifically, for architectural and engineering design we use the SPPI for the related industry, “Technical testing and analysis”, for advertising we use the SPPI for “Advertising Placement”, for market research we use the SPPI for “Market Research”, for organisational capital we use the SPPI for “Business and Management Services”, and for training we use the SPPI for “Adult Education”. However, these price indices only extend back to the mid-2000s. Therefore in terms of their impact on our growth-accounting estimates, they only affect results for the latest period, 2005-11. Since these price indices typically rise slightly slower than a value-added price index, estimated real intangible investment therefore grows slightly faster than it otherwise would. The only remaining assets for which we do not have a specific deflator are financial product innovation and non-scientific R&D, and we deflate each with the implied UK value-added deflator.

For software, mineral exploration, R&D and artistic originals we use the deflators from the ONS VICS system. In the case of purchased software, the index is based on the hedonic price index produced by the BEA.[30] The own-account index is based on the reported wages of software writers with a small adjustment for assumed growth in productivity, based on labour productivity growth in the wider service sector. However, it might be argued that productivity growth in the creation of own-account software has likely been similar to that in the creation of purchased software.[31] In that case, application of the own-account index would underestimate growth in real investment and software capital services. We therefore test the impact, on the contribution of software, of deflating own-account software with the purchased index. The result is shown in the second panel of Table 11.

30 The UK price index for pre-packaged software is actually the BEA pre-packaged index, adjusted for the UK:US exchange rate. The purchased index is then estimated as an unweighted average of the pre-packaged and own-account indices, with the latter incorporated to take account of purchased custom software.

31 After all, considering that the writers of own-account and purchased software likely move between such roles, and considering the factors that affect productivity, such as growth in the availability of open-source software, growth in the processing power of hardware, and progress in programming languages, apply to production of both types of software, then it seems reasonable that productivity growth in the creation of each is similar.

**Table 11: Alternative deflators for intangible assets**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **DlnV/H** | **sDln(L/H)** | **sDln(K/H) cmp** | **sDln(K/H) telecom** | **sDln(K/H) othtan** | **sDln(K/H) software** | **sDln(K/H) innov less rd** | **sDln(K/H) rd** | **sDln(K/H) ec comp** | **DlnTFP** | **Memo: sLAB** |
| 1) Baseline | | | | | | | | | | | |
| All CHS Intangibles | | | | | | | | | | | |
| 1990-95 | 3.20% | 0.33% | 0.17% | 0.03% | 1.05% | 0.18% | 0.09% | 0.07% | 0.25% | 1.03% | 0.57 |
| 1995-00 | 2.51% | 0.47% | 0.23% | 0.03% | 0.50% | 0.21% | 0.03% | 0.03% | 0.27% | 0.75% | 0.56 |
| 2000-05 | 2.13% | 0.12% | 0.06% | 0.00% | 0.59% | 0.17% | 0.02% | 0.01% | 0.21% | 0.94% | 0.60 |
| 2005-10 | 0.49% | 0.53% | 0.04% | 0.01% | 0.72% | 0.09% | 0.04% | 0.05% | 0.01% | -0.99% | 0.60 |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.05% | 0.05% | -0.05% | -0.02% | -0.14% | -0.16% | 0.60 |
| | | | | | | | | | | | |
| 2) Using UK purchased software deflator for own-account software | | | | | | | | | | | |
| All CHS Intangibles | | | | | | | | | | | |
| 1990-95 | 3.20% | 0.33% | 0.17% | 0.03% | 1.05% | 0.27% | 0.09% | 0.07% | 0.25% | 0.94% | 0.57 |
| 1995-00 | 2.51% | 0.47% | 0.23% | 0.03% | 0.50% | 0.28% | 0.03% | 0.03% | 0.27% | 0.68% | 0.56 |
| 2000-05 | 2.13% | 0.12% | 0.06% | 0.00% | 0.59% | 0.21% | 0.02% | 0.01% | 0.21% | 0.90% | 0.60 |
| 2005-10 | 0.49% | 0.53% | 0.04% | 0.01% | 0.72% | 0.11% | 0.04% | 0.05% | 0.01% | -1.01% | 0.60 |
| 2010-14 | 0.06% | 0.30% | 0.02% | 0.00% | 0.05% | 0.06% | -0.05% | -0.02% | -0.14% | -0.17% | 0.60 |

Note to table. Panel 1 are baseline estimates as presented previously. Panel 2 uses the implied UK value-added price index to deflate R&D. 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.

The results show that deflating own-account software with the UK purchased software deflator has a significant impact on the estimated contribution, raising the contribution by between 0.01 and 0.09 pppa in all periods. These results suggest that, due to the size of investment in this asset category, estimating an appropriate price index for software investment is a first-order issue, particularly for own-account software.

## 6.7 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 compilation of the NESTA Innovation Index (Goodridge, Haskel and Wallis, 2014b). The results differ for a number of reasons. In short there have been changes to:

- estimated growth in labour services due to the use of EUKLEMS data for before 1997,
- (tangible and intangible) capital deepening. Tangible capital deepening in particular has been revised up due to revisions to gross fixed capital formation, ONS asset price deflators and nominal investment shares, as well as revisions to value-added and Gross Operating Surplus,

- estimated growth in measured output which has been revised throughout the period studied, and

- estimated rentals due to updated deflators.

As a result of these changes, relative to the last report our data show weaker growth in labour productivity in the 1990s and early 2000s, especially the late 1990s, but stronger in the late 2000s; stronger growth in labour composition particularly in the 1990s (due to use of EUKLEMS data for years before 1997); weaker growth in tangible capital deepening in the late 1990s and 2000s, and weaker growth in intangible capital deepening in the late 1990s and early 2000s, but stronger growth in the late 2000s. TFP is estimated as weaker in the 1990s but stronger in the 2000s. Changes to the contribution of tangible capital deepening are largely because of ONS revisions to nominal and real investment.

### Table 12: Comparison with previous results

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | **DlnV/H** | **sDln(L/H)** | **sDln(K/H) tang** | **sDln(K/H) intang** | **DlnTFP** |
| Innovation Index (2016): All CHS Intangibles | | | | | |
| 1990-95 | 3.20% | 0.33% | 1.25% | 0.59% | 1.03% |
| 1995-00 | 2.51% | 0.47% | 0.75% | 0.54% | 0.75% |
| 2000-05 | 2.13% | 0.12% | 0.65% | 0.41% | 0.94% |
| 2005-11 | 0.55% | 0.53% | 0.70% | 0.13% | -0.81% |
| | | | | | |
| Innovation Index (2014): All CHS Intangibles | | | | | |
| 1990-95 | 3.25% | 0.14% | 1.16% | 0.68% | 1.28% |
| 1995-00 | 2.89% | 0.25% | 0.92% | 0.63% | 1.08% |
| 2000-05 | 2.53% | 0.16% | 0.77% | 0.66% | 0.93% |
| 2005-11 | 0.40% | 0.49% | 0.75% | 0.07% | -0.91% |

Note to table. For comparison, data are based on the same periods. The top panel are our most recent results.

# 7. Growth accounting results: industry-level

Our industry growth accounting is feasible between 2000-14.[32] Thus we start with comparing our aggregated results with those based on data for the total market sector to check the two are closely comparable. Then we look more closely industry by industry on a value-added basis.

## 7.1 Comparing industry and market sector data

Table 13 sets out our results. The top row shows our market sector estimates, with intangibles, 2000-14. The second row shows results for 2000-14 using the aggregated industry data, where we aggregate industry contributions according to the industry share in nominal value-added. The two methods give similar but different results. One significant difference is that, in the industry dataset, aggregate labour productivity growth is the share-weighted sum of industry labour productivity growth, where the weights are industry shares of value-added. The relation between aggregate and industry labour productivity is:

$$\begin{aligned}\Delta \ln(V/H) &\equiv \sum_j \overline{w}_j \Delta \ln V_j - \Delta \ln H \\ &= \left( \sum_j \overline{w}_j \overline{v}_{K,j} \Delta \ln(K/H)_j \right) + \left( \sum_j \overline{w}_j \overline{v}_{L,j} \Delta \ln(L/H)_j \right) + \sum_j \overline{w}_j \Delta \ln TFP_j + R^H\end{aligned} \tag{9}$$

Thus, using the market sector dataset, market sector labour productivity growth is estimated as in the top line of (9). This produces a different result to a share-weighted aggregation of labour productivity growth, which introduces the labour reallocation term, RH. This arises because aggregate value added per hour can grow via growth in all industry value added per hour but also with a reallocation of hours towards high-productivity industries.

A second difference is in the aggregation of value-added: in the market sector file, real value-added is aggregated across industries and then additional intangibles are capitalised at the market sector level. In the industry-file, intangibles are capitalised at the industry-level before aggregating across industries. Thus industry real value-added, and industry shares, are different, generating a slightly different estimate at the aggregate level.

32 We have data based on the Supply-Use Tables back to 1997, but due to uncertainty about initial capital stocks we confine ourselves to growth accounting starting in 2000.

Finally, in the industry data, we have consistent industry-year output data on the SIC2007 classification. To match these we construct capital data at industry-asset-year level and labour data at industry-type-year level, so all data 2000-2014, are consistently aggregated bottom-up data. In the aggregate market sector dataset, we use output and capital data at asset-year level, without an industry dimension. As shown in Table 13, this method gives very similar growth rates except for differences mainly in in non-computer tangible growth rates.

## 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 14. These are on a value-added basis: we show how they relate to the whole economy value-added level below.

**Table 13: Growth accounting: comparison of ONS market sector and weighted Market Sector Aggregates, 2000-11**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **2000-2014** | **Capital deepening contributions:** | | | | | | | | |
| | **ALPG** | **Total** | **Computers** | **Telecom** | **Other tang** | **Intangibles** | **Labour Composition** | | **Reall** |
| | **DlnV/H** | **sDln (K/H)** | **sDln (K/H) cmp** | **sDln (K/H) telecom** | **sDln (K/H) othtan** | **sDln (K/H) intan** | **sDln (L/H)** | **DlnTFP** | **$R^H$** |
| **Market Sector data, with all CHS intangibles** | 0.95% | 0.70% | 0.04% | 0.00% | 0.48% | 0.17% | 0.32% | -0.06% | - |
| **Aggregated Industry data, with all CHS intangibles** | 1.08% | 0.83% | 0.06% | 0.00% | 0.59% | 0.18% | 0.39% | -0.09% | -0.05% |

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 four columns), column 3, contribution of IT hardware capital, column 4, contribution of CT capital, column 5, contribution of other non-ICT tangible capital, column 6, contribution of intangibles, column 7, contribution of labour services per person hour, column 8, TFP, being column 1 less the sum of columns 2 plus 7. Row 1 is based on ONS data with the capitalisation of intangibles for the market sector. Row 2 is ONS industry data, with intangibles, 2000-14, aggregated to the market sector. In each the market sector is defined using our definition of SIC(2007) A-K, MN, R-T. Source: authors' calculations.

## Table 14: Industry level value-added growth accounting, 2000-2014, including intangibles

| Industry | DlnV/H | sDln(K/H) | sDln(K/H) IT | sDln(K/H) CT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| *2000-14* | | | | | | | | |
| **AgMinUtil** | -3.52 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.37 | -5.89 |
| **Mfr** | 2.38 | 0.79 | -0.01 | 0.00 | 0.46 | 0.34 | 0.40 | 1.19 |
| **Constr** | 0.37 | 1.15 | 0.04 | 0.00 | 1.01 | 0.09 | 0.08 | -0.86 |
| **RtAcc** | 1.38 | 0.66 | 0.06 | 0.01 | 0.43 | 0.16 | 0.33 | 0.38 |
| **Tran** | 0.19 | 0.67 | 0.01 | 0.00 | 0.51 | 0.15 | 0.35 | -0.83 |
| **InfoCom** | 1.99 | 0.36 | 0.13 | 0.00 | 0.16 | 0.07 | 0.33 | 1.29 |
| **FinSvc** | 1.71 | 1.21 | 0.21 | 0.00 | 0.57 | 0.43 | 0.60 | -0.10 |
| **ProfAdmin** | 1.99 | 0.32 | 0.05 | 0.00 | 0.21 | 0.06 | 0.49 | 1.17 |
| **PersSvc** | -0.07 | 1.14 | 0.04 | 0.00 | 0.94 | 0.17 | 0.50 | -1.71 |

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 changes in natural logs of: column 1, real value-added per hour, column 2, contribution of total capital (which is the sum of the next four columns), column 3, contribution of IT hardware capital, column 4, contribution of CT (telecoms) capital, column 5, contribution of other non-ICT tangible capital, column 6, contribution of intangibles, column 7, contribution of labour services per person hour, column 8, TFP, being column 1 less the sum of columns 2 plus 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 8: Decomposition of industry-level value added, 2000-14


Note to figure: Data as presented in Table 14. Data are annual average growth rates for 2000-14. All CHS intangibles capitalised. Labelled data points are industry growth in real value-added per hour. Stacked bars are contributions from labour composition and capital deepening (for broad asset definitions), all expressed in terms of per hour worked, and TFP.

We just report the results including all intangibles. Column 1 shows ΔlnV/H, average growth in *value-added* per employee-hour. It is strongly negative in agriculture; mining and utilities at -3.52% pa and marginally negative at -0.07% pa in recreational and personal services. In all other industries, LPG is positive. It is strongest in manufacturing (2.38% pa), information and communication (1.99% pa), professional and administrative services (1.99% pa), financial services (1.71% pa) and wholesale and retail/accommodation and food (1.38% pa). LPG is weaker in construction (0.37% pa) and transportation & storage (0.19% pa).

Column 2 shows total capital deepening per employee-hour, being positive in all industries but lowest in professional and administrative services and information and communication. Columns 3 to 6 shed further light on this. The contribution of computer hardware is strongest in financial services followed by information and communication. In most other industries it is relatively weak. The contribution of telecommunications capital deepening is strongest in wholesale and retail/accommodation and food. The contribution of other tangibles (buildings, plant, vehicles) is strongest in agriculture; mining and utilities, followed by construction, and recreational and personal services, where the latter includes a lot of infrastructure capital which was also boosted during the Olympics.[33] On intangibles, the contribution is strongest in financial services, followed by manufacturing, both of which are knowledge-intensive industries.

Column 7 presents the contribution of labour composition. It is positive in all industries but we note that it is weakest in construction and is particularly strong in both financial services, professional and administrative services and also recreational and personal services.

Finally, column 8 presents industry TFP. The depth of the recession means that it is measured as negative in all but four industries, which are: information and communication (1.29% pa); manufacturing (1.19% pa), professional and administrative services (1.17% pa) and wholesale and retail/accommodation and food (0.38% pa). The industries where TFP is negative are: agriculture, mining and utilities (-5.89% pa), recreational and personal services (-1.71% pa), construction (-0.86% pa), transportation & storage (-0.83% pa), and financial services (-0.1% pa).

On the strong negative TFP observed in recreational and personal services, it is worth noting a few points about that sector. First, as is well-known, measurement of prices and quantities in the service sector is notoriously difficult, and so real output and TFP may not be well estimated. Second, this industry also includes 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. However, 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 creative and performing arts. Given that this is a significant industry in size in terms of

33 For instance, industry capital includes sports stadia as well as theatres, galleries, museums, libraries, historical sites etc.

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.

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 50% of that LPG is due to TFPG, with 14% due to intangible growth and 17% due to labour quality. Or put another way, in manufacturing, around (50+14+17=) 81% of growth in labour productivity can be explained by growth in knowledge or innovation. In information & communication, labour productivity growth is slightly lower, but TFP is slightly higher. In that sector, 65% of LPG can be explained by TFP, just 3% by intangible capital deepening, and 17% by labour quality, so that overall (65+3+17=)85% of growth is explained by innovation. In professional & administrative services, 59% of LPG is due to TFPG, 3% by intangible capital deepening, and 25% by labour quality, so that innovation accounts for (59+3+25=)87% of LPG.

Of the other sectors, it is worth noting that 25% of LPG in finance comes from intangible capital deepening, with 35% from labour quality and a negative contribution from TFP (of course growth in real output and TFP in this sector was heavily impacted by the financial crisis). Also, in construction, 28% of LPG comes from investment in intangibles, such as in architectural and engineering design, but TFP is negative. Intangible capital deepening also accounts for 79% of LPG in transportation & storage, although LPG in that industry is weak. Figure 8 presents the same data but in graphical form.

Finally, the appendix shows the impact of adding intangibles, which is that $\Delta \ln V/H$ and $\Delta \ln TFP$ are lower than without intangibles. Thus for example, without intangibles one would conclude $\Delta \ln TFP$=-0.01% instead of -0.09% 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 15 sets this out.

## Table 15: Industry contributions to growth in aggregate value added, capital deepening, labour quality and TFP (growth rates and contributions are %pa per employee hour, 2000-14)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value added | | | Capital contributions | | | | | Labour contrib | | | | | |
| | | | | | | of which | | | | | | | | |
| Industry | VA weight | DlnVA/H | contrib to agg va/h | Cap weight | Contrib to agg K/H | Contrib to ICT dlnK/H | Contrib to agg non-ICT dlnK/H | Contrib to agg Intan dlnK/H | Lab weight | Contrib to agg lab qual per hr | DlnTFP | Contrib to agg TFP | Memo: % total hrs | |
| Agriculture, Mining and Utilities | 0.07 | -3.52 | -0.25 | 0.05 | 0.14 | 0.00 | 0.14 | 0.00 | 0.02 | 0.03 | -5.89 | -0.42 | 4% | |
| Manufacturing | 0.16 | 2.38 | 0.41 | 0.05 | 0.14 | 0.00 | 0.08 | 0.06 | 0.11 | 0.06 | 1.19 | 0.20 | 15% | |
| Construction | 0.09 | 0.37 | 0.03 | 0.04 | 0.10 | 0.00 | 0.09 | 0.01 | 0.05 | 0.01 | -0.86 | -0.08 | 11% | |
| Wholesale and Retail Trade, Accomodation and Food | 0.20 | 1.38 | 0.28 | 0.07 | 0.13 | 0.01 | 0.09 | 0.03 | 0.13 | 0.07 | 0.38 | 0.08 | 27% | |
| Transportation and Storage | 0.06 | 0.19 | 0.01 | 0.02 | 0.04 | 0.00 | 0.03 | 0.01 | 0.05 | 0.02 | -0.83 | -0.05 | 7% | |
| Information and Communication | 0.09 | 1.99 | 0.18 | 0.04 | 0.03 | 0.01 | 0.01 | 0.01 | 0.05 | 0.03 | 1.29 | 0.12 | 6% | |
| Financial Services | 0.11 | 1.71 | 0.15 | 0.05 | 0.12 | 0.02 | 0.06 | 0.04 | 0.05 | 0.07 | -0.10 | -0.04 | 5% | |
| Professional and Administrative Services | 0.16 | 1.99 | 0.32 | 0.06 | 0.05 | 0.01 | 0.03 | 0.01 | 0.10 | 0.08 | 1.17 | 0.19 | 19% | |
| Recreational and Personal Services | 0.05 | -0.07 | 0.00 | 0.02 | 0.06 | 0.00 | 0.05 | 0.01 | 0.03 | 0.03 | -1.71 | -0.09 | 6% | |
| **Sum** | 1.00 | | 1.13 | | 0.83 | 0.06 | 0.59 | 0.18 | | 0.39 | | -0.09 | 100% | |
| **%ages of summed contributions** | | | | | | | | | | | | | Memo: % total hrs | (8+10+12)/ (Σ8+Σ10+Σ12) |
| Agriculture, Mining and Utilities | | | -22% | | 17% | 0% | 24% | 0% | | 7% | | 450% | 4% | -85% |
| Manufacturing | | | 36% | | 17% | -3% | 14% | 35% | | 16% | | -216% | 15% | 70% |
| Construction | | | 2% | | 12% | 6% | 15% | 5% | | 2% | | 87% | 11% | -14% |
| Wholesale and Retail Trade, Accomodation and Food | | | 25% | | 16% | 24% | 15% | 19% | | 17% | | -85% | 27% | 38% |
| Transportation and Storage | | | 1% | | 5% | 1% | 5% | 5% | | 5% | | 53% | 7% | -4% |
| Information and Communication | | | 16% | | 4% | 20% | 3% | 4% | | 8% | | -125% | 6% | 33% |
| Financial Services | | | 14% | | 15% | 36% | 10% | 24% | | 17% | | 41% | 5% | 15% |
| Professional and Administrative Services | | | 28% | | 6% | 14% | 6% | 4% | | 20% | | -202% | 19% | 59% |
| Recreational and Personal Services | | | 0% | | 7% | 3% | 8% | 5% | | 7% | | 97% | 6% | -12% |
| **Sum** | | | 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 and the input share in industry value-added. 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. 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 LPG (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 13 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 each industries contribution to the aggregate. Finally, as a memo item, column 13 shows actual hours worked as a fraction of the total. The lower panel shows the contributions as a proportion of the total.[34]

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 16%, although column 13 shows the employment share is 15% (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 0.14%pa, which is, lower panel, 17% of the total. Column 8 shows that the contribution of intangibles in manufacturing is significant: 35% (see lower panel) of the total intangible contribution. Column 10 shows the contribution of labour quality, 16%, and column 12 shows the industry made the largest contribution to TFP, of 0.2% pa, with aggregate TFP estimated negative at -0.09% pa. Thus manufacturing, accounting for 16% of value added and 15% of employment, accounts for 35% of total intangible capital deepening and made the largest contribution to aggregate 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 industry that makes the second biggest contribution to TFP, at 0.19% pa just slightly less than manufacturing, is professional and administrative services. With a value-added weight of 16%, and a share in hours worked of 19%, this industry accounts for 28% of LPG. However, the contribution of capital deepening is 0.05% pa, which is just 6% of the total. The contribution of ICT capital deepening is 14% of the total, and the contribution of intangible capital deepening is 4% of the total.

The largest contributions to aggregate capital deepening are from agriculture, mining andutilities, manufacturing, wholesale and retail/accommodation and food, and financial services. Financial services also makes the largest contribution to aggregate ICT capital deepening, at 36% of the total, and the second largest contribution to intangible capital deepening, at 24% of the total. However, partly due to the impact of the financial crisis, over 14 years the TFP contribution of financial services to the aggregate is negative.

34 In this report we are unable to present the contribution of TFP in each industry to the aggregate. The reason is that aggregate TFP is negative, so that for instance an industry with negative TFP would be estimated as making a positive contribution as the aggregate is also negative.

The other large contribution of capital deepening is from the distributive trades, which contributed 16% of aggregate capital deepening. Within this, the industry contributed 24% of IT capital deepening, 15% of other tangible capital deepening, and 19% of intangible capital deepening.

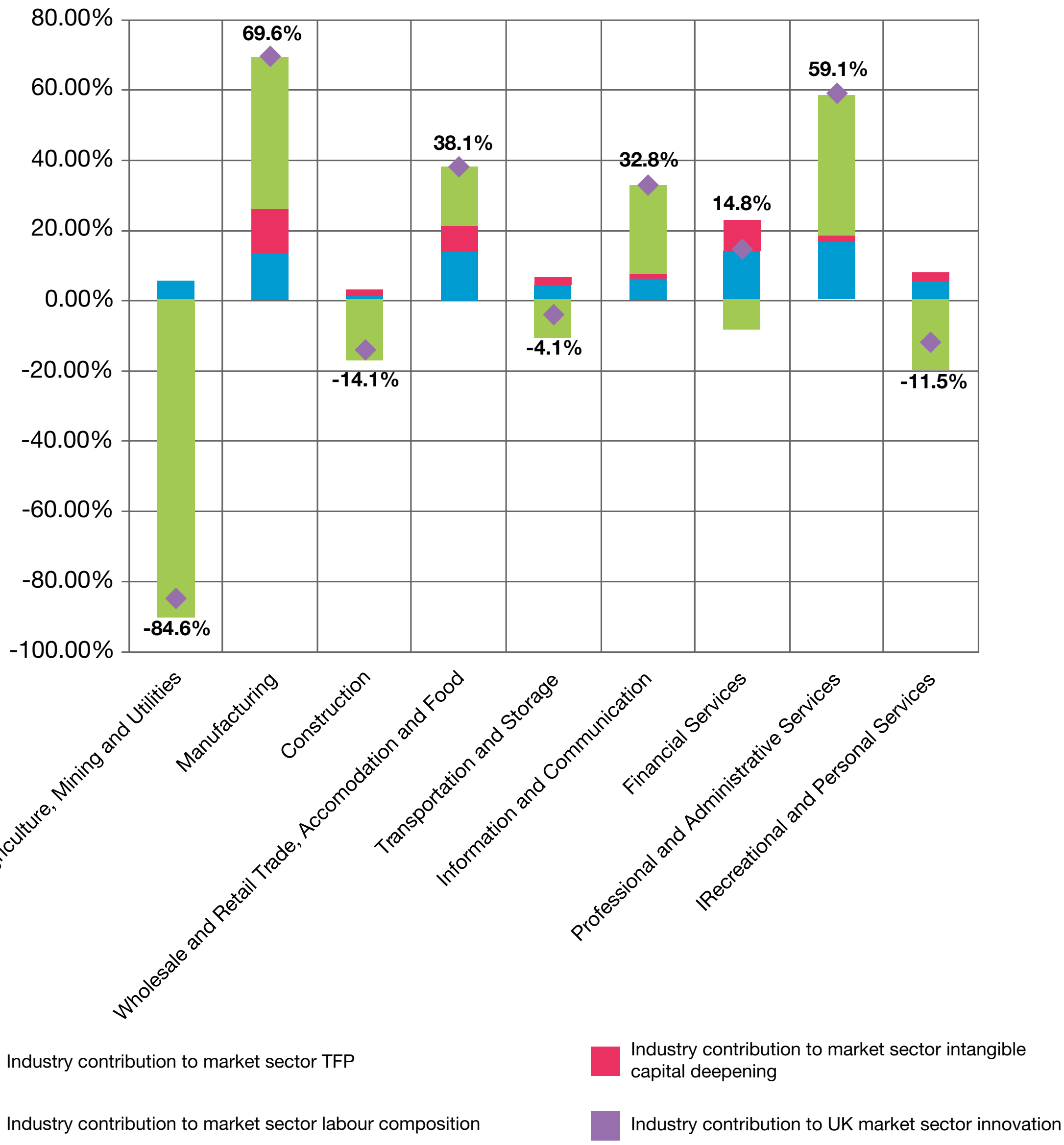
Overall therefore, manufacturing and financial services account for 58% of intangible capital deepening, with a combined share in hours worked of just 20%. If we include the distributive trades, that rises to 77%, but the employment share rises to 47%, with distribution accounting for 27% of hours worked in the UK market sector.

On ΔlnTFP, as noted the largest contribution comes from manufacturing. Although TFP in information and communication is also high (1.29% pa), its weight in value-added is just over half that in manufacturing (9% compared to 16%), so its contribution to the aggregate is smaller.

Finally, one might summarise these results by asking what industries account for the contribution of innovation to ΔlnV/H? If we define innovation as the contributions of ΔlnTFP+sΔlnK/H(intang)+sΔlnL/H to the total, we see that manufacturing accounts for 70%, professional and administrative services 59%, distribution 38%, information andcommunication 33%, and finance 15%. All other industries make a negative contribution, with the largest negative contribution being in agriculture; mining and utilities (-85%).

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

**Figure 9: Industry contributions to UK market sector innovation, 2000-14**




Note to figure: data as presented in Table 15. All figures are weighted annual averages. Contributions are the product of the weights and the input growth averaged over years, where input growth is in per hour terms.

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 we just note here that without intangibles, ΔlnTFP in financial services is estimated positive at 0.24% pa compared to -0.1% pa with. Similarly, in manufacturing, ΔlnTFP is 1.47% pa without, and 1.19% with. In information and communication, it is 1.95% pa without and 1.29% pa with. So in these knowledge-intensive industries, the exclusion of intangibles means that ΔlnTFP is very much overstated.

# 8. Conclusions

This paper provides an update of the UK 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 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:

## 8.1 Investment in knowledge.

a. Investment in knowledge, which we call intangible assets, is now greater than investment in tangible assets, at around, in 2014, £133bn and £121bn respectively, 12% and 11% of (adjusted) MSGVA, quantifying the UK move to a knowledge-based economy.

b. In 2014, R&D was about 14% of total intangible investment, software 21%, design 11%, training 20% and organizational capital 16%.

c. The most intangible-intensive industry is information & communication (intangible investment as a proportion of value added =18%), closely followed by manufacturing (=13%). Financial services and information & communication invest around 3:1 on intangibles: tangibles. In manufacturing that ratio is around 2:1.

d. Relative to the national accounts, the effect of treating additional intangible expenditure as investment is to raise growth in market sector value added in the 1990s and early 2000s (the internet investment boom), but lower it in the late 2000s.

## 8.2 Contribution to growth, 2010-14.

a. For the most recent period of 2010-2014, intangible capital deepening made a negative contribution to growth in market sector value added per hour ($\Delta lnV/H$). Over the 2000s the contribution from IT tangibles (computer hardware) has dropped substantially, and the contribution of TFP is negative over the last 10 years, driven by large declines in the 2008-9 recession and continued weakness post-recession.

b. With (without) intangibles $\Delta lnV/H$ is 0.06%pa (0.44%pa) and $\Delta lnTFP$ is -0.16%pa (0%pa). Thus, for this latest period, adding intangibles to growth accounting lowers both $\Delta lnTFP$ and $\Delta lnV/H$. Note that the latest period therefore stands out, as in previous periods we typically find that inclusion of intangibles lowers $\Delta lnTFP$ and raises $\Delta lnV/H$.

## 8.3 Contribution by industries to growth.

a. The main finding here is the importance of manufacturing and professional & administrative (business) services, which together account for 129% of innovation in the UK market sector (many industries make a negative contribution, hence a figure greater than 100%).

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.

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## Appendix Table 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value added | | | Capital contributions | | | | | Labour contrib | | | | | |
| | | | | | | of which | | | | | | | | |
| Industry | VA weight | DlnVA/H | contrib to agg va/h | Cap weight | Contrib to agg K/H | Contrib to ICT dlnK/H | Contrib to agg non-ICT dlnK/H | Contrib to agg Intan dlnK/H | Lab weight | Contrib to agg lab qual per hr | DlnTFP | Contrib to agg TFP | Memo: % total hrs | |
| Agriculture, Mining and Utilities | 0.08 | -3.93 | -0.30 | 0.05 | 0.17 | 0.00 | 0.17 | | 0.02 | 0.03 | -6.49 | -0.49 | 4% | |
| Manufacturing | 0.16 | 2.39 | 0.40 | 0.04 | 0.08 | 0.00 | 0.08 | | 0.12 | 0.07 | 1.47 | 0.25 | 15% | |
| Construction | 0.09 | 0.33 | 0.03 | 0.03 | 0.10 | 0.00 | 0.10 | | 0.06 | 0.01 | -0.84 | -0.08 | 11% | |
| Wholesale and Retail Trade, Accomodation and Food | 0.20 | 1.37 | 0.28 | 0.06 | 0.12 | 0.02 | 0.10 | | 0.14 | 0.08 | 0.44 | 0.09 | 27% | |
| Transportation and Storage | 0.06 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.03 | | 0.05 | 0.02 | -0.85 | -0.05 | 7% | |
| Information and Communication | 0.08 | 2.70 | 0.22 | 0.02 | 0.03 | 0.01 | 0.01 | | 0.06 | 0.03 | 1.95 | 0.16 | 6% | |
| Financial Services | 0.11 | 1.90 | 0.16 | 0.05 | 0.10 | 0.03 | 0.08 | | 0.06 | 0.08 | 0.24 | -0.02 | 5% | |
| Professional and Administrative Services | 0.16 | 2.40 | 0.38 | 0.04 | 0.05 | 0.01 | 0.04 | | 0.12 | 0.09 | 1.50 | 0.24 | 19% | |
| Recreational and Personal Services | 0.06 | -0.16 | -0.01 | 0.02 | 0.06 | 0.00 | 0.06 | | 0.04 | 0.03 | -1.81 | -0.10 | 6% | |
| **Sum** | **1.00** | | **1.16** | | **0.74** | **0.07** | **0.66** | | | **0.44** | | **-0.01** | **100%** | |
| **% ages of summed contributions** | | | | | | | | | | | | | **Memo: % total hrs** | **(8+10+12)/(Σ8+Σ10+Σ12)** |
| Agriculture, Mining and Utilities | | | -26% | | 23% | 0% | 25% | | | 7% | | | 4% | -108% |
| Manufacturing | | | 34% | | 11% | -3% | 12% | | | 16% | | | 15% | 75% |
| Construction | | | 2% | | 14% | 6% | 15% | | | 2% | | | 11% | -18% |
| Wholesale and Retail Trade, Accomodation and Food | | | 24% | | 16% | 23% | 15% | | | 17% | | | 27% | 39% |
| Transportation and Storage | | | 0% | | 4% | 1% | 4% | | | 5% | | | 7% | -7% |
| Information and Communication | | | 19% | | 4% | 19% | 2% | | | 8% | | | 6% | 45% |
| Financial Services | | | 14% | | 14% | 37% | 11% | | | 17% | | | 5% | 13% |
| Professional and Administrative Services | | | 32% | | 7% | 15% | 6% | | | 20% | | | 19% | 76% |
| Recreational and Personal Services | | | -1% | | 8% | 3% | 9% | | | 7% | | | 6% | -16% |
| **Sum** | | | **100%** | | **100%** | **100%** | **100%** | | | **100%** | | | **100%** | **100%** |

**Note:** See notes to Table 15. All figures are annual averages. Weights depend on the industry share in aggregate value-added and the input share in industry value-added. 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. **Source:** authors' calculations

## Appendix 2: 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.

| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| AgMinUtil | 2001 | 6.67 | 5.09 | -0.09 | 5.06 | 0.13 | 0.31 | 1.27 |
| | 2002 | 3.52 | 4.85 | 0.01 | 4.64 | 0.19 | 0.54 | -1.87 |
| | 2003 | -3.94 | 3.71 | 0.17 | 3.36 | 0.17 | 0.41 | -8.05 |
| | 2004 | -3.48 | 3.06 | 0.03 | 2.93 | 0.10 | -0.10 | -6.44 |
| | 2005 | -5.70 | -1.12 | -0.06 | -0.65 | -0.41 | -0.26 | -4.33 |
| | 2006 | -3.53 | 2.30 | -0.01 | 2.33 | -0.03 | 0.39 | -6.22 |
| | 2007 | -0.95 | 3.67 | -0.05 | 3.61 | 0.11 | 0.30 | -4.91 |
| | 2008 | -6.70 | 0.33 | 0.08 | 0.54 | -0.29 | -0.21 | -6.81 |
| | 2009 | -12.97 | -1.43 | -0.02 | -0.90 | -0.52 | 0.01 | -11.55 |
| | 2010 | -8.61 | -3.43 | 0.02 | -2.94 | -0.51 | 0.36 | -5.54 |
| | 2011 | -5.95 | 2.72 | -0.05 | 2.56 | 0.21 | 0.45 | -9.11 |
| | 2012 | -4.81 | 4.26 | -0.01 | 3.82 | 0.45 | 0.70 | -9.77 |
| | 2013 | 2.81 | 5.13 | 0.02 | 4.55 | 0.57 | 1.38 | -3.69 |
| | 2014 | -5.68 | -1.12 | -0.03 | -0.90 | -0.19 | 0.84 | -5.39 |
| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
| Mfr | 2001 | 2.99 | 1.70 | -0.17 | 1.01 | 0.85 | -0.03 | 1.32 |
| | 2002 | 3.55 | 1.85 | -0.04 | 1.01 | 0.88 | 0.44 | 1.26 |
| | 2003 | 5.49 | 1.84 | 0.00 | 1.06 | 0.78 | 0.74 | 2.92 |
| | 2004 | 5.01 | 0.84 | 0.01 | 0.40 | 0.43 | -0.32 | 4.48 |
| | 2005 | 4.77 | 2.92 | 0.02 | 2.29 | 0.61 | 1.27 | 0.59 |
| | 2006 | 4.10 | 0.54 | 0.01 | 0.14 | 0.38 | 0.34 | 3.23 |
| | 2007 | 2.96 | 0.50 | 0.02 | 0.19 | 0.29 | 0.40 | 2.06 |
| | 2008 | -0.09 | 0.75 | 0.03 | 0.38 | 0.35 | 0.29 | -1.13 |
| | 2009 | -0.67 | 2.20 | -0.02 | 1.29 | 0.93 | 1.00 | -3.88 |
| | 2010 | 3.89 | -0.76 | 0.00 | -0.40 | -0.36 | 0.40 | 4.24 |
| | 2011 | 2.63 | -0.15 | 0.01 | -0.03 | -0.13 | 0.81 | 1.97 |
| | 2012 | -1.71 | -0.46 | 0.01 | -0.27 | -0.20 | 1.32 | -2.57 |
| | 2013 | -1.67 | -0.45 | 0.01 | -0.37 | -0.08 | -0.32 | -0.90 |
| | 2014 | 2.07 | -0.21 | -0.01 | -0.25 | 0.05 | -0.74 | 3.03 |

| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| **Constr** | 2001 | 0.23 | 0.99 | 0.30 | 0.51 | 0.19 | -0.07 | -0.69 |
| | 2002 | 4.85 | 1.24 | 0.10 | 0.87 | 0.26 | -0.34 | 3.96 |
| | 2003 | 3.72 | 0.88 | 0.08 | 0.55 | 0.25 | 0.08 | 2.76 |
| | 2004 | 2.67 | 0.79 | 0.06 | 0.54 | 0.19 | -0.08 | 1.96 |
| | 2005 | -5.17 | 0.29 | -0.01 | 0.19 | 0.10 | 0.05 | -5.51 |
| | 2006 | 0.46 | 1.67 | 0.03 | 1.42 | 0.22 | 0.02 | -1.23 |
| | 2007 | -0.61 | 0.90 | 0.03 | 0.75 | 0.12 | -0.28 | -1.23 |
| | 2008 | -1.87 | 2.49 | -0.01 | 2.24 | 0.26 | -0.63 | -3.73 |
| | 2009 | -7.85 | 3.35 | -0.01 | 3.02 | 0.33 | 1.86 | -13.06 |
| | 2010 | 11.55 | 2.31 | 0.02 | 2.20 | 0.09 | -0.76 | 9.99 |
| | 2011 | 3.89 | 1.79 | 0.00 | 1.80 | -0.01 | -0.02 | 2.13 |
| | 2012 | -6.97 | 1.09 | 0.01 | 1.18 | -0.11 | 0.89 | -8.95 |
| | 2013 | -1.04 | -0.47 | 0.00 | -0.23 | -0.24 | 1.12 | -1.70 |
| | 2014 | 1.32 | -1.26 | 0.00 | -0.91 | -0.35 | -0.69 | 3.26 |
| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
| **RtAcc** | 2001 | 2.78 | 0.62 | 0.11 | 0.23 | 0.28 | 0.09 | 2.08 |
| | 2002 | 5.07 | 1.23 | 0.06 | 0.68 | 0.49 | 0.09 | 3.76 |
| | 2003 | 1.10 | 0.76 | 0.19 | 0.26 | 0.31 | 0.34 | 0.00 |
| | 2004 | 1.69 | 0.60 | 0.16 | 0.20 | 0.25 | -0.14 | 1.23 |
| | 2005 | 1.06 | 1.19 | 0.15 | 0.67 | 0.37 | 0.58 | -0.70 |
| | 2006 | 4.19 | 1.03 | 0.06 | 0.65 | 0.33 | 0.85 | 2.30 |
| | 2007 | 2.75 | 0.70 | 0.15 | 0.42 | 0.13 | 0.33 | 1.71 |
| | 2008 | -3.95 | 0.54 | 0.04 | 0.43 | 0.07 | -0.42 | -4.07 |
| | 2009 | -1.15 | 1.84 | 0.05 | 1.34 | 0.45 | 1.23 | -4.22 |
| | 2010 | 1.69 | 0.41 | 0.02 | 0.41 | -0.02 | 0.52 | 0.77 |
| | 2011 | 1.23 | 0.48 | -0.02 | 0.55 | -0.06 | 0.36 | 0.39 |
| | 2012 | -0.56 | -0.26 | -0.03 | -0.03 | -0.20 | 0.35 | -0.64 |
| | 2013 | 1.60 | -0.07 | 0.03 | 0.01 | -0.11 | 0.51 | 1.15 |
| | 2014 | 1.84 | 0.23 | 0.02 | 0.21 | 0.00 | -0.02 | 1.64 |

| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| Tran | 2001 | -2.57 | 0.93 | -0.07 | 0.79 | 0.21 | -0.55 | -2.96 |
| | 2002 | -0.60 | 1.73 | 0.04 | 1.47 | 0.23 | 0.12 | -2.45 |
| | 2003 | 1.16 | 1.46 | 0.08 | 1.15 | 0.23 | -0.07 | -0.24 |
| | 2004 | 3.69 | 1.30 | -0.02 | 1.02 | 0.30 | -0.12 | 2.52 |
| | 2005 | 1.46 | 0.02 | -0.01 | -0.03 | 0.05 | 0.29 | 1.15 |
| | 2006 | -1.40 | 0.80 | 0.02 | 0.65 | 0.13 | -0.20 | -2.00 |
| | 2007 | 3.13 | 1.63 | 0.07 | 1.23 | 0.32 | 0.76 | 0.74 |
| | 2008 | -1.47 | 1.05 | 0.03 | 0.89 | 0.13 | 0.53 | -3.05 |
| | 2009 | -7.68 | 1.03 | -0.01 | 0.84 | 0.20 | 0.52 | -9.23 |
| | 2010 | 1.39 | 1.56 | -0.01 | 1.43 | 0.15 | 0.25 | -0.42 |
| | 2011 | 1.85 | -0.14 | 0.04 | -0.27 | 0.09 | 0.81 | 1.17 |
| | 2012 | -3.70 | -1.48 | -0.01 | -1.30 | -0.17 | 0.72 | -2.94 |
| | 2013 | 1.63 | -0.44 | 0.02 | -0.55 | 0.09 | -0.17 | 2.23 |
| | 2014 | 5.83 | -0.06 | -0.04 | -0.19 | 0.16 | 2.04 | 3.85 |
| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
| InfoCom | 2001 | 4.53 | 1.33 | 0.30 | 0.18 | 0.86 | -0.04 | 3.25 |
| | 2002 | 2.86 | 1.77 | -0.12 | 0.72 | 1.17 | 1.24 | -0.15 |
| | 2003 | 6.20 | 0.73 | -0.11 | 0.12 | 0.71 | 0.02 | 5.46 |
| | 2004 | 5.32 | 2.60 | 0.62 | 0.86 | 1.12 | -0.25 | 2.97 |
| | 2005 | 2.03 | -0.15 | 0.31 | -0.33 | -0.13 | 0.68 | 1.50 |
| | 2006 | 0.33 | 0.87 | 0.40 | 0.29 | 0.18 | 0.56 | -1.10 |
| | 2007 | 4.48 | 0.73 | 0.28 | 0.23 | 0.21 | 0.05 | 3.70 |
| | 2008 | 3.78 | 1.82 | 0.24 | 0.85 | 0.73 | -0.61 | 2.57 |
| | 2009 | -1.05 | 1.38 | 0.09 | 0.71 | 0.58 | 2.49 | -4.92 |
| | 2010 | 4.73 | -0.44 | -0.03 | 0.18 | -0.58 | 0.76 | 4.41 |
| | 2011 | -2.60 | -2.05 | -0.18 | -0.45 | -1.42 | 0.66 | -1.21 |
| | 2012 | 2.85 | -0.39 | 0.00 | 0.08 | -0.47 | 0.78 | 2.46 |
| | 2013 | -1.56 | -1.58 | 0.06 | -0.58 | -1.06 | -0.98 | 1.00 |
| | 2014 | -4.04 | -1.54 | 0.02 | -0.58 | -0.98 | -0.68 | -1.82 |

| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| **FinSvc** | 2001 | 2.02 | 1.84 | 0.20 | 0.18 | 1.47 | 0.12 | 0.06 |
| | 2002 | 3.52 | 2.39 | 0.39 | 0.83 | 1.16 | 0.62 | 0.52 |
| | 2003 | 6.48 | 1.48 | 0.20 | 0.70 | 0.58 | 0.96 | 4.04 |
| | 2004 | 5.78 | 1.78 | 0.08 | 1.23 | 0.47 | -0.06 | 4.06 |
| | 2005 | 4.65 | 0.83 | 0.67 | 0.46 | -0.30 | 1.01 | 2.82 |
| | 2006 | 7.95 | 1.41 | 0.27 | 0.90 | 0.24 | 0.51 | 6.03 |
| | 2007 | 1.47 | -0.31 | 0.25 | -0.38 | -0.18 | 1.85 | -0.07 |
| | 2008 | -0.47 | 0.74 | 0.31 | 0.22 | 0.21 | 0.25 | -1.46 |
| | 2009 | 2.79 | 1.86 | -0.12 | 1.34 | 0.63 | 1.41 | -0.48 |
| | 2010 | -6.24 | 1.14 | 0.10 | 0.85 | 0.18 | 0.99 | -8.37 |
| | 2011 | -3.48 | -0.47 | 0.18 | -0.46 | -0.19 | 0.78 | -3.79 |
| | 2012 | -0.46 | 1.63 | 0.52 | 0.60 | 0.51 | 0.19 | -2.28 |
| | 2013 | 1.75 | 2.00 | 0.04 | 1.03 | 0.93 | -0.17 | -0.08 |
| | 2014 | -1.77 | 0.67 | -0.10 | 0.50 | 0.28 | -0.01 | -2.43 |
| **Industry** | **Year** | **DlnV/H** | **sDln(K/H)** | **sDln(K/H) ICT** | **sDln(K/H) othtan** | **sDln(K/H) intan** | **sDln(L/H)** | **DlnTFP** |
| **Prof Admin** | 2001 | 3.57 | 1.43 | 0.01 | 0.84 | 0.57 | -0.23 | 2.37 |
| | 2002 | -0.12 | 2.13 | -0.16 | 1.19 | 1.10 | 0.37 | -2.62 |
| | 2003 | 4.44 | 1.01 | 0.12 | 0.48 | 0.41 | 1.21 | 2.22 |
| | 2004 | 0.32 | 0.11 | 0.15 | -0.10 | 0.06 | -0.91 | 1.13 |
| | 2005 | 3.32 | -0.69 | 0.07 | -0.34 | -0.42 | 0.76 | 3.25 |
| | 2006 | 4.29 | 1.08 | 0.12 | 0.61 | 0.35 | 1.40 | 1.82 |
| | 2007 | 3.91 | 0.12 | 0.29 | 0.10 | -0.28 | 0.51 | 3.28 |
| | 2008 | -1.40 | 0.02 | 0.07 | -0.27 | 0.23 | -0.66 | -0.77 |
| | 2009 | -3.27 | 1.97 | -0.08 | 0.76 | 1.29 | 1.65 | -6.89 |
| | 2010 | 3.99 | -0.35 | -0.07 | -0.17 | -0.11 | 1.36 | 2.97 |
| | 2011 | 3.10 | -0.14 | 0.06 | 0.12 | -0.33 | 0.24 | 3.00 |
| | 2012 | 0.24 | -1.04 | 0.05 | -0.18 | -0.90 | 0.71 | 0.58 |
| | 2013 | 3.19 | -0.40 | 0.10 | 0.02 | -0.53 | 0.53 | 3.06 |
| | 2014 | 2.24 | -0.69 | 0.01 | -0.08 | -0.62 | -0.08 | 3.01 |

| Industry | Year | DlnV/H | sDln(K/H) | sDln(K/H) ICT | sDln(K/H) othtan | sDln(K/H) intan | sDln(L/H) | DlnTFP |
|---|---|---|---|---|---|---|---|---|
| **PersSvc** | 2001 | -2.14 | 1.46 | 0.23 | 0.85 | 0.37 | -0.16 | -3.44 |
| | 2002 | 0.88 | 1.72 | -0.04 | 1.25 | 0.51 | 0.65 | -1.49 |
| | 2003 | 0.63 | 1.45 | 0.08 | 1.03 | 0.34 | 0.10 | -0.92 |
| | 2004 | -3.79 | 0.76 | 0.13 | 0.63 | 0.00 | -0.40 | -4.15 |
| | 2005 | 4.71 | 1.86 | 0.11 | 1.48 | 0.28 | 0.55 | 2.29 |
| | 2006 | 0.48 | 0.57 | 0.00 | 0.42 | 0.15 | 0.67 | -0.77 |
| | 2007 | -4.05 | 1.80 | 0.04 | 1.48 | 0.28 | -0.39 | -5.46 |
| | 2008 | 0.08 | 0.90 | 0.14 | 0.80 | -0.04 | 0.68 | -1.50 |
| | 2009 | 0.94 | 3.10 | 0.00 | 2.54 | 0.57 | 1.75 | -3.91 |
| | 2010 | -1.25 | 1.19 | -0.09 | 1.11 | 0.17 | 0.80 | -3.24 |
| | 2011 | 2.21 | 0.51 | -0.04 | 0.57 | -0.02 | -0.22 | 1.91 |
| | 2012 | 0.68 | 1.28 | -0.03 | 1.14 | 0.17 | 1.35 | -1.95 |
| | 2013 | -0.34 | 0.36 | 0.00 | 0.36 | -0.01 | 1.07 | -1.76 |
| | 2014 | -0.04 | -0.96 | -0.01 | -0.55 | -0.40 | 0.50 | 0.42 |

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