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NESTA Making Innovation Flourish

# Driving economic growth

## Innovation, knowledge spending and productivity growth in the UK

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$$s^R \Delta \ln R + \Delta \ln TFP$$

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### Foreword

Since the publication of the interim report in 2009, the Innovation Index project has made significant steps to enhance the significance and accuracy of measurement of investments in knowledge assets. These developments are detailed within this final Index report.

The report's findings are a valuable and timely contribution to the important debate around how the UK can achieve sustainable and balanced economic growth. The Index findings reinforce the significant contribution that innovation makes to productivity growth. Continued investments in knowledge assets at a time of recession are also shown to soften the negative impact on productivity growth. Furthermore, by extending the framework to examine investment in intangibles activity between sectors, the Index demonstrates the continued importance of manufacturing as well as business services in driving overall growth in the UK since 2000.

At a time of increased international agreement on the importance of effective and accurate measurement of intangible assets, the Innovation Index places the UK in a strong position to be an active and influential partner in this area.

As always we welcome your comments.

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**January, 2011**

# Executive summary

This report is an essential component of NESTA's Innovation Index project. It follows the publication in 2009 of the interim report which presented the pilot UK Innovation Index. The interim report detailed the first significant steps in developing the framework for measuring investment in intangible assets in the UK and the contribution these investments make to market sector labour productivity growth.

The measures for business investments in intangible assets detailed in this report are more accurate than the interim report as they draw on the data of a bespoke survey of business investments in intangibles and the expected lifespan of these assets. The data from this survey was further supported by wider consultation with industry fora.

## A new framework for measuring innovation

The framework and methodology detailed within this report has been driven by two key research questions:

1. How much does innovation contribute to UK economic growth?

2. How much does innovation in UK industries contribute to overall economic growth?

There are a number of different methods to measure innovation such as levels of patents and trademarks, the history of ideas, innovation as assessed by managers and the wider conditions for innovation in a country.

Each of these methods has weaknesses when attempting to address the two research questions: a study of patenting behaviour might help with innovation in some industries, but not in others, while study of self-assessed innovation by managers would need a link from such self-assessment to National Accounts data.

For the purposes of this report, the methodology has to be able to effectively answer the questions above. That means that any choice of approach needs to be:

- Consistent with official UK National Accounts on macroeconomic data on GDP, investments and profits. Consistency with national accounts means that the methodology can answer how much innovation contributes to economic growth as measured as GDP per hour, as distinct from other factors that might affect it.

- An approach that can deal with the changing nature of innovation in industries:

  - innovation that needs co-investment with R&D, such as branding in pharmaceuticals;

  - innovation in the increasingly dominant service industries that do no measured R&D, or indeed patenting, at all, such as banking and retailing;

  - innovation in industries where output is changing such as 'servitisation' where manufacturing firms offer design and consulting services.

Given the research questions and the requirement for the framework to address the conditions above, the framework adopted will measure industry investment in 'knowledge' or 'intangible' assets and thereby measure innovation, which we define as the contribution of knowledge to growth (as opposed to the contribution due to investment in physical inputs and labour).

## Innovation and economic growth

The approach is centred on the economic analysis of growth accounting, which develops innovation indicators in a logically consistent economic framework based on the national accounts, avoiding double counting, and directly linked to key economic indicators (such as productivity and investment). The methodology also draws on a number of other measures of innovation available from official and unofficial surveys. These complement but do not substitute the task set here – to produce an index which is integrated with, and helps explain, macroeconomic aggregates.

The report makes three important contributions.

1. It sets out the approach and results on innovation accounting, advancing the estimate of how much firms are spending on knowledge.

2. It sets out the approach and presents results using a growth accounting-based Innovation Index, further highlighting how much all forms of knowledge contribute to growth.

3. It provides new estimates of growth in the UK economy over the period 1990-2008, restated by adding in to the official national accounts investments in knowledge assets normally counted as intermediate input purchases by firms. Treating these inputs as investment has the effect of raising GDP levels and changing growth rates over the period. We do this for (a) the whole market sector and (b) for seven disaggregated industries.

## 1. Investment in knowledge

UK investment in intangible or knowledge assets has been greater than that for tangible assets since the early 2000s. In 2008 it stood at £137 billion, as opposed to £104 billion tangible investment. Of that intangible spend, training by firms and organisational capital account for £27 billion and £31 billion, design £23 billion, software £22 billion and R&D £16 billion.

The industry that is most intensive in intangible spend is manufacturing, which invests 20 per cent of its value added on intangibles (agriculture is the least at 4 per cent). Financial services was the clear intensity leader in the late 1990s, spending 25 per cent of its value added in intangibles (mostly software), but it has since fallen back to 16 per cent.

The effect of treating intangible expenditure as capital spending[1] is to raise market sector gross value added (MGVA) growth in the late 1990s, with little change in the 2000s. MGVA growth is raised in the late 1990s due to strong investment in software, training and organisational change which accompanied the rise of the internet and boom in ICT hardware investment.

## 2. Innovation in the market sector

Beginning with some background, if we ignore intangibles, labour productivity growth accelerated between the early and late 1990s, from 2.94 per cent p.a. 1990-95 to 3.25 per cent p.a. 1995-2000. This is contrary to the slowdown in most studies before last year's interim index and is not due to intangibles, but the results of the incorporation of FISIM[2] in *Blue Book* 2008, along with own-account software and numerous methodological reviews, particularly for the service sector, which were all incorporated in *Blue Book* 2006. Labour productivity growth slowed down in the 2000s to 2.23 per cent p.a.

When we included intangibles, labour productivity also speeds up in the 1990s, from 2.94 per cent p.a. 1990-95 to 3.53 per cent p.a. 1995-00. From 2000-08, it grew at 2.25 per cent p.a., consisting of 2.69 per cent p.a. between 2000-07 and -0.71 per cent p.a. 2007-08. Of the 2000-08 growth in value added per hour of 2.31 per cent p.a., we have the following contributions:

- Intangible capital investment by firms: 0.51 per cent p.a.

- Total factor productivity, that is, learning from knowledge spillovers (plus other mismeasured factors): 0.90 per cent p.a.

1. In the National Accounts, intangible spending is categorised as intermediate consumption. Since gross value-added is defined as gross output less intermediate consumption, treating such spending as investment results in an increase to MGVA.
2. Financial Institutions generate revenue in two ways, via direct charges or interest differentials in their lending and borrowing activities. FISIM represents the second, and stands for 'Financial Intermediation Services Indirectly Measured'. More details on FISIM, the new methodology, and associated revisions are provided in the accompanying document, in the section entitled 'Blue Book revisions and the Impact of FISIM'.

- Improved general worker human capital due to formal qualifications, age and experience changes: 0.16 per cent p.a.

If we define innovation as the contribution of knowledge capital and TFP, then innovation raised growth in output per person-hour in the UK by 0.51%+0.90% = 1.41% in 2000-08, which is 63 per cent (1.41/2.25) of labour productivity growth. On this measure, innovation was responsible for about 72 per cent p.a. of labour productivity growth in the late 1990s, reflecting the boom in investment in software along with the mass take-up of the internet and 62 per cent in the early 1990s.[3]

(If we define innovation more widely, that is the contribution of knowledge capital, TFP and general human capital,[4] we have that innovation raised growth in output per person-hour in the 2000s 0.51% p.a. +0.90% p.a. +0.16% p.a. = 1.57% in the 2000s, which is 70 per cent (1.57/2.25) of labour productivity growth).

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

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

The contributions however of each sector to overall innovation depend upon both this and their weights in overall activity. For intangible investment this depends on the sector's intangible contribution weight in the total. For TFP, it depends upon the sector's Domar weight (since an increase in TFP in sector A raises overall TFP, but also TFP in other sectors to the extent that sector A's input is an intermediate into other sectors). When all this is added consistently, we find that manufacturing is particularly important. It accounts for 42 per cent of the innovation in the UK market sector (its employment share is 19 per cent). We also find important contributions of retail/hotels/transport, accounting for 27 per cent of innovation, business services contributing 22 per cent and finance 12 per cent (their employment shares are 39 per cent, 5 per cent and 22 per cent respectively).

The importance of manufacturing reflects its increasing 'servitisation', a concept that we can measure more precisely and we discuss it below. We also look at the question of rebalancing the economy between manufacturing and services.

3. In last year's report these numbers were 67 per cent for 2000-07, 62 per cent for 1995-2000 and 57 per cent 1990-95. The slight changes in the earlier years are due to downward revisions in computer investment.

4. General human capital or labour services are an adjusted measure of labour input where growth in hours of different worker types is weighted by their share of the total wage-bill. The methodology used is in line with the internationally accepted OECD methodology. Further details are provided in the accompanying document to the last report, 'Labour Services'. Labour services input has grown steadily through the period, reflecting growth in the quality of labour input, while total hours worked have been relatively flat since 1998. The proportion of productivity growth accounted for by improving labour quality is steady at around 7 per cent.

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# Part I: Introduction

## 1.1 Background

The NESTA Innovation Index project has a number of streams concentrating on innovation in the UK private sector. This report is the central component, measuring the investments in intangible assets and their contributions to economic growth. It makes three important contributions.

First, the report details the framework and results for *innovation accounting*, namely improvements in the measurements of how much firms are spending on innovation. Second, the report details the approach and results on a growth accounting-based *Innovation Index*, demonstrating how much all forms of new knowledge, which includes knowledge that is freely available or embodied within the labour force, as well as knowledge acquired through investment by firms, contribute to labour productivity growth. Finally, the framework contributes to the discussion on the changing sectoral landscape by providing a breakdown to seven broad sectors.

## 1.2 Building a framework for measuring innovation

This section provides an overview to the two main approaches for developing an Innovation Index.[5]

One approach is to calculate a composite index of available indicators and present this as corresponding to innovation. An example of this approach is the European Innovation Scoreboard (EIS).[6] The EIS is a weighted average across countries built on data for broadband penetration, R&D spend, public support for innovation, employment in high tech companies and patents/trademarks. Indices of this type are often developed with little reference to an underlying definition on either the choice of variables or how to weight them. With these caveats this approach will remain subject to debate.

The second approach is the reverse: namely, propose a definition of innovation and then produce an index to reflect this. A number of definitions have been developed by experts over the years, each in turn endeavouring to address emerging new challenges.

The Frascati Manual (2002),[7] being the official R&D manual, proposes: *"Technological innovation activities are all of the scientific, technological, organisational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes"*. It should be noted that specific mention is made of *"organisational, financial and commercial steps"* and that innovation is clearly considered as much wider than just R&D. However, the *Frascati Manual* is less clear on how 'implementation' might be measured.

The Oslo Manual[8] also makes specific mention of organisational innovations: *"A technological product innovation is the implementation/commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a*

5. For a more comprehensive discussion, see Haskel *et al.* (2009) 'Innovation, Knowledge, Spending and Productivity Growth in the UK: Interim report for the NESTA Innovation Index project.' London: NESTA.
6. See for example 'European Innovation Scoreboard 2009.' Available at: http://www.proinno-europe.eu/page/european-innovation-scoreboard-2009
7. OECD (2002) 'Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development.' Paris: OECD.
8. OECD (2005) 'Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data.' 3rd Edition. Paris: OECD.

*combination of these"*. Therefore the definition is fairly wide, and the Manual also allows for innovation in activities such as marketing. But it also introduces the term *"objectively new or improved"* without defining it.

NESTA proposed that there be a discussion around a definition of innovation *"change associated with the creation and adoption of ideas that are new-to-world, new-to-nation/ region, new-to-industry or new-to-firm."* While intended to stimulate discussion, the issue is that the definition is not clear on what "change" is and how it might be measured.

Finally, the US Advisory Committee on measuring innovation proposes: *"The design, invention, development and/or implementation of new or altered products, services, processes, systems, organizational structures, or business models for the purpose of creating new value for customers and financial returns for the firm"*, which is broad in innovation scope but focuses on commercialised products and so is, as they point out, orientated at a private sector definition.

The approach adopted within this report proceeds in the light of these definitions. Firstly a common feature of these definitions is that innovation produces something new. Thus the framework assumes that innovation is the output from the commercialisation of ideas and inventions. This follows Schumpeter's argument that a new idea or invention is not necessarily innovation. Rather, innovation is defined as increased productivity as a result of its application. Applying this 'market test' provides an economic value for innovation, and allows us to avoid the virtually impossible task of valuing or weighting ideas. This approach then confines us to the market sector, for it uses the commercial value of new ideas as a measure of the output of innovation, which is very hard to measure in the public sector.

Secondly, the definitions are all clear that the inputs to such ideas are the building of new knowledge, but vary in the scope of such inputs. One might just measure R&D for example, or, one might extend this to encompass design, organisational innovation and other intangible activities. The focus here is to measure spending on a wide range of innovation inputs, thus following the spirit of the Oslo Manual and the Advisory Committee to the US Commerce Department (Innovation Measurement, 2008). It also fits with the economists' view of innovation captured by Total Factor Productivity (TFP). Our approach therefore is to measure:

a. The spending on new ideas.

b. The contribution to output of the commercialisation of these ideas.

How does the adopted approach achieve the second of these? The way to understand our approach is to consider how one could get more output without innovation. The answer is to add more to existing physical capital and labour. For example, we could have more flights from London to Glasgow by adding more aircraft and hiring more crew, i.e. *duplication of physical capital and labour.*

How could we get more output with innovation? The answer is to apply new ideas: more frequent flights with ticketless boarding, better-written software to roster crews etc. That defines innovation as the commercialisation of ideas, or equivalently the extra output net of the duplication of physical capital and labour. This is the growth accounting approach, which seeks to measure the contributions to output of duplication of labour and physical capital and the contribution from ideas from both investments in new ideas and improvements in labour human capital.[9]

A number of points are worth making. First, part of the new ideas might be embodied in new capital equipment, e.g. if an airline flies better aircraft. However, this is a result of knowledge investment and innovation in the aircraft industry and not the airline industry: hence it would be double counting to count the aircraft as innovation too.[10]

Second, an existing idea might be 'duplicated' if it is applied in many contexts or markets. This does not affect our measure of innovation, which is commercialisation of ideas, but highlights that duplication of tangible capital is different from intangible capital, for the former cannot be spread across other users at zero cost.

Third, and related, since knowledge can leak across firms (in the way that tangible capital cannot), the framework also includes in our Innovation Index the impact of freely-available knowledge on growth using TFP, the growth accounting residual.

The next section provides an overview of the framework of intangible assets and details the approach adopted for measuring investments in these assets.

9. Formally, our definition of innovation is TFP plus the part of capital deepening accounted for by new knowledge investment. For those without an economics background, further explanation is provided in the accompanying document 'Non-technical explanatory note on Growth Accounting'. It therefore follows the research program set out in the expanded view of capital and TFP measurement proposed by Corrado, Hulten and Sichel (2006), which builds in turn on the work on growth accounting set out for example in the Jorgenson volumes (Jorgenson, 2007). It extends the TFP argument by explicitly recognising that not all knowledge comes to firms for free and therefore attempts to measure the accumulation in knowledge that firms have to spend on, as well as that which is free.

10. Potential double-counting in the context of innovation is discussed further in previous papers including Giorgio Marrano, Haskel and Wallis (2007) and Clayton, Del Borgo and Haskel (2008).

# Part 2: A framework for measuring Intangible Assets

Knowledge takes different forms, so quantifying it is not straightforward. We measure investment in intangible assets to approximate the knowledge created by firms. Following CHS (2006), we have distinguished between three main classes of intangible assets:

1. Computerised information.

2. Innovative property.

3. Economic competencies.

The first comprises software and databases; the second mainly covers R&D and design (including architectural and engineering design), but also product development in the financial industry; and the last one consists of firm investment in branding, human and organisational capital.

The data is constructed from the bottom-up, that is derived at the industry level and aggregated subsequently. Aggregation of nominal variables is by simple addition. The aggregation of real variables are a share-weighted superlative index for changes, benchmarked in levels to 2005 nominal data. For intangible spending, we have data at time of writing up to 2008. The framework only looks at the market sector and omits the residential housing sector.

The methodology and sources used to get the data on intangible expenditure by industry are described in previous papers extensively, therefore we cover them here only briefly. Most of the sources and methods used below follow Corrado, Hulten and Sichel (2006) and Giorgio Marrano, Haskel and Wallis (2007),[11] who conduct their estimates for the total private sector. A complete list of knowledge assets, their sources and further comments are provided in the table in the Appendix.

## 2.1 Computerised information

Computerised information comprises computer software, both purchased and own-account, and computerised databases. Software is already capitalised in the National Accounts, and the main source for computer software investment is contained in the ONS work described by Chesson and Chamberlin (2006). The estimates of purchased software are based on company investment surveys. And for own-account software, they use the earnings of employees in computer software occupations. Note that to avoid double counting, additional spending on computerised databases is not considered as it is already included in the ONS software estimates. The data in this paper rely on updated data from the ONS, consistent with *Blue Book 2010*. The data run from 1970 to 2008. Further details on the methodology for software investment are provided in the accompanying document, *Measuring Software Investment in the UK National Accounts*.

## 2.2 Innovative property

For *Scientific R&D* performed by businesses in the UK, expenditure data are derived from the Business Enterprise R&D survey (BERD). To avoid double counting of R&D and software investment, R&D spending in 'computer and related activities' (SIC 72) is subtracted from R&D spending,[12] since this is already included in the software investment data.

11. Corrado, C.A., Hulten, C.R. and Sichel, D.E. (2006) 'Intangible Capital and Economic Growth.' NBER Working Papers 11948. Cambridge, MA: National Bureau of Economic Research; Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HMT.
12. Work at ONS on the upcoming capitalisation of R&D is currently ongoing. Therefore although further work is required, our data will be made fully consistent with the ONS R&D satellite account during Phase 2 of the project.

Like computerised information, *mineral exploration, and copyright and licence costs* are already capitalised in the National Accounts and the data here are simply data for Gross Fixed Capital Formation (GFCF) from the ONS. The copyright and licence cost 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."* UK National Accounts report the subcategories: a) artistic originals, broadcasting and recording; b) entertainment, literary and artistic originals; and c) artistic originals and publishing. The data covers 1970 to 2008. Based on work currently in progress for the Intellectual Property Office (IPO), the expectation is that these investment numbers are understated and so should be regarded as a lower bound on the actual effect. Further work is necessary to amplify this.

Expenses on *mineral exploration* are valued based on *"payments made to contractors or costs incurred on own account. The costs of past exploration, which have not yet been written-off, are re-valued (which in this case may well reduce the value). This expenditure covers the costs of drilling and related activities such as surveys. It is included in GFCF whether or not the exploration is successful,"*[13] (ONS National Accounts, 2008). Three subcategories are reported: a) mineral exploration other than oil and coal; b) continental shelf exploration expenditure; and c) coal mineral exploration. Further information on these categories is provided in the accompanying note *"Mineral Exploration, Copyright and Licence Costs"*.

The measurement methodology for *new products development costs in the financial industry* follows that of own account software, used by the ONS, and therefore replaces the CHS approach of assuming 20 per cent of total intermediate consumption by the financial services industry as the cost of new product development in the financial industry. This new method reduces this category substantially. Further details are in Haskel and Pesole (2009).[14]

For new *architectural and engineering design* we also use the software method for own-account, and purchased data are taken from the supply-use Input Output (IO) tables. Full details are set out in Galindo-Rueda *et al.* (2010). Finally, R&D in social sciences and humanities is estimated as twice the turnover of R&D in 'Social sciences and humanities' (SIC 2003 73.2), where the doubling is assumed to capture own-account spending. Turnover data is taken from ABI and is available for 1992 to 2006. This is a small number and we suspect the marginal benefit to improving its measurement is slight.

### 2.3 Economic competencies

*Advertising expenditure* is estimated from the IO Tables by summing intermediate consumption on Advertising (product group 113) across all industries. At time of writing these data go up to 2004 and subsequent years are interpolated using market research data from the IO tables.

*Firm specific human capital*, that is training provided by firms, was estimated as follows. We have cross sections from the National Employer Skills Survey (NESS) for 2004, 2006, 2007. We also have data for 1988 from an unpublished paper by John Barber. We thus backcast the series using EU KLEMS wage bill time series benchmarking the data to three cross sections.

The NESS is conducted by the Learning and Skills Council in partnership with the Department for Innovation, Universities and Skills and the Sector Skills Development Agency. The main survey contains information on the training behaviour from 79,000 establishments in England. Information about expenditure on training is collected in a follow-up survey to measure employer training among establishments who reported during the main NESS07 survey that they had funded or arranged training in the previous 12 months. Information on training expenditure was collected from 7,190 employers. The results were grossed-up to the profile of trainers derived from the main NESS07 survey findings. Population figures for establishments providing training were drawn from the weighted NESS07 survey data, using a grid interlocking the training type (on-the-job training only, off-the-job training only, both) by size and by region, with an additional Sector Skills Council sector weight added at national level. Findings, therefore, are representative of all employers (for more details see Appendix 2). For further details on the data and methodology for training expenditure, please consult the accompanying document 'Training Measures'.

One adjustment to the data since the interim pilot report in 2009 is that we have subtracted spending on Health and Safety training. Such spending is about 10 per cent of total spend (firms are asked in the training survey to

13. ONS (2007) 'National Accounts: Sources and Methods, 1998.' Newport: ONS. For more details see www.statistics.gov.uk/downloads/theme_economy/concepts_sources_&_methods.pdf
14. Haskel, J. and Pesole, A. (2009) 'Productivity and Innovation in the UK Financial Services Sector.' Preliminary CeRiBA Working Paper. London: CeRiBA.

quantify this) and it has been put to us that such training should not be regarded as an investment in knowledge capital for workers. We lack independent evidence on this issue, but note here that whilst this subtraction lowers the level of training spending, it turns out to affect the contribution of training to growth at only the 4th decimal place.

Finally, the data on investment in *organisational structure* relies on purchased management consulting, on which we have consulted the Management Consultancy Association (MCA), and own-account time-spend, as before. This method relies on identifying managers by occupation. An ONS decision has been taken to re-classify some managers in the Standard Occupational Classification, since UK employers tend to use the title 'manager' more liberally than employers in other countries, which will lower the UK managerial total. This work is highly preliminary and it has not been possible to incorporate this into the current index calculations. Further information on the implications of the re-classification of managers according to the Standard Occupational Classification are provided in the 'Reclassification of Managers, SOC2010' section in the accompanying technical paper. Nonetheless, it is worth stating that this part of measurement is much the weakest which is why we look at robustness below.

### 2.4 Accuracy of intangible measures

Data on investments in intangibles is not included as investments in the National Accounts, therefore the data sources are not typically covered by the kind of official surveys used to construct National Accounts investment data, e.g. investment surveys. Full details of the measurement of investments are provided in Appendix 1.

A significant advance of the Index approach is to increase the accuracy in the measurement of these investments. The following section details the steps taken to validate the data used within the model.

Firstly, data on minerals, copyright, branding and software are taken from official National Accounts sources and so do use a consistent methodology. As mentioned above, very preliminary work suggests an undercounting of copyright spending, so if anything our results are an understatement of intangible spending.

Secondly, data on R&D are taken from the official UK R&D survey. This survey has been running for many years and uses official methods with a very high response rate. Thirdly, data on workplace training is taken from successive waves of a government survey, weighted using ONS sampling weights. Once again one might worry that such data is subject to biases and the like but this does look like the best source currently available.

Fourth, data on design, finance and investment in organisational capital is calculated using the software method for own-account spending, but the IO tables for bought-in spend. The use of the IO tables at least ensures the bought-in data is consistent with the *Blue Book*. The use of the own account software method means that the project team has to identify the occupations that undertake knowledge investment, the time fraction they spend on it and additional overhead costs in doing so. For design and financial services, the approach has 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 an assumed fraction of time spent (20 per cent) by managers on organisational development is used. The project team has been unable to improve on this estimate in interviews and so this remains a subject for future work.

To examine these estimates further, the project team undertook two further studies. First, data from NESTA's firm level survey[15] and described in detail in Barnett (2009)[16] was used to validate the initial data used to develop the investments data. The approach taken is detailed in the interim report published in 2009.[17]

Second, to increase the accuracy of the data beyond the pilot Index a survey of business investments in intangible assets was conducted, in partnership with ONS.[18] In terms of the spending numbers here, the survey 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 suggests that this investment data requires further work.

15. See Roper *et al.* (2009) 'Measuring sectoral innovation capability in nine areas of the UK economy.' London: NESTA
16. Barnett, D. (2009) 'UK Intangible Investment: Evidence from the Innovation Index Survey.' London: CeRiBA.
17. Haskel *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project.' London: NESTA.
18. See Awano *et al.* (2010) 'Investing in innovation: Findings from the UK Investment in Intangible Asset Survey.' London: NESTA; and Awano *et al.* (2010) Measuring investment in intangible assets in the UK: results from a new survey. 'Economic & Labour Market Review.' Vol. 4, No. 07, pp.66-71.

# Part 3: A formal model and definitions

This section details the formal model used to build the Innovation Index as described in section 3.2. The formal model is set out fully in Haskel *et al.* (2009) and follows entirely Corrado, Hulten and Sichel (2006).[19] Briefly, the model assumes three sectors. The final goods sector produces consumption goods, that is, goods that have no investment property. The other two sectors produce investment goods, that is goods that create an asset. These sectors produce new tangible capital ($I$) and new knowledge/intangible capital ($N$). The tangible capital stock accumulates according to:

19. Haskel *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project' London: NESTA; Corrado, C.A., Hulten, C.R. and Sichel, D.E. (2006) 'Intangible Capital and Economic Growth.' NBER Working Papers 11948. Cambridge, MA: National Bureau of Economic Research.

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

where K is the real stock of tangible capital, and I is investment in tangible capital. The intangible capital stock is given by $R_t$ which also accumulates according to:

$$R_t = N_t + (1-\delta_R)R_{t-1} \quad (2)$$

Rather than knowledge being an intermediate input, the model assumes that all sectors rent tangible and knowledge capital so that their production functions and profit identities can be written as:

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

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

(c) Consumption sector: $C_t = F^C(L_{C,t}, K_{C,t}, R_{C,t}, t);\quad P_t^C C_t = P_t^L L_{C,t} + P_t^K K_{C,t} + P_t^R R_{C,t}$ (3)

As above, we may now add up value added across each sector to give economy-wide value added and its corresponding real growth rate:

$$P^V V = P^C C + P^I I + P^N N$$

$$\Delta \ln V = \frac{P^C C}{P^V V}\Delta \ln C + \frac{P^I I}{P^V V}\Delta \ln I + \frac{P^N N}{P^V V}\Delta \ln N \quad (4)$$

To derive the economy-wide Innovation Index, the model assumes that all inputs are paid the same across all sectors, giving economy-wide definitions as:

$$X = \sum_{i=C,I,N} X^i, \quad X = K, L, N$$

$$\Delta \ln X = \sum_{i=C,I,N} \frac{P^X X^i}{P^X X}\Delta \ln X^i, \quad X = K, L, N \quad (5)$$

Where the first term simply defines economy-wide employment of input $X$ as the sum across industries and the second defines the growth of aggregate real inputs as the share-weighted industry-specific growth. We are now in a position to write how real aggregate output grows, i.e. the relation between increased output and increased human, tangible and intangible inputs. Differentiating the production functions in (3) and substituting the resulting expressions for $\Delta \ln C$, $\Delta \ln I$ and $\Delta \ln N$ into (4) and using (5) we can write the sources of economy-wide value added growth in terms of economy-wide input growth as the following:

$$\Delta \ln V = s^{K} \Delta \ln K + s^{L} \Delta \ln L + s^{R} \Delta \ln R + \Delta \ln TFP \quad (6)$$

where $s^{X} = (P^{X} X / P^{V} V)$, $X = K, L, R$, i.e. the factor input shares of value added.

Equation (6) shows that the economy can grow due to $\Delta \ln K$ and $\Delta \ln L$, i.e. with the addition of more tangible capital and labour alone. It can also grow due to commercialisation of knowledge. The effect of ideas on $\Delta \ln V$ are captured by the $s^{R} \Delta \ln R$ and $\Delta \ln TFP$ terms. The first measures the impact on output growth from knowledge spending at the firm and the second from knowledge flows from outside the firm (and other unmeasured factors). Thus, since we define the Innovation Index, $II$, as to exclude the effects of physical capital and labour, we have:

$$\begin{aligned} II &= \Delta \ln V - (s^{K} \Delta \ln K + s^{L} \Delta \ln L) \quad (7) \\ &= s^{R} \Delta \ln R + \Delta \ln TFP \end{aligned}$$

We shall implement this framework using new data.

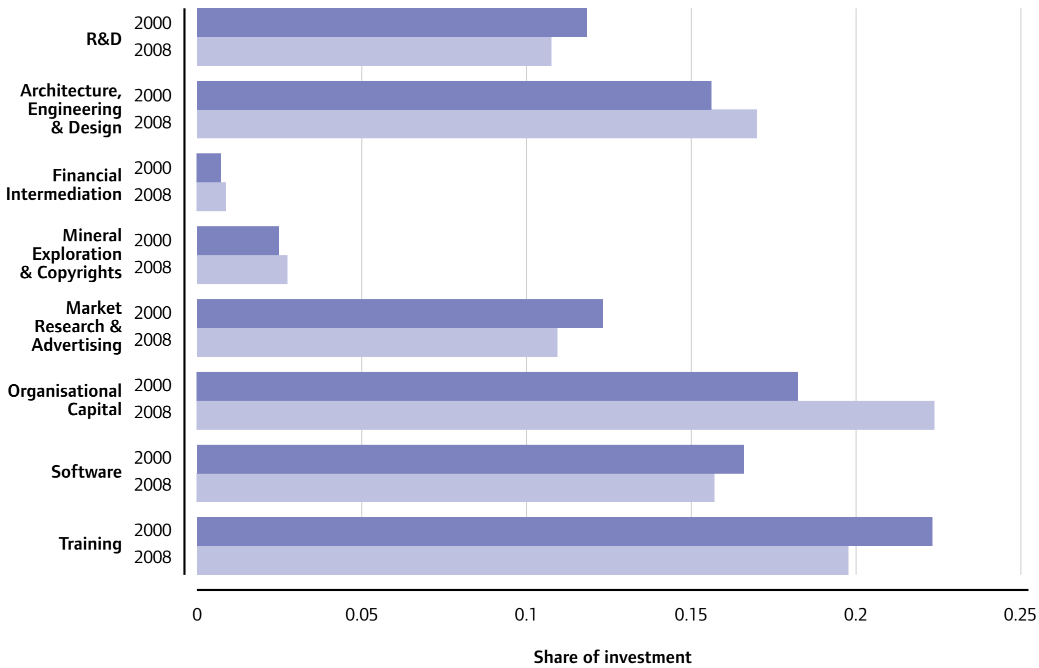
# Part 4: Results

## 4.1 Intangible investment accounting

Figure 1 sets out our intangible investment categories. They are by now standard and the interested reader is referred to the Appendix for further detail or GHW for a discussion. Figure 1 shows the fraction of all intangible investment in 2000 and 2008 accounted for by each intangible asset type. Investment in training (or more formally, firm-specific human capital) is the most important in terms of its share in total intangible investment (around 19 per cent). Organisational capital, software and design are next in importance. The proportions are not much changed over the period. Note that R&D is around 10 per cent of total intangible investment.

The actual values for investment in each category are shown in Table 1 for the years 1990, 1995, 2000 and 2008, alongside the corresponding values for tangible investment. It shows intangible investment to be higher than tangible investment for each snapshot except

**Figure 1:** Shares of total intangible investment of individual categories, 2000 and 2008




**Note:** Figures are percentages of total intangible spend across all asset categories for each year.

**Table 1:** Tangible and Intangible Investment, £bns

| Year | 1990 | 1995 | 2000 | 2008 |
|---|---|---|---|---|
| **All tangibles** | **67** | **62** | **87** | **104** |
| **Intangible category** | | | | |
| Software Development | 6 | 10 | 16 | 22 |
| R&D | 8 | 9 | 12 | 16 |
| Design | 13 | 13 | 15 | 23 |
| Mineral Exploration & Copyrights | 3 | 3 | 2 | 4 |
| Branding | 5 | 7 | 12 | 15 |
| Training | 12 | 15 | 21 | 27 |
| Organisational Capital | 9 | 12 | 17 | 31 |
| **All intangibles** | **56** | **69** | **95** | **137** |

**Note:** Data are absolute investment figures, in £bns, current prices. For clarity, 'Design' refers to architectural and engineering design, and financial product development.

**Source:** ONS data for tangibles, this paper for intangibles.

20. Note that cross-country differences in intangible investment should not be used to try and explain productivity gaps between countries. This is because the contribution of capital to productivity is via capital services that flow from the stock of accumulated (tangible and intangible) capital.

1990.[20] Additionally, the intangible category with the highest investment figures over time is training, growing to approximately a third of tangible investment by 2008.

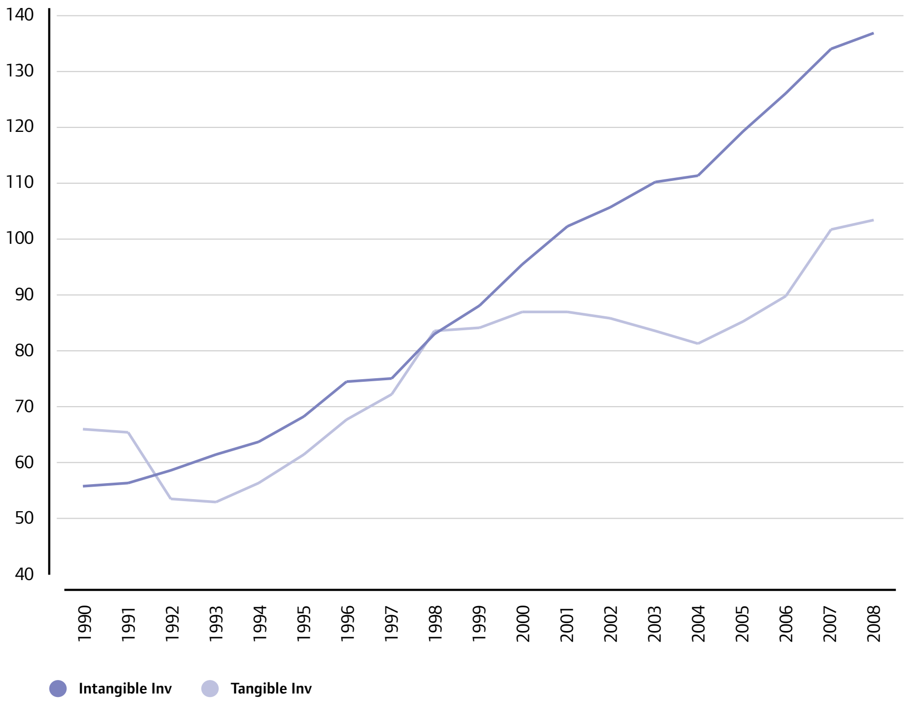
Figure 2 presents the same nominal investment data but as a time-series for aggregate tangible and intangible investment. As can be seen, in 1990 tangible investment was at a slightly higher level than intangible investment, before falling during the recession in the early 1990s and then again in the 2000s. Thus, since 2000, intangible investment spending has exceeded tangible.

Regarding cyclical behaviour, intangible investment tends to hold up pretty well during the recession, that is, it falls less and recovers more quickly. The view is that there are a number of factors behind this. Firstly, the recession and subsequent recovery would have forced some of the less productive firms out of the market, leaving behind the more productive firms and new entrants, which are likely to be more innovative and intangible-intensive than those that have exited. More specifically investment in assets such as brand and human capital is particularly important for young firms new to the market. Secondly, assets such as organisational own-account are estimated using assumptions on the time-use of relevant occupations. So for this example, unless very large numbers of managers are laid off during downturns and re-hired in the recovery, the investment figure is relatively stable.

It is worth noting however, that depreciation rates for intangible assets are significantly faster than those for tangible assets. Thus a relatively small slowdown in intangible spend turns out to generate the same fall in capital stock as a steep fall in tangible spend, so the changes in resulting capital services are similar even though the investment rates are different.

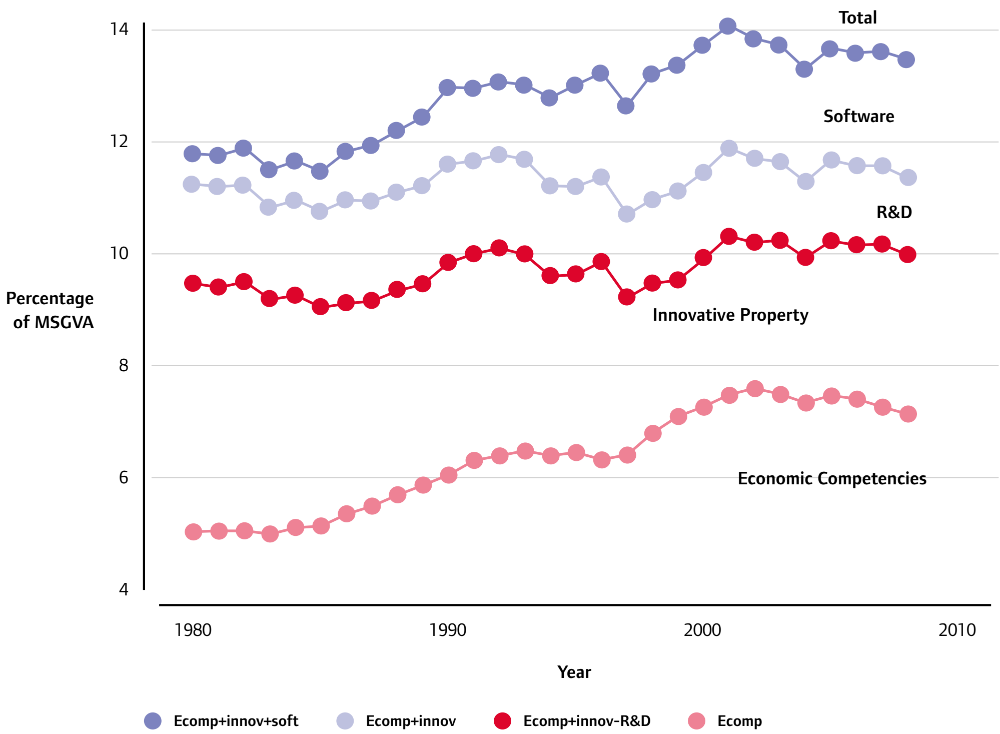
Figure 3 shows a time series of total investment in intangibles categories, for the period 1980-2008 as a proportion of Market Sector Gross Value Added (MSGVA). The bottom line shows the share in total MSGVA of economic competencies. The second line is this share, plus the share of innovative property, less the share of R&D. Thus the gap between the first and second line is non-R&D innovative property, which as the graph shows has been rising over the period. The third line includes R&D and thus the gap between the second and third line is R&D spend as a percentage of MSGVA, which has been falling slightly over the period. The final gap includes software which is rising as a share of MSGVA. The numbers suggest that intangible investment is a sizeable fraction of MSGVA, here around 13 per cent in total. However, that fraction has been falling since 2000.

**Figure 2:** Time series of total tangible and intangible investment, Current Prices £bns, 1990-2008




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

**Figure 3:** Time series of shares of selected intangible investment categories in Market Sector Gross Value Added




**Notes:** EC is Economic Competencies; InnProp is Innovative Property; R&D is Research & Development; Sof is Software; Tot is Total. ecomp+innov+soft = Economic Competencies plus Innovative Property plus Software. ecomp+innov-R&D = Economic Competencies plus Innovative Property minus R&D. ecomp+innov = Economic Competencies plus Innovative Property. ecomp = Economic Competencies, where: Economic Competencies are Advertising & Market Research, Training and Organisational Investment; and Innovative Property is Mineral Exploration and Copyright Creation, Design, Financial Product Development and Social Research.

### 4.2 Labour quality

Figure 4 sets out our sources for data on labour services, hours worked and services per hour since 1985. Growth rates are calculated as changes in natural logs and the series is normalised to zero in 1985. Hours, specifically person-hours in the market sector, rose strongly in the late 1980s and then fell, sharply. They recovered with another strong rise from 1993, but have not grown as fast in the 2000s, indeed falling somewhat in the early 2000s. Labour services follow a very similar pattern, but do not fall as much in the late 1990s, suggesting that the person-hours reduction at that time was concentrated in a reduction in person-hours of the low skilled. This is supported in data presented in the section on 'Labour Services' in the accompanying document. Thus the resulting labour services per hour grew steadily over the period, although at a slower rate in the 2000s.

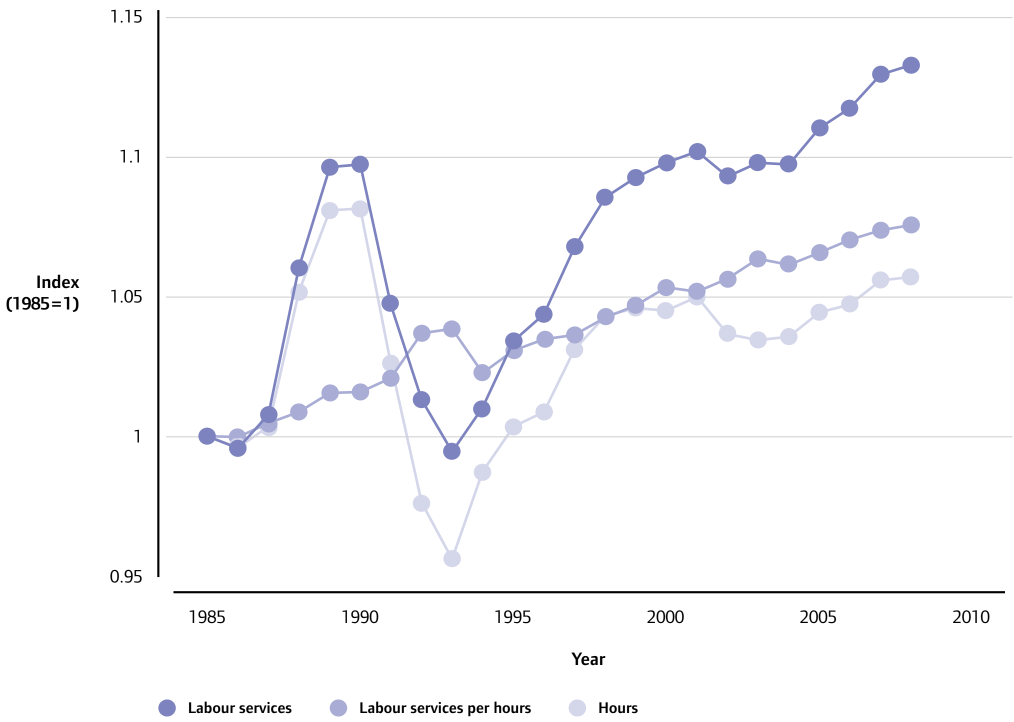
### 4.3 Shares of Gross Operating Surplus in total Market Sector Gross Value Added

Figure 5 shows the shares of Gross Operating Surplus (GOS), in MSGVA, again without and with intangibles. When intangibles are included then GOS rises since firms are renting more capital than is the case when intangibles remain uncapitalised. MSGVA rises as well, so the effect on the share is ambiguous. As the graph shows, the effect is to raise the gross operating surplus share by around ten percentage points. The extra capital when intangibles are included of course boosts the role of capital in growth accounting.

### 4.4 MSGVA, Average Labour Productivity (ALP) and person hours growth

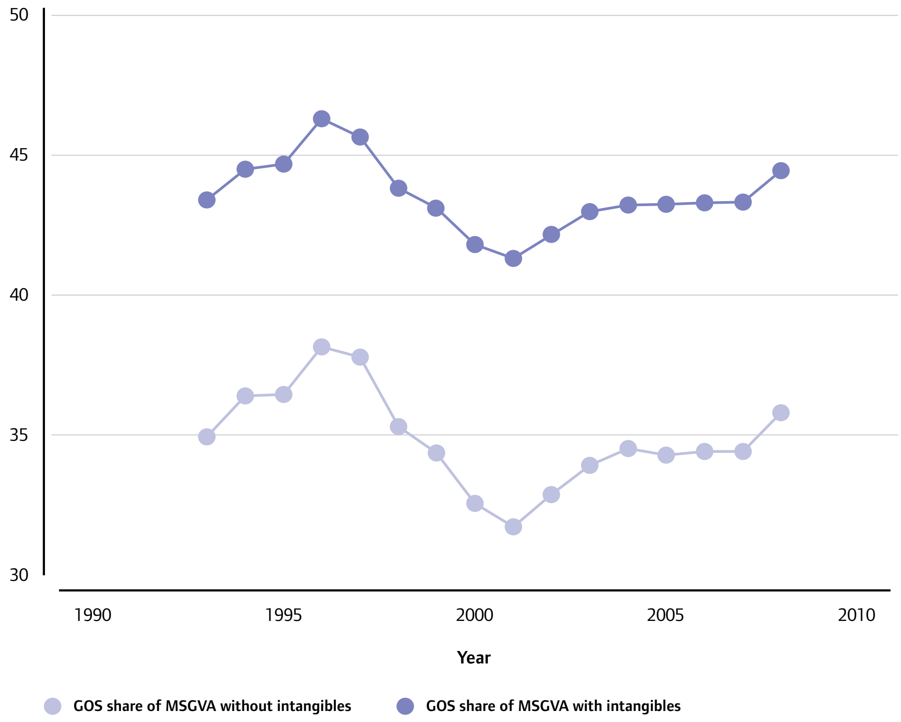
Before proceeding to our growth accounting results, this section presents data on growth of some basic series. Figures 6.1 and 6.2 show our basic series without and with intangibles. They are smoothed using a 3-year centred moving average to help see the picture. Consider first the 'without' data, which excludes software and so is not quite the same as official ONS data. It shows rising then falling labour productivity growth (LPG), that is growth in real value added per person hour per year in the early 1990s, rising in the late 1990s, and then a slowdown in the 2000s.

**Figure 4:** Labour services, hours and labour services per hour




**Note:** Labour Services are a volume index of labour input adjusted for composition or quality. Labour Services per hour are just that, and represent the composition adjustment. Hours are hours worked by employees and the self-employed.

**Figure 5:** Time series of shares of Gross Operating Surplus in nominal Market Sector Gross Value Added with and without intangibles




**Note:** GOS includes allocation of mixed income. MSGVA is market sector gross value-added.

21. Details are provided in the supporting paper Blue Book revisions and the Impact of FISIM.
22. This data, and all other growth rates in this paper, are average annual rates calculated as changes in natural logs. Contributions are Tornquist indices.

It is important to note the movement of LPG in the late 1990s relative to the early 1990s. This data shows an improvement in LPG in contrast with earlier work that had displayed a fall in LPG. The source of this are revisions to the *Blue Book* GVA in 2008. This revised data is used here. In turn, these revisions correspond to the introduction of FISIM in the *Blue Book*.[21]

Figure 6b shows the data with intangibles. The main feature is the somewhat stronger LPG growth in the earlier period and weaker growth in the 2000s. Note that in both cases output declines in 2008, with a faster decline with intangibles.

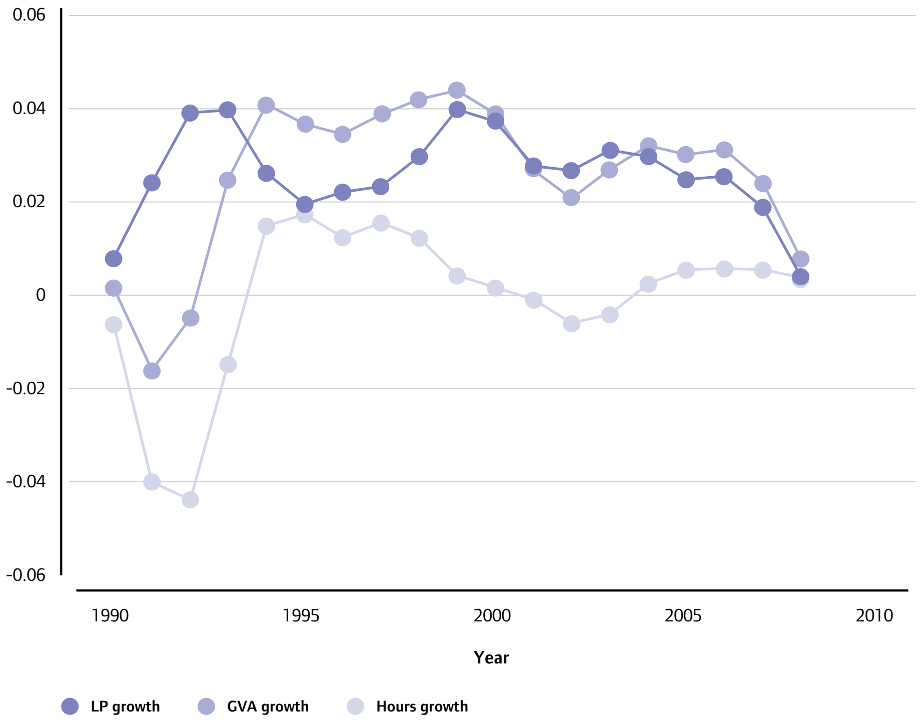
## 4.5 Growth accounting results

The report now moves to the growth accounting results, which are set out in Table 2 (Panel 1) and Figures 7 and 8.[22]

Consider Table 2 which reads as follows. The first column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times the share of labour in MSGVA. Column 3 is growth in computer capital services times the share of payments for computer services in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) times share in MSGVA. Column 5 is growth in intangible capital services times share in MSGVA. Column 6 is TFP, namely column 1 minus the sum of columns 2 to 5. Column 7 is the share of labour payments in MSGVA.

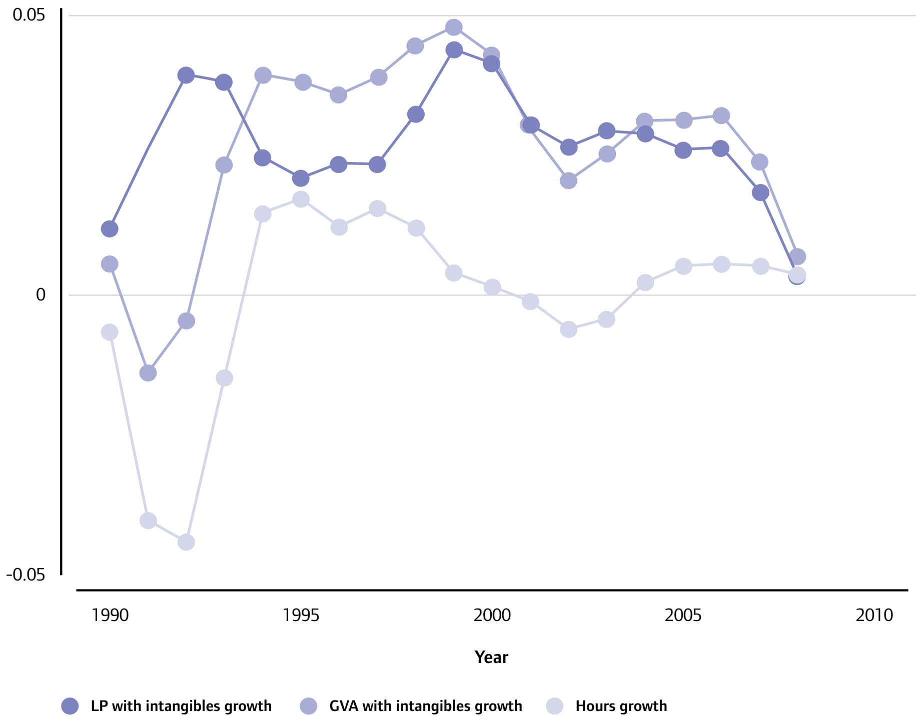
Consider first the top panel of data, which shows the contributions to growth in a standard framework that doesn't include intangibles. LPG rose in the 1990s and then fell back somewhat in the 2000s. The rise in the late 1990s is due to the FISIM effect, and other methodological changes, as discussed above. The contribution of labour quality, column 2, is fairly steady throughout. Tangible capital input grew quickly in the 1990s, but fell in the 2000s, especially computer hardware. Thus the overall TFP record was a rise in the second half of the 1990s and then a fall.

**Figure 6a:** Smoothed Labour Productivity, Market Sector Growth Value Added and hours growth, without intangibles




**Note:** LP growth is growth in market sector GVA per hour worked. These are person-hours, i.e. persons times hours worked per person. GVA growth and Hours growth show the growth in the numerator and denominator respectively. These are conventional calculations where intangibles are not capitalised.

**Figure 6b:** Smoothed Labour Productivity, Market Sector Growth Value Added and hours growth, with intangibles



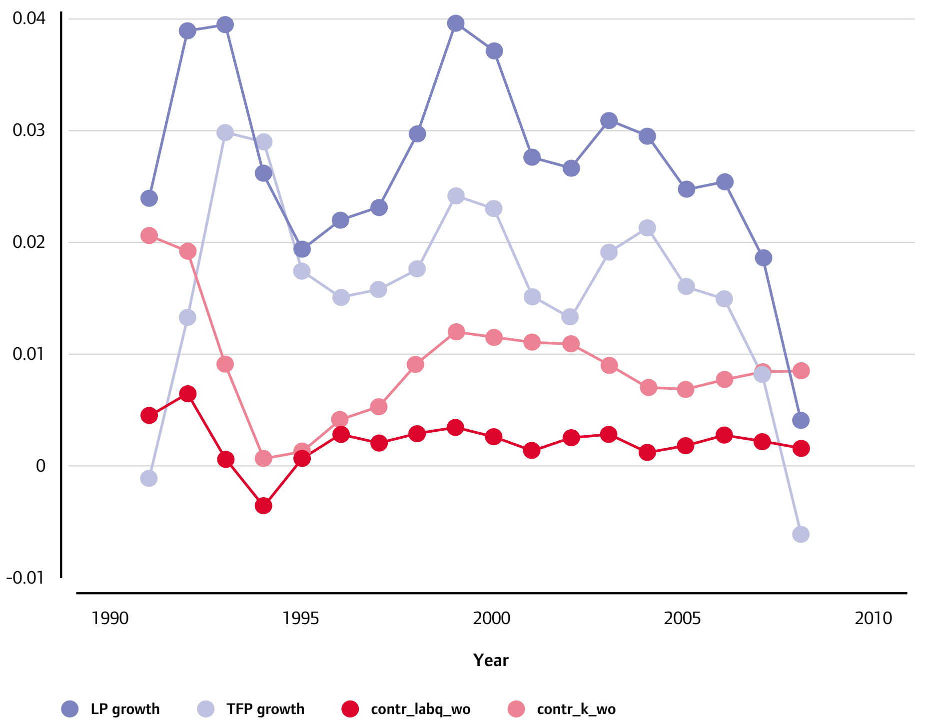

**Note:** LP growth is growth in market sector GVA per hour worked. These are person-hours, i.e. persons times hours worked per person. GVA growth and Hours growth show the growth in the numerator and denominator respectively.

**Table 2:** Growth accounting with and without intangibles and versions of Innovation Index

| | 1<br>Average Labour Productivity Growth | 2<br>Average contribution of labour composition | 3<br>Average contribution of computer capital deepening | 4<br>Average contribution of 'other tangible' capital deepening | 5<br>Average contribution of intangible capital deepening | 6<br>Average TFP Growth | 7<br>Share of labour payments in MSGVA | 8<br>InnIndex1 | 9<br>InnIndex2 | 10<br>InnIndex3 | 11<br>InnIndex4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1) Baseline Results: with and without intangibles** | | | | | | | | | | | |
| **Without intangibles** | | | | | | | | **(6/1)** | **(5+6)/1** | **(2+5+6)/1** | **(5+6)** |
| 1990-95 | 2.94% | 0.20% | 0.25% | 0.84% | | 1.66% | 0.66 | 0.56 | 0.56 | 0.63 | 1.66% |
| 1995-00 | 3.25% | 0.29% | 0.57% | 0.32% | | 2.07% | 0.64 | 0.64 | 0.64 | 0.73 | 2.07% |
| 2000-08 | 2.23% | 0.19% | 0.31% | 0.54% | | 1.19% | 0.66 | 0.53 | 0.53 | 0.62 | 1.19% |
| **With intangibles** | | | | | | | | | | | |
| 1990-95 | 2.94% | 0.17% | 0.22% | 0.73% | 0.64% | 1.19% | 0.57 | 0.40 | 0.62 | 0.68 | 1.83% |
| 1995-00 | 3.53% | 0.25% | 0.49% | 0.25% | 0.67% | 1.87% | 0.56 | 0.53 | 0.72 | 0.79 | 2.54% |
| 2000-08 | 2.25% | 0.16% | 0.26% | 0.41% | 0.51% | 0.90% | 0.57 | 0.40 | 0.63 | 0.70 | 1.41% |
| **2) Including i) just software ii) just software and R&D** | | | | | | | | | | | |
| **Only Software** | | | | | | | | **(6/1)** | **(5+6)/1** | **(2+5+6)/1** | **(5+6)** |
| 1990-95 | 3.02% | 0.20% | 0.25% | 0.84% | 0.20% | 1.54% | 0.64 | 0.51 | 0.58 | 0.64 | 1.74% |
| 1995-00 | 3.33% | 0.28% | 0.56% | 0.31% | 0.27% | 1.91% | 0.62 | 0.57 | 0.65 | 0.74 | 2.18% |
| 2000-08 | 2.27% | 0.18% | 0.30% | 0.53% | 0.11% | 1.14% | 0.64 | 0.50 | 0.55 | 0.63 | 1.25% |
| **Software and R&D** | | | | | | | | | | | |
| 1990-95 | 2.98% | 0.19% | 0.24% | 0.82% | 0.26% | 1.46% | 0.63 | 0.49 | 0.58 | 0.64 | 1.72% |
| 1995-00 | 3.35% | 0.28% | 0.54% | 0.30% | 0.30% | 1.92% | 0.61 | 0.57 | 0.66 | 0.75 | 2.22% |
| 2000-08 | 2.24% | 0.18% | 0.30% | 0.51% | 0.16% | 1.10% | 0.63 | 0.49 | 0.56 | 0.64 | 1.26% |
| **3) Altering Depreciation rates** | | | | | | | | | | | |
| **Halve Dep rates** | | | | | | | | **(6/1)** | **(5+6)/1** | **(2+5+6)/1** | **(5+6)** |
| 1990-95 | 2.98% | 0.19% | 0.24% | 0.84% | 0.29% | 1.42% | 0.63 | 0.48 | 0.57 | 0.64 | 1.71% |
| 1995-00 | 3.35% | 0.28% | 0.54% | 0.30% | 0.32% | 1.91% | 0.61 | 0.57 | 0.67 | 0.75 | 2.23% |
| 2000-08 | 2.24% | 0.18% | 0.30% | 0.50% | 0.22% | 1.05% | 0.63 | 0.47 | 0.57 | 0.65 | 1.27% |
| **Double Dep rates** | | | | | | | | | | | |
| 1990-95 | 2.98% | 0.19% | 0.24% | 0.82% | 0.23% | 1.50% | 0.63 | 0.50 | 0.58 | 0.64 | 1.73% |
| 1995-00 | 3.35% | 0.28% | 0.54% | 0.30% | 0.30% | 1.92% | 0.61 | 0.57 | 0.66 | 0.75 | 2.22% |
| 2000-08 | 2.24% | 0.18% | 0.30% | 0.51% | 0.12% | 1.13% | 0.63 | 0.50 | 0.56 | 0.64 | 1.25% |
| **4) Excluding 75% of Organisational own-account** | | | | | | | | | | | |
| **0.25 (Own-account org)** | | | | | | | | **(6/1)** | **(5+6)/1** | **(2+5+6)/1** | **(5+6)** |
| 1990-95 | 2.98% | 0.19% | 0.24% | 0.82% | 0.26% | 1.46% | 0.63 | 0.49 | 0.58 | 0.64 | 1.72% |
| 1995-00 | 3.35% | 0.28% | 0.54% | 0.30% | 0.30% | 1.92% | 0.61 | 0.57 | 0.66 | 0.75 | 2.22% |
| 2000-08 | 2.24% | 0.18% | 0.30% | 0.51% | 0.16% | 1.10% | 0.63 | 0.49 | 0.56 | 0.64 | 1.26% |

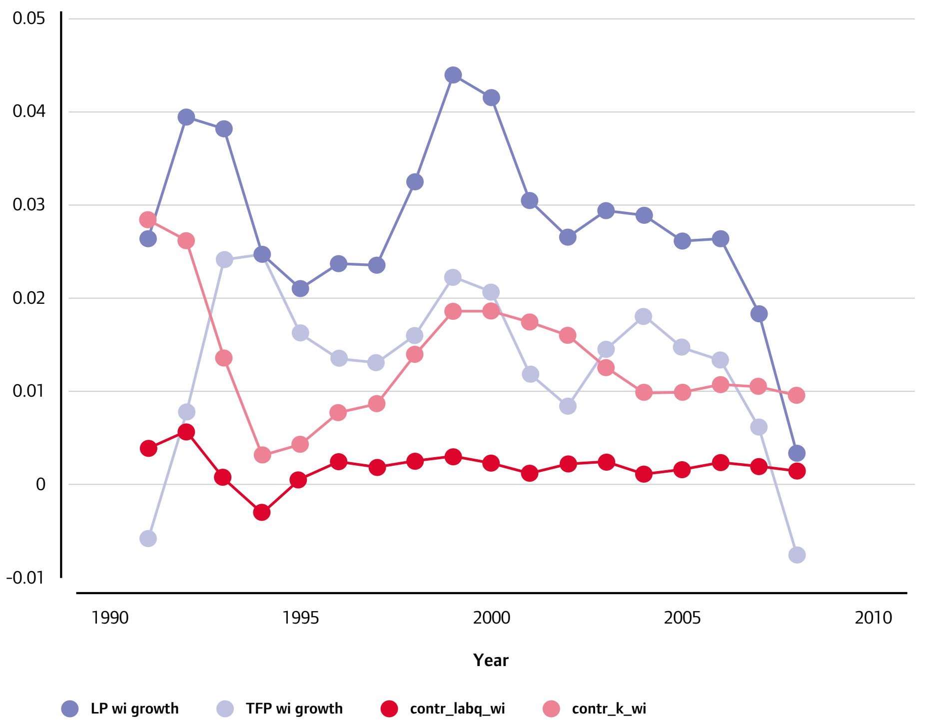
**Note:** Data is average growth rates per year for intervals shown. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in MSGVA. Column 3 is growth in computer capital services times share in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) times share in MSGVA. Column 5 is growth in intangible capital services times share in MSGVA. Column 6 is TFP, namely column 1 minus the sum of columns 2 to 5. Column 7 is the share of labour payments in MSGVA. Columns 8-11 present alternative versions of the Innovation Index.

**Figure 7:** Time series of growth in selected aggregates without intangibles, smoothed




**Note:** TFPG (total factor productivity growth) is ALPG (average labour productivity growth) less the two contributions. The two contributions (contr in legend) are 'labour quality', i.e. growth in labour services per hour times the share in MSGVA of labour and capital, i.e. growth in capital services per hours times the share in MSGVA of capital. Capital services here are computers, buildings, plant and vehicles.

**Figure 8:** Time series of growth in selected aggregates with intangibles, smoothed




**Note:** As Figure 7, except here capital services are computers, buildings, plant, vehicles PLUS all intangibles categories including software.

Note that a market sector TFP growth rate of over 1.5 per cent is comparatively high by historical data (that is, based on studies pre-FISIM). The reason for this is that FISIM has added around 0.5 to 1pppa to ALPG, all of which adds to TFPG almost directly since no new inputs are involved. Further details are in Haskel *et al.* (2009). Thus even without intangibles, the productivity picture changes.

**The contribution of intangibles to productivity growth slowed down in the 2000s**

Consider now the second set of results in panel 1. The inclusion of intangibles raises output growth in the 1990s and lowers it in the 2000s, due to a decline in intangible investment growth in the 2000s. The impact of labour quality, column 2, is about the same, but the impact of tangible capital, columns 3 and 4, falls somewhat relative to the upper panel as the inclusion of intangibles alters the factor shares of these inputs. In column 5 the data shows the contribution of the intangible inputs; stronger in the 1990s and weaker – though still important – in the 2000s. Thus the overall TFPG record in column 6 is acceleration in the late 1990s and then some weakening.

**A proposed Innovation Index**

The final columns set out various versions of the Innovation Index. The first three are presented as a share of LPG, and the fourth version is what output growth would be with zero growth in physical capital services or labour quality. So Column 8 shows TFP growth as a share of LPG, clearly larger without intangibles. Column 9 adds the contribution of intangible capital services, which is of course zero in the upper panel and column 10 adds the contribution of labour quality.

What can be established from this data? First, looking at the final bottom right figure, 70 per cent of LPG is due to innovation. Second, without intangibles, the total fraction of ALPG due to innovation is lower, at 62 per cent, with 85 per cent (=53/62) of that being due to TFPG. With intangibles included, 57 per cent (=40/70) is due to TFPG and 33 per cent (=23/70) due to intangibles. Thus the inclusion of intangibles raises both the fraction of ALPG due to innovation and the fraction due to measured inputs.

One might wish instead to express innovation not as the fraction of LPG but simply as the contribution to LPG from various factors. If one does that and looks at the time series, the largest pace of innovation was occurring in the late 90s, as the contributions of labour quality, intangible spending and TFPG were highest at that time. That period coincides of course with the take-up of the internet and the boom in ICT investment. But another key figure is that since 2000 the growth contribution of intangibles (0.51 per cent p.a.) has exceeded that from tangibles in the forms of computers (0.26 per cent p.a.) and, separately, other tangibles (0.41 per cent p.a., see the final row of the first panel of Table 2).

# Part 5: Growth accounting: further details and robustness checks

### 5.1 Robustness checks

As has been shown, necessarily a number of assumptions need to be made when implementing the growth accounting exercise. How robust are the findings to key assumptions? Panel 2 a) (in Table 2) shows the results when only software is included as an intangible. On its own, software contributes about 30 per cent of the total effect of intangible capital deepening in the full intangible case. In terms of proportions, software contributes between 4-8 per cent of labour productivity growth over all periods (that is its contribution, column 5, as a fraction of its contribution, column 1). The Innovation Index, in terms of shares, is somewhat less then in the full case where our other intangible asset categories were included, at around 63 per cent.

Second, one might ask what is the impact of capitalising R&D, as recommended in the System of National Accounts and as ONS is intending to do in 2014. To do this, the estimates which capitalise only R&D and software are presented. Note that these make assumptions on depreciation rates which might not correspond to those made in the ONS's R&D capitalisation work. The choice of which price index to use to deflate R&D in the official capitalisation will also have a significant impact on both growth and the contributions to growth. Panel 2b) shows our results. Relative to the software case, the contribution of intangibles is raised only slightly when R&D is included, with LPG remaining largely the same. The overall Innovation Index, column 10, is only very slightly raised.

Third, the role of the depreciation rates are examined. The results in Panel 3 (Table 2) show that doubling and halving the depreciation rates lowers and raises the contribution of intangible capital respectively, as would be expected. Since TFPG is correspondingly raised and lowered, it makes little difference to the overall Innovation Index.

Fourth, since own account organisational capital is particularly uncertain, Panel 4 of Table 2 presents results where we reduce such spending by 75 per cent. In this case there is a significant reduction in the contribution of intangible capital. This is to be expected since organisational own-account is such a large component of total intangible investment. However, note that the effect of this is to increase the contribution of TFP. Since less output growth is explained by the contribution of intangible capital deepening, instead it is explained by growth in TFP. Therefore, when we look at them together and in the context of overall labour productivity for our Innovation Index, as in Columns 9 and 10, the two effects approximately balance out, showing the final index to be robust to changes in the least well-measured of the assets.

Fifth, Table 3 sets out the results for each year. As year-by-year volatility can be high for a number of reasons, not least the economic cycle, readers are urged to be cautious in interpreting short-term movements in the Innovation Index and concentrate on period averages. Note for example, the fall in measured productivity in the final period, 2007 to 2008.

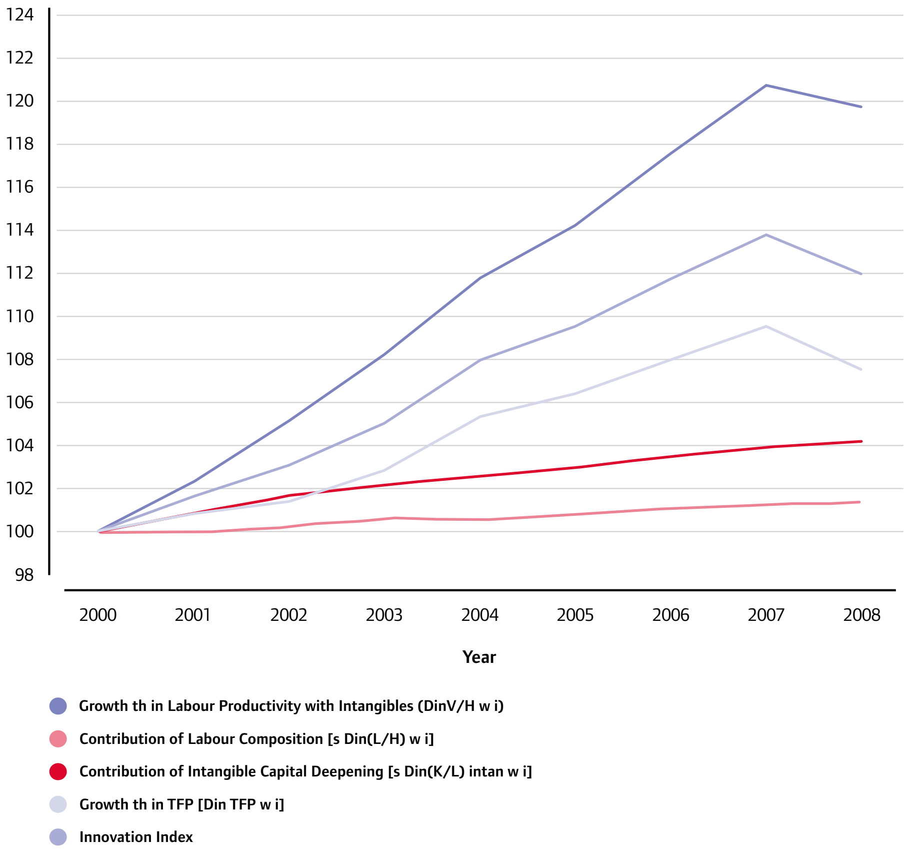
The start of the last recession is observed in the fall in economic output in the second half of 2008 which negatively impacted on labour productivity growth. By making use of the annual results set out above, we can show the

**Table 3:** Annual results

| | 1 Average Labour Productivity Growth | 2 Average contribution of labour composition | 3 Average contribution of computer capital deepening | 4 Average contribution of 'other tangible' capital deepening | 5 Average contribution of intangible capital deepening | 6 Average TFP Growth | 7 Share of labour payments in MSGVA | 8 InnIndex1 | 9 InnIndex2 | 10 InnIndex3 | 11 InnIndex4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Without intangibles** | | | | | | | | **(6/1)** | **(5+6)/1** | **(2+5+6)/1** | **(5+6)** |
| 1995 | 1.22% | 0.51% | 0.42% | -0.26% | | 0.55% | 0.64 | 0.45 | 0.45 | 0.87 | 0.55% |
| 1996 | 2.97% | 0.27% | 0.48% | 0.21% | | 2.01% | 0.63 | 0.68 | 0.68 | 0.77 | 2.01% |
| 1997 | 1.66% | 0.09% | 0.36% | -0.24% | | 1.46% | 0.62 | 0.88 | 0.88 | 0.93 | 1.46% |
| 1998 | 2.97% | 0.39% | 0.75% | 0.45% | | 1.38% | 0.63 | 0.46 | 0.46 | 0.60 | 1.38% |
| 1999 | 4.26% | 0.28% | 0.62% | 0.54% | | 2.82% | 0.65 | 0.66 | 0.66 | 0.73 | 2.82% |
| 2000 | 4.37% | 0.43% | 0.65% | 0.62% | | 2.66% | 0.67 | 0.61 | 0.61 | 0.71 | 2.66% |
| 2001 | 1.85% | -0.10% | 0.49% | 0.40% | | 1.06% | 0.68 | 0.57 | 0.57 | 0.52 | 1.06% |
| 2002 | 2.96% | 0.32% | 0.36% | 0.99% | | 1.29% | 0.68 | 0.44 | 0.44 | 0.54 | 1.29% |
| 2003 | 2.89% | 0.46% | 0.21% | 0.56% | | 1.66% | 0.67 | 0.57 | 0.57 | 0.73 | 1.66% |
| 2004 | 3.65% | -0.13% | 0.32% | 0.40% | | 3.05% | 0.66 | 0.84 | 0.84 | 0.80 | 3.05% |
| 2005 | 1.64% | 0.29% | 0.37% | 0.23% | | 0.76% | 0.66 | 0.46 | 0.46 | 0.64 | 0.76% |
| 2006 | 2.95% | 0.29% | 0.34% | 0.49% | | 1.84% | 0.66 | 0.62 | 0.62 | 0.72 | 1.84% |
| 2007 | 2.61% | 0.23% | 0.27% | 0.58% | | 1.53% | 0.66 | 0.59 | 0.59 | 0.67 | 1.53% |
| 2008 | -0.71% | 0.12% | 0.15% | 0.71% | | -1.68% | 0.65 | | | | -1.68% |
| **With intangibles** | | | | | | | | | | | |
| 1995 | 1.50% | 0.44% | 0.36% | -0.22% | 0.35% | 0.57% | 0.55 | 0.38 | 0.61 | 0.91 | 0.92% |
| 1996 | 3.39% | 0.23% | 0.41% | 0.16% | 0.58% | 2.01% | 0.54 | 0.59 | 0.76 | 0.83 | 2.59% |
| 1997 | 1.19% | 0.08% | 0.30% | -0.20% | 0.20% | 0.82% | 0.54 | 0.69 | 0.86 | 0.92 | 1.02% |
| 1998 | 3.64% | 0.34% | 0.64% | 0.36% | 0.71% | 1.59% | 0.55 | 0.44 | 0.63 | 0.73 | 2.30% |
| 1999 | 4.52% | 0.24% | 0.53% | 0.44% | 0.90% | 2.41% | 0.57 | 0.53 | 0.73 | 0.79 | 3.31% |
| 2000 | 4.91% | 0.38% | 0.55% | 0.50% | 0.97% | 2.51% | 0.58 | 0.51 | 0.71 | 0.79 | 3.48% |
| 2001 | 2.28% | -0.09% | 0.42% | 0.32% | 0.80% | 0.83% | 0.58 | 0.36 | 0.71 | 0.68 | 1.63% |
| 2002 | 2.72% | 0.28% | 0.30% | 0.77% | 0.80% | 0.57% | 0.58 | 0.21 | 0.50 | 0.61 | 1.37% |
| 2003 | 2.89% | 0.40% | 0.18% | 0.42% | 0.50% | 1.39% | 0.57 | 0.48 | 0.65 | 0.79 | 1.89% |
| 2004 | 3.26% | -0.11% | 0.27% | 0.31% | 0.36% | 2.43% | 0.57 | 0.75 | 0.86 | 0.82 | 2.79% |
| 2005 | 2.16% | 0.25% | 0.31% | 0.17% | 0.45% | 0.99% | 0.57 | 0.46 | 0.67 | 0.78 | 1.44% |
| 2006 | 2.86% | 0.25% | 0.28% | 0.36% | 0.50% | 1.46% | 0.57 | 0.51 | 0.69 | 0.77 | 1.96% |
| 2007 | 2.69% | 0.20% | 0.23% | 0.44% | 0.41% | 1.41% | 0.57 | 0.52 | 0.68 | 0.75 | 1.82% |
| 2008 | -0.85% | 0.11% | 0.12% | 0.53% | 0.25% | -1.85% | 0.56 | | | | -1.60% |

**Source:** Authors' calculations
**Note:** See notes to Table 2

**Figure 9:** Indices for Labour Productivity, Innovation and their components, 2000-08, set to 2000=100




**Note:** Data is calculated using the annual data from Table 3. Data is first calculated on a cumulative basis and the exponent taken to generate an index, set to 100 for all series in 2000. From the lowest to the highest, data shows the contribution of labour composition per hour (increase from 100 to 111.46), intangible capital deepening per hour (from 100 to 104.56), increase in TFP (from 100 to 107.4) the sum of these two (from 100 to 111.96) and overall labour productivity per hour (from 100 in 2000 to 119.73 in 2008).

index in a different way, set out in Figure 9 to examine the impact on intangible investments and productivity. This shows innovation alongside indices for labour productivity, the contribution of intangible capital services to labour productivity, the contribution of labour composition to labour productivity and total factor productivity. Note that in the chart and all of the following discussion, the output measure used in deriving labour productivity is correctly adjusted for the capitalisation of knowledge assets.

All data is normalised to 100 in 2000 to allow percentage changes to be read off easily. So, for example, the top line shows that labour productivity rose, from 2000 to 2008, and that there was overall growth in labour productivity of around 20 per cent. The very lowest line shows that improvements in the composition of the labour force contributed around 1.5 per cent; or that without such improvements, labour productivity growth would have been 1.5 per cent lower by 2008. The second lowest line shows the contributions of intangible capital deepening. This line shows that productivity grew by 4.07 per cent due to the contribution of internally generated knowledge capital services per hour worked: that is, increased use of organisational, training, R&D and other forms of knowledge capital for each unit of labour input invested by firms. The contribution of total factor productivity over this period was 7.23 per cent, capturing a range of impacts including, among other things, an increase in the knowledge stock that is freely available to the market economy, and spillovers of knowledge capital to areas outside of where the original investment was made. Thus the heavy solid line shows the sum of these two, i.e. innovation implied a rise of 12 per cent in labour productivity over the period (the remaining around 8 per cent of labour productivity growth came from the contribution of tangible capital services per hour, or the increased use of computers, plant and machinery, buildings and vehicles per unit of labour input (not shown in the chart) and labour composition).

Thus the chart shows that with no innovation, that is, with no contribution of intangible capital deepening plus TFP, labour productivity would have been 11.3 per cent less in 2008, i.e. it would have lowered labour productivity by 63 per cent (111.96/119.73). Of that, growth in TFP made up 64 per cent of innovation, and 36 per cent came from knowledge capital deepening. If one includes the contribution of the improved composition of the labour force, the implication is that without innovation labour productivity would have been 70 per cent (113.42/119.73) less.

Until now the discussion has been only about mean or aggregate changes over 2000 to 2008. One interesting question is: what has been the impact of the recession on innovation? Looking at the changes in each of the indices from between 2007 and 2008, a decline of -0.85 per cent in adjusted labour productivity can be seen. Intangible capital deepening and labour composition have not changed very much. Measured TFP falls by 1.85 per cent due to a small fall (not shown in the graph of the contribution of tangible capital capital deepening). It is likely however that in very severe recessions we do not measure the actual fall in tangible capital that likely comes about due to premature scrapping and under-utilisation, and since TFP is a residual, this renders TFP negative. As a result the Innovation Index fell by -1.60 per cent in 2007-8. Thus the recession has taken us back to labour productivity levels in 2006 but the reader should be careful about interpreting year-to-year movements in the Innovation Index as outlined above.

## 5.2 Contributions of individual intangible assets

One might also ask what the roles are of the individual intangible assets. To examine this, these need to split up their impact into the categories for intangible assets – software, R&D, innovative property (excluding R&D) and economic competencies. Each contribution is set out in Table 4. Starting with column 5, it can be seen that software is an important driver, with a very strong contribution in the 1990s of between 0.18 per cent and 0.23 per cent p.a., but less so this century, contributing 0.10 per cent p.a. Note that in the late 1990s the contribution of software came close to that of non-computer tangibles, a remarkable result

**Table 4:** Contributions of individual assets

| | 1 Average Labour Productivity Growth | 2 Average contribution of labour composition | 3 Average contribution of computer capital deepening | 4 Average contribution of 'other tangible' capital deepening | 5 Average contribution of capital deepening in software | 6 Average contribution of capital deepening in innovative property (less R&D) | 7 Average contribution of capital deepening in R&D | 8 Average contribution of capital deepening in economic competencies | 9 DlnTFP | 10 Share of labour payments in MSGVA |
|---|---|---|---|---|---|---|---|---|---|---|
| **With intangibles** | | | | | | | | | | |
| 1990-95 | 2.94% | 0.17% | 0.22% | 0.73% | 0.18% | 0.09% | 0.05% | 0.31% | 1.19% | 0.57 |
| 1995-00 | 3.53% | 0.25% | 0.49% | 0.25% | 0.23% | -0.02% | 0.04% | 0.42% | 1.87% | 0.56 |
| 2000-08 | 2.25% | 0.16% | 0.26% | 0.41% | 0.10% | 0.10% | 0.04% | 0.27% | 0.90% | 0.57 |

**Note:** Data is 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 MSGVA. Column 3 is growth in computer capital services per hour times share in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) per hour times share in MSGVA. Column 5 is growth in software capital services per hour times share in GVA. Column 6 is growth in capital services from innovative property (less R&D) per hour times share in GVA. Column 7 is growth in R&D capital services per hour times share in MSGVA. Column 8 is growth in capital services from economic competencies per hour times share in MSGVA. Column 9 is TFP, namely column 1 minus the sum of columns 2 to 8. Column 10 is the share of labour payments in MSGVA.

**Of the broader categories:** Innovative Property is: Scientific R&D, Mineral Exploration, Copyright and licence costs, New product development costs in the financial industry, New architectural and engineering designs (both purchased and own-account), R&D is social sciences and humanities. Economic competencies are: Advertising, Market Research, Firm-specific Human Capital, Organisational Structure (both purchased and own-account).

**Table 5:** Contributions of individual assets: Detailed breakdown

| | 1 Average Labour Productivity Growth | 2 Average contribution of labour composition | 3 Average contribution of computer capital deepening | 4 Average contribution of 'other tangible' capital deepening | 5 Average contribution of capital deepening in software | 6 Average contribution of capital deepening in mineral exploration and copyrights | 7 Average contribution of capital deepening in design | 8 Average contribution of capital deepening in R&D | 9 Average contribution of capital deepening in branding | 10 Average contribution of capital deepening in training | 11 Average contribution of capital deepening in organisational improvement | 12 DlnTFP | 13 Share of labour payments in MSGVA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990-95 | 2.94% | 0.17% | 0.22% | 0.73% | 0.18% | 0.02% | 0.07% | 0.05% | 0.07% | 0.10% | 0.14% | 1.19% | 0.57 |
| 1995-00 | 3.53% | 0.25% | 0.49% | 0.25% | 0.23% | 0.00% | -0.02% | 0.04% | 0.14% | 0.15% | 0.13% | 1.87% | 0.56 |
| 2000-08 | 2.25% | 0.16% | 0.26% | 0.41% | 0.10% | 0.00% | 0.09% | 0.05% | 0.03% | 0.08% | 0.17% | 0.90% | 0.57 |

**Note:** Data is 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 MSGVA. Column 3 is growth in computer capital services per hour times share in MSGVA. Column 4 is growth in other tangible capital services per hour (buildings, plant, vehicles) times share in MSGVA. Column 5 is growth in software capital services per hour times share in MSGVA. Column 6 is growth in capital services from mineral exploration and copyright per hour times share in MSGVA. Column 7 is capital services from design per hour times share in GVA. Column 8 is growth in R&D capital services per hour times share in GVA. Column 9 is capital services from advertising and market research per hour times share in MSGVA. Column 10 is capital services from firm-level training per hour times share in MSGVA. Column 11 is organisational capital services per hour times share in MSGVA. Column 12 is TFP, namely column 1 minus the sum of columns 2 to 11. Column 13 is the share of labour payments in MSGVA.

highlighting the importance of knowledge assets. It also shows why the National Accounts revisions to incorporate the new methodology for measuring software investment made such a large difference to growth in the late 1990s, referred to in the discussion of data revisions above. Column 6 shows the contribution of innovative property, less R&D. This is less important in the growth in the 1990s, but contributes 0.10 per cent p.a. in 2000.[23] In Column 7 the data on R&D is reported separately; this is of interest given the proposal to capitalise R&D by 2012. This contribution is rather small at 0.04-0.05 per cent p.a. Finally, column 8 shows the contribution of economic competencies. This is substantial, and provides the largest contribution at 0.27-0.42 per cent, but has fallen this century.

Given the significance of the contributions of innovative property less R&D and economic competencies, Table 5 reports the complete breakdown of contributions for assets within each category. Within innovative property it can be seen that almost all of its contribution is made up from the contribution of capital services in design. Looking at economic competencies, the most significant contributions are from training and organisational capital, although branding and market research also made a substantial contribution in the 1990s, particularly towards the end of the decade.

23. The contribution in the late 1990s is less then we found last year in Haskel (2009), due to the revised, and improved, method of counting innovation in financial services.

### 5.3 Comparison with earlier work

Table 6 sets out comparisons with earlier work. In the top panel the decomposition is reported, using the latest data, up to 2007, i.e. the finishing year in the last report. In the lower table the findings of previous research are reported for convenience. The main points to note are as follows. First, labour productivity growth and the contributions of human capital (columns 1 and 2) are barely changed. Second, in column 3, the contribution of tangible capital is less in our latest data. This is due to a downward revision of the computer capital data. Third, the contribution of intangible capital is more or less the same in the 2000s, but has fallen slightly relative to earlier periods, due to the downward revision of training (having excluded Health and Safety within this project) and financial services innovation.

What does this mean in terms of the overall Innovation Index? The index on the new data in the upper panel is 75 per cent of labour productivity growth in the 2000s accounted for by innovation ((0.17%+0.55%+1.30%)/2.69%). In last year's data it is 73% = ((0.17%+0.54%+1.27%)/2.72%). So both results are rather similar.

**Table 6:** Comparisons with earlier work

| | Labour Productivity Growth (% p.a.) | Contribution of Human Capital Contribution Deepening (% p.a.) | Contribution of Tangible Capital Deepening (% p.a.) | Contribution of Intangible Capital Deepening (% p.a.) | TFP Growth (% p.a.) |
|---|---|---|---|---|---|
| **(1) NESTA (2010)** | | | | | |
| **Without intangibles** | | | | | |
| 1990-1995 | 2.94% | 0.20% | 1.09% | | 1.66% |
| 1995-2000 | 3.25% | 0.29% | 0.89% | | 2.07% |
| 2000-2007 | 2.65% | 0.19% | 0.86% | | 1.60% |
| **With intangibles** | | | | | |
| 1990-1995 | 2.94% | 0.17% | 0.95% | 0.64% | 1.19% |
| 1995-2000 | 3.53% | 0.25% | 0.74% | 0.67% | 1.87% |
| 2000-2007 | 2.69% | 0.17% | 0.68% | 0.55% | 1.30% |
| **(2) NESTA (2009)** | | | | | |
| **Without intangibles** | | | | | |
| 1990-1995 | 2.87% | 0.20% | 1.28% | | 1.39% |
| 1995-2000 | 3.35% | 0.28% | 1.39% | | 1.66% |
| 2000-2007 | 2.81% | 0.19% | 0.93% | | 1.68% |
| **With intangibles** | | | | | |
| 1990-1995 | 3.03% | 0.18% | 1.12% | 0.74% | 1.00% |
| 1995-2000 | 3.72% | 0.25% | 1.17% | 0.84% | 1.46% |
| 2000-2007 | 2.72% | 0.17% | 0.75% | 0.54% | 1.27% |

**Note:** the upper panel shows the decomposition up to 2007, based on current data. The lower panel reproduces the decomposition up to 2007 based on last year's report.

**Source:** Authors' calculations.

# Part 6: Industry analysis

A significant development in the Index framework is the dis-aggregation to industry level. The pilot Index and the discussion above focus solely on the national economic level. This obviously masks the variations in the intensities of investments in intangible assets within different sectors and the different contributions sectors make to overall productivity growth. In this section the model detailed in section 5 is applied to seven broad sectors of the UK economy.

24. The EU KLEMS project ran from 2003 until 2008. It was funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, 'Policy Support and Anticipating Scientific and Technological Needs'. See www.euklems.net

## 6.1 Data

The report now looks at the new industry-level analysis. The choice of data is limited by availability. The ONS does not publish real intermediate input data and so EU KLEMS, November 2009 release, which gives data up to 2007, was used.[24] So the data in this section will not be for the same period as the ONS data presented in the previous analysis, which goes up to 2008. For intangibles, the industry level data is available from roughly 1992-2007, depending somewhat on the asset and hence the focus here is on the 2000-2007 period. The EU KLEMS data includes measures of output, and various categories of employment and capital at the industry level for 71 industries, classified according to the European NACE revision 1 classification. We then have carried out the aggregation needed to collapse this data according to the seven industries described in Table 7. The choice of the seven industries is dictated by the availability of the intangible data. It should be noted that EU KLEMS also provides growth accounting data, but since we have expanded the amount of capital and changed value added it is necessary to modify these results.

From the output and intermediate accounts of the EU KLEMS dataset the project team used the series of industry Gross Output and Gross Value Added at current basic prices, Intermediate Inputs at current purchasers' prices and their corresponding price and volume indices. Intermediate inputs comprise energy, materials and services. To measure labour services, the project team use the EU KLEMS data on person hours and composition-adjusted person hours worked by persons engaged, which include hours worked by self-employed and family workers. Labour compensation reflects total labour costs and also includes both labour compensation of employees and of self-employed. Note that, as labour compensation of self-employed is not registered in the National Accounts, the EU KLEMS data are based on an assumption that the compensation per hour of self-employed is equal to the compensation per hours of employees.

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

The EU KLEMS capital data distinguishes nine types of assets, of which we use transport equipment, computing and communications equipment and other machinery and equipment, and total non-residential investment, while ONS estimates for software are used. Residential structures are excluded because they should not be considered for productivity-measurement purposes.

Depreciation rates for ICT tangible capital are as in the EU KLEMS, which in turn follows Jorgenson *et al.* (2005) and are 0.315 for computing equipment and 0.115 for Communication equipment. As for intangible assets, they are assumed to be the same for all industries. Given that the EU KLEMS database does not provide data on capital tax rates by country, industry and year and that Timmer *et al*. (2007) point out that evidence for major European countries shows that their inclusion has only a very minor effect on growth rates of capital services and TFP, we did not introduce a tax adjustment.

How does this data compare with disaggregated ONS data? The real output data is almost exactly the same, as is the capital services data. The labour input data is different. First, the KLEMS data has fewer workers in financial services, but more in business services than the ONS data. We suspect this may be due to the treatment of agency workers of whom there are many in financial services, but employed by agencies in business services and hence their appropriate treatment is a problem. This means that productivity growth in financial services is much higher in KLEMS relative to the ONS, but somewhat less in business services. Second, the KLEMS quality adjusted labour series grows faster than the ONS series.

The data on intangibles is an update of the data set out in Gill and Haskel (2008).[25] To build intangible investment at an industry level, the approach proceeds as follows. 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. finance, minerals, copyright) are allocated to that industry.

Data availability restricts us to seven industries, the definitions of which are set out in Table 7. A decision was taken to separate out financial intermediation from business services, as it was found that they have very different productivity patterns.

25. Gill, V. and Haskel, J. (2008) 'Intangible Investment in UK Industries.' Working Paper.

**Table 7:** Assignment of SIC codes and NACE1 sections to our seven industries

| | Proposed sector categories | SIC code | | NACE1 sections |
|---|---|---|---|---|
| 1 | Agriculture, Fishing & Mining | 1 - 14 | A | Agriculture, hunting and forestry |
| | | | B | Fishing |
| | | | C | Mining and quarrying |
| 2 | Manufacturing | 15 - 37 | D | Total manufacturing |
| 3 | Electricity, Gas & Water Supply | 40 - 41 | E | Electricity, gas and water supply |
| 4 | Construction | 45 | F | Construction |
| 5 | Wholesale and Retail Trade, Hotels and Restaurants, Transport and Communications | 50 - 64 | G | Wholesale and retail trade |
| | | | H | Hotels and restaurants |
| | | | I | Transport and storage and communication |
| 6 | Financial Intermediation | 65 – 69 | J | Financial intermediation |
| 7 | Business Services | 71- 74 | K | Business activities, excluding real estate and renting of dwellings |

**Table 8:** Tangible and Intangible investment, by industry, 1997-2007, Current Prices £bns

| Year | Agriculture, Fishing & Mining | | Manufacturing | | Electricity, Gas & Water Supply | | Construction | | Retail, Trade Hotels & Transport | | Financial Intermediation | | Business Services | | Market Sector | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible | Tangible | Intangible |
| **1997** | 6.98 | 1.45 | 18.11 | 27.45 | 4.98 | 1.57 | 1.80 | 3.44 | 28.43 | 19.19 | 4.05 | 9.06 | 8.23 | 15.35 | 72.58 | 77.51 |
| **1998** | 7.76 | 1.43 | 18.47 | 29.14 | 5.26 | 1.81 | 1.70 | 3.69 | 33.14 | 21.76 | 6.24 | 10.36 | 13.81 | 17.51 | 86.37 | 85.70 |
| **1999** | 6.22 | 1.45 | 16.54 | 30.14 | 5.56 | 1.78 | 1.89 | 4.07 | 33.94 | 23.82 | 5.26 | 11.24 | 13.70 | 18.67 | 83.11 | 91.17 |
| **2000** | 5.04 | 1.37 | 16.18 | 30.47 | 5.06 | 1.91 | 1.99 | 4.33 | 38.60 | 25.66 | 5.25 | 12.72 | 12.82 | 21.85 | 84.95 | 98.32 |
| **2001** | 6.13 | 1.40 | 14.67 | 31.47 | 5.33 | 1.92 | 2.15 | 4.60 | 38.13 | 27.70 | 4.74 | 13.54 | 12.09 | 24.94 | 83.24 | 105.57 |
| **2002** | 7.24 | 1.50 | 12.26 | 31.51 | 4.77 | 1.94 | 3.12 | 5.32 | 38.11 | 28.91 | 4.91 | 14.17 | 10.53 | 25.45 | 80.94 | 108.77 |
| **2003** | 6.88 | 1.58 | 11.93 | 32.20 | 4.82 | 1.84 | 3.11 | 5.85 | 35.08 | 29.92 | 4.23 | 14.27 | 10.41 | 27.88 | 76.47 | 113.55 |
| **2004** | 6.81 | 1.57 | 11.78 | 32.84 | 2.68 | 1.88 | 3.63 | 6.10 | 36.65 | 30.87 | 3.62 | 14.29 | 8.46 | 27.51 | 73.63 | 115.06 |
| **2005** | 6.63 | 1.63 | 11.57 | 33.68 | 3.73 | 2.20 | 2.70 | 6.87 | 35.58 | 32.00 | 5.02 | 15.53 | 10.54 | 31.13 | 75.78 | 123.03 |
| **2006** | 7.04 | 1.72 | 11.16 | 34.40 | 5.04 | 2.44 | 3.20 | 7.75 | 35.81 | 33.45 | 4.63 | 16.08 | 11.60 | 34.05 | 78.49 | 129.90 |
| **2007** | 8.26 | 1.81 | 11.98 | 35.53 | 6.92 | 2.69 | 3.15 | 8.42 | 39.81 | 34.89 | 5.46 | 17.50 | 12.99 | 36.94 | 88.58 | 137.79 |

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

26. Clayton, T., Dal Borgo, M. and Haskel, J. (2008) 'An Innovation Index Based on Knowledge Capital Investment: Definition and Results for the UK Market Sector.' Draft Report for NESTA Innovation Index 2008 Summer Project. London: NESTA.

**a. Industry spending data**
Table 8 reports the levels of investment, both in tangible and intangible assets, for the seven industries and the whole market sector for the period 1997-2005. Note that finance and manufacturing invest very strongly in intangibles relative to tangibles: in both sectors, intangible investment is three times tangible. It is interesting to note in passing that this of course raises important questions on how to classify manufacturing since it is undertaking a very good deal of intangible activity (strictly speaking, one needs to look at own-account activity to look at this). Figure 10 charts this data.

Figure 11 shows the ratios of total investment in all intangible categories to industry value added (where industry value added equals conventional value added plus intangible investment). This shows that manufacturing and financial and business services are the most investment intensive and have been so for a while.

Lastly, Figure 12 shows, in three panels, intangible spending data in £bn, by asset class and industry. Retail is important in total spend in organisational capital and software, whereas manufacturing is important in R&D.

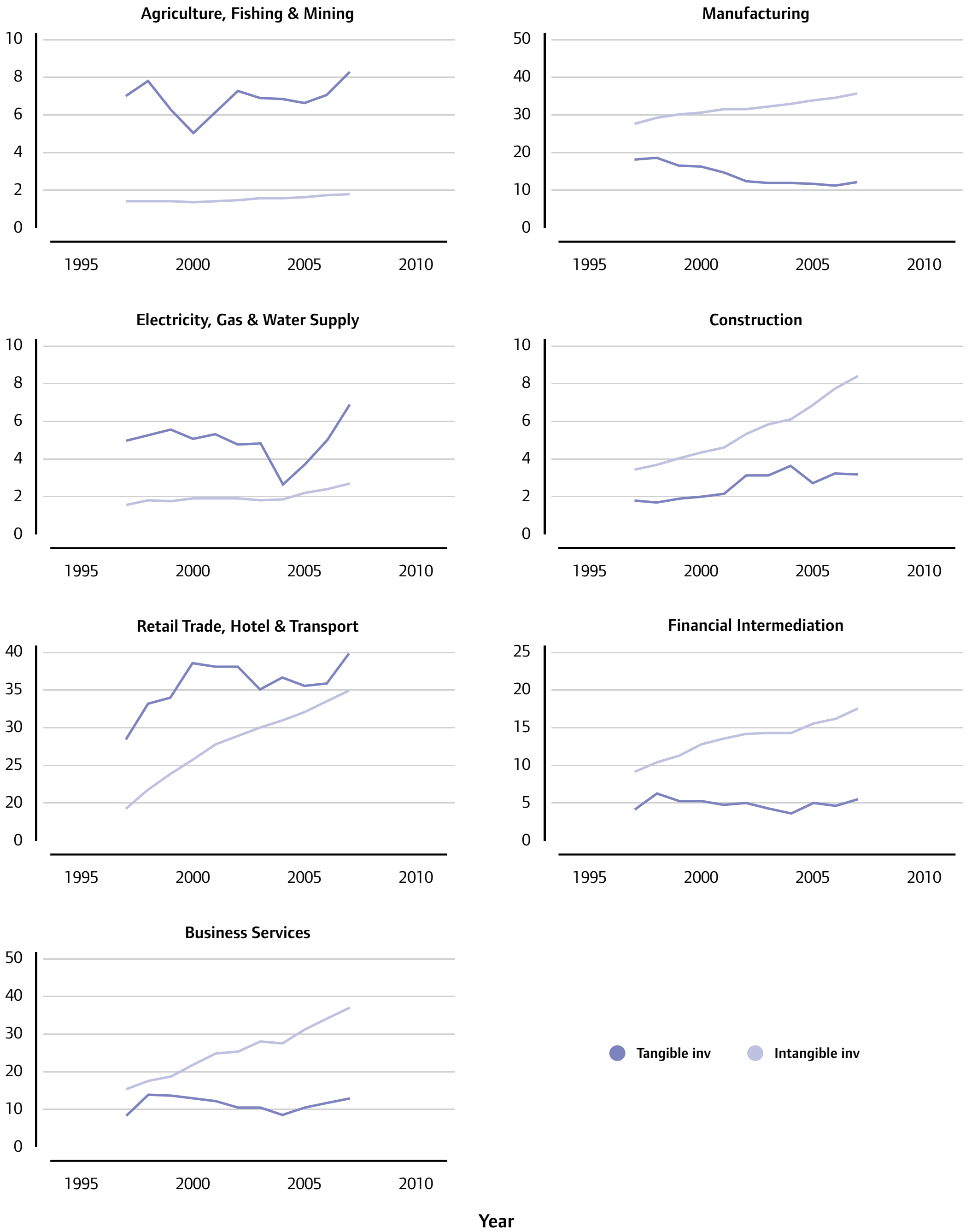
**b. Growth accounting**
Our growth accounting method is set out in Clayton *et al.* (2008).[26] The analysis performs industry growth accounting using gross output methods and then aggregates the data and contributions up to the market sector level so that market sector value added growth accounts are the Domar-weighted aggregates from our industry-level results. This follows Jorgenson *et al*. (2007).

## 6.2 Results for whole market sector

The discussion begins by considering the results for the whole market sector. These are set out in Table 9.

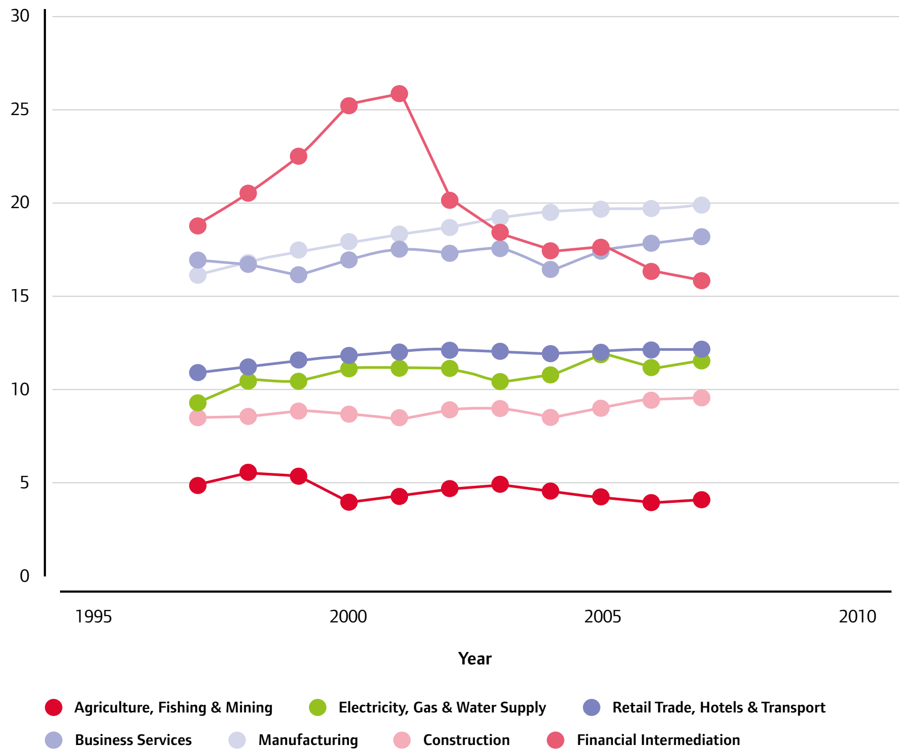
The growth rates are on the left and contributions to LPG on the right. The row entitled 'no intangibles' shows data which excludes all intangibles, i.e. excludes software

**Figure 10:** Tangible and Intangible investment, by industry, 1997-2005, Current Prices £bns




**Note:** EUKLEMS and authors' calculations

**Figure 11:** Investment to (adjusted) value-added ratios, by industry




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

**Figure 12a:** Economic competencies – investment by asset class and industry, current prices £bns

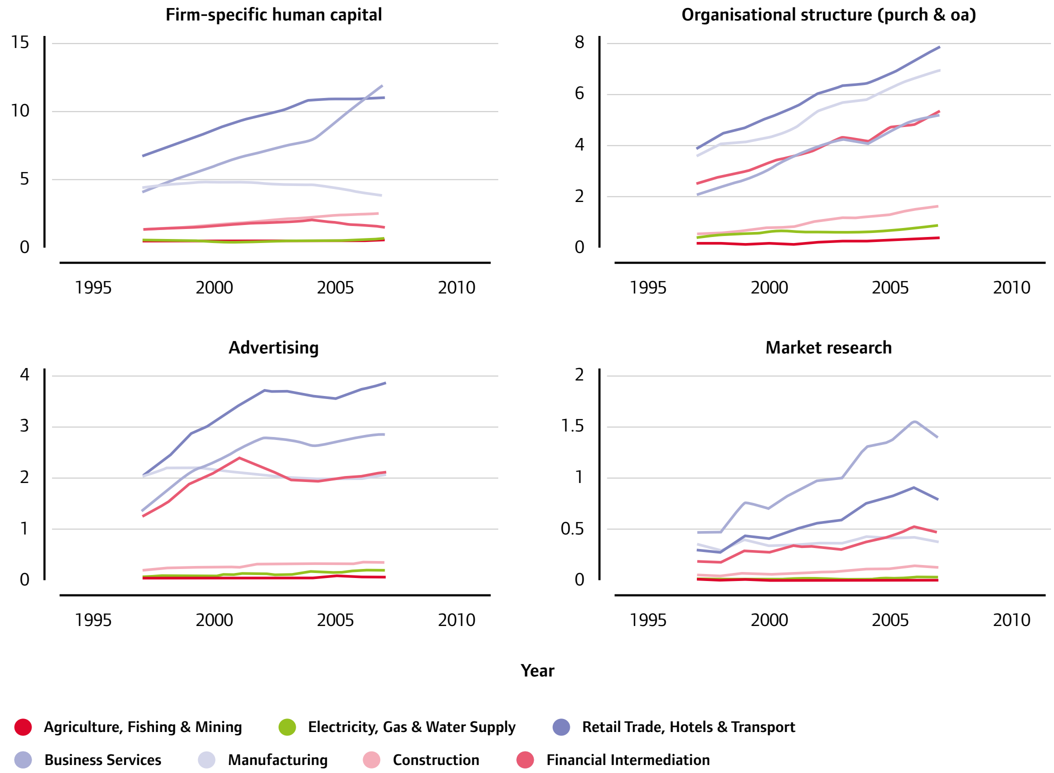


**Figure 12b:** Software – investment by asset class and industry, current prices £bns

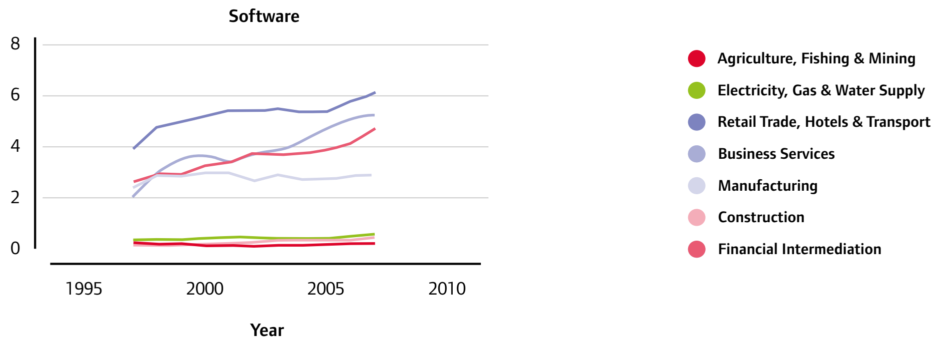



**Figure 12bc:** Innovative properties – investment by asset class and industry, current prices £bns

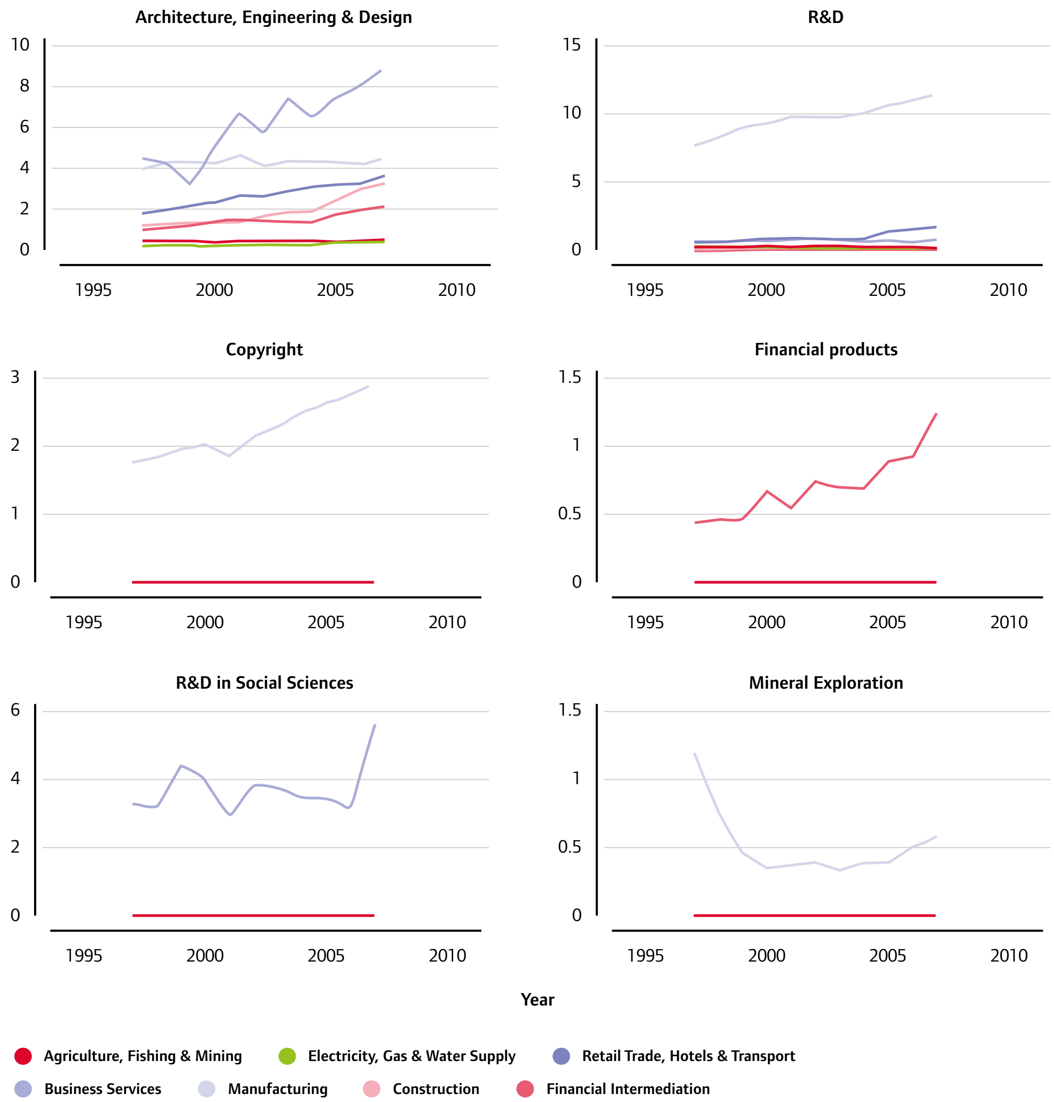


**Table 9:** Contributions of individual assets

| | Average growth in value-added | Average growth in person-hours | Average growth in labour productivity | Average contribution of total capital deepening | Average contribution of capital deepening in computers | Average contribution of capital deepening in 'other tangibles' | Average contribution of capital deepening in intangibles | Average contribution of labour composition | Average TFP Growth |
|---|---|---|---|---|---|---|---|---|---|
| No intangibles | 3.07 | 0.08 | 2.99 | 0.76 | 0.39 | 0.37 | | 0.36 | 1.88 |
| With intangibles | 2.90 | 0.07 | 2.82 | 1.16 | 0.31 | 0.32 | 0.53 | 0.31 | 1.35 |
| ONS data, with intangibles | | | 2.69 | 1.23 | 0.28 | 0.40 | 0.55 | 0.17 | 1.30 |

**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, column 2, person-hours, column 3, value added per person hour, column 4, contribution of total capital (which is the sum of the next three columns), column 5, contribution of computer capital, column 6, contribution of other non-computer tangible capital, column 7, contribution of intangibles, column 8, contribution of labour quality per person hour, column 9, TFP, being column 3 less the sum of column 4 and column 8. Rows 1 and 2 are EUKLEMS data, first without the capitalisation of intangibles and second with intangibles, 2000-07, aggregated to the market sector. Row 3 is based on ONS data with the capitalisation of intangibles for the market sector. In each the market sector is defined using our definition of SIC(2003) A-K excluding dwellings.

**Source:** Authors' calculations

**Table 10:** Industry-level growth accounting, 2000-2007

| | Average growth in gross output | Average growth in person-hours | Average growth in labour productivity (GO) | Average contribution of total capital deepening | Average contribution of capital deepening in computers | Average contribution of capital deepening in 'other tangibles' | Average contribution of capital deepening in intangibles | Average contribution of labour composition | Average contribution of intermediate inputs per hour | Average TFP Growth |
|---|---|---|---|---|---|---|---|---|---|---|
| **2000-07** | | | | | | | | | | |
| Agriculture, Fishing & Mining | -2.30 | -3.04 | 0.74 | 1.29 | 0.00 | 1.28 | 0.00 | 0.24 | 1.19 | -1.97 |
| Manufacturing | -0.56 | -4.21 | 3.65 | 0.71 | 0.07 | 0.14 | 0.50 | 0.17 | 1.70 | 1.06 |
| Electricity, Gas & Water Supply | -2.27 | 1.31 | -3.58 | 0.02 | 0.16 | -0.14 | 0.01 | -0.02 | -3.47 | -0.11 |
| Construction | 3.43 | 1.32 | 2.11 | 0.17 | 0.02 | 0.21 | -0.06 | -0.07 | 1.61 | 0.40 |
| Retail Trade, Hotels & Transport | 3.29 | 0.58 | 2.71 | 0.73 | 0.21 | 0.28 | 0.24 | 0.16 | 1.22 | 0.60 |
| Financial Intermediation | 3.23 | 1.68 | 1.55 | -0.12 | 0.33 | -0.27 | -0.18 | 0.35 | -0.03 | 1.36 |
| Business Services | 5.24 | 3.01 | 2.23 | 0.80 | 0.23 | 0.03 | 0.54 | 0.16 | 0.47 | 0.80 |

**Note:** All figures are average annual percentages. The contribution of an output or input is the growth rate weighted by the corresponding average share. Columns are annual average change in natural logs of: column 1, real gross output, column 2, person-hours, column 3, gross output per person hour, column 4, contribution of total capital (which is the sum of the next three columns), column 5, contribution of computer capital, column 6, contribution of other non-computer tangible capital, column 7, contribution of intangibles, column 8, contribution of labour quality per person hour, column 9, contribution of intermediates, column 10, TFP, being column 3 less the sum of column 4, 8 and 9. Note also that Health & Safety training are excluded from the investment figures used for the above calculation.

**Source:** Authors' calculations

and other intangibles; that entitled 'including all intangibles' includes all intangibles with software. The final row shows, for comparison, the results from the market sector data obtained using ONS data without the aggregation step.

Looking at the first two rows, overall value-added growth is positive under both settings and equals 3.07 per cent p.a. for 2000-2007 without intangibles and 2.90 per cent with.[27] The hours growth is almost the same, giving an overall growth rate of 2.69 per cent p.a. with intangibles in labour productivity per hour. Turning to the contributions, the contribution with intangibles shows more capital deepening (1.16 per cent p.a. as opposed to 0.76 per cent p.a.) and less ΔlnTFP (1.35 per cent p.a. as opposed to 1.88 per cent p.a.). This gives an Innovation Index of 78 per cent ((1.35%+0.31%)/2.82%), that is, innovation accounted for 59 per cent of market sector growth in GDP per person, 2000-2007.

Looking at the final column, the overall labour productivity growth figure is very similar indeed, which is reassuring. The overall Innovation Index is 69 per cent on this data, but the split of contributions is somewhat different, for in the ONS data the contribution of labour quality is lower than in the KLEMS. However, overall labour productivity is also lower, so the contribution of innovation is around the same.

27. Thus in these results the effect of capitalising intangibles is to somewhat lower output growth. This contrasts with the market sector results where capitalising intangibles very slightly raises output growth. This is likely due to the aggregate here being constructed as a weighted average of the industry totals, whereas the aggregate in the market sector results is not re-weighted with and without intangibles.

**Results by industry**

What were the industry contributions to these overall figures? How much did, for example, innovation in financial services or manufacturing contribute to overall innovation?

To start to answer this question, the results for each of the seven sectors are set out in Table 10 for 2000-2007.

The discussion above just reports the results including all intangibles. The first two columns show the growth rates of gross output and of hours worked, the difference between the two being LPG in column 3. In the fourth column the table shows total capital deepening contribution to LPG (defined as the product of the value share of capital and the growth rate of capital services per hour worked), decomposed into the ICT tangible and non-ICT tangible components and also the intangible component in the bottom panel. Next, the table presents labour quality contribution (the product of the value share of labour and the growth rate of labour services per hour worked), intermediate input deepening (the product of the share of intermediate input and its growth rate per hour worked) and TFP growth, which contributes to LGP one-for-one.

The following points emerge from the Table. First, the high performing LPG sectors were 'Manufacturing' and 'Trade, Hotels and Transport', with an expansion of 3.65 per cent p.a. and 2.71 per cent p.a. respectively. Finance shows relatively low LPG at 1.68 per cent p.a.

Second, what are the causes of these changes? Capital deepening per hour is important in manufacturing and business services, but has fallen in finance, essentially because hours have risen so very greatly. Of the capital deepening, computers are key in finance, and not so important in manufacturing. Intangible investment is very important in manufacturing, but labour quality is high in finance. Looking at the final column, it can be seen that TFP growth is very high in finance and manufacturing.

So the overall picture of intangibles at the industry level is as follows. In manufacturing, labour productivity is high, particularly with a lot of labour shedding. About 30 per cent of that LPG is due to TFPG, with 15 per cent due to intangible growth and 5 per cent due to labour quality. In financial services, measured labour productivity is lower, but TFP accounts for almost 90 per cent of it. The rest is due to labour quality and computers, with intangible investment intensity falling over the period. So manufacturing is very much driven by within-industry intangible investment, whilst finance is very much driven by TFP (which could of course reflect within-industry spillovers of intangible investment). In retailing, computers and intangibles account for around 19 per cent of LPG.

Thus in Table 11 the seven industries are ranked by their mean growth in innovation.

As has been shown by the discussion above, on pure monetary terms, the Business Services industry made the most investment in intangible assets at £36.94 billion, over a quarter of knowledge investment in our definition of the market sector. Closely following were the Distribution & Transport industries and Manufacturing, at £34.89 billion and £35.3 billion respectively. Taken together, these three industries made almost four-fifths of total market sector knowledge investment. As the table shows, the topmost innovative

**Table 11:** Mean Growth in Innovation, by industry, 2000-2007

| Industry | SIC (2003) | Mean growth in innovation (2000-07) | Rank |
|---|---|---|---|
| **1** | Agriculture, Fishing & Mining | -1.97 | 7 |
| **2** | Manufacturing | 1.56 | 1 |
| **3** | Electricity, Gas & Water Supply | -0.10 | 6 |
| **4** | Construction | 0.34 | 5 |
| **5** | Retail Trade, Hotels & Transport | 0.84 | 4 |
| **6** | Financal Intermediation | 1.18 | 3 |
| **7** | Business Services | 1.34 | 2 |

**Note:** Innovation is defined as the contribution to that industry's growth in gross output per hour of intangible capital deepening plus TFP.

industry, between 2000-07 is manufacturing, closely followed by finance and business services. The importance of manufacturing and finance in innovation reflects their very high TFP growth, even though other sectors have higher knowledge spend.

Of course the size of each of these industries needs to be considered to correctly assess the contribution to aggregate growth, and we do this in the section that follows.

**Contributions of industry innovation to overall innovation**

The discussion extends the subsection of industry results immediately above to calculating how much each industry contributes to the overall market economy. That is a combination of their contributions within each industry and the weight of each industry in the market sector as a whole. Thus for example, there may be much innovation in manufacturing but it might be a small sector in the market sector as a whole.

The discussion starts with capital deepening. Since it has been shown that capital deepening is a major contribution to LPG, one can ask what industries are contributing to the overall capital deepening? For example, the data shows fast intangible capital deepening in manufacturing, but if manufacturing is a small weight in the overall economy, does it have an impact? Table 12 answers this question. The sum of the weighted contributions shown in the bottom line of the panel equals the aggregate (middle row) in Table 9. In the case of total capital, the industry share (column 1) and the growth rate of total capital input per hours worked in that industry (column 2) are reported, giving, in column 3, the contribution to total capital per hour growth by industry.

The next columns show the contribution of the sub-components, ICT tangible, non-ICT tangible and intangible capital. For labour input we also presented first the industry share (column 7), then the growth rate of labour quality (column 8) and finally the product of these two terms, which defines the industry contribution to aggregate labour quality. For comparative purposes, the industry employment level as a share of total employment is also included in the last two columns.

Table 12 shows two interesting findings. First, regarding ICT tangible capital deepening, the leading sector contributions are Trade and Financial and Business Services. Manufacturing is a very small contributor. But, second, regarding intangible capital deepening, the leading sector contribution is from Manufacturing. Indeed, manufacturing has contributed 0.27/0.53=51 per cent of intangible capital deepening despite being 19 per cent of employment. All this makes clear just how 'intangible' manufacturing has become: indeed, it is not clear that the name manufacturing is suitable any more.

Finally, Table 13 reports the contribution of each industry to market sector value-added and TFP growth for the period 2000-2007, the totals being the totals for the decomposition for market sector value added. For value-added, the first column shows the average share of industry value-added in the aggregate,

**Table 12:** Industry contributions to aggregate capital deepening and labour quality growth

| Industry | Share of total capital | Average growth in capital deepening | Average contribution to aggregate capital deepening | Average contribution to aggregate ICT capital deepening | Average contribution to aggregate non-ICT capital deepening | Average contribution to aggregate intangible capital deepening | Average Labour weight | Average growth in person-hours | Average contribution to aggregate labour composition per hour | Memo: Fraction total employment |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture, Fishing & Mining | 0.03 | 2.95 | 0.10 | 0.0 | 0.10 | 0.0 | 0.01 | 1.24 | 0.02 | 0.03 |
| Manufacturing | 0.07 | 5.12 | 0.38 | 0.04 | 0.08 | 0.27 | 0.14 | 0.64 | 0.09 | 0.19 |
| Electricity, Gas & Water Supply | 0.02 | -0.13 | 0.0 | 0.01 | -0.01 | 0.0 | 0.01 | -0.29 | 0.0 | 0.01 |
| Construction | 0.02 | 1.89 | 0.04 | 0.0 | 0.04 | -0.01 | 0.07 | -0.22 | -0.02 | 0.11 |
| Retail Trade, Hotels & Transport | 0.11 | 4.11 | 0.43 | 0.13 | 0.16 | 0.14 | 0.22 | 0.44 | 0.09 | 0.39 |
| Financial Intermediation | 0.05 | 0.44 | -0.03 | 0.06 | -0.05 | -0.04 | 0.05 | 1.30 | 0.07 | 0.05 |
| Business Services | 0.07 | 3.46 | 0.25 | 0.07 | 0.01 | 0.17 | 0.14 | 0.36 | 0.05 | 0.22 |
| **Sum** | **0.37** | | **1.17** | **0.31** | **0.33** | **0.53** | **0.64** | | **0.30** | **1.00** |

**Note:** All figures are annual averages. Weights depend on the industry share in aggregate value-added, the input share in gross output and the share of value-added in gross output. Contributions are the product of the weights and the input growth. Employment is the share of the industry's hours worked over total hours worked by persons engaged. Column 1 times column 2 equals column 3. Rows 4, 5 and 6, add to column 3. Column 7 times column 8 equals column 9. Columns 3 and 9 sum to the contributions of capital and labour quality in Table 9, second row.

**Source:** Authors' calculations

**Table 13:** Industry contributions to aggregated VA and TFPG, 2000-07

| Industry | 1 Average industry share of value-added | 2 Average growth in value-added | 3 Average contribution to aggregate value-added | 4 Domar weight | 5 Average TFP Growth | 6 Average contribution to aggregate TFP growth | 7 Average contribution to aggregate TFP growth as proportion of total | 8 Contribution to aggregate value-added growth as proportion of total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, Fishing & Mining | 0.05 | -0.64 | -0.03 | 0.07 | -1.97 | -0.14 | -10% | -1% |
| Manufacturing | 0.22 | 4.75 | 1.03 | 0.53 | 1.06 | 0.55 | 41% | 36% |
| Electricity, Gas & Water Supply | 0.02 | -0.64 | -0.01 | 0.07 | -0.11 | -0.01 | -1% | 0% |
| Construction | 0.09 | 1.21 | 0.10 | 0.21 | 0.40 | 0.08 | 6% | 4% |
| Retail Trade, Hotels & Transport | 0.32 | 2.74 | 0.88 | 0.59 | 0.60 | 0.35 | 26% | 31% |
| Financial Intermediation | 0.10 | 3.32 | 0.31 | 0.20 | 1.36 | 0.27 | 20% | 11% |
| Business Services | 0.21 | 2.59 | 0.55 | 0.31 | 0.80 | 0.25 | 19% | 19% |
| **Total** | **1.01** | | **2.83** | **1.98** | | **1.35** | **100%** | **100%** |

**Note:** All figures are annual averages. Contributions are the product of the weights and the input growth. Column 1 times column 2 equals column 3. Column 4 times column 5 equals column 6. Columns 3 and 6 sum to value added and the contributions of TFP respectively, in the second row of Table 9. Columns 7 and 8 show industry shares of the total contributions of columns 6 and 3.

**Source:** Authors' calculations

**Table 14:** Industry contributions to aggregated contributions of intangible capital, TFPG, labour composition and the Innovation Index

| Industry | 1<br>Contrib to agg Intan (from Table 12) | 2<br>Contrib to TFP (from column 6, Table 13) | 3<br>Contrib to agg lab qual (from Table 12) | 4<br>Total (1+2) | 5<br>1+2/ sum(1+2) | 6<br>(1+2+3)/ sum(1+2+3) |
|---|---|---|---|---|---|---|
| Agriculture, Fishing & Mining | 0.0 | -0.14 | 0.02 | -0.14 | -7% | -6% |
| Manufacturing | 0.27 | 0.55 | 0.09 | 0.82 | 44% | 42% |
| Electricity, Gas & Water Supply | 0.0 | -0.01 | 0.0 | -0.01 | -1% | 0% |
| Construction | -0.01 | 0.08 | -0.02 | 0.07 | 4% | 2% |
| Retail Trade, Hotels & Transport | 0.14 | 0.35 | 0.09 | 0.49 | 26% | 27% |
| Financial Intermediation | -0.04 | 0.27 | 0.07 | 0.23 | 12% | 14% |
| Business Services | 0.17 | 0.25 | 0.05 | 0.42 | 22% | 22% |
| **Sum** | **0.53** | **1.35** | **0.30** | **1.88** | **100%** | **100%** |

**Note:** Each row shows the contribution to the market sector of the column variable accounted for by the industry in that row.
**Source:** Authors' calculations

while in the second column the growth rate of real value added per hour worked in that industry, and in the last one the product of these two terms, which measures the industry contribution to market sector value-added per hours worked. For TFP growth, the Domar weight, the industry TFP growth and the product of these terms that is the industry contribution to market sector TFP are shown. Note that the Domar weights sum to 1.98, i.e. higher than 1.

This table reveals that manufacturing accounts for almost 36 per cent of LPG growth for the whole market sector, (1.03/2.83 = 36 per cent) with strong contributions from Trade, Hotels and Restaurants and from business services. Regarding TFP contribution, manufacturing accounts for 44 per cent of the total contribution (0.55/1.35), followed by Retail Trade, Finance and Business Services. Indeed, 70 per cent of market sector TFP is accounted for by manufacturing and Retail Trade/Hotels/Restaurants. But note that whilst the value added share of retail is large, its Domar weight is very similar, whereas this is decidedly not the case for manufacturing, finance and business services. So, in conclusion, manufacturing, whilst a small sector, has a fast LPG growth and so contributes more then retailing, which has slower LPG growth, but is much larger in VA. But, retail contributes comparatively little to TFPG, for whilst it has reasonable TFP growth, its Domar weight is similar to its value added weight, where as manufacturing has both a very high Domar weight and TFP growth.

## 6.3 Industry contributions to market sector innovation

Table 14 presents contributions of each industry to the overall market sector Innovation Index. The columns shows, for each industry, the contribution to overall intangible capital deepening, TFP and labour quality. Column 4 and 5 shows the fraction for each industry, of its contribution to total intangible capital deepening and TFPG (column 5) and that plus labour quality, column 6. The figures tell a consistent story. Manufacturing accounts for around 42 per cent of the total Innovation Index, followed by retail/hotels/transport, accounting for 27 per cent. Business services contributes 22 per cent and finance 12 per cent.

# Part 7: Discussion

## 7.1 Policy

What policy conclusions can possibly be drawn from this work? As a general principle, if government is to subsidise an activity, public money should be spent if the activity generates a public good, or a positive spillover. At the moment, the UK tax system subsidises tangible investment, via tax relief on some investment goods, and some private sector intangible investment, notably R&D (it of course subsidises public sector R&D via universities). Thus the policy question is (a) do such activities generate public goods/spillovers and (b) does intangible investment in other assets besides R&D generate public goods/spillovers: so should, for example, the R&D tax credit be extended to software?

As to the first question, there is an extensive literature on R&D spillovers, summarised in, for example, Hall, Mairesse and Mohnen (2010).[28] That finds R&D spillovers to be positive but *"…variable and imprecisely measured in many cases"*.

28. Hall, B., Mairesse, J. and Mohen, P. (2010) Measuring the returns to R&D. Draft of chapter prepared for Hall, B.H. and Rosenberg, N. (Eds) (2010) 'Elsevier Handbook of the Economics of Innovation.' Amsterdam: Elsevier.

An initial look at the second question is set out in Haskel and Wallis (2010). That paper use the intangibles framework here to address two questions. First, are productivity spillovers from intangible investments wider than R&D or do all the benefits of such intangible investment accrue to those firms either producing or using intangible capital? Second, are there productivity spillovers to the market sector from direct public sector spend on R&D and if so what spend (research council, civil, defence) is most effective? The paper uses an econometric/growth accounting approach but with intangibles. It calculates TFP growth using growth accounting methods that assume no excess of social over private returns and then examines possible spillovers from intangible spending by regressing associated stocks of intangible assets on market sector TFP growth.

The main findings is of no spillover effects from intangible investment, including R&D (but strong evidence of spillovers to market sector productivity from public R&D spend on research councils). Such findings therefore support strongly, in a world of constrained fiscal spending, a focus on spending on the 'science budget' that is direct spending on innovation via research councils. Further studies on better data would expand the evidence base in this area; for example, the industry data in this paper could be used to conduct a much more detailed study of spillovers of intangible assets.

## 7.2 Rebalancing

The issue of rebalancing the economy has become a widely debated issue among policymakers. What does the approach described above imply for 'rebalancing'? Starting with broad principles: why should there be concern about the industrial composition of an economy? The economy has been, after all, through remarkable changes in composition, from an agrarian economy to a manufacturing to a service one. Should we be concerned about this? The starting point is that the industrial composition of the economy is of almost no intrinsic interest, beyond that of classification. The key question is to ask (a) what are the underlying worries one has about economic policy, e.g. innovation, unemployment etc. and (b) does industrial composition matter for these?

In the era of floating exchange rates and trading of services, we no longer have to worry about the Balance of Payments. Industrial structure over the very long run has changed from agriculture to manufacturing to services whereas unemployment is more or less untrended. In open economies, even countries with small financial sectors have been affected by financial shocks, so other than tax receipts, the size of the financial sector seems not to be relevant. That leaves productivity and hence the question is how productivity is affected by industrial structure.

There are at least two arguments here; the stagnationist and agglomeration arguments. First, Baumol (1967)[29] argued that if manufacturing naturally exhibits high productivity growth, and services low or no productivity growth, then a shift from manufacturing condemns economies to slowing productivity growth rates. This turns out to be wrong in our data. Services has seen strong productivity gains, likely due to considerable technical and organisational change; witness internet banking, low-cost airlines and mobile phones. As pointed out in an important paper by Oulton (2001),[30] however, many services are in fact intermediate inputs into other goods: many financial services for example, such as corporate overdraft facilities, are intermediate inputs into company production; likewise transport services into retailing. As long as there is some productivity growth in an intermediate good, then overall productivity growth will rise.

Second, the size of a sector might matter if there are agglomeration externalities, much as a telephone network with two callers is orders of magnitude less useful than one with 200 callers. These are likely to be present in financial services and indeed financial services has shown very substantial productivity growth, even controlling for a host of intangible investment they make, such as software.

As has been shown above, manufacturing, financial and business services have employment shares (of market sector output) of 19 per cent, 5 per cent and 22 per cent. Their shares of total innovation are respectively, 44 per cent, 12 per cent and 22 per cent. So whilst manufacturing and retailing both contribute to innovation well above their employment weight, it is not clear that rebalancing the economy back to manufacturing, even if it could be done, would necessarily raise innovation.

All this suggests that the question of rebalancing industries is the wrong question.

What is likely to matter much more is rebalancing of intangible assets. That is, if some intangible assets, like R&D and training, have spillovers, then tax and policy should be designed to affect them and industry structure left to its own devices.

### 7.3 Servitisation

The discussion now turns to the question of manufacturing, services and 'servitisation'. In a series of papers, Neely (2008)[31] has investigated the idea that manufacturing firms now offer more than just the manufactured good, but a bundle of services with it. He presents some graphic examples: *"Rolls-Royce Aerospace no longer sells aero engines, it offers a TotalCare Solution, where customers buy the capability the engines deliver – 'power by the hour'. Rolls-Royce retains responsibility for risk and maintenance, generating revenues by making the engine available for use. Other traditional 'manufacturing' firms, such as IBM, have fundamentally reinvented themselves as service businesses, moving away from the production of hardware to offer business solutions. Yet others have integrated service operations with traditional manufacturing. BP and Shell both manufacture oil, yet they also both run extensive service retail operations."* To gather data on this, he looks at whether firms classified as manufacturing in fact mention a 'service'-like word in their activity description in a field in the OSIRIS company database on 10,078 firms incorporated in 23 different countries. He finds that *"despite the fact that all of these 10,827 firms were classified as manufacturing, in terms of their primary SIC codes, 29.52 per cent of them offered a combination of manufacturing and service, while 1.78 per cent of them appeared to be pure service firms…the most common service offerings include design and development services [21.92 per cent], followed by systems and solutions [15.70 per cent], retail and distribution [12.18 per cent] and maintenance and support [11.94 per cent]."*

Our data sheds some light on this question. Suppose a manufacturing firm starts to write its own software rather than buying it in, and then sells some on. In our data the following occurs.

Firstly, unless the firms sell more manufacturing output by value than software, it remains

29. Baumol, W.J. (1967) Macroeconomics of unbalanced growth: the anatomy of urban crisis. 'American Economic Review.' 57, pp.415-26.
30. Oulton, N. (2001) 'Must the Growth Rate Decline? Baumol's Unbalanced Growth Revisited.' Oxford Economic Papers, Vol.53(4), pp.605-27, October. Oxford: OUP.
31. Neely, A.D. (2008) Exploring the financial consequences of the servitization of manufacturing. 'Operations Management Research.' 1(2), pp.103-118.

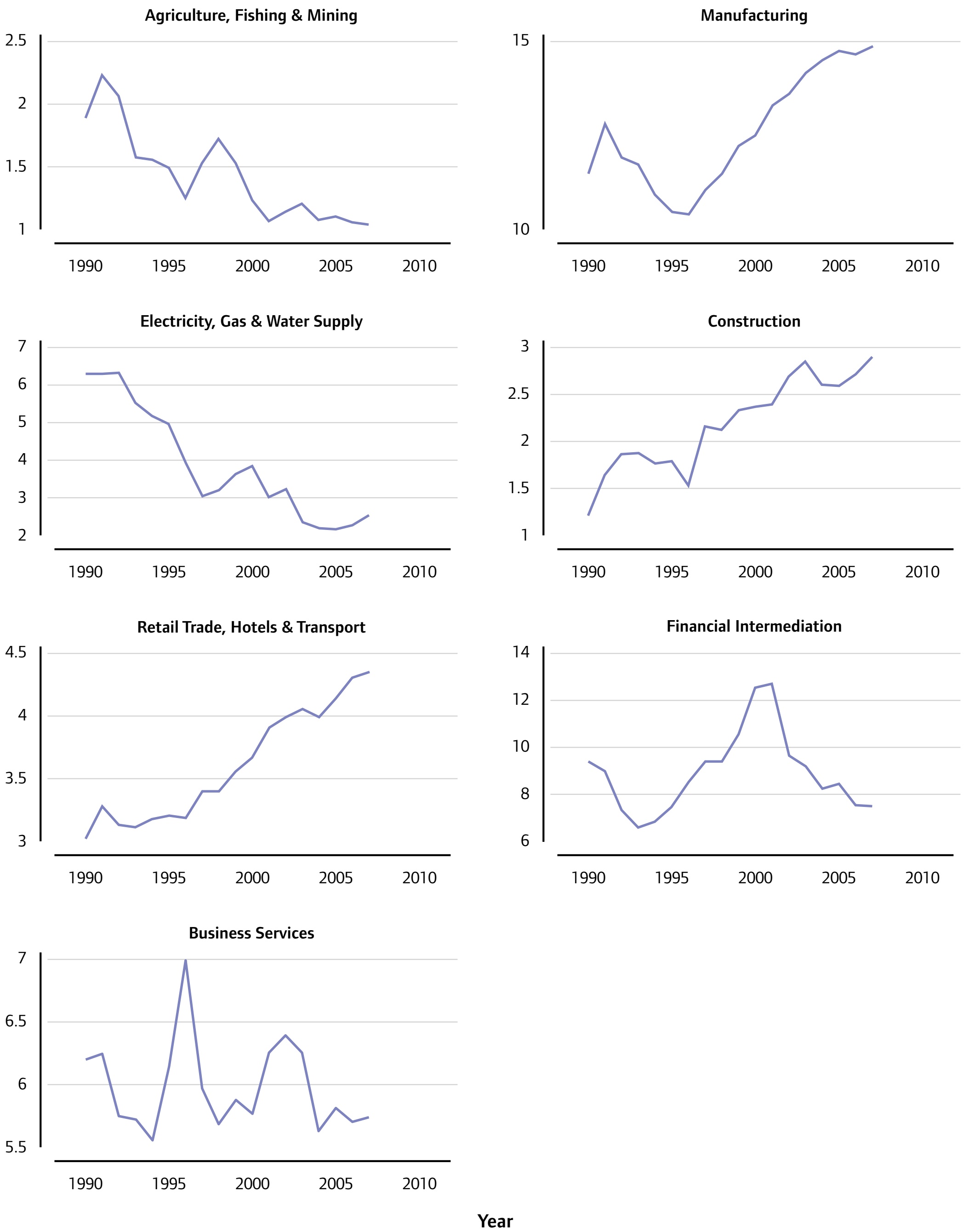
classified as manufacturing. Secondly, the approach will count the software written as intangible investment. Thirdly, the value of software sales will be part of total sales reported and therefore classified to manufacturing.[32] The ONS adjusts by looking at the number of software writers in the industry workforce and using prior intuition on the composition for industry sales.

In practice, this means that the ONS excludes the sales of the software industry itself, as well as the industries that manufacture ICT goods as it is assumed that they are selling some software embedded in their products.

Such sale values are small, so unless this is a mis-measurement, the bulk of servitisation is, in practice, the production of long-lasting intangible service goods on the company's own account. However, if more software is being sold from industries not considered by the ONS, then some of the expenditure is being double-counted.

To look at this, Figure 13 sets out own-account intangible investment as a fraction of value added. In manufacturing, the percentage is growing and reaches as high as 15 per cent by 2007, supporting the view the servitisation is concentrated in manufacturing.

**Figure 13:** Own-account investment as a percentage of value-added




32. The exact allocation will depend on whether software sales take place within a distinct reporting unit or the same reporting unit.

# Part 8: Conclusions

This report has proposed and implemented an Innovation Index for the UK which quantifies (a) spending on knowledge and (b) how much knowledge contributes to growth. The implementation of the framework has shown the following. First, investment in knowledge, which is categorised as intangible assets, is now greater than investment on tangible assets, at around, in 2008, £141 billion and £104 billion respectively, quantifying the idea that the UK is increasingly moving to a knowledge-based economy. Intangible investment as a percentage of MSGVA peaked in 2000, with the largest category being training. The effect of treating intangible expenditure as investment is to raise growth in MSGVA in the 1990s partly due to the ICT investment boom at this time, but slightly reduce growth in the 2000s.

Second, the contribution of knowledge to growth, which is defined as innovation within the framework, is considerable. For the most recent period of 2000-2008, intangible capital deepening accounts for 23 per cent of labour productivity growth, a larger contribution than computer hardware (12 per cent), other tangible investments (18 per cent, buildings, vehicles, plant) or human capital (7 per cent). The largest contribution is TFP, being 40 per cent. So if innovation is measured as TFP plus the contribution of intangible capital deepening, then it has contributed 63 per cent of growth in labour productivity. Adding the contribution of an increasingly educated workforce, innovation has contributed 70 per cent of growth in labour productivity, 2000-2008.

Finally, a new industry analysis has been added to give more depth to the Innovation Index. The main finding here is the importance of manufacturing, which accounts for just over 40 per cent of the innovation in the UK market sector. This is due to a combination of its high intangible investment and TFP, even though it is a comparatively small sector in terms of employment share. We also find important contributions of retail/hotels/transport, accounting for 27 per cent of innovation, business services contributing 22 per cent and finance 12 per cent.

Whilst it is not the central concern of the project, a brief discussion on the policy implications has been provided, focusing on a prioritisation of the science budget, and on rebalancing and servitsation. It has been argued that rebalancing industries is the wrong question: the correct issue is rebalancing intangible assets, i.e. whether to favour tax breaks in favour of investment in intangible assets or not.

# Appendix 1: Details of measurement

## A1.1 Value added

Nominal output data is nominal gross value added at current basic prices. We measure output for the market sector, defined here as industries A to K, excluding actual and imputed housing rents. Note this differs from the ONS official market sector definition, which includes part of sections O and P, as well as the private delivery of education, health and social care. Since sections O and P include hard-to-measure areas like museums and refuse collection, we omitted them. We also used disaggregated real value added data for this industry definition. We aggregate both these measures and construct market sector GVA, and an implicit MSGVA deflator. The underlying industry data is from 1978 to 2008 and are consistent with BB2010. Note that this data therefore includes the quite large revisions in the BB2008 to value added with the incorporation of FISIM and the BBB2006 software revision, all of which are reviewed in Haskel *et al.* (2009). First, in BB2006 own account software was incorporated adding around 0.25 per cent p.a. to real value added growth in the 2000s. It added considerably to growth in the late 1990s, in 1999 adding 1 per cent p.a. for example. Second, in BB2008, FISIM added 0.5 per cent p.a. in the late 1990s, but had little impact in the 2000s.

## A1.2 Tangible asset capital services, deflators and depreciation rates

Data on tangible assets was supplied from the ONS National Accounts and is BB2010 consistent. They run from 1970 to 2008. They consist of (our) market sector data for real capital stocks of vehicles, buildings, plant and computer equipment, with the stocks built using a Perpetual Inventory Method (PIM). Deflators for these assets are as used in the UK National Accounts by ONS, with the ONS computer deflator the same as that used by the Bureau of Economic Analysis (BEA) in the US. Further information on the Deflators and revisions since GHW (2006) are provided in the accompanying note 'Deflators'. Depreciation is assumed to be geometric at rates for vehicles, buildings, plant and computer equipment of 0.25, 0.025, 0.13 and 0.40 respectively. Due to lack of data availability, we do not adjust costs of capital for taxes.

Depreciation and prices of intangible assets are less well established. In the intangible assets survey we asked for life lengths for various intangibles. The responses we obtained were close to the assumed depreciation rates in this paper, depending on the assumptions one makes about declining balance depreciation. Those depreciation rates are 0.33 for software and most other intangible assets, but 0.60 for market research.

The asset price deflator for intangibles is the official deflator for software, but elsewhere the GDP deflator. This is an area where almost nothing is known, aside from some very exploratory work by the BEA and Corrado, Goodridge and Haskel (2010). These papers attempt to derive price deflators for knowledge from the price behaviour of knowledge-intensive industries and from productivity of knowledge-producing industries, in the context of R&D. 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. The impact of these new deflators is a much larger rise in the knowledge stock compared to the use of a GDP deflator, providing insight into why the nominal data shows that the R&D expenditure share is flat or even falling in the UK, whilst applications for patents are rising. If knowledge creation is becoming more productive and the prices of knowledge assets are falling, then real R&D spend is actually increasing, as is real aggregate output, the contribution of knowledge capital services and innovation. However, since this work is ongoing, this report contains results using a conventional GDP deflator.

### A1.3 Labour services

Hours are annual person-hours, with persons including the employed, self-employed and those with two jobs. Labour services are these hours multiplied by wage-bill shares. To measure these series consistently, we proceed as follows. First, we use 16 years of LFS microdata to generate wages and average hours worked at the individual level and then gross up using population weights. Second, we constrain industry total hours worked to be the same as official ONS industry hours. Third, we generate labour services by weighting growth in hours for different worker groups using wages; the groups are created using characteristics data on educational attainment, age, industry and gender. The weights to adjust are shares of total wage costs, where the wage costs are again constrained to be consistent with published data. For data prior to 1993, we use growth rates from EU KLEMS to backcast our data on hours and labour services. Thus the resulting series on hours is used to generate labour productivity, i.e. MSGVA per hour and labour services per hour. The hours data for 1993-2008 is consistent with the ONS Productivity First Release. An official ONS industry breakdown of hours prior to 1992 is not available. Further information on Labour Services and the adjustment process can be found in the accompanying note 'Labour Services'.

### A1.4 Labour and capital shares

The issue here is dealing with mixed income (compensation for the self-employed) which is comprised of the returns accruing to both capital and labour. We start with the raw data on cost of employment and nominal MSGVA. The Compensation of Employees (COE) data is consistent with the labour services data. We obtain mixed income data from the National Accounts. Mixed income is allocated to labour according to the ratio of labour payments to MSGVA excluding mixed income. With intangibles capitalised, MSGVA changes, and the allocation is done on the basis of this changed ratio. Gross operating surplus (GOS) is always computed as MSGVA less COE so that GOS and COE add up to MSGVA.

# Appendix 2: Assets and data sources

**Table 15:** Intangible Investment Data

| | Type of intangible investment | Current source | Period availability | Comments |
|---|---|---|---|---|
| | **Computerised information** | | | |
| 1 | Software own-account | ONS estimates | 1970-2008 | Updated data consistent with BB2008. Source: G Chamberlain, ONS |
| | Software purchased | ONS estimates | 1970-2008 | Updated data consistent with BB2008. Source: G Chamberlain, ONS |
| | **Innovative property** | | | |
| 1 | Scientific R&D | Estimates based on Business Enterprise R&D survey (BERD) and ONS data | 1980-2009 | Updated data. Computer services (software) industry subtracted from total number as before. |
| 2 | Mineral exploration | National Accounts | 1948-2009 | National Accounts. Source: Khalid Khan, ONS |
| 3 | Copyright and licence costs | National Accounts | 1970-2009 | National Accounts. Source: Khalid Khan, ONS |
| 4 | New product development costs in the financial industry | For own-account, software methodology using Annual Survey of Hours and Earnings (ASHE) wage bills and interviews. Purchased: assumed zero | 1970-2008 | Previous method assumed 20% of intermediate purchases. Current method uses software method to calculate own account spending, based on research-type occupations (excluding software and management). Mark-ups on labour costs assumed from software method. Fraction of time uses interview data. |
| 5 | New architectural and engineering designs | For own-account, software methodology using ASHE wage bills and interviews. Purchased: uses IO tables | 1992-2008 | GHW used 50% of design industry turnover. CDH used this method on older data. This method uses design occupations (excluding software and management) with occupation titles checked with Design Council. Mark-ups on labour costs assumed from software method. Fraction of time uses interview data. |
| 7 | R&D in social sciences and humanities | Estimates based on turnover data from ABI and GHW methodology | | ABI turnover , SIC 73.2 |
| | **Economic competencies** | | | |
| 1 | Advertising | Estimates based on IO Tables | 1992-2008 | By assumption 2005=2004. Last *Blue Book* version up to 2007. |
| 2 | Market research | Estimates based on Use and IO Tables and data from ABI | 1992-2008 | By assumption 2005=2004. Last *Blue Book* version up to 2007. |
| 3 | Firm-specific human capital | Estimates based on the National Employer Skills Survey 2004 (NESS2004) | 1970-2008 | Previous work used NESS04 and backcasted using sectoral wage bill data. Current work uses NESS04 and 07 as benchmarks and 1978 data summarised in Barber to generate time series. |
| | **Organisational structure** | | | |
| 4 | Purchased | Estimates based on data from a survey set up by the UK Management Consulting Association (MCA) | 1997-2008 | Data from MCA for 2005 backcasted. |
| 1 | Own-account | Estimates based on data from the ASHE | 1997-2008 | ASHE wage bills. |

**Table 16:** Tangible/Traditional Data

| Type of tangible investment | Current source | Period availability | Comments |
|---|---|---|---|
| Gross Value Added at current and constant basic prices, market sector | ONS estimates | 1970-2009 | We build up the market sector, excluding real estate and dwellings from the section data. Nominal value added is simply summed across sections. Real value added for each section is calculated from ONS indices of real value added data by section, rebased to equal the nominal value in 2005. Market sector real value added data is nominal share weighted sum of section real value added. |
| Gross Operating Surplus | Implied ONS estimates | 1970-2009 | Generated as a residual from section GVA and COE data. |
| Labour compensation/ compensation of employees | ONS estimates | 1970-2009 | CoE taken from ONS National Accounts. The labour share of MI (based on CoE/GOS % split) is added on to give total labour compensation. |
| Total hours worked by persons engaged | ONS estimates | 1970-2009 | The ONS series used is 'Productivity Hours', as used in the ONS Productivity First Release, consistent with both QALI and ONS 'Productivity Jobs'. However the actual figures are not published by ONS, and are only published in index form. |
| **Tangible Capital by asset** | | | |
| **Assets: buildings, plant, vehicles, machines, computers etc.** | | | |
| Real capital stock | ONS estimates | 1970- 2009 | Real capital stock generated by ONS using highly disaggregated investment data and a PIM. Tangible asset data is for buildings, vehicles, computer machinery, non-computer plant and machinery. Software supplied with computers valued with computer machinery. Aggregated to market sector. Buildings data starts in mid 19th Century, computers in mid 1970s. Deflators from ONS and computer machinery from BEA. |
| **Labour Services** | | | |
| Hours worked by education, gender, age, industry | Labour Force Survey (LFS) and EU-KLEMS to backcast from 1993. ONS will continue to produce, replacing the existing ONS series | 1970-2009 | Data for 1993-2008 extracted from LFS microdata, with industry totals scaled to equal ONS productivity jobs and hours figures. Pre-1993 data are interpolated using EUKLEMS data, which in turn uses GHS micro data. There are six education groups, two genders, three age groups. Industries are at section-level, but agriculture, mining and quarrying (A, B and C) are combined due to low cell sizes. This gives a breakdown of nine market sector industries. Data are computed by industry and for our market sector definition. Data for hours, quality-adjusted hours and composition (=quality per hour). |
| Wages by education, gender, age, industry | Labour Force Survey (LFS) and EU-KLEMS to backcast from 1993. ONS will continue to produce, replacing the existing ONS series | 1970-2009 | Wages and salaries consistent with above definitions, scaled to equal COE. Data for self-employed are included, with wages imputed using wages of employees with the same characteristics, in line with KLEMS methodology. |

**Table 17:** Other data

| Type of tangible investment | Current source | Period availability | Comments |
|---|---|---|---|
| **Deflator** | | | |
| Software own-account | ONS estimates | 1970-2008 | Updated data consistent with BB2008. Source: G Chamberlain, ONS |
| Software purchased | ONS estimates | 1970-2008 | Updated data consistent with BB2008. Source: G Chamberlain, ONS |
| All other intangibles | ONS estimates | | Use value added deflator, generated as above. |
| Tangible assets | ONS estimates | | Investment prices for deflating investment data in PIM are from ONS. |
| User costs, rates of return and capital gains | | | User cost data calculated endogenously such that rates of return equalise across assets and capital rental costs (user costs times capital stocks) exhaust GOS. Capital gains calculated as three-year uncentered moving averages of the relevant investment deflator. |
| **Depreciation rate** | | | |
| Intangible assets | CHS | | Currently using CHS assumptions. As informed by Intangible Asset Survey (IAS). |
| Tangible assets | ONS estimates | | Depreciation rates for vehicles, machines, buildings change according to the sector. |

# Appendix 3: Results including health and safety training expenditure

This table sets out growth accounting results for comparison with Table 10 where health and safety is treated as part of training. For most industries the impact is minimal, with the exception of the Financial Services industry.

**Table 18:** Industry level growth accounting 1995-2007

| | Average growth in gross output | Average growth in person-hours | Average growth in labour productivity (GO) | Average contribution of total capital deepening | Average contribution of capital deepening in computers | Average contribution of capital deepening in 'other tangibles' | Average contribution of capital deepening in intangibles | Average contribution of labour composition | Average contribution of intermediate inputs per hour | Average TFP Growth |
|---|---|---|---|---|---|---|---|---|---|---|
| **1995-2007, without intangibles** | | | | | | | | | | |
| Agriculture, Fishing & Mining | -1.50 | -2.58 | 1.08 | 0.89 | 0.00 | 0.89 | | 0.19 | 0.72 | -0.72 |
| Manufacturing | 0.41 | -2.77 | 3.18 | 0.26 | 0.11 | 0.15 | | 0.18 | 2.03 | 0.72 |
| Electricity, Gas & Water Supply | 0.57 | -0.90 | 1.47 | 0.63 | 0.18 | 0.44 | | -0.08 | 0.50 | 0.43 |
| Construction | 2.91 | 0.91 | 2.00 | 0.27 | 0.03 | 0.24 | | -0.03 | 1.55 | 0.21 |
| Retail Trade, Hotels & Transport | 4.60 | 0.74 | 3.86 | 0.65 | 0.39 | 0.25 | | 0.14 | 2.26 | 0.80 |
| Financial Intermediation | 5.04 | 1.12 | 3.92 | 0.32 | 0.41 | -0.09 | | 0.23 | 2.25 | 1.11 |
| Business Services | 7.17 | 3.52 | 3.65 | 0.82 | 0.56 | 0.25 | | 0.19 | 1.73 | 0.91 |
| **1995-2007, with intangibles** | | | | | | | | | | |
| Agriculture, Fishing & Mining | -1.55 | -2.58 | 1.03 | 0.90 | 0.00 | 0.87 | 0.03 | 0.19 | 0.67 | -0.74 |
| Manufacturing | 0.43 | -2.77 | 3.21 | 0.65 | 0.11 | 0.14 | 0.40 | 0.18 | 1.71 | 0.66 |
| Electricity, Gas & Water Supply | 0.42 | -0.90 | 1.32 | 0.59 | 0.18 | 0.38 | 0.03 | -0.08 | 0.34 | 0.47 |
| Construction | 3.03 | 0.91 | 2.12 | 0.08 | 0.02 | 0.16 | -0.10 | -0.03 | 1.61 | 0.45 |
| Retail Trade, Hotels & Transport | 4.45 | 0.74 | 3.72 | 0.95 | 0.40 | 0.27 | 0.27 | 0.14 | 1.93 | 0.70 |
| Financial Intermediation | 4.73 | 1.12 | 3.61 | 0.56 | 0.36 | -0.05 | 0.25 | 0.23 | 1.76 | 1.05 |
| Business Services | 6.78 | 3.52 | 3.26 | 1.43 | 0.54 | 0.24 | 0.65 | 0.19 | 1.18 | 0.46 |

**Note:** All figures are average annual percentages. The contribution of an output or input is the growth rate weighted by the corresponding average share. Columns are annual average change in natural logs of: column 1, real gross output, column 2, person-hours, column 3, gross output per person hour, column 4, contribution of total capital (which is the sum of the next three columns), column 5, contribution of computer capital, column 6, contribution of other non-computer tangible capital, column 7, contribution of intangibles, column 8, contribution of labour quality per person hour, column 9, contribution of intermediates, column 10, TFP, being column 3 less the sum of column 4, 8 and 9. Note also that Health & Safety training are included in the investment figures used for the above calculation.

**Source:** Authors' calculations

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