NESTA Making Innovation Flourish

Innovation, knowledge spending and productivity growth in the UK

Interim report for NESTA Innovation Index project

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Foreword

Measuring innovation is a challenging but important task. This report sets out the interim findings of work commissioned by NESTA to measure the UK's investment in innovation and the impact it has on productivity growth. This forms one of the key strands of NESTA's Innovation Index.

The report's findings provide a valuable measure of innovation investment, taking into account several types of innovation often regarded as 'hidden', and linking these investments to revised productivity growth figures.

The work begun in this report will be developed over the next 12 months, in particular with the help of a new survey of innovation investment that will provide a wealth of new data to develop the interim findings.

As always, we welcome your comments.

Stian Westlake
Executive Director of Policy and Research, NESTA

November, 2009

NESTA is the National Endowment for Science, Technology and the Arts.

Our aim is to transform the UK's capacity for innovation. We invest in early-stage companies, inform innovation policy and encourage a culture that helps innovation to flourish.

Executive summary

1. 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; see also Van Ark, B. and Hulten, C. (2007) 'Innovation, Intangibles and Economic Growth: Towards a Comprehensive Accounting of the Knowledge Economy.' Economics Program Working Paper Series. New York: The Conference Board.

2. Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HM Treasury.

3. 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.

This report forms a central part of NESTA's pilot Innovation Index. It presents the interim findings of the Growth Accounting workstream, which measures spending on private sector investment in innovation and its contribution to productivity growth.

This report sets out the work undertaken so far as part of the Growth Accounting stream, which is expected to be completed in autumn 2010. The final report will draw on the results of a new pilot survey which should improve the measurement of spending on innovative assets.

The growth accounting approach provides the opportunity to develop innovation indicators in a logically consistent economic framework based on the national accounts, avoiding double counting, and directly linked to economic measures used for policy (such as productivity and investment). The methodology draws on a wide range of measures of innovation, which are covered in the innovation literature. They complement, but do not substitute, the task set here: to produce an index which is integrated with, and helps explain, macroeconomic measures of output growth, employment and productivity.

The definition of innovation, on which the report bases our innovation index, is the contribution of all forms of knowledge to growth, as opposed to the contribution due to investment in physical inputs and labour.

With this in mind, this paper makes three contributions. First, it sets out an approach and results on innovation accounting, namely the best estimate of how much firms are spending on knowledge. Second, it sets out an approach and presents results using a growth accounting-based innovation index, namely an estimate of how much all forms of knowledge contribute to growth. Third, it provides new estimates of growth in the UK economy over the period 1990-2007, 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.

Knowledge takes different forms, so quantifying it is all but straightforward. In this framework the report measures investment in intangible assets to approximate the knowledge stock created by firms. Finally, since knowledge can leak across firms (in the way that tangible capital cannot), the report also considers freely-available knowledge. The report also considers improvements in the knowledge held by workers in the labour force thanks largely to their qualifications and experience.

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

This interim report builds on previous work on intangible asset spending and growth. It continues the research programme set out in previous international studies[1] and incorporates some of the previous work for the UK,[2] and the additional industry detail used in the earlier paper for NESTA.[3] So what is new in this report?

The key improvements are:

- Newly developed measures of investment in design and financial innovation following the same methodology used for own-account software expenditure.

- Validation of the underlying assumptions by cross-checking them with newly collected micro data.

- Presentation of an up-to-date analysis (to 2007).

More specifically, in compiling these estimates the report has used:

- The latest Blue Book data[4] for ONS, published in detail at end of July 2009 with data up to 2007. The short time since Blue Book publication has made it difficult to test revisions in new data. Among these new data are new data on gross value added, deflators for software and other forms of capital, labour shares, mixed income and tangible capital stocks. In previous work on intangibles the authors did not use these revised data and ended in 2005.

- Estimates of organisational/business process investment based on the same method as Corrado, Hulten and Sichel.[5]

- New survey data available on software (own-account[6] via employment surveys, purchased software via supply-use tables[7]) and R&D expenditure, from ONS surveys and the Blue Book, using established methods. The dataset used for this project will be made fully consistent with data published in the ONS R&D satellite account in time for the final report.

- A new methodology for new product development costs in the financial industry, based on industry interviews which have pinpointed more precisely who does financial innovation (largely researchers including actuaries, economists, statisticians); this has led to a significant downward revision, although note that the financial services industry spends a great deal of money on software which is included elsewhere.

- Updated estimates of design expenditure, based on Blue Book and labour market data (similar method as used for software).

- Mineral exploration and copyright data direct from the Blue Book.

- Advertising and market research from supply-use tables.

- Firm-funded training from the National Employer Skills Survey, for which the report now has two waves, and a much better historical benchmark.

- New data on person-hours adjusted for skills mix, consistent with the latest productivity, jobs and hours series in the ONS Productivity First Release.[8]

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

Findings

1. UK productivity growth shows a different, and stronger, picture from previously published work for the late 1990s. Labour productivity growth accelerated between the early and late 1990s, contrary to a slowdown in previous data. Labour productivity growth slowed in the 2000s. The results arise before any consideration regarding innovation or intangibles, and instead are the result of the incorporation of FISIM[9] 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.

2. Innovation, defined as the contribution of knowledge capital and TFP, raised growth in output per person-hour in the UK by 1.81 per cent p.a. in the 2000s, which is 67 per cent of labour productivity growth. Innovation was responsible for about 2.3 per cent p.a. of labour productivity growth in the late 1990s, reflecting the boom in

4. The Blue Book is the annual publication of ONS National Accounts.

5. 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.

6. Own-account refers to that produced within the firm. Since there is no associated market value, the investment is estimated using the value of time spent by relevant employees. This is discussed in further detail in the 'Measuring software investment in the UK National Accounts' section of the accompanying document Haskel et al. (2009) 'Supporting document for growth accounting interim report'.

7. Input-Output Supply Use Tables break down transactions between industries and products, linking supply and demand (use) throughout the economy.

8. The Productivity First Release is published by the ONS every quarter and provides productivity data for the whole economy and most industries.

9. The revision of national accounts to include FISIM is a new way of measuring economic activity relating to financial services. 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 Haskel et al. (2009) 'Supporting document for growth accounting interim report', in the section entitled 'Blue Book revisions and the Impact of FISIM'.

investment in software along with the mass take-up of the internet. However, given the strong labour productivity growth in this period, this is a somewhat smaller share of labour productivity growth than in the 2000s.

3. UK investment in intangible or knowledge assets has been greater than that for tangible assets since the late 1990s. Intangible investment as a percentage of Market Sector Gross Value Added (MSGVA) peaked in 2000 and has been declining since, although still growing in absolute terms. From the current price investment data, training by firms is the biggest category of investment in this period, followed by organisational capital, software, design and R&D.

4. The effect of treating intangible expenditure as capital spending[10] is to raise MSGVA growth in the 1990s, but slightly reduce it in the 2000s. Overall labour productivity growth peaked in the late 1990s, partly due to the strong growth in software, training and organisational change which accompanied the rise of the internet and boom in ICT investment.

5. Labour services input[11] 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.

6. The contribution of knowledge investment to growth rose from the early to late 1990s but then fell back, reflecting Y2K spend and the bursting of the dot.com bubble. In terms of proportions, the labour productivity growth accounted for by growth in intangible capital fell from 24 per cent to 20 per cent from the early 1990s to the period 2000-2007 (via 23 per cent in the late 1990s).

7. TFP growth rose from the early to late 1990s and then fell back, but remained above the early 1990s growth rates. The proportion of growth accounted for by TFP rose from 33 per cent in the early 1990s to 47 per cent in the 2000s. Whilst adding intangibles to output doesn't significantly affect the profile of productivity growth over 1990-1995, 1995-2000, 2000-2007, it does reduce TFP growth over the period as a whole by around a quarter.[12]

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Part 1: Introduction

1.1 Significance of this report in context of the Innovation Index

This paper sets out the work from one workstream of NESTA's Innovation Index: that relating to innovation growth accounting. It consists of two contributions.

First, the report sets out the approach and results on innovation accounting, namely the best estimate of how much firms are spending on innovation. Second, the report sets out the approach and results on a growth accounting-based innovation index, namely the best estimate of 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 the new estimates of labour productivity growth.

Growth accounting is the statistical method used by economists to measure the contribution of different factors, in particular labour and capital services, to economic growth. The residual growth not accounted for by labour and capital is used as a measure of technological progress. Economists call this Total Factor Productivity (TFP) growth.

One attraction of growth accounting is that it can be applied to official measures of GDP growth, using consistent estimates of employment and fixed capital investment from the national accounts.

In practice however, changes in TFP growth reflect all drivers of firms' production levels other than measured labour and capital, not just technological progress. These drivers include variations in the intensity which labour and capital are worked, for example, as well as plain measurement error. Nonetheless, TFP growth remains, to date, the closest thing macroeconomic policymakers have to a measure of innovation.

One potentially important source of measurement error in traditional growth accounts is if some categories of business spending are incorrectly measured as current expenses as opposed to investments in productive capital. Investments in fixed capital and therefore GDP (and GDP per worker i.e. labour productivity) are then incorrectly measured. As a result, the residual in the growth account – TFP growth – is also mismeasured. In this research project we tackle these sources of mismeasurement head on.

1.2 What gaps does this report fill and how does it help the understanding of innovation?

There are two main current approaches to an innovation index. The first, which the report follows, is to propose a definition of innovation and then produce an index. Whilst so far there are plenty of proposals, there are rather fewer implementations of such proposals.

The second approach is the reverse, namely to calculate an index and assume (explicitly or implicitly) it is innovation. An example of the second stream is the European Innovation Scoreboard.[13] This is a weighted average across countries of various indicators such as broadband penetration, R&D spend, public support for innovation, employment in high tech companies and patents/trademarks.

Some of the definitions of innovation that have recently been proposed include the following. NESTA in 2007 proposed "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" without being very clear on what "change" is and how it might be measured.

The *Frascati Manual* (2002),[14] 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*[15] 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 combination of these". Therefore the definition is fairly wide, and the *Oslo Manual* also allows for innovation in activities such as marketing. But it also introduces the term "objectively new

or improved" without defining it. Finally, the US Advisory Committee to the US Commerce Department 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",[16] 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 first approach is adopted in this report, i.e. propose a definition of innovation and then produce an index. It is reasoned that all additions to knowledge are innovation, provided they are commercialised. This stems from Schumpeter's argument that a new idea or invention is not actually innovation. Rather, innovation is defined as increased productivity as a result of its application. Therefore applying this 'market test' provides an economic value for innovation, and allows us to avoid the virtually impossible task of valuing or weighting ideas. Then the choice was made 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.

One area not so far discussed is the potential for double-counting in innovation measures. As with economic measurement in other areas in the National Accounts, it is possible to measure or estimate either from the supply-side (i.e. production or output) or the demand-side (i.e. purchases). When using a combination of these approaches it is particularly important to avoid double-counting, that is not to count both the sales and purchases of the same 'good'. For instance, imagine that a company develops and sells a more advanced machine. Double-counting may arise if both the development of this machine by one firm and the acquisition by other firms of the machine are counted as innovation, as many existing indicators do. Another aspect of potential double-counting is that sometimes a new good will be largely made up of an old good, therefore it is important to measure that which is new. This can perhaps be best described by thinking of a piece of software. If a firm decides to invest in software by updating or improving the underlying code, then the investment is the new lines of code that are written. The rest of the code has already been included as an investment when it was written in a previous period. Potential double-counting in the context of innovation is discussed further in

13. See for example PRO INNO Europe (2008) 'European Innovation Scoreboard 2007: Comparative Analysis of Innovation Performance.' Available at: www. proinno-europe.eu/admin/ uploaded_documents/ European_Innovation_ Scoreboard_2007.pdf

14. OECD (2002) 'Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development.' Paris: OECD.

15. OECD (2005) 'Oslo Manual: Proposed Guidelines for Collecting and Interpreting Innovation Data, Third edition.' Paris: OECD.

16. The Advisory Committee on Measuring Innovation in the 21st Century Economy (2008) 'Innovation Measurement: Tackling the State of Innovation in the American Economy.' A Report to the Secretary of Commerce. Washington, DC: Department of Commerce.

section 11 of the supplementary document that accompanys this report,[17] and in previous papers[18] including Giorgio Marrano, Haskel and Wallis (2007) and Clayton, Del Borgo and Haskel (2008).

1.3 The main approach, results and the following sections of the report

In light of the preceding discussion, the report's main approach is as follows. First, the report defines innovation expenditure as spending on new knowledge. Second, the report measures the impact of innovation as the effect of such spending on growth. That is, the view of innovation output is the commercialised outputs of knowledge spend or, more loosely, the commercialisation of ideas. Third, since knowledge can leak across firms (in the way that tangible capital cannot), the report also includes in the innovation index the impact of freely-available knowledge on growth using the growth accounting residual (TFP).

A number of points are worth making regarding this definition. First, the focus here is on the output of innovation as commercialised output. This is pragmatic for the approach is unable here to measure the output of an idea: that is, it is not known how to compare penicillin with a Beatles song. Second, such a definition fits in with that proposed recently by the US Advisory Committee.[19] It also fits with the economists' view of innovation captured by TFP. Formally, the report's definition of innovation is TFP plus the part of capital deepening accounted for by new knowledge investment.[20] It therefore follows the research program set out in the expanded view of capital and TFP measurement proposed by Corrado, Hulten and Sichel (2004, 2006), which builds in turn on the work on growth accounting set out for example in the Jorgenson volumes.[21] 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.

The formal model is set out below. It is assumed that production comes from labour, physical/tangible capital and knowledge/intangible capital. But where does the increased knowledge capital or ideas come from? Unlike tangible capital, which has a location and cannot be used by others, intangible capital may be non-rivalrous. So some firms might get ideas for free by simply imitating what other firms do. Other firms might discover new ideas themselves. Such discoveries, it is assumed, require resources. R&D is the usual measure for the spending needed to generate new ideas, but the report broadens the scope of spending to other expenditure that builds knowledge capital: spending on software, design, training, organisational capital at firms. This assumption is described as tantamount to trying to measure innovation spending at all stages of the innovation process:[22] both the upstream spending of scientists, artists and designers on new ideas and the downstream spending on the commercialisation of these ideas by means of marketing, training and organisational change. Both spending on innovative ideas and obtaining them for free will show up as innovation in the measure as follows.

To account for how much this extra spending on knowledge and that obtained for free raises output the report applies the economic technique of growth accounting, which uses observable prices and quantities to infer the impact of increased inputs on outputs. This step involves a number of assumptions, such as competitive markets, the depreciation of the knowledge stock and prices of knowledge, all of which will be tested for robustness and will be looked at in phase 2 of the project. Thus the report's proposed index is the part of capital deepening in the economy that is knowledge capital deepening plus TFP growth. The report also identifies output growth due to increased quality of labour services attributable to qualifications and knowledge. This arguably represents human capital growth and could be considered part of the innovation index. It turns out to be stable across our sample period (1990-2007).

17. Haskel *et al.* (2009) 'Supporting document for growth accounting interim report'.

18. Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HM Treasury; also 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.

19. The Advisory Committee on Measuring Innovation in the 21st Century Economy (2008) 'Innovation Measurement: Tackling the State of Innovation in the American Economy.' A Report to the Secretary of Commerce. Washington, DC: Department of Commerce.

20. For those without an economics background, further explanation is provided in the "Non-technical explanatory note on Growth Accounting" section of the accompanying document Haskel *et al.* (2009) 'Supporting document for growth accounting interim report'.

21. Jorgenson, D.W. (2007) 'Productivity.' Cambridge, MA: MIT Press.

22. Corrado, C. (2007) 'Comment submitted to the Advisory Committee on Measuring Innovation in the 21st Century Economy.' Available at: http://www.innovationmetrics.gov/comments/051107FederalReserveBoard.pdf

Part 2: Methodology[23]

The report's method is to propose a conceptual definition of innovation and then to try to measure it. Thus to understand our method it is perhaps best to start with some background concepts and definitions to try to clarify what our index does and does not measure.

2.1 Creative activity: discovery, invention, adoption and innovation

Let us start very broadly. At the heart of creative activity would appear to be additions to knowledge, both prescriptive and propositional.[24] A discovery such as the existence of a new planet (which cannot be patented) would be an addition to propositional knowledge, whereas a patenting of a chemical formula would be an addition to prescriptive knowledge. Either addition to knowledge, insofar as it is commercialised, will be counted as an innovation in our definition (see below).

Other terms often used under the heading of creative activity are invention, innovation and technical change. These are discussed in for example Schumpeter (1943) and the report follows his definitions here.[25] Schumpeter's distinction between invention and innovation centred on the market: he viewed the entrepreneur as taking an invention to market which therefore constituted an innovation. He argued that an invention does not necessarily produce innovation. An 'innovation' was defined in terms of productivity: an innovation enables a firm to obtain more output from existing inputs. Note that such a shift can come from both 'technical change', e.g. the scientific engineering of a faster microchip (which may or may not be patentable) or 'organisational

change', e.g. changes in business process (which are generally not patentable).

Three points follow from this. First, the question of where 'creativity' or 'inventions' come from (a great genius, a combination of small steps, top down, bottom up etc.) is interesting, but only part of the innovation process which refers to the translation of the invention into a sellable product. Second, the Schumpeterian view that innovation is the fruit of the commercialisation of inventions solves the problem of how to deal with ideas. Some have argued that ideas are the foundation of innovation and these are what should be measured. The great difficulty is how to weight ideas: what weights should be put on calculus, the microchip and the SatNav? By applying a market test, the approach weights ideas by the price that customers are willing to pay for the goods and services that flow from them. Third, to the extent that innovation is due to knowledge discovery, then the report has to acknowledge that some firms can obtain knowledge for free (e.g. Ryanair developed ticketless boarding by observing ticketless boarding on South West Airlines).

Finally, adoption. There are a number of questions here. First, one question relating to adoption is whether a particular new product is really new or not (e.g. a mobile phone is simply a different version of a phone or a new fashion that reproduces an old fashion). Such arguments are rather in the history of technology domain; and sidestepped here by applying the market test. Since innovation is measured in terms of its sales to customers, an adopted innovation that sells for a pound is the same as a new-to-the-world innovation that sells for a pound (a mobile phone introduced

23. This section draws on earlier work by 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.

24. Mokyr, J. (2005) Long-Term Economic Growth and the History of Technology. In Aghion, P. and Durlauf, S. (Eds) 'Handbook of Economic Growth.' Oxford: North-Holland.

25. Schumpeter, J.A. (1943) 'Capitalism, Socialism and Democracy.' London: Allen and Unwin (originally published in the USA in 1942, reprinted by Routledge in London 1994).

today in a country that previously had no mobile phones for example).

Second, firms might adopt capital, which has many ideas embodied in it, e.g. an airline buys a new aircraft. This would appear to be innovation in the aircraft sector and not the airline sector. Thus it would seem prudent, when counting innovation, to avoid double counting and purchases of capital from innovation. It is worth discussing the case of duplication and innovation in intangible assets. Let us use the example of organisational investment. Suppose a management consultant thinks of a new idea. Suppose next that n firms buy that idea from the management consultancy company. For any given firm, such a purchase, it is assumed, constitutes an intangible investment and so raises its within-firm knowledge stock. What of innovation? If the management consultancy company has had the idea, then the innovation ought to be allocated to that company, not the n purchasing companies, potentially constituting, in this case n-fold counting. In sum, to be fully consistent with the report's treatment of tangible capital, and the argument for excluding duplication, one might argue that it is in fact the consultancy firm that is innovating by creating the knowledge, rather than the purchasing firm. The same argument could be made for firm-level training, that is, it is the firm that writes and delivers the course that is innovating rather than the firm buying in the training.

To really get this correct, the approach would also have to note some element of the consultancy advice, or training, will be tailored to the purchasing firm, and so a more accurate measure of innovative investment would require data on how much of the knowledge is duplication, and how much is tailored to the individual firm.[26] Therefore, it may be that innovation is overstated in this exercise, since there is some duplication of knowledge capital, but any improvements to the model would require further data on the proportion of knowledge sales that are tailored or new, and the proportion that is simply replicated. Such data are currently unavailable. Against, this however we should note that if firms merely duplicate knowledge that already exists, then it is less likely to succeed in the market. This drives down its rental price and correctly gives the service flows from duplicated knowledge low or zero weight in the growth accounting. Thus the market signals the extent to which the service flow from an idea is tailored or not.

Third, firms may import new ideas embodied in tangible capital which are excluded in the report's definition of the innovation index. The report's position is that these reflect innovations that have taken place overseas and are not innovations in the UK.

2.2 Existing proposed innovation definitions

2.2.1 *Frascati Manual*[27] (2002)
The *Frascati Manual* (2002) definition is perhaps the natural starting point since it is the definition from the R&D data. It is as follows (Para 1.5.3):

> *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. R&D is only one of these activities and may be carried out at different phases of the innovation process. It may act not only as the original source of inventive ideas but also as a means of problem solving which can be called upon at any point up to implementation.*

The main feature of this definition is the stress on activities, although the outputs are not expressly set out. In particular the verb 'implementation' is somewhat broad. It fits with the idea of using marketed output but could also be non-marketed. However, the *Frascati Manual* definition does leave room for other activities beyond R&D, adding further weight to the view that innovation cannot be so narrowly defined as equating to R&D.

2.2.2 *Oslo Manual*[28] definition of innovation

> *24. 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 combination of these.*

The final statement in the above definition acknowledges the role of other forms of

26. A similar concept has been considered in the development of the ONS R&D satellite account (see Galido-Rueda, F. (2007) Developing an R&D satellite account for the UK; a preliminary analysis. 'Economic & Labour Market Review.' Vol. 2, No. 9, pp.18–29; also Wenzel, L., Khan, M.K. and Evans, P. (2009) Capitalising research and development: towards the new System of National Accounts. 'Economic & Labour Market Review.' Vol. 3, No. 9, pp.16–23. For R&D the ONS solution is to allocate the majority of ownership to the funding sector and the remainder to the performing sector. This is somewhat consistent with our approach, except that we have not re-allocated to the supplying industry.

27. OECD (2002) 'Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development.' Paris: OECD.

28. OECD (2005) 'Oslo Manual: Proposed Guidelines for Collecting and Interpreting Innovation Data, Third edition.' Paris: OECD.

knowledge investment within innovation, including improvements in human and organisational capital (although it also seems to include tangible capital). This point is expanded on later in the manual and specific reference made to a number of the intangible asset classes including marketing, design, organisational investment (both purchased and own-account), and firm-specific human capital (again both purchased and own-account):

84. Non-R&D: The firm may engage in many other activities that do not have any straightforward relation to R&D, and are not defined as R&D, yet play a major role in corporate innovation and performance:

- *it can identify new product concepts and production technologies: i) via its marketing side and relations with users; ii) via the identification of opportunities for commercialisation resulting from its own or others' basic or strategic research; iii) via its design and engineering capabilities; iv) by monitoring competitors; and v) by using consultants;*

- *it can develop pilot and then full-scale production facilities;*

- *it can buy technical information, paying fees or royalties for patented inventions (which usually require research and engineering work to adapt and modify), or buy know-how and skills through engineering and design consultancy of various types;*

- *human skills relevant to production can be developed (through internal training) or purchased (by hiring); tacit and informal learning – 'learning-by-doing' – may also be involved;*

- *it can invest in process equipment or intermediate inputs which embody the innovative work of others; this may cover components, machines or an entire plant;*

- *it can reorganise management systems and the overall production system and its methods, including new types of inventory management and quality control, and continuous quality improvement.*

Therefore the *Oslo Manual* clearly acknowledges that additions in knowledge in areas including non-scientific R&D, advertising and market research, design, observation of

other firms, the purchase of licences, training of the workforce and organisational investment all constitute innovation.

The objective performance characteristics described later in the Manual refer to technological product or process innovations (TPPs). In the model we apply the market test, since if a firm merely replicates what already exists without adding any new knowledge, then this is unlikely to succeed and will receive zero weight. Therefore, the report's interpretation of 'objectively new' is the creation of additional value-added.

We also feel that using the contribution of knowledge capital deepening and growth in TFP, as well as optionally the contribution of labour quality to productivity growth, is a novel approach of measuring innovation outside the restrictions of 'technological product and process' (TPP) innovation, which only refers to products or processes with significantly improved technological characteristics or uses. Therefore, the report's definition takes on board all other forms of innovation described in the *Frascati* and *Oslo Manual*s, and extends the definition to include all forms of commercialised knowledge.

2.2.3 'Innovation metrics' definition
The definition adopted by the US Advisory Committee[29] is as follows:

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.

This definition fits with the Schumpeter definition closely. First, it concentrates in the final part of the sentence on commercialised products (as they point out, it is orientated at a private sector definition). Second it is broader in its inclusion of new products and services than just scientific and technological ideas, and includes organisational ideas too.

2.2.4 Other definitions
Barber[30] reviews a number of definitions. First he points out the DTI (past Department of Trade and Industry) definition namely the *"exploitation of new ideas"* which focuses on new knowledge, but is not clear on how to measure exploitation. Second, he reviews Nelson's *"the processes by which firms master product designs and production processes that are new to them, if not to the world,*

29. The Advisory Committee on Measuring Innovation in the 21st Century Economy (2008) 'Innovation Measurement: Tackling the State of Innovation in the American Economy.' A Report to the Secretary of Commerce. Washington, DC: Department of Commerce.

30. Barber (2008) 'Company Investment on Intangible Assets.' Unpublished DTI Paper. London: DTI.

nation or sector", which is not clear on how to measure mastering. Third, he suggests *"innovation is the process by which firms and other organisations master new product designs, production processes and business methods and commercially exploit them or bring them into use. New means new to the firm or organisation, if not to the world, nation or sector"*, which fits well with the US Advisory Committee definition and explicitly stresses both the 'mastering' of a new design or processes and its commercialisation.

2.3 Total factor productivity: A method of measuring innovation and its contribution to the economy

A popular measure of innovation is set out by Jorgenson[31] in his evidence to the US Advisory Committee. He stresses the distinction between expanding output via duplication or innovation. He argues: *"What is the relationship between TFP and innovation? To answer this question it is useful to begin by considering economic growth without innovation. This can take place through expansion of the labor force as the population grows and expansion of capital services through investment in existing technologies. If there is no innovation, output will increase in proportion to the growth in capital and labor inputs. New or altered processes, systems, organizational structures or business models generate growth of output that exceeds the growth of capital and labor inputs. This produces growth of Total Factor Productivity. Total Factor Productivity growth also captures innovation through new and improved products and services. These innovations create new value for consumers and generate financial returns for successful innovators. The new and improved products and services are included in the measures of output. Output expands more than in proportion to the growth of inputs. For example, new computers, telecommunications equipment, and software compete with existing products. If they are successful in penetrating markets for information technology, they are included in the gross domestic product, as well as in the outputs of the industries where the new products and services originate."*

Therefore, we believe we are consistent with the report for the US Advisory Committee, but we go a little further. First, we include not just TFP but also contributions to labour productivity growth from intangible investments. Second, we also include data on labour quality improvement, which can be thought of as knowledge investment in people, and therefore can potentially also be added to the innovation index.

2.4 Details of measurement of 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 Corrado, Hulten and Sichel,[32] and Giorgio Marrano and Haskel,[33] we have distinguished between three main classes of intangible assets: i) *computerised information*; ii) *innovative property*; and iii) *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 reputation, human and organisational capital.

The data used in the report are almost entirely bottom-up, that is derived at the industry level and aggregated subsequently. Aggregation of nominal variables is by simple addition. Aggregation of real variables is a share-weighted superlative index for changes, benchmarked in levels to 2000 nominal data. For intangible spending, we have data, at time of writing up to 2007. We only look at the market sector and we omit the residential housing sector.

The methodology and sources used to get the data on intangible expenditure by industry are described extensively in other past papers, therefore the report covers them here only briefly. Most of the sources and methods used below follow Corrado, Hulten and Sichel (CHS)[34] and Giorgio Marrano, Haskel and Wallis,[35] which 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.

2.4.1 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.[36] The

31. Dale W. Jorgenson (2007) "Public Comment to the Measuring Innovation in the 21st Century Advisory Committee" http://www.innovationmetrics.gov/comments/041807JorgensonDale.pdf

32. 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.

33. Giorgio Marrano, M. and Haskel, J. (2006) 'How Much Does the UK Invest in Intangible Assets?' CEPR Discussion Paper No. 6287. London: CEPR.

34. 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.

35. Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HM Treasury.

36. Chesson, A. and Chamberlin, G. (2006) Survey-based Measures of Software investment in the UK. 'Economic Trends.' No.627, pp.61-72.

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 2008. The data run from 1970 to 2007. Further details on the methodology for software investment are provided in the 'Measuring Software Investment in the UK National Accounts' section of the accompanying document.[37]

2.4.2 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 by 'computer and related activities' (SIC 72) is subtracted from R&D spending,[38] since this is already included in the software investment data.

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 cover 1970 to 2008.

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".[39] Three subcategories are reported: a) mineral exploration other than oil and coal, b) continental shelf exploration expenditure, and c) coal mineral exploration. Data for copyright and licence cost, and mineral explorations are from UK National Accounts. The data are available for 1948-2008. 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* is revised considerably compared with previous published work. The method for own-account software, used by the ONS, has replaced the previous method that calculated 20 percent 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.[40]

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.* (2008).[41]

Finally, R&D in social sciences and humanities is estimated as twice the turnover of R&D in 'Social sciences and humanities' (SIC 73.2), where the doubling is assumed to capture own-account spending. Turnover data are taken from ABI and are available for 1992 to 2006.

2.4.3 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 duplicate 2004. Market research is estimated using data on market research from the IO tables.

Firm specific human capital, that is training provided by firms, was estimated in previous work using a single cross section from the National Employer Skills Survey (NESS 2004), which collects data on employer expenditure on on-the-job and off-the-job training. This survey provides a split by sector for 2004; an industry-level time series was derived by backcasting 2004 figures with the EU KLEMS wage bill time series (there was also an adjustment to account for the data only being for England). In this current work the report has additional data for 2006 from the most recent NESS. The report also has data for 1988 from an unpublished paper by John Barber. Previously we have used an assumption of an additional 2 per cent per year growth to adjust the NESS data. As it turns out, the 1988 data were almost identical to the backcasted data

37. Haskel *et al.* (2009) 'Supporting document for growth accounting interim report'.

38. 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.

39. ONS (2007) 'National Accounts: Sources and Methods.' Newport: ONS. For more details see www.statistics.gov.uk/downloads/theme_economy/concepts_sources_&_methods.pdf

40. Haskel, J. and Pesole, A. (2009) 'Productivity and Innovation in the UK Financial Services Sector.' Preliminary CeRIBA Working Paper. London: CeRIBA.

41. Galindo-Rueda, F., Haskel, J. and Pesole, A. (2008) 'How much does the UK employ, spend and invest in design?' CeRIBA Working paper, April 2008. London: CeRIBA.

without the 2 per cent adjustment, and so the assumption was dropped.

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 Annex 1). For further details on the data and methodology for training expenditure, please consult the section in the accompanying document on 'Training Measures'.[42] At present it is assumed that all this time spent training builds a knowledge asset lasting more than a year, the accounting requirement for spending to be considered investment. The new Intangible Assets Survey that is being conducted over the next year will be useful to test the validity of this assumption.

Finally, the data on investment in *organisational structure* rely on purchased management consulting, for which the Management Consultancy Association (MCA) was consulted, 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. It would be expected that it would reduce the numbers of managers, perhaps by as much as 1/3rd, so future estimates might be rather lower than present. However, it is worth noting that the current estimates are not too far from those

presented in Barnett (2009)[43] on spending on organisational structure, so it is not at all clear that the current work overstates managerial spend even if the number of managers was overstated. 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.

2.5 Accuracy of intangible measures

Because most of the intangibles are not included as investments in the National Accounts, the data sources are not typically covered by the kind of official surveys used to construct National Accounts investment data, e.g. investment surveys. Thus one might wonder about the accuracy of the data. The following points are worth making. First, data on minerals, copyright, branding and software are taken from official National Accounts sources and so do use a consistent methodology. Second, data on R&D are taken from the official R&D survey. Third, data on workplace training are taken from successive waves of a government survey administered by DIUS. Fourth, data on design and investment in organisational capital are calculated indirectly. Design uses the method used for software, i.e. the method is to count bought-in design using the supply-use tables and own-account design from the wage bills of designers in non-design industries, adjusted for the fraction of time designers spend on innovative design activities. As for organisational capital, the report uses the method set out by CHS. For bought-in organisation and process improvement acquired from consultants the report uses management consulting revenues, (which MCA data broadly support although it should be noted that the MCA data do not cover the whole economy), and for own-account an assumed fraction of time spent (20 per cent) by managers on organisational development is used. Thus organisational capital and design are perhaps the least well-measured areas in the investment data, for there is uncertainty about these time fractions.

To examine this further, data was used from the second stream in NESTA's Innovation Index project, supplied by Roper *et al.*[44] and described in detail in Barnett (2009),[45] which has been included in the accompanying paper. These data ask around 1,500 firms about their spending on software, branding,

42. Haskel *et al.* (2009) 'Supporting document for growth accounting interim report'.
43. Barnett, D. (2009) 'UK Intangible Investment: Evidence from the Innovation Index Survey.' London: CeRIBA.
44. Roper et al. (2009) 'Measuring sectoral innovation capability in nine areas of the UK economy.' London: NESTA.
45. Barnett, D. (2009) 'UK Intangible Investment: Evidence from the Innovation Index Survey.' London: CeRIBA.

R&D, design and organisational capital. The firms are sampled from service and hi-tech manufacturing industries, including aerospace, software and design. Without grossing factors, it was not possible to gross the data up to estimate whole economy spending levels, but it was possible to compare the proportions of spend on the intangible assets covered by the survey with those proportions from the sources used in this report. To obtain a better comparison the report took two steps. First, it compared the micro data with industry-level intangible spending in manufacturing and business services. Second, it removed the top 5 per cent of spenders from the micro data in case they distorted the comparison: there are a small number of firms reporting spending on intangibles in the millions (with very many reporting zero). When we do this, we obtain spending proportions on the micro data that are very close to those on the macro data.[46] The report also has new breakdowns of UK management consultancy fee income by type of work from the MCA. The data suggest that CHS's treatment of purchased management consultancy is not out of line with UK expenditure patterns.

46. To get to investment numbers we multiply the spending number by 50 per cent, using information from a Design Council survey that suggests 50 per cent of spending on design is innovation. Thus our final numbers that we use for design investment are in fact 50 per cent of those used for design expenditure.

Part 3: Details of measurement

3.1 Value added

Nominal output data are gross value added at current basic prices. The report measures 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. We also used disaggregated real value added data for this industry definition. Both these measures were aggregated and then used to construct market sector GVA, and an implicit MSGVA deflator. The underlying industry data are from 1978 to 2007 and are consistent with BB2009.

There is an important difference between these data and those used in earlier published work. Since 2005 – the latest year covered in previous work – major revisions have affected real value added growth, more details of which are set out in the 'Blue Book Revisions and the Impact of FISIM' section in the accompanying technical paper. First, in BB2006 own-account software was incorporated adding around 0.25pppa to real value added growth in the 2000s. It added considerably to growth in the late 1990s, in 1999 adding 1pppa for example. Second, in BB2008, FISIM added 0.5pppa in the late 1990s and between 0.25pppa and 0.5pppa in the 2000s.

The inclusion of software spending raises both value added, but also capital, in this case the flow of capital services from software. By contrast, the addition of FISIM adds wholly to output growth but nothing to input growth and so contributes almost directly to TFP growth. FISIM does also generate a greater operating surplus for financial corporations, thus causing a slight increase in the capital share, and therefore capital's contribution to growth for that industry, but the overall effect is small

Additionally FISIM also lowers value-added for non-financial corporations, since much of it is allocated to intermediate consumption.

3.2 Tangible asset capital services, deflators and depreciation rates

Data on tangible assets were supplied from the ONS National Accounts and are BB2009 consistent. They run from 1970 to 2007. They consist of (the report) 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, the report does not adjust costs of capital for taxes.

3.3 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, the method proceeds as follows. First, the report uses 16 years of LFS microdata to generate wages and average hours worked at the individual level and then grossed up using population

weights. Second, industry total hours worked are constrained to be the same as official ONS industry hours. Third, labour services are generated 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, growth rates from EU KLEMS are used to backcast the data on hours and labour services. Thus the resulting hours series is used to generate labour productivity, i.e. MSGVA per hour and labour services per hour. The hours data for 1993-2008 are 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'.

3.4 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. The raw data on cost of employment and nominal MSGVA are used to start with. The Compensation of Employees (COE) data are consistent with the labour services data. Mixed income data are obtained 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.

Part 4: A formal model and definitions

The report's formal model follows CHS.[47] The report takes up a number of related issues here. First, it is shown how considering intangibles raises MSGVA. Second, in practice, a number of the intangible assets are measured via their labour costs (suitably adjusted). This has led some to ask if there is double counting labour if it used it to generate a series for spending and also as an input to production. Third, the report examines the role of physical capital versus knowledge investment in the index. Suppose for example there is an improvement in computer technology that causes firms to buy more computers: will that show up as innovation?

The CHS 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:

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

where K is the real stock of tangible capital, and I investment in tangible capital.

4.1 Intangibles not capitalised

Consider first the case where it is assumed that the intangible sector produces knowledge that is an intermediate input into the other sectors. The relationship can be stated as:

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

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

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

(2)

where the first term here is a production function and the second describes flows of payments in the sector/industry. It is now possible to write down the definition of value added for each sector which is $PV'^N = P^N V'^N = P^N N^I + P^N N^C$ with $PV'^I = P^I I - P^N N^I$ and $PV'^C = P^C C - P^N N^C$ where a prime indicates that intangibles are not capitalised. Economy-wide value added is simply the sum of sectoral value added, giving economy-wide GVA as below and a corresponding defined growth rate of real GVA.

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

$$\Delta \ln V' = \frac{P^C C}{P^V V'} \Delta \ln C + \frac{P^I I}{P^V V'} \Delta \ln I \qquad (3)$$

4.2 Intangibles capitalised

If the case with intangibles is considered the following can be expressed. The intangible capital stock is given by R_t which also accumulates according to:

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

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

47. 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.

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

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

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

(5)

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

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

$$\Delta \ln V = \frac{P^C C}{P^V V} \Delta \ln C + \frac{P^I I}{P^V V} \Delta \ln I + \frac{P^N N}{P^V V} \Delta \ln N$$

(6)

where the V without a prime indicates the case where intangibles are capitalised.

A number of points can be made at this stage. First, comparing the top equation in (3) with the top equation in (6) it can be seen that the treatment of intangibles as investment goods has raised the level of GVA. The reason can be thought of by analogy to tangible long-lived goods. Suppose an aircraft factory buys in aluminium and produces both final output and its own machines. Then its output should be properly treated as both the final aeroplanes but also the machines, i.e. one might think of the factory as consisting of both an aircraft factory and also a machine factory. Suppose now consideration is given to a bank which both stores money for safe keeping but also writes software to process customer accounts. Then the bank should be thought of as both a financial service provider, but also a software factory and count the extra output from the software.

Second, comparing the bottom equation in (3) with the bottom equation in (6) the effect on the growth rate of GVA depends on the net effect of $\Delta \ln N$ and the shares, and so may be positive or negative.

Third, continuing the bank analogy, in practice own-account intangibles, in this case software, are rarely sold. Thus it can be reasonably approximated what it might be sold for via the costs involved in producing it, roughly the wage bill of software writers times a mark-up for overhead costs. At first sight this might suggest that software writers should be

omitted from the employment in the firm since they have already been counted. This reasoning is wrong. It is correct to say that the software writers do not contribute directly to the output of money in safe-keeping. Thus, if that were the only output to be measured, the software writers might be excluded. However, in this approach there is extra output measured, produced by the software engineers and so it is not double counting to include them.

Finally, the approach is now in a position to define the growth accounting-based innovation index. If it is assumed that all inputs are paid the same across all sectors giving economy-wide definitions as:

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

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

(7)

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. It is now possible 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 (5) and substituting the resulting expressions for $\Delta \ln C$, $\Delta \ln I$ and $\Delta \ln N$ into (6) and using (7) the sources of economy-wide value added growth in terms of economy-wide input growth can be written as the following:

$$\Delta \ln V = s^K \Delta \ln K + s^L \Delta \ln L + s^R \Delta \ln R + \Delta \ln TFP$$

(8)

where:

$$s^X = (P^X X / P^V V), \quad X = K, L, R$$

$$\Delta \ln TFP = \sum_{j = C, I, N} \left(\frac{P^j Y_j}{P^V V} \right) \Delta \ln TFP^j, \quad j = C, I, N$$

(9)

where the s^X terms are the factor input shares of value added, which weight the primary factors and Y = gross output in each of the three sectors. Thus, economy wide value-added TFP growth is the sum of the Domar weighted sector $\Delta \ln TFP$ terms. Equation (8) has the following interpretation. Economy value grows due to primary factors and TFP growth in each sector. The primary inputs in this case are K,

L and the stock of intangible knowledge R. These growth rates are weighted by the shares of each factor in final output. The TFP growth rates are rates of technical progress in each sector and they are weighted by the ratio of each sector's output to final output (Domar weights, Domar, 1961). The Domar weights add to more than unity since a TFP increase in a given sector raises overall TFP by both the direct contribution of the increase plus the indirect contribution of that good into other sectors.

Equation (8) 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 the report defines the innovation index, II, as to exclude the effects of physical capital and labour it can be written:

$$II = \Delta \ln V - (s^K \Delta \ln K + s^L \Delta \ln L) \qquad (10)$$
$$= s^R \Delta \ln R + \Delta \ln TFP$$

This framework is the one which is implemented in the results section of this report, using new data.

The following points are worth noting. First, when intangibles are not capitalised, the innovation index, $II = II'$ is then:

$$II' = \Delta \ln V' - (s^{K'} \Delta \ln K + s^{L'} \Delta \ln L) \qquad (11)$$
$$= \Delta \ln TFP$$

So, all of innovation is registered in TFP. This is of course perfectly correct if all knowledge spills over costlessly to firms.

Second, consider the case where there is an innovation in, say, computers, such that the output per unit of input of the microprocessor sector rises. What is the effect on the economy and what is the effect on innovation? The answer depends upon the source of the innovation in the computer industry. Suppose first that is it for free, for example, from some publicly-supported research, generated and funded from outside the model, e.g. abroad. This is, by definition, a rise in (market sector) TFP growth in the UK's computer sector, the tangible sector in the model. That has, in turn, two effects. First, since market sector TFP growth is a weighted-average of TFP growth

in individual sectors, market sector TFP growth rises directly. Note that the weights are Domar weights and so take account of both the effect of TFP in the computer-producing sector, that raises TFP growth in that sector, and any induced effect from TFP in the computer-using sector onto the output of other sectors using computers.[48] Second, if there is a reallocation of production between sectors, market sector TFP growth can also rise. (This latter effect is not shown explicitly here since industry level data were not available). Suppose next that this rise is due to increased R&D spending in the computer sector. Then this will again be captured as part of the overall R&D spend.

48. The induced effect on TFP depends on the net extent to which the change in prices of computers affects the change in real output of the computer-using sector and the change in capital use of the computer-using sector. The Domar weight turns out to describe this net effect.
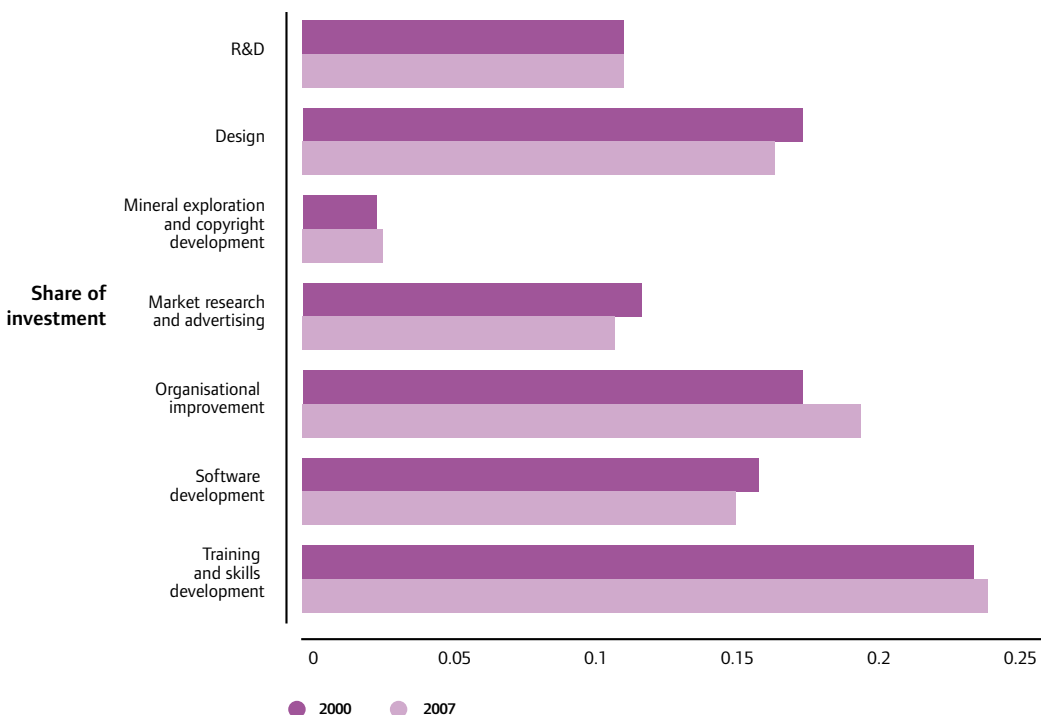
Part 5: Results

5.1 Intangible investment accounting

Figure 1 sets out the intangible investment categories. They are by now standard and the interested reader is referred to the Appendix for further detail or Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007),[49] for a discussion. Figure 1 shows the fraction of all intangible investment in 2000 and 2007 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 25 per cent). Organisational capital, software and design are next in importance. The proportions are not much changed over the period.

The actual values for investment in each category are shown in Table 1 for the years 1990, 1995, 2000 and 2007, alongside the corresponding values for tangible investment. It shows intangible investment to be higher than tangible investment for each snapshot except 1990.[50] Additionally, the intangible category

49. Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HM Treasury.

50. Note that there is no simple relationship between a country's investment in intangibles in any given period and its productivity. This is because productivity is driven by the services from the stock of capital accumulated over time, and not investment in a single period.

Figure 1: Shares of total intangible investment of individual categories, 2000 and 2007

Source: ONS Business Structure Database.

Table 1: Tangible and Intangible Investment, £ billions

Year	1990	1995	2000	2007
All tangibles	**67**	**62**	**87**	**95**
Intangible category				
Software development	6	10	16	20
R&D	8	8	11	15
Design	9	12	18	22
Mineral exploration and copyrights	3	3	2	4
Branding	5	7	12	14
Training	13	16	24	32
Organisational	9	12	17	26
All intangibles	**52**	**68**	**100**	**133**

Note: Data are absolute investment figures, in £ billions, current prices.

For clarity, 'Design' refers to architectural & engineering design, and financial product development

Figure 2: Time series of shares of selected intangible investment categories in MSGVA
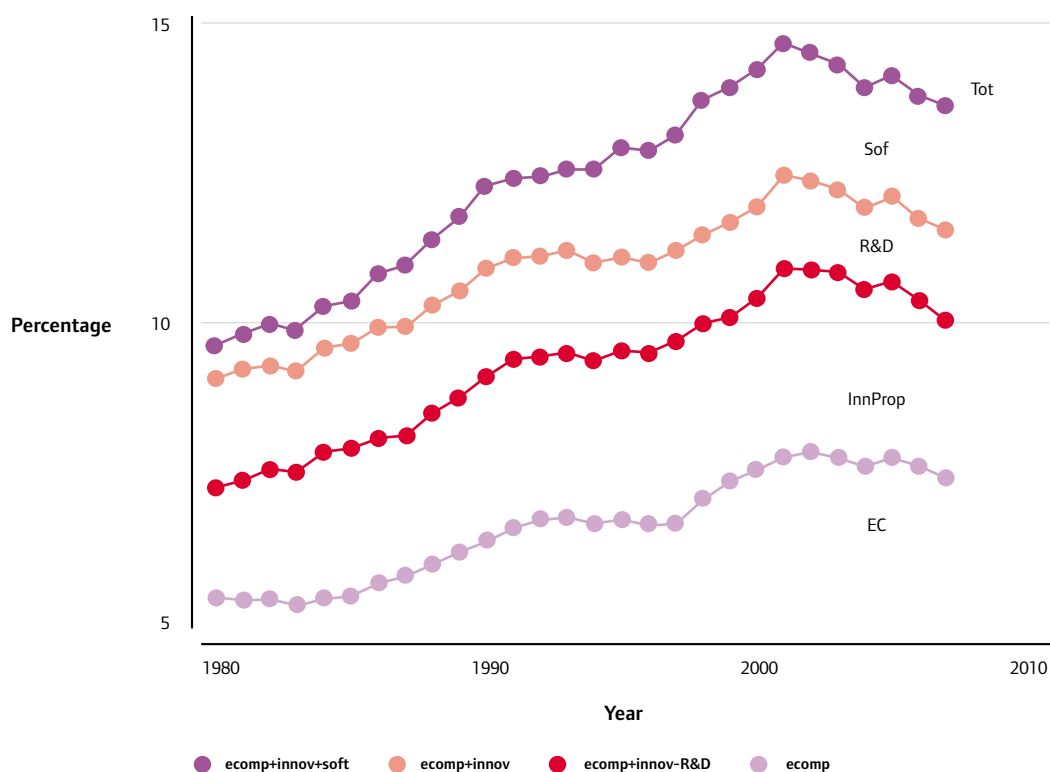
Note: EC is Economic Competencies; InnProp is Innovative Property; R&D is Research & Development; Sof is Software; Tot is Total; ecomp+innov+soft = Economic Competencies plus Innovative Property plus Software; ecomp+innov-R&D = Economic Competencies plus Innovative Property minus R&D; ecomp+innov = Economic Competencies plus Innovative Property; ecomp = Economic Competencies

Figure 3: Labour services, hours and labour services per hour (Index 1985=100)

with the highest investment figures is Training, growing to approximately a quarter of tangible investment by 2007.

Figure 2 shows a time series of total investment in intangibles categories, for the period 1980-2007 as a proportion of 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 per cent of MSGVA, which has been falling slightly over the period. The final gap includes software which is rising as a per cent of MSGVA. The numbers suggest that intangible investment is a sizeable fraction of MSGVA, here around 14 per cent in total. However, that fraction has been falling since 2000.

5.2 Labour quality

Figure 3 sets out the 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.

5.3 Shares of Gross Operating Surplus in total Market Sector Gross Value Added

Figure 4 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

Figure 4: Time series of shares of Gross Operating Surplus in Market Sector Gross Value Added with and without intangibles

Note: Gross Operating Surplus includes allocation of mixed income.

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.

5.4 Market Sector Gross Value Added, Average Labour Productivity (ALP) and person-hours growth

Before proceeding to the growth accounting results, data on growth of some basic series are presented. Figures 5 and 6 show the 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 exclude software and so are 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.

It is important to note the movement of LPG in the late 1990s relative to the early 1990s. These data show 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, the data that are used here. In turn, these revisions correspond to the introduction of FISIM in the Blue Book. A commentary on this is set out in the accompanying note 'Blue Book Revisions and the Impact of FISIM'.

Figure 6 shows the data with intangibles. The main feature is the somewhat stronger LPG growth in the earlier period and weaker growth in the 2000s.

5.5 Growth accounting results

The next section moves now to the growth accounting results, which are set out in Table 2 (Panel 1) and Figures 7 and 8.[51]

Figure 5: Smoothed Labour Productivity, Market Sector Gross Value Added growth, without intangibles
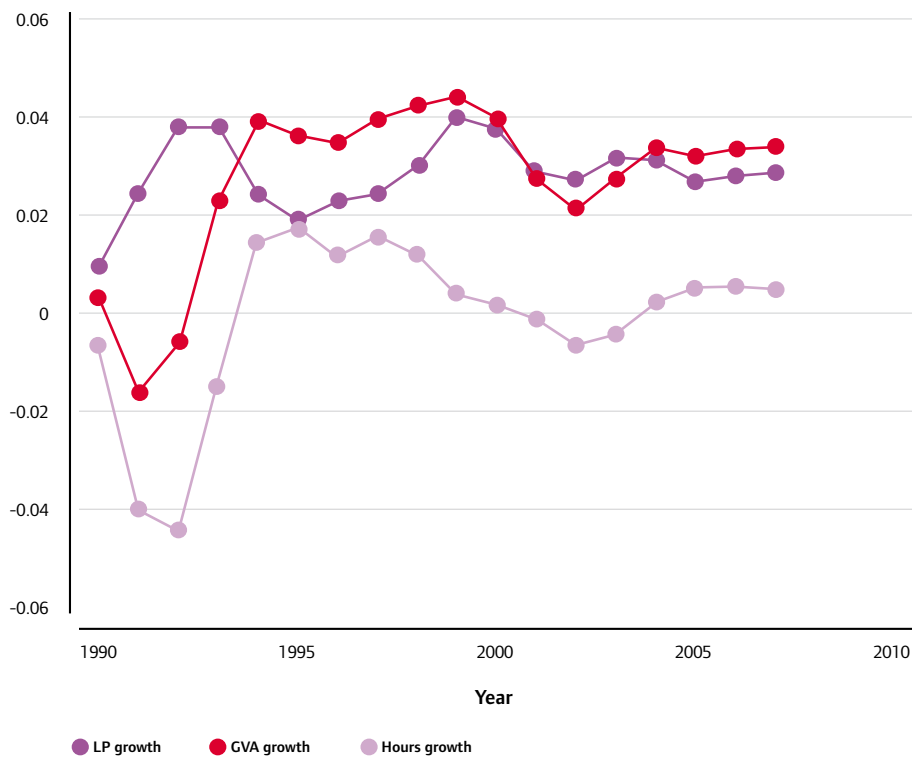
Figure 6: Smoothed Labour Productivity and Market Sector Gross Value Added growth, with intangibles
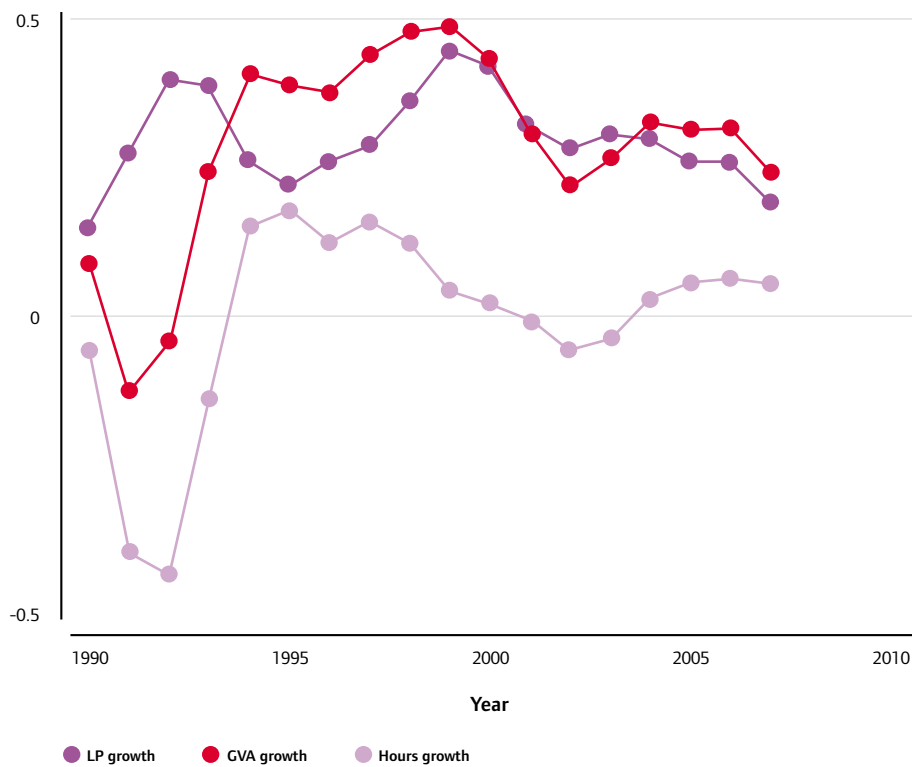
5.5.1 The productivity picture changes even without the inclusion of intangibles

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. The TFP record was a rise of 0.27pp in the second half of the 1990s and then it levelled off in the 2000s, in overall terms a fairly steady picture.

Note that a market sector TFP growth rate of over 1.5 per cent is comparatively high by UK standards. The reason for this is that FISIM has added around 0.5 to 1pppa to LP growth, all of which adds to TFP growth almost directly since no new inputs are involved. Further details are in the accompanying document.[52]

5.5.2 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 contribution of the intangible inputs can be seen; it is stronger in the 1990s and weaker – though still important – in the 2000s. Thus the overall TFP growth record in column 6 is acceleration in the late 1990s and then some weakening.

5.5.3 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 (NESTA's preferred variant of the Innovation Index). 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.

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 intangible spending and TFP growth 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 (0.54 per cent p.a.) has exceeded that from tangibles in the forms of computers (0.38 per cent p.a.) and, separately, other tangibles (0.37 per cent p.a.).

Some points to note are as follows. First, looking at column 9 the results show that 67 per cent of LPG between 2000 and 2007 is due to innovation. Second, without intangibles, the total fraction of LP growth due to innovation is understated at 60 per cent. Decomposing the growth with intangibles included, the contribution of innovation to LP growth, 70 per cent (1.27/(1.27+0.54)) is found to be due to TFP growth and 30 per cent (=0.54/(1.27+0.54)) due to intangibles. Thus the inclusion of intangibles raises both the fraction of LP growth due to innovation and the fraction due to measured inputs.

52. Haskel *et al.* (2009) 'Supporting document for growth accounting interim report'.

Table 2: Growth accounting with and without intangibles and versions of innovation index

	1 DlnV/H	2 sDln(L/H)	3 sDln(K/L) cmp	4 sDln(K/L) othtan	5 sDln(K/L) intan	6 DlnTFP	7 Memo: sLAB	8 InnIndex1	9 InnIndex2	10 InnIndex3	11 InnIndex4
(1) Baseline results											
Without intangibles								(6/1)	(5+6)/1	(2+5+6)/1	(5+6)
1990-95	2.87%	0.20%	0.47%	0.81%		1.39%	0.66	0.48	0.48	0.55	1.39%
1995-00	3.35%	0.29%	1.06%	0.33%		1.66%	0.64	0.50	0.50	0.58	1.66%
2000-07	2.81%	0.19%	0.45%	0.48%		1.68%	0.66	0.60	0.60	0.67	1.68%
With intangibles											
1990-95	3.03%	0.18%	0.41%	0.71%	0.74%	1.00%	0.57	0.33	0.57	0.63	1.74%
195-00	3.72%	0.25%	0.90%	0.27%	0.84%	1.46%	0.55	0.39	0.62	0.69	2.30%
2000-07	2.72%	0.17%	0.38%	0.37%	0.54%	1.27%	0.57	0.47	0.67	0.73	1.81%
(2) Including just Software / Software and R&D											
a) Only Software											
1990-95	2.96%	0.20%	0.46%	0.81%	0.20%	1.28%	0.64	0.43	0.50	0.57	1.48%
1995-00	3.44%	0.28%	1.03%	0.33%	0.27%	1.52%	0.62	0.44	0.52	0.60	1.79%
2000-07	2.82%	0.19%	0.44%	0.47%	0.11%	1.62%	0.64	0.57	0.61	0.68	1.73%
b) Software and R&D											
1990-95	2.92%	0.19%	0.45%	0.79%	0.27%	1.21%	0.63	0.41	0.51	0.57	1.48%
1995-00	3.45%	0.28%	1.01%	0.32%	0.30%	1.53%	0.61	0.44	0.53	0.61	1.83%
2000-07	2.80%	0.19%	0.43%	0.45%	0.15%	1.58%	0.63	0.56	0.62	0.69	1.73%
(3) Robustness Checks on Depreciation Rates											
Halve Dep Rates											
1990-95	3.04%	0.18%	0.41%	0.75%	0.85%	0.85%	0.57	0.28	0.56	0.62	1.70%
1995-00	3.72%	0.25%	0.90%	0.27%	0.83%	1.47%	0.55	0.40	0.62	0.69	2.30%
2000-07	2.72%	0.17%	0.37%	0.36%	0.71%	1.12%	0.57	0.41	0.67	0.74	1.83%
Double Dep Rates											
1990-95	3.03%	0.18%	0.41%	0.68%	0.65%	1.11%	0.57	0.37	0.58	0.64	1.76%
1995-00	3.72%	0.25%	0.91%	0.27%	0.88%	1.41%	0.55	0.38	0.62	0.68	2.29%
2000-07	2.72%	0.17%	0.38%	0.38%	0.40%	1.40%	0.57	0.51	0.66	0.72	1.80%

Note: Data are average growth rates per year for intervals shown. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in GVA. Column 3 is growth in computer capital services times share in GVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) times share in GVA. Column 5 is growth in intangible capital services times share in GVA. Column 6 is TFP, namely column 1 minus the sum of columns 2 to 5. Column 7 is the share of labour payments in GVA. Columns 8, 9 and 10 present three different versions of the innovation index.

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

- LP growth
- TFP growth
- Contribution of labour quality without intangibles
- Contribution of capital without intangibles
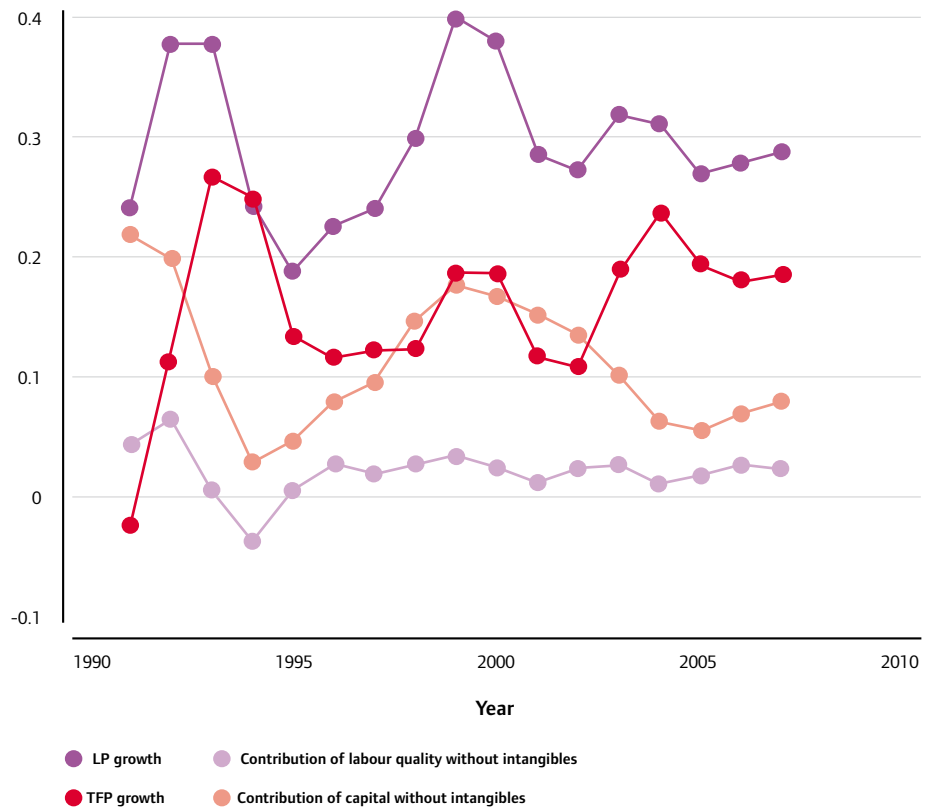
Note: TFP growth (total factor productivity growth) is LP growth (average labour productivity growth) less the two contributions. The two contributions are 'labour quality', i.e. growth in labour services per hour times the share in MSGVA of labour and capital i.e. growth in capital, services per hours 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

- LP_wi growth
- TFP_wi growth
- Contribution of labour quality with intangibles
- Contribution of capital with intangibles
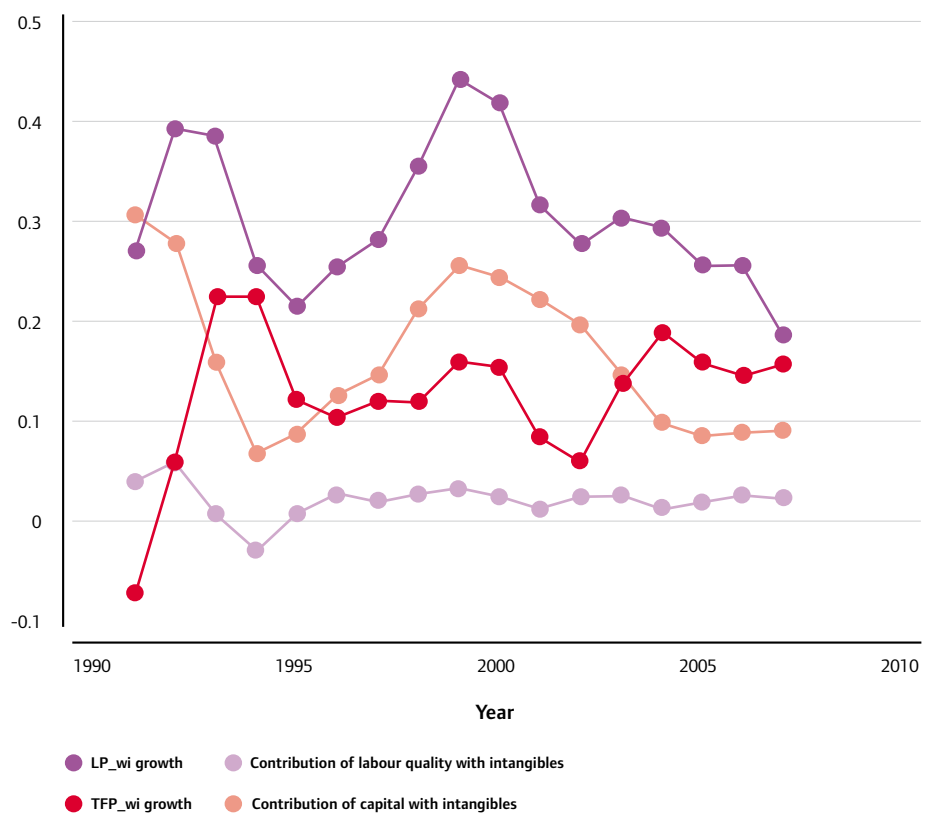
Note: As Figure 7, except here capital services are computers, buildings, plant, vehicles PLUS all intangibles categories including software.

Part 6: Growth accounting: further details and robustness checks

6.1 Robustness checks

As it has been shown, it is necessary to make a number of assumptions when implementing the growth accounting exercise. How robust are the report's 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 ¼ 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. The innovation index, in terms of shares, is somewhat less then in the full case where the other intangible asset categories were included.

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 assumptions are made 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 the results. Relative to the software case, the contribution of intangibles are raised only slightly when R&D is included, with LPG remaining largely the same.

Third, the role of the depreciation rates is considered. The results in Panel 3 (Table 2) show that doubling and halving the depreciation rates lowers and raises the contribution of intangible capital respectively in 1990-95 and 2000-07, while it barely changes in 1995-2000. Since TFP growth is correspondingly raised and lowered, it makes little difference to the overall innovation index.

Fourth, 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, the reader is urged to be cautious in interpreting short-term movements in the innovation index and concentrate on period averages.

6.2 Contributions of individual intangible assets

One might also ask what are the roles of the individual intangible assets. To examine this, the report first splits up their impact into 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 0.18per cent and 0.23 per cent p.a., but less so this century, contributing 0.09 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 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 important in explaining growth in productivity (0.12-0.16 per cent), and the contribution is fairly steady at about a quarter to a half of the contribution of non-computer tangibles. In Column 7 R&D is reported separately; this is of interest given the proposal to capitalise R&D by 2012. This contribution is rather small at

Table 3: Annual results

	1	2	3	4	5	6	7	8	9	10	10
Year	DlnV/H	sDln(L/H)	sDln(K/L) cmp	sDln(K/L) othtan	sDln(K/L) intan	DlnTFP	Memo: sLAB	InnIndex1	InnIndex2	InnIndex3	InnIndex4
Without intangibles								(6/1)	(5+6)/1	(2+5+6)/1	(5+6)
1995	1.22%	0.51%	0.78%	-0.24%		0.18%	0.64	0.15	0.15	0.57	0.18%
1996	3.01%	0.27%	0.89%	0.22%		1.63%	0.63	0.54	0.54	0.63	1.63%
1997	1.81%	0.09%	0.67%	-0.22%		1.28%	0.62	0.71	0.71	0.76	1.28%
1998	3.09%	0.39%	1.39%	0.47%		0.83%	0.63	0.27	0.27	0.39	0.83%
1999	4.27%	0.28%	1.14%	0.56%		2.28%	0.65	0.53	0.53	0.60	2.28%
2000	4.58%	0.43%	1.21%	0.63%		2.30%	0.67	0.50	0.50	0.60	2.30%
2001	1.99%	-0.10%	0.91%	0.42%		0.75%	0.68	0.38	0.38	0.33	0.75%
2002	2.97%	0.32%	0.67%	0.96%		1.02%	0.68	0.34	0.34	0.45	1.02%
2003	2.99%	0.46%	0.38%	0.55%		1.60%	0.67	0.54	0.54	0.69	1.60%
2004	3.83%	-0.13%	0.26%	0.33%		3.36%	0.66	0.88	0.88	0.84	3.36%
2005	1.84%	0.29%	0.26%	0.20%		1.09%	0.66	0.59	0.59	0.75	1.09%
2006	3.29%	0.29%	0.27%	0.48%		2.25%	0.65	0.68	0.68	0.77	2.25%
2007	2.73%	0.23%	0.39%	0.45%		1.67%	0.65	0.61	0.61	0.70	1.67%
With intangibles											
1995	1.67%	0.44%	0.67%	-0.21%	0.53%	0.23%	0.55	0.14	0.46	0.72	0.76%
1996	3.10%	0.23%	0.76%	0.18%	0.61%	1.32%	0.55	0.43	0.62	0.70	1.93%
1997	2.22%	0.08%	0.57%	-0.18%	0.49%	1.27%	0.54	0.57	0.79	0.83	1.76%
1998	3.80%	0.34%	1.19%	0.39%	0.94%	0.94%	0.55	0.25	0.49	0.58	1.88%
1999	4.59%	0.24%	0.97%	0.46%	1.09%	1.82%	0.56	0.40	0.63	0.69	2.91%
2000	4.90%	0.37%	1.03%	0.51%	1.06%	1.93%	0.57	0.39	0.61	0.69	2.99%
2001	2.50%	-0.09%	0.77%	0.34%	0.91%	0.58%	0.58	0.23	0.60	0.56	1.49%
2002	2.83%	0.28%	0.56%	0.76%	0.92%	0.32%	0.58	0.11	0.44	0.54	1.24%
2003	2.91%	0.39%	0.32%	0.42%	0.58%	1.20%	0.57	0.41	0.61	0.75	1.78%
2004	3.43%	-0.11%	0.22%	0.24%	0.44%	2.65%	0.57	0.77	0.90	0.87	3.09%
2005	2.00%	0.25%	0.22%	0.14%	0.39%	1.00%	0.56	0.50	0.70	0.82	1.39%
2006	2.81%	0.25%	0.22%	0.35%	0.34%	1.65%	0.56	0.59	0.71	0.80	1.99%
2007	2.57%	0.20%	0.32%	0.33%	0.23%	1.49%	0.56	0.58	0.67	0.75	1.72%

0.04-0.06 per cent p.a. Finally, column 8 shows the contribution of economic competencies. This is substantial, and provides the largest contribution at 0.29-0.43 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

Table 4: Contributions of individual assets

Year	1 DlnV/H	2 sDln(L/H)	3 sDln(K/L) cmp	4 sDln(K/L) othtan	5 sDln(K/L) software	6 sDln(K/L) innov prop (less R&D)	7 sDln(K/L) R&D	8 sDln(K/L) econ comp	9 DlnTFP	10 Memo: sLAB
With intangibles										
1990-95	3.03%	0.18%	0.41%	0.71%	0.18%	0.16%	0.06%	0.34%	1.00%	0.57
1995-00	3.72%	0.25%	0.90%	0.27%	0.23%	0.14%	0.04%	0.43%	1.46%	0.55
2000-07	2.72%	0.17%	0.38%	0.37%	0.09%	0.12%	0.04%	0.29%	1.27%	0.57

Note: Data are average growth rates per year for intervals shown. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in 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 in 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

Year	1 DlnV/H	2 sDln(L/H)	3 sDln(K/L) cmp	4 sDln(K/L) othtan	5 sDln(K/L) software	6 sDln(K/L) min & cop	7 sDln(K/L) design	8 sDln(K/L) r&d	9 sDln(K/L) adv & mr	10 sDln(K/L) training	11 sDln(K/L) org	12 DlnTFP	13 Memo: sLAB
1990-95	3.03%	0.18%	0.41%	0.71%	0.18%	0.02%	0.14%	0.06%	0.07%	0.12%	0.15%	1.00%	0.5747
1995-00	3.72%	0.25%	0.90%	0.27%	0.23%	0.00%	0.14%	0.04%	0.13%	0.17%	0.13%	1.46%	0.5537
2000-07	2.72%	0.17%	0.38%	0.37%	0.09%	0.00%	0.11%	0.04%	0.03%	0.12%	0.14%	1.27%	0.5682

Note: Data are average growth rates per year for intervals shown. First column is labour productivity growth in per hour terms. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in 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 10 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.

Table 6: Comparisons with earlier work (GHW and CDH)

	Labour Productivity Growth (% p.a)	Contribution of Human Capital Deepening (% p.a)	Contribution of Tangible Capital Deepening (% p.a)	Contribution of Intangible Capital Deepening (% p.a)	TFP Growth (% p.a)
(1) HMT working paper					
Without intangibles					
1990-1995	2.93	0.83	1.4		0.7
1995-2000	2.72	0.44	1.82		0.46
2000-2004	2.53	0.29	1.18		1.07
With intangibles					
1990-1995	3.09	0.73	1.55	0.36	0.46
1995-2000	3.23	0.38	1.89	0.39	0.57
2000-2004	2.61	0.25	1.28	0.42	0.65
(2) Imperial/ONS					
Without intangibles					
1990-1995	2.87	0.2	1.28		1.39
1995-2000	3.35	0.29	1.39		1.66
2000-2004	2.95	0.14	1.12		1.68
With intangibles					
1990-1995	3.03	0.18	1.12	0.74	1
1995-2000	3.72	0.25	1.17	0.84	1.46
2000-2004	2.92	0.12	0.91	0.71	1.19
(3) CDH					
Without intangibles					
2000-2005	2.74	0.52	1.15		1.07
With intangibles					
2000-2005	2.74	0.45	1.04	1.19	0.05
(4) Imperial/ONS					
Without intangibles					
2000-2005	2.72	0.17	0.99		1.56
With intangibles					
2000-2005	2.73	0.14	0.8	0.65	1.15

Note: Panel 4 shows results for 2000-05 on current data, and Panel 3 for Clayton, del Borgo, Haskel (2008, NESTA summer project data) for comparison. The two are not strictly compatible, since the CDH study aggregates up from industry-level gross output growth accounting, and in addition the labour quality data are different. In column 1, LP growth data are similar. Column 2 shows a lower contribution of labour services. This is because the EUKLEMS labour quality adjustment series grows faster than the series here. In column 5, there is a higher contribution of intangible capital deepening. This is being investigated: note that the level of financial services investment is much lower in the current data. Column 6 shows much lower TFP growth in the CDH study, reflecting the higher capital contribution. The final innovation index, column 10 is around the same.

and organisational capital, although branding and market research also made a substantial contribution in the 1990s, particularly towards the end of the decade.

6.3 Comparison with earlier work

Table 6 sets out comparisons with earlier work. The top panel shows the results from Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007).[53] The second panel shows the current results for the years in the HMT paper. The comparison is not straightforward, so the report discusses comparisons step by step.

First, consider the new results without intangibles (2). The main feature is that the current post-1995 LP growth rates are higher than before, with a particular increase in the 1995-2000 period by around 0.6pppa. Second, TFP growth rates are also much higher, by around 1.2pppa in 1995-2000.

These are the main data changes. So what explains them? Since both are without software and other intangibles, the rise in LP growth is due to FISIM plus changes in person-hours (see the accompanying technical paper, which is particularly important in the late 1990s). As explained above, this adds directly to TFP growth and so accounts for around half the TFP growth increase. The other parts of the rise in TFP growth are due to a fall in the contribution of labour quality and capital. The fall in labour quality contribution is due to a revision of the person-hours series by the ONS and the fall in tangible capital deepening due to a fall in the share of computers in the tangible capital stock, due in turn to a revised series for Plant & Machinery Buildings.

Finally, consider the effect of including intangibles. In both cases intangibles raise LP growth and, of course, introduce an intangible contribution. In the most recent results there is a higher intangible contribution which, since the underlying investment data are the same, must be due to a higher intangible share. Turning to the lower panel, the CDH work used EUKLEMS data which has both lower LP growth and higher capital deepening, hence lower TFP growth.

Lastly, what are the differences between the report's results and those MFP results published by ONS? Turvey (2009)[54] reports, for the ONS-defined market sector, 2001-2007 LP growth of 2.10 per cent, labour and capital composition contribution of 0.26 per cent p.a. and 0.72 per cent and TFP growth of 1.12 per cent. These data incorporate BB2008 revisions and so the report's comparable measures are those incorporating software which are, for 2000-2007 LP growth 2.82 per cent, labour and capital composition contribution of 0.19 per cent p.a. and 1.02 per cent and TFP growth of 1.62 per cent. The main reason for the difference is that the ONS definition of the market sector includes sectors OP and parts of M and N (education and health), whereas in the report just A to K are included. These additional sectors in the ONS analysis are low LP growth and low TFP growth sectors (Turvey reports data of -0.28 per cent p.a. and -1.15 per cent p.a. respectively) which would account for the somewhat higher LP growth and so TFP growth. Further comparisons with ONS results are provided in the accompanying document 'Comparison with ONS growth accounting analyses'.

Finally, for 2000-05, the EUKLEMS data reports LP growth of 2.2 per cent p.a., labour and capital composition contribution of 0.4 per cent p.a. and 0.6 per cent p.a., and TFP Growth of 1.2 per cent p.a., for their own market economy definition.

53. Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007) 'Intangible investment and Britain's productivity.' Treasury Economic Working Paper No.1. London: HM Treasury.

54. Turvey (2009) Multi-factor productivity: estimates for 1998 to 2007 Economic & Labour Market Review | Vol 3 | No 3 | March 2009 Available at http://www.statistics.gov.uk/elmr/03_09/downloads/ELMR_Mar09_Turvey.pdf

Part 7: 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 report finds the following. First, investment in knowledge, which the report calls intangible assets, is now greater than investment on tangible assets, at around, in 2007, £133 billion and £95 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 the report calls innovation, is considerable. For the most recent period of 2000-2007, if innovation is measured as TFP plus the contribution of intangible capital deepening, then it has contributed 67 per cent of growth in labour productivity. Adding the contribution of an increasingly educated workforce, innovation has contributed 73 per cent of growth in labour productivity, 2000-2007.

Appendix: Assets and data sources

Table 7: Intangible Investment Data

Type of intangible investment	Current source	Period availability	Comments
Computerised information			
Software Own-Account	ONS estimates	1970-2007	Updated data consistent with BB2008. Source: G Chamberlain, ONS
Software purchased	ONS estimates	1970-2007	Updated data consistent with BB2008. Source: G Chamberlain, ONS
Innovative property			
Scientific R&D	Estimates based on Business Enterprise R&D survey (BERD) and ONS data	1980-2007	Updated data. Computer industry subtracted from total number as before
Mineral exploration	National Accounts	1948-2008	National Accounts. Source: Khalid Khan, ONS
Copyright and licence costs	National Accounts	1970-2008	National Accounts. Source: Khalid Khan, ONS
New product development costs in the financial industry	For own-account, software methodology using ASHE wage bills and interviews. Purchased: assumed zero	1970-2006	Previous method assumed 20 per cent 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.
New architectural and engineering designs	For own-account, software methodology using ASHE wage bills and interviews. Purchased: uses IO tables	1992-2006	GHW used 50 per cent 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.
R&D in social sciences and humanities	Estimates based on turnover data from ABI and GHW methodology		ABI turnover , SIC 73.2
Economic competencies			
Advertising	Estimates based on IO Tables	1992-2004	By assumption 2005=2004. Last Blue Book version up to 2007
Market research	Estimates based on Use and IO Tables and data from ABI	1992-2004	By assumption 2005=2004. Last Blue Book version up to 2007
Firm-specific human capital	Estimates based on the National Employer Skills Survey 2004 (NESS2004)	1970-2004	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			
Purchased	Estimates based on data from a survey set up by the UK Management Consulting Association (MCA)	1997-2005	Data from MCA for 2005 backcasted
Own-account	Estimates based on data from the Annual Survey of Hours and Earnings (ASHE)	1997-2006	ASHE wage bills

Table 8: 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	1970-2005	The market sector is built up without real estate and dwellings from 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 2003. Market sector real value added data is nominal share weighted sum of section real value added
Gross Operating Surplus	Implied ONS estimates	1970-2005	Generated as a residual from section GVA and COE data
Labour compensation/ compensation of employees	ONS estimates	1970-2005	CoE taken from ONS National Accounts. The labour share of MI (based on CoE/GOS percentage split) is added on to give total labour compensation
Total hours worked by persons engaged	ONS estimates	1970-2005	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	Real capital stock generated by ONS using highly disaggregated investment data and a PIM. Tangible asset data are 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	1970-2008	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 6 education groups, 2 genders, 3 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 9 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	1970-2008	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 9: Other Data

Type of tangible investment	Current source	Period availability	Comments
Deflator			
Software Own-Account	ONS estimates	1970-2007	Updated data consistent with BB2008. Source: G Chamberlain, ONS
Software purchased	ONS estimates	1970-2007	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. To be informed by IAS
Tangible assets	ONS estimates		Depreciation rates for vehicles, machines, buildings change according to the sector.

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