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Productivity and Innovation in UK Financial Services: An Intangible Assets Approach*

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Abstract

Financial services are typically described as highly innovative (indeed excessively so according to some commentators). Case studies suggest very high innovation around IT, software and the internet, and new products including those via financial engineering. However, it is hard to see this by many standard IO and productivity measures. Patenting for financial products (at least in the UK) is almost zero. R&D as a fraction of sales in UK financial services is 0.02%, putting finance (on this measure) less innovative than furniture manufacture (0.3%). Whilst measured labour and total factor productivity growth have been quite rapid, there are doubts over measurement and the residual nature of TFP growth leave open the question of what drives financial innovation. This paper looks at innovation in UK financial services by trying to bring together the industry productivity/TFP literature with some of the case study evidence. Such evidence suggests that much financial innovation (a) can be readily copied and (b) requires investment in product development, software, marketing, training and organisational change. Whilst copying can be captured by TFP, these investments are almost certainly not captured by conventional R&D. Thus we follow the Corrado, Hulten and Sichel (2005) intangibles framework and measure the broad range of intangible/knowledge assets that case studies suggest are important in finance. We document these investments are very large in UK finance, and that conventional R&D understates them. Incorporating them into the growth accounting picture we show the method seems to capture much of innovation in financial services and changes the productivity/TFP growth picture to give more intuitive numbers.

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1 Introduction

Financial services is widely regarded as being highly innovative. Retail users of banks for example, can bank online, transfer money electronically and trade exotic financial instruments. Indeed, the benefits of some financial innovation are hotly contested. Alan Greenspan, speaking in 2002, allocated to financial innovation much of credit for a previously stable macroenviroment. Warren Buffett, writing in 2002, allocated to (particular forms of) financial innovation the epithet "financial weapons of mass destruction". Rarely has innovation in any industry been accused of bringing down the entire capitalist system.[1]

Despite such popular interest, recent surveys bemoan a comparative lack of academic empirical work on financial innovation: see for example, the excellent survey papers by Frame and White (2004) and Tufano (2002). Indeed, in their comprehensive survey, Frame and White (2004) were only able to find 39 empirical studies of financial innovation studying 21 separate phenomena, with six studies preceding the 1990s and 23 since 1998.

An important strand of the literature consist of studies of particular forms of financial innovations, suggested by, for example, interviews with market participants or newspaper records. Black and Scholes (1974) for example describe the introduction by Wells Fargo Bank of what would now be called an index fund. Tufano (1989) considers 58 financial innovations, 1974-86, where his sample are innovative corporate or mortgage-backed securities, as identified in literature searches or by industry experts. Lerner (2002) documents innovation 1990-2002 via a search for particular news stories in the Wall Street Journal.

Frame and White (2004) point out that the conventional IO/productivity literature which relies on such measures as R&D, patents and labour or total factor productivity growth (LPG, TFPG) has not been used very much in financial services. On patents, as Hall (2009) points out, this is for good reasons; in the UK for example, financial innovation is essentially unpatentable (there are a very few exceptions). On R&D, UK officially produced R&D scoreboard points out, Financial Services has more or less the lowest R&D intensity of all industries (these data rely on R&D from company accounts, which only allow software in the course of development to be counted as R&D). For the US, Using such accounting data Lerner (2002) reports that "for instance, neither Citigroup nor Merrill Lynch report any R&D between 1990 and 2002". As we document below, R&D intensity (spend over sales) measured by the UK official R&D survey

[1] Both quoted in Jenkinson (2008), who notes the pace of change in finance (which may or may not be related to innovation) "The outstanding value of interest rate swaps and other derivatives reached almost $600 trillion or some 11 times annual global GDP by the end of 2007, according to the BIS. Ten years ago the value was around $75 trillion (2 ½ times GDP). The global derivatives market expanded almost 50% during 2007."

puts financial services (at 0.02%) below furniture manufacture (0.3%).[2] LGP and TFPG for finance are typically mentioned in official data, or industry levels studies of productivity, particular in those studies attempting to link IT, which financial services seems to use intensively, with economic performance. But doubts exist over output measurement and since TFPG is a residual this leaves open what is driving financial innovation (besides pure knowledge spillovers).

One reaction to this is to abandon the "conventional" LPG/TFPG/R&D literature and pursue more "extended case/event" studies. This paper instead attempts to incorporate (at least some of) the important findings of the latter work into the conventional LPG/TFPG/R&D literature to see if results in this area can be improved. It does this expressly *not* to deny the importance of the detailed innovation literature. Rather, in the light of Frame and White's (2004) request for more empirical work in the area, we wish to see if extending the conventional approach can yield insights. In addition, industry-level productivity studies continue to be staple tools of the profession and with increasing emphasis on measurement of the service sector, this study might be seen as contributing to that literature.[3]

To summarise our work, we proceed as follows. Detailed work on financial services, surveyed below, suggests a number of interesting features of financial innovation. First, much financial innovation is due to (a) new products and services (e.g. subprime mortgages, internet banking, ATMs) (b) new production processes (e.g. electronic money processing, credit scoring) and (c) new organisational forms (e.g. internet only banks) (Frame and White, 2004). Second, much financial innovation can be copied readily (Frame and White, 2004 Lerner, 2002, Tufano, 2002).

Third, new financial products typically require co-investment beyond just the development of the product (for example, marketing and training of staff to support a new product), Tufano (1998) for example states that his case studies indicate that a typical financial innovation needs

> *"an investment of $50,000 to $5 million, which includes (a) payments for legal, accounting, regulatory, and tax advice, (b) time spent educating issuers, investors, and traders, (c) investments in computer systems for pricing and trading, and (d) capital and personnel commitments to support market-making. In addition, investment banks that innovate typically pay $1 million annually to staff product development groups."*

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[2] This is similar for the US. US data breaks down R&D in "Finance, Insurance and Real Estate" and finds a share of sales of 0.5% in 2005, compared wth 3.6% in manufacturing as a whole (http://www.nsf.gov/statistics/seind08/append/c4/at04-22.xls from http://www.nsf.gov/statistics/seind08/c4/c4s3.htm#c4s31). That puts financial R&D intensity less than half that of furniture manufacturing (0.8%).

[3] We have nothing to say on patents in this paper, other than to document that UK regulations are that patenting in financial services is more or less completely excluded.

How does this fit into the conventional LPG/TFPG/R&D Solow-type framework? In that framework, output comes from physical capital, labour and knowledge. As typically measured in conventional growth accounting work, knowledge is measured by TFP. This is appropriate if knowledge is freely available. If knowledge is not free, then one can extend the model to include knowledge capital as an additional input, with R&D is an investment in that input. Thus TFPG captures growth from free knowledge (plus measurement error).

Some of the features of the detailed studies *can* be captured in this framework at least conceptually (measurement issues aside for the moment). First, such studies emphasise the importance of computers: they are part of physical capital. Second, since products seem to be able to be imitated very quickly and cheaply as knowledge passes very rapidly between financial firms, this can in principle be captured by TFP.

Third, studies suggest that at least some innovation is not free but needs investment in new knowledge, but outside that conventionally measured R&D. That is, conventionally measured R&D does not capture much of the types of investment in knowledge that actual financial innovation involves; investment such as software, product development, marketing, training and organisational form.

Thus our key argument in this paper is that whilst the productivity/growth accounting framework allows for spending on knowledge capital, which is what detailed studies suggest financial innovation involves, the implementation of the framework requires us to expand allowed spending beyond just that of R&D. This is exactly what the recent contributions by Corrado, Hulten, Sichel (2005, 2007), applied to the macro economy, do. They argue that knowledge spending should embrace a broad range of investment in knowledge assets, as well as R&D, software, marketing, training, organisational capital and that incorporation of such spending should improve our understanding of growth by, for example, explaining much of the unexplained residual TFPG.[4]

The purpose of this paper is then to apply the CHS framework to see if it gives a more informative picture of innovation and growth in financial services. To the best of our knowledge, this is the first paper to do this. Of course, in so doing we have to rely on a number of assumptions regarding e.g. measurement, returns to scale, competition etc. Thus we regard this paper as an initial exploration into whether it is worthwhile for future work to examine these issues.

We obtain a number of results. First, in applying the framework to financial services we have also to apply it to the rest of the economy (to solve endogenously for rates of return to

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[4] Some of these categories are now counted in the official data are investment, notably software. Software was only fully integrated as investment into the UK National Accounts in 2005 however. R&D will be integrated but only in 2012. .

compute consistent intangible and tangible capital rental rates). Thus we start by comparing (broadly defined) knowledge investment in financial services with the rest of the economy. As discussed above, financial services accounts for a very small share of total measured R&D spend. But it is a disproportionately[5] large spender on other intangible assets: 22% of all software spend, 17% of all marketing spend and 19% of all organisational capital spend, as shown in Table 5, column 4. Using the wider definition then, financial services is actually very "innovation spending" intensive, contrary to the view if one just used R&D.

Second, if the conventional measure of R&D is inappropriate for financial services, we need to develop a new one. We do this by following the standard method for measuring own-account software[6]. Using the labour force data, we identify "research" type occupations, where we assume that such occupations produce a knowledge asset, like a new product. The wage bill, times the fraction of such occupational time spent on "research", times an estimate of overheads, gives a cost-based estimate of "R&D" spending. Thus for example, if a firm pays a PhD economist to invent a new financial instrument, we capture this "R&D" spending from the occupational data. To do this requires assumptions on what occupations undertake knowledge spending and how much time they spend. We gather these data from interviews with major financial firms. Such spending turns out to be around £2bn for 2006. Relative to the official R&D measure, of around £20m, this is much larger, although it is small relative to software spending of £4.1bn.

Third, we then estimate the contributions of all these assets to LPG (measured as annual growth in gross output per hour) and the resulting TFPG. Taking no account of intangibles (i.e. spending on knowledge assets such as R&D spend, software, product development etc), LPG in financial services, 2000-05 is 2.94%pa, against 3.03%pa in retail and 3.79%pa in manufacturing. TFPG in financial services is 1.40%pa, about 1½ times manufacturing and 2½ times retail, and around 50% of LPG, whereas TFPG is 23% of LPG in manufacturing and 20% in retail. Capital deepening is around 12% of LPG in finance, almost all of which is due to ICT capital.

When we incorporate intangible capital, the picture changes. First, a much larger fraction of LPG in financial services is accounted for by capital deepening, 26%. Second, intangible capital deepening accounts for around 50% of that total capital deepening, with the bulk of the contributions from software, organisational capital, training and product design. The contribution

[5] Financial services value added is about 8% of the market sector and employment 3%.

[6] First, occupations are identified that are part of the creation of software (e.g. software engineers and programmers, IT managers). Second, estimates of wage bills using occupational data are computed. Third, the wage bills are multiplied by a fraction of time spend on long-lasting software creation (e.g. this is 70% for software professionals and 15% for managers) and another fraction for overhead costs (1.6). The resulting number is an estimate of the "R&D" costs that firms incur in producing own-account software and these numbers are added to purchased software from surveys (for the UK in 2004, own-account and purchased software came to around £10bn each).

of software (0.13%pa) in finance is larger than that of manufacturing and retail (both 0.08%pa), according with the intuition that software-related capital deepening is important in financial services. The contribution of organisational capital (0.14%pa) is similar to that in other sectors, but a higher fraction (around 5%) of LPG. Third, hardware is also very important in financial services, with half of capital deepening due to hardware (in manufacturing and retail the figures are 9% and 11% of total capital deepening), again suggesting the importance of ICT in the sector. Indeed, the sum of hardware and software contributes 20% of (gross output) LPG in financial services as opposed to 14% in retail and 5% in manufacturing. Finally, TFPG in finance is still twice that in manufacturing and 2½ that in retail, but 30% of LPG, thus allowing us to account for much more of LPG when intangibles are included. So, if one scores "innovation" in industries as the fraction of LPG accounted for by intangible capital deepening and TFPG, financial services are the most innovative (43%) , followed by manufacturing and retail (34% and 26%).

In sum, whilst there is clearly more work to be done relaxing assumptions etc., and we present a number of robustness tests, we think these findings offer a more complete picture than much of the previous work that either relegated all knowledge to TFP or just used R&D and they accord with much of the findings in the detailed industry-specific studies.

The rest of this paper proceeds as follows. The next section reviews the literature on financial innovation. Section 3 sets out our data on knowledge capital in financial services, section 4 our growth accounting results and section 5 concludes.

2 Previous work on financial services innovation

In this paper we seek to measure productivity and innovation in financial services via a growth accounting method. This is of course by no means the only method. We stress very strongly that this method is but one contribution to a literature which will rightly draw evidence from a number of methods. So the purpose of this section here is to better understand how this method will fit with other methods, what parts of other methods it will capture and its relative advantages and disadvantages.

Frame and White (2004), in an exhaustive survey, document that there are very few empirical studies of financial innovation, a conclusion supported by Lerner (2002) and the survey of Tufano (2002). In addition, they argue there seems to be no single preferred categorisation of either research method or innovation category.

To start with then, perhaps the most straightforward, and venerable, approach to innovation is to categorise innovation by product. For example, Tufano's survey of financial innovation, documents the various lists of different types of securities that have been collated since at least the 1930s. He himself also sets out a list, from 1980 to 2001, of new securities. As he mentions, this is but a small amount of innovation in the field and many securities on such a list are near-identical products by different banks. In a similar vein, Lerner (2002) documents innovation 1990-2002 via a search for particular news stories in the Wall Street Journal.

Another approach is case studies. Black and Scholes (1974) describe the introduction by Wells Fargo Bank of (what would now be called) an index fund, the innovation being a product enabling investors to hold a collection of stocks but economising on the transactions costs that would be incurred by buying every stock in the particular collection individually. Black and Scholes (1974) described Wells Fargo's attempts as encountering "…a variety of problems, especially legal and sales problems". They emphasise that Wells felt they needed to spend $60m to go ahead with the fund and also discuss the high costs of selling the product.

Tufano (1992, page 25) discusses Exchange Traded Funds and personal funds (the latter being a follow up to index funds, essentially allowing trading in the market index during the trading day with fractional shares). He comments that although the motivation, to offer diversified baskets, is old, "..it is technology, embedded in improvements in information technologies, that permit personal funds to be technically feasible. Technology may enable these innovators to market these products via the web as well as execute transactions at low costs."

Tufano (1989) considers 58 financial innovations, 1974-86, where his sample are innovative corporate or mortgage-backed securities, as identified in literature searches or by industry experts. He has as number of interesting findings in relation to our growth accounting approach here. First, reports that bankers estimate that developing a new financial product requires "an investment of $50,000 to $5 million, which includes (a) payments for legal, accounting, regulatory, and tax advice, (b) time spent educating issuers, investors, and traders, (c) investments in computer systems for pricing and trading, and (d) capital and personnel commitments to support market-making. In addition, investment banks that innovate typically pay $1 million annually to staff product development groups with two to six bankers.". Second, he estimates that imitation of the innovative product is typically very fast: the mean number of days until a rival entered with an imitative product was 77.6 days and 35 of the products surveyed were imitated within a year of initial marketisation. Third, he suggests that innovation might give economies of scale and scope in other products where revenues are made.

Frame and White categorise classes of innovation by purpose[7] in the financial system. First, they discuss new products (e.g., subprime mortgages) or services (e.g., ATM, debit and pre-

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[7] There is no one way of classifying innovation in finance. Mayer (1986) surveys innovation by (a) new instruments and (b) changing practices and structures (such as cross border banking: his survey was written before the internet). Merton (1992) sets out functions of a financial system namely (1) moving funds across time and space; (2) the pooling of funds; (3) managing risk; (4) extracting information to support decision-making; (5) addressing moral hazard and asymmetric information problems; and (6) facilitating the sale of purchase of goods and services through a payment system.

paid cards and internet banking for transactions). Second, new production processes. Examples included credit scoring, the electronic processing of payments, asset securitization and new methods of risk management, helped in turn by advances in IT and financial theory. Finally, they discuss, new organizational forms (e.g., Internet-only banks).

Lerner (2006) sets out some reasons why innovation in finance might be very different from that in manufacturing. First, he argues that financial innovation is unlikely to be appropriable. Patents in finance have only been introduced very recently (in the US), are essentially unpatentable in the UK (Hall, 2009), and hence new product ideas are diffused very quickly.8 Indeed, he finds, in his analysis of financial innovations 1990-2002, spillover effects with more financial innovations occurring when there are more innovation in the two-digit zip code. Second, much innovation is due to regulation, particularly with respect to taxes. Third, collaboration is likely to be particularly important for example in the syndication of securities.

How does all this fit in with our approach? To stress again, we do not claim that our approach is better than others, but wish here to "stress test" our approach by seeing what elements of other approaches it can and cannot incorporate.

First, there seems much evidence of spillovers: e.g. the banks offering "near identical" securities in Tufano (1992), very fast entry in Tufano (1989), limited use of patents and use of collaboration (Lerner, 2002). All this suggests that one needs a framework which accommodates that spillovers will be an important sources of knowledge, or in terms of our approach, TFPG will be important in growth. Second, although there are spillovers, we also have direct evidence that innovation requires investment. The most direct evidence is that from bankers themselves summarised in Black and Scholes (1975) and Tufano (1989). Note that such spending is a just

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Tufano (2002) says that innovation in finance exists for the following reasons: 1. complete inherently incomplete markets. *2) Innovation persists to address inherent agency concerns and information asymmetries*: *(3) Innovation exists so parties can minimize transaction, search or marketing costs. (4) Innovation is a response to taxes and regulation*: *(5) Increasing globalization and risk motivate innovation. (6) Technological shocks stimulate innovation* . however, he then documents some innovations that, in practice cross over all these motivations.

[8] Lerner (2002) reports the following on US patents. In the US and UK business methods had not been considered patentable. In the US, this changed with the Signature decision. Signature had a patent on a software program to determine the value of mutual funds. They successfully defended the patent and it appears that business methods can be patented. Despite this, at the time of his paper, patenting was not widespread. For example, universities and academics had patented 4 innovations. However, the position is different for the UK, as reported in Hall (2009). "In the UK, for example, the Patent Office introduced special treatment for business method applications in November 2004, due to the increasing number that had little or no chance of being granted (MIP Week 2004). In so doing, the Director cited applications from Fujitsu for optimizing the scheduling of airline crew, and a system for managing a debt-recovering process as being inherently unpatentable. In general UK practice with respect to software patents is viewed by practitioners as more restrictive than that at the EPO (MIP Week 2007)."

pure product development (which might be thought of as "R&D" in a manufacturing context) but also marketing, computer systems, and within-company education.

Third, and related, such innovation spending is almost certainly not captured by reported R&D. The UK accounting rules exclude almost all of the headings above (only some software is allowed). Reporting rules for the ONS R&D survey exclude software, marketing and training.

Fourth, and similarly related, if knowledge can easily spillover and so first-mover advantage is particularly important, this suggests that much innovation will be developed in house. Thus it will be not captured in standard business spending surveys that typically ask about purchases of investment goods: such surveys are typically well suited to tangible investment (computers are not made in-house by banks) but not intangible investment.

Finally, much of the evidence on innovation seems to emphasise the importance of IT, in particular, hardware and software used by firms to both perform large-scale statistical analysis and the internet access by consumers. Frame and White's list of innovations, for example, credit scoring, electronic money transfer and internet banking seem especially IT-intensive. So it will be important to measure this and, given the quality-changes in IT, quality adjust for IT.

There has of course been much work on financial services output since the National Accounts has to incorporate financial services when measuring GDP. This work is somewhat unappreciated, perhaps because it is behind the National Accounts scenes and perhaps too because it is recent (so for example, the new measures of financial services were incorporated into US National Accounts in 2003 and in the UK in Summer 2009). Such work is summarised most recently in Fixler, Reinsdorf and Smith (2009), but draws on previous work surveyed in, for example, Triplett and Bosworth (2004) Fixler, Reisnsdorf and Smith (2003) and Fixler and Zieschang (1999). Perhaps the easiest way to see this work is to view banking as providing a stream of financial services rewarded by explicit charges and margins. The calculation of the margin is the typical issue and different views are set out in Wang (2003) and Basu et al (2008), see also the survey in Schryrer (2009). We shall not attempt to adjudicate on such arguments, but use the official UK data, and note the relevant caveats for our approach, which is reviewed in Section 4.

3 Knowledge investment in UK financial services

3.1 Industry definitions

Table 1 sets out our industries of interest. The first three columns show the relevant UK SIC codes by letter and number and description. In the paper below we will contrast our data with the official Business Enterprise R&D data (BERD) and the fourth column shows the industry breakdown which they report, namely "AD" defined as "Miscellaneous business activities; Technical testing and analysis". As the table shows, the BERD category covers most of the J to K sections, with the exception of SIC72 "Computer-related activities" and SIC73 "Research and development". The final column shows the industries that our paper covers. We present industry analysis for "financial intermediation" and "business services" separately. It will be important in our productivity analysis to note too that sector the 2digit SIC sector 70 "real estate" also include sub sector 70.2 "letting of own property". This subsector has imputed rents included in it. We therefore omit this industry for TFP purposes for we do not measure household dwellings in our capital stock.

3.2 Knowledge occupation definitions

Our requirement here is to pick "knowledge" occupations, where the choice is motivated by whether the workers concerned are producing an "asset", in this case a knowledge asset, the definition of which is that it has to last for more than one year.

We start then with available occupational data, which is the Standard Occupational Classification (SOC). The SOC (2000) has nine "major occupational groups".[9] We decided to exclude all those occupations which perform administrative and routine activities, which therefore excludes SOC (2000) major occupational group codes 4 to 9. This leaves us with "managers and senior officials", major occupational group code 1, "professional occupations" major group 2 and "associate professional and technical occupations" major group 3. Within these groups we then selected occupations that might be involved in knowledge building. Note that we decided to exclude "financial technicians (brokers, analysts, adviser, etc)" (these occupations are in major group 3) since we judged that they mostly do sales rather than research. We settled then the detailed occupational headings set out in Table 2, under the four broad headings "researchers", "other researchers", "software" and "managers". We discuss each in turn.

Following from the case studies above, our prime interest here is in researchers who devise new products etc. In Table 2, we set them out under the headings of "researchers" and "other researchers". Researchers are those whose occupational title seems to correspond to the type of occupations one would expect to be designing new products, carrying out analysis and building knowledge capital in financial services, most notably "management consultants, actuaries, economists and statisticians" (who turn out to be much the largest group). We also

[9] The major groups in SOC (2000) are: 1 "managers and senior officials", 2 "professional occupations",3 "associate professional and technical occupations", 4 "administrative and secretarial occupations", 5 "skilled trades occupations", 6 "personal services occupations", 7."sales and customer services occupations", 8 "process, plant and machine operatives", 9 "elementary occupations".

include scientific and social science researchers. "Other researchers", a group who turns out empirically to be rather small, consists of a rather disparate group of engineers and other professionals who one might expect to be knowledge creators. We set these out to facilitate the comparability of this work to similar work in the US carried by Hunt (2009).

Second, we have software workers. Whilst some of what software workers do is likely short-lived, for example fixing bugs and day-to-day advice, some activities, particularly writing code, is likely creating a long lived (knowledge) asset. Our interviews with financial firms have indicated for example, that many buy in software and then use their own in-house software specialists to modify it. Finally, we also have ICT staff, here being software strategy and planning and software professionals. Official ONS data includes these types with, in addition, other ICT staff such as technicians. We shall be using the official ONS data for software, but include these data here to give some sense of comparison.

Finally, the case studies suggest that innovation in, and spending on, organisational form is important. Such spending is very hard to obtain. CHS suggest two ways of measuring this. First, one might measure management consulting services bought it, to the extent that they are helping firms in organisational innovation. Second, some fraction of managerial time might be spend on "in-house" development of organisations. Of course, a manager likely builds up experience etc. which is embodied in themselves, but firms have a clear incentive to try to capture and codify at least some of this knowledge, not least because managers might leave. To capture the in-house part we therefore chose a list of managers, set out in Table 2. Looking at Table 2, SOC2000 has an express category of managers in Finance called "Financial Institution Managers" described as workers who "..plan, organise, direct and co-ordinate the activities and resources of banks, building societies, insurance companies and post offices". This would appear to capture neatly the managers we need to look at, with the exclusion of Post Office managers.[10]

3.3 Employment and spending on knowledge

We start with employment data and compare these numbers with those reported for employment from BERD. Table 3 reports employment data for our chosen groups. Researchers and other researchers together come close to software employment, but both are less than managers. It is

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[10] In our GHW earlier work we also looked at managers as creating an intangible asset. We considered a broader range of mangers there, including the financial services managers set out in Table 2. We did not however include there ICT managers of customer care managers. Finally, these are of course job titles and not qualifications. Thus the considerable interest in scientists leaving science and going into the City is not captured here directly, in that we do not know if the qualification of the worker is a science one, but indirectly if they work as e.g. management consultants. The recent Royal Society report (2009, section 2.3.2) reported that "in 2006/7 only 8.5% of university leavers with a first degree in a core STEM subject were working in the 'Financial activities' sector. Considering just physical sciences and engineering and technology 8.6% and 5%

worth noting just how many IT employees there are in financial services, suggesting they are significant part of innovation in finance.[11]

How do these numbers compare with those for R&D? The BERD reports, for 2005, for the UK whole economy, 77,000 scientists and engineers working on civilian R&D and 17,000 working on defence (with respectively 24,000 and 2,000 and 25,000 and 4,000 "technicians, laboratory assistants" and "admin and clerical staff"). Now, for sector AD, which includes financial intermediation, miscellaneous business activities and technical and testing analysis" the data are 6,000, total, 3,000 scientists, and 2,000 technicians and 1,000 admin. Our numbers are of course very much higher than this, with over 30,000 "researchers" and "other researchers" in 2005 in Financial Intermediation.

Having chosen the occupations we believe are potential "knowledge" occupations we are now in a position to estimate implied spending on broad knowledge, or "R&D". To do this, we adopt the software method by taking the wage bill and assuming (a) the fraction of time each occupation spends on research activities (b) the mark-up on wage costs (due to overheads and ancillary costs) that firms incur on such workers. The resulting figure gives the "own-account" spending on broad knowledge activities. The method mirrors the spending in the official R&D survey, which asks for spending on R&D employees, including taxes, plus capital stock associated with such spending and other ancillary costs.

Establishing the fractions in (a) and (b) is a matter of ongoing research. Our data for overheads uses the standard assumptions in software (1.6). Turning to (a) for software the official data uses the results of industry consultations, cross-checked with other countries and we use this: they use, for example, a figure of 50% for software professionals and 15% for managers.

The fraction of time spent by research occupations in financial has not been examined systematically thus far by official data. We therefore undertook our own preliminary surveys as

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(respectively) of first degree leavers entered financial services, and just 2.9%/2.4% of leavers with doctorate degrees."

[11] Employment by occupation is complicated because of two different sources of employment data, the ASHE (Annual Survey of Employment and Hours) and the LFS (labour force survey). The ASHE is a sample of 1% of workers whom have a National Insurance number ending in a certain 2 digits. Employers fill out the survey and report occupation and wages, information on which is then weighted by ONS to be nationally representative. The LFS is a quarterly household survey where workers self-report wages and occupation. Relative to the ASHE, the aggregated employment data from the LFS is sometimes argued to be more accurate, whilst the wage and occupation data to be less accurate, the latter because there is considerable poor reporting in the wage data e.g. for respondents if householders are absent when the surveyor calls and likewise for occupations. In data available on request, we explored both surveys. Managerial employment and researchers are quite close, whereas the LFS has more software. We therefore used in our growth accounting the LFS software numbers, which are about 10,000 employees more than those set out in the table, which are therefore set out for illustrative purposes. We also, for compatibility with ONS data, allocated IT mangers to software.

follows. First, we were given access to an unpublished study of time allocation undertaken by the Council for Industry and Higher Education (2007) for the London office of a very large US-owned investment bank. This covered a number of different grades and occupations and suggested a figure of 50% for researchers, that is, 50% of their time is spend on asset-building activities. Second, we conducted interviews with two other London-based major banks and found a similar kind of figure. Clearly more needs to be done here, although since banking is so concentrated we have covered a rather large fraction of banks even with just a small number of firms.

Finally, on management, we have no time-use data and so will take 20%, the estimate used by Corrado, Hulten and Sichel (2005). Though it was not our main focus, we did ask about this in some of our interviews and this figure was not out of range.

To deal with the legion uncertainties around these data we also did the following. First, we report below robustness checks to different assumed time fractions and overhead rates. Our data for researchers are pretty robust to even large variations in this. Second, regarding managerial time, we do have two (albeit small) microdata surveys on intangible investment, set out in Haskel and Pesole (2009) and Barnett (2009). These papers use, respectively, intangible spending from the ONS pilot Intangible Investment Survey, carried out in Summer 2008 and the Warwick/Aston survey, carried out in Summer 2009. In both those surveys, respondents were asked directly about spending on organisational capital, including asking them to estimate managerial time. In both cases, the spending figure is remarkably close to the derived figure assuming 20% of managerial time. At the time of writing the new extended ONS survey, that asks companies for spending on all intangible assets is in the field, so this will provide vital extra information. Our current starting point is at least in line with the current data on this area.

Table 4 therefore sets out our base case data. Column 1 and 2 shows our assumed R&D spend, in £bn, for selected years due to researchers and "other researchers". Columns 3 and 4 are the data on software and organisational capital, purchased and own-account where own-account organisational capital is 20% of managerial wages and salaries in managerial occupations applied consistently across industries and the software data are official ONS data. As the data show, spending on other researchers is not large. But spending on researchers is about half that of total spending on software in recent times, but both less than spending on organisational capital.

Finally, for comparison columns 5 and 6 set out R&D in financial services. In column 5, we show R&D from the Department for Business Innovation and Skills (BIS) R&D scoreboard publication, giving R&D reported in company accounts[12]. This is £0.86bn, a fraction of 0.45% of

[12] According to the Scoreboard (2008) notes, the only type of R&D capitalised by banks is investment in the development of internally generated software. For a comparison see figure 8 where R&D as a fraction of sales in banks is very low (figure 8, p20).

sales in the lower panel. This number is well below that our research number and indeed below software, which accords with the point that only some software is allowable to be capitalised as R&D in company accounts.

Column 6 sets out our estimates of the spend as in the BERD data from ONS. The position here is rather complicated for it is hard to know what sector J firms report on when they report their R&D to the ONS. First, the R&D definition in the Frascati manual upon which BERD draws has changed somewhat over the years, with pre1992 excluding pretty much all R&D in financial services. Second, whilst in recent years the opening part of the form has asked for R&D not mentioning the word scientific, the final part asks firms to report scientists, technicians and related administrative workers, a classification that might make financial institutions not report their R&D work.

Third, as set out in Table 1, the reported BERD R&D data is for is reported for the sector AD which consists of SIC65, 66, 67 (financial intermediation, pensions, and auxiliary activities) plus SIC74 (other business activities). We wish to allocate the sector AD BERD spend data to the financial sector. There are a number of reasons to suppose that quite a small proportion should be allocated to J. First, ONS informed us that a very small number of financial firms actually returned the BERD, too small to pass disclosure (that is, under 10 firms). Indeed, the ABI, which forms the sampling frame for the R&D questionnaire was not sent to financial service firms and so another survey was required to form the sampling frame. Second, the R&D survey (until 2009) asks respondents to allocate employment into that covered by scientists, technicians and other R&D-related administrative areas. If we duplicate these classifications, using the Standard occupational codes from the ASHE for SICs 65, 66, 67 and 74, we find that 95% of scientists are employed in SIC74 (and 92% of technicians, but the bulk of technicians in Sector J are in the "not elsewhere classified" part of the technicians' occupation classification). Thus we decided to allocate 5% of the BERD spending for BERD sector AD to financial services. That figure, for 2006, is about £19m (allocating by total employment gives £92m).

What conclusions can we draw from this? First, the BERD data suggests a "research" spend of about $1/100^{th}$ of that from the researchers evidence. So "research" spend, we believe is underestimated by the BERD: instead of being 0.01% of sales it is 1.04% of sales. Second, spending on other knowledge assets is considerable; software investment for example is 2.14% of sales.

4 Productivity growth and innovation in financial services revisited

4.1 Output values and price indices in financial services

In constructing the official data, statistics agencies wish to measure the volume of output supplied by financial services. These type of services presumably include safekeeping of money, facilitation of financial transaction (e.g. providing overseas currency) and the process by which suppliers of credit and demanders are matched (the screening process). In addition, the bank might also provide financial products services such as vehicles to invest in particular assets etc.

The usual approach to measuring such a volume of services in other areas of National Accounts is to measure the value of such services and then deflate to get a volume. Direct volume measure are sometimes used when they are available (such as the volume of letters delivered, by class) and previous methods of measuring banking services used volume indicators such as the number of cheques processed (see Crespi at al, 2006 for a review). Thus the first question is what is the value of bank services. For those services that the bank sells directly e.g. processing a cheque, this can be measured. However, many services are not charged directly but instead are part of the margins that banks earn. For example, safeguarding money in the bank safe is not charged for explicitly, but is presumably covered in the margin between with the bank rewards lenders and charges borrowers. Thus the value of bank services is calculated as the sum of direct charges plus a value for these indirect charges. That indirect value is called Financial Intermediation Services Indirectly Measured (FISIM). It is calculated as the differential between the interest charged on loans or paid out on deposits and a "reference" or risk-free rate. So for example, a loan of £100,000 to the business sector (loans including mortgages to the household sector are defined as outside business sector activity) at 6%, with a reference rate of 2%, generates a FISIM value of 100,000*(6%-2%) = £4,000[13]. That £4,000 represents the value of financial services that the bank is providing to the business sector for the facility of arranging the loan and so is allocated as the output of a bank and the intermediate consumption of private non-financial corporations.[14]

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[13] This example is for illustrative purposes. The actual ONS method involves collecting data from Banks on the interest payments received and the stocks of loans or deposits. Therefore the implied interest rate margin is the interest payments divided by the loan stock; for an extended example of this in the US context, see Fixler, Reinsdorf and Smith (2003). For details on the UK, see Akritidis (2007).

[14] This is a new method implemented by ONS this year. In previous years, ONS had a hybrid method involving some volume indicators and some direct charges. They included as well the gap between interest received and paid out, but did not have a method to allocate these implicit flows of services across sectors (so for example, some lending is to households and some abroad and some is for final consumption and some for e.g. a mortgage which is an intermediate service to household production). Thus the entire gap between interest received and paid out was treated as intermediate

The incorporation of this idea to banking output has been only recently completed into UK data and is subject to quite a number of caveats. In the latest ONS data release (July 2009) there is for example a major jump in real bank output in 1999 which seems to correspond to changes in data collection arrangements. Similarly, the method has been called into question with the recent turmoil in financial markets, as reference rates have fallen essentially to zero and margins have risen, possibly due to the exercise of market power or a change in attitudes of banks to risk. Thus the measure that we use is that in EUKLEMS, which is a partial adoption of FISIM into financial services which does not appear to have any unusual patterns in it.[15]

The next question is what deflator should be used to get a value index from these volume measures. This is set out in Williams, Fender and Drew (2009). FISIM is deflated by the GDP deflator. The other output indicators are deflated by, in Banks and Building Societies, the "average earnings index AEI for Financial Intermediation, excluding bonuses – adjusted for changes in productivity". This reflects the unavailability of adequate price indices, and so the average earnings index is used instead with the assumption that the price of output is largely dependent on the price on the main input, labour, with the price adjusted for assumed changes in productivity. There are a number of issues here however. First, the index excludes bonuses for lack of data. This could be a substantial distortion depending upon how widespread bonuses are in the sector. Second, the productivity adjustment to the deflator of course automatically confers some productivity growth to financial services by construction, which turns out to be 0.27%pa.[16]

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consumption in a separate adjustment sector and so subtracted from bank value added. This typically reduced the share of banking in value added from around 6% to 3%.

[15] Insurance output is a direct volume indicator of the number of policies written. It is worth noting that controversy surrounds the conceptual ideas behind the FISIM adjustment in any case. So for example, Basu et al, (2008), Wang (2003) argue that it is not banks who take the risk of a loan but their shareholders. Thus the risk-free (e.g. the overnight inter-bank) rate is not the appropriate referenence interest rate to use and the FISIM method that uses this overstates bank output. Instead, the reference rate should incorporate a risk premium incorporating the systematic risk associated with loans. Their point is that this systematic risk of loans is borne by the bank's shareholders, and not by the bank itself and since they are not assuming that risk then the risk-assumption service should not be identified as part of bank output. As Scheryer points out in his comment the practical question is how to choose the appropriate risk-adjusted rate that reflects the required return to shareholders. As shown in WBF's model, the theoretically correct rate is the risk-free rate plus a risk premium for the representative consumer.

[16] ONS have reported to us that the productivity adjustment used is taken from the growth in GVA per Job for 'Total Services' (G-P), as published in the ONS First Release and is incorporated: Deflator growth = ((AEI growth - Prod growth Adj) + RPIY) / 2 where AEI is average earnings index and RPIY is the retail price index less alcohol and housing. . To get some idea of this adjustment, average growth in the AEI for Financial Intermediation (excl bonuses) is 3.7% from 2000-08. Average growth in labour productivity for total services over the same period was 1.7% (note the productivity adjustment used is that for total services rather than Private Sector Services, and so includes the public sector). Since 32% of monetary intermediation (65.1: Banks & BS) is deflated by this adjustment, then the everything else remained constant, real output in this sector would grow by 0.27%pa purely from the assumed productivity adjustment (0.32*[1.7%]/2).

4.2 *Productivity growth with intangibles: theory*

We now apply these ideas to the productivity growth data. For a full discussion, see Corrado, Hulten and Sichel (2004, 2006). Define the accumulation of tangible and intangible/knowledge capital as follows

$$\begin{aligned} \Delta K^{TAN} &= I^{TAN} - \delta^{TAN} K^{TAN} \\ \Delta K^{INTAN} &= I^{INTAN} - \delta^{INTAN} K^{INTAN} \end{aligned} \tag{1}$$

Where K^{TAN} is tangible capital stock (i.e. plant, machinery, industrial buildings, vehicles), I^{TAN} investment in K^{TAN} and K^{INTAN}, intangible capital stock (i.e. stock of knowledge in software, design, reputation, training, organisational capital etc.) , and investment in intangibles I^{INTAN}. If we suppose a consumption sector, producing final consumers goods from stocks of labour, tangible capital and intangible/knowledge capital; an investment sector, using the same inputs to produce investment goods and an "ideas" sector, producing new ideas from those inputs, a production function in each sector and perfect competition, we may write economy-wide output growth as

$$\Delta \ln V \equiv s_L \Delta \ln L + s_{K^{TAN}} \Delta \ln K^{TAN} + s_{K^{INTAN}} \Delta \ln K^{INTAN} + \Delta \ln TFP$$

(2)

where V is real value added and L is labour. Relative to the conventional approach, growth accounting is expanded, since we have an extra capital asset, namely K^{INTAN}. Note too that value added rises since there is more production, in this case of intangible capital and that increased value added is equal to a payment for the use of such capital, captured in the share of intangibles, s_K^{INTAN}.

Finally, it will be important to distinguish between product and process innovation. In the case of a process innovation, with competition all output goes to the lowest cost firm and prices falls in proportion to TFPG in the process innovation. In the case of a product innovation in one of the inputs, computers for example, that should be accounted for by the hedonic adjustment of computer, which follows US methods. In the case of a product innovation in output, statistical practice is not to quality adjust output. Thus the growth in real-quality adjusted output is faster than $\Delta\ln V$ in (2) and thus $\Delta\ln TFP$ is understated. See e.g. Hulten (2009).[17]

4.3 Growth accounting data and results

Before setting out our growth accounting results we give fuller details on the input measures on the right hand side of (2). The primary source of our data is the industry-level data from EUKLEMS (March 2008 release, the most recent at time of writing). Since the intangibles data by industry is only feasible for seven industry groups (Gil and Haskel, 2008) this is the level of aggregation we use (our industry groups are: 1 Agriculture, Fishing and Mining, 2, Manufacturing, 3 Electricity, Gas and Water Supply, 4 Construction, 5 Wholesale and Retail Trade, Hotels and Restaurants, Transport and Communications, 6 Financial Intermediation and 7 Business Services).

Beginning with L, it is often thought that financial services uses increasingly skilled labour and so we have to allow for this. Therefore, we use quality-adjusted person hours, taken from EUKLEMS which generates labour services by weighting growth in hours for different age/education and gender worker groups using wages.

Turning to tangible capital, these are the EUKLEMS measures consisting of 12 different capital groups. Real capital stocks, of both tangible and intangible capital, are build by a perpetual inventory method and then changes in log real stocks are weighted together by capital shares, the capital shares using rental rates endogenously determined to exhaust all factor payments including intangibles.

Turning to intangible capital, following CHS (2006) we distinguished between three main classes of intangible assets: i) computerised information (software and databases); ii) innovative property(R&D, mineral exploration, copyright, product development in finance, design) ; and iii) economic competencies (branding, firm-funded training, organisational investment).

Computerised information comprises computer software, both purchased and own-account, and computerized databases. Such data are already capitalised in the National Accounts and we use this data.

Innovative property consists of the following headings. For Scientific R&D performed by businesses in the UK, expenditure data are derived from the Business Enterprise R&D survey

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[17] In Hulten's model, define quality adjusted ouput $Q^E=V/P^E$ where V=PQ. Then $Q^E/Q=P/P^E$ and since $P^E<P$ i.e. quality corrected prices are less then observed prices, then $Q^E>Q$ i.e. a "better" good is like having "more of the good". In this model, Hulten derives $\Delta\ln TFP = \Delta\ln TFP^e - (\Delta\ln p - \Delta\ln p^e)$ where ΔlnTFP in efficiency units is denoted $\Delta\ln TFP^E$. This expression shows the relation between observed TFPG, which reflects process innovation and quality adjusted TFPG, which reflects process and product innovation and the term -($\Delta\ln p$ - $\Delta\ln p^E$). Assuming improvements in product quality, $\Delta\ln p^E < \Delta\ln p$, and hence -($\Delta\ln p$ - $\Delta\ln p^E$)<0. Thus observed ΔlnTFP grows more slowly $\Delta\ln TFP^E$.

(BERD). To avoid double counting of R&D and software investment, R&D spending in "computer and related activities" (SIC 72) is subtracted from R&D spending, since this is already included in the software investment data. Mineral exploration, and copyright and license costs are already capitalised in the National Accounts and our data here are simply data for Gross Fixed Capital Formation (GFCF) from the ONS. Products development cost in the financial industry are measured as set out above, being derived from occupations. Architectural and engineering design also uses the software method for own-account, using the wages and salaries of designers outside the design industry, and purchased data are taken from the supply-use Input Output (IO) tables. Full details are set out in Galindo-Rueda et al (2008). Finally, we add 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.

The final group of intangible spending is economic competencies. Advertising expenditure is estimated from the IO Tables by summing intermediate consumption on Advertising (product group 113) across all industries. Firm specific human capital, is estimated from cross sections of the National Employer Skills Survey (NESS 2004, 5) and a one-off survey from 1998. Finally, as above, investment in organisational structure relies on purchased management consulting, on which we have used the Management Consultancy Association (MCA), and own-account time-spend, as above.[18]

Table 5 sets out the share of investment in the particular asset in the indicated industry as a share of total investment of the same asset in the total market sector. Thus, looking at column 1 for example, in 2000, manufacturing accounted for 19% of software investment, 79% of R&D investment, 33% of design etc. Financial services is much less R&D intensive (R&D here includes our imputed R&D figure based on occupations) but very software intensive, accounting for 21% of all market sector software investment. This is considerable bearing in mind the size of financial services. Likewise, there is a large share of investment, relative to employment or value added share, in brand equity and organisational capital.

Table 6 sets out the results of applying this framework for financial and business services (sector J to K, but excluding real estate) for 2000-2005, with J and K, financial intermediation and business services, separately. In the upper panel, which uses EUKLEMS data, we set out the data for manufacturing and retail, hotels and transport (for comparison) as well. In this panel, the only assets are tangible capital assets and (quality adjusted labour). The tangible assets are split into ICT-hardware (which is computers and communications equipment) and other tangible capital assets.

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[18] Confirmation of the applicability of these assumptions clearly needs better microdata. From the patchy evidence we have so far, Barnett (2009), these assumptions do not look too far off.

In the lower panel, we include intangible capital assets. These assets are software plus the all intangible spending set out in the data above. We report software, R&D (which in finance is our measure derived from researcher time but otherwise is BERD R&D), brand equity, firm-financed human capital and organisational capital.

The top panel shows slow LPG in financial services relative to manufacturing, retailing and business services (2.94%pa against 3.79%pa , 3.03%pa and 1.93%pa). The total capital deepening column shows that in manufacturing 8% (0.30/3.79) of LPG is due to total capital deepening, with 33%(0.09/0.30) of that capital deepening due to ICT. By contrast, in TFPG is about 25% of LPG. In Financial Services, almost 50% of LPG is TFPG (1.4/2.94). Of the capital deepening all of it (135%) is due to ICT-hardware. In business services almost a quarter of LPG is due to capital deepening which in turn is mostly due to ICT. TFPG is about 33%.

Thus the conventional results stress the importance of software and hardware in financial services, but leave other intangibles in the TFPG term, which is itself 50% of LPG. Can the augmented approach give more information?

The lower panel shows the augmented approach with all intangibles. First, TFPG is now 11% of LPG in manufacturing and retailing (0.42/3.74 and 0.31/3.06) and 31% in financial services (0.89/2.89). It is of interest to notice that TFP in business services once we account for intangible goes to a very small number, only 5%. So our first result is that whilst TFPG in finance is relatively high, which is to be expected if products are costless to imitate, it has gone from 50% of LPG to 31%.

Second, consider capital deepening. In finance, intangible capital deepening accounts for around 50% of that total capital deepening, with the bulk of the contributions from software, organisational capital, training and product design. The contribution of software (0.13%pa) in finance is larger than that of manufacturing and retail (both 0.08%pa), according with the intuition that software-related capital deepening is important in financial services. The contribution of organisational capital (0.14%pa) is similar to that in other sectors, but a higher fraction (around 5%) of LPG. Hardware is also very important in financial services, with half of capital deepening due to hardware (in manufacturing and retail the figures are 9% and 11% of total capital deepening), again suggesting the importance of ICT in the sector. Indeed, the sum of hardware and software contributes 20% of (gross output) LPG in financial services as opposed to 14% in retail and 5% in manufacturing.

We also undertook a number of robustness checks. First, to guard against double counting we subtracted the BERD R&D spend from our research occupation measure, but the results were almost identical. Second, we halved the fraction of managerial time allocated to knowledge building to 10% (full results reported in the appendix). This did affect the results, essentially raising financial services TFP by 0.06pppa, and lowering the contribution of organisational capital to 0.06pppa (changing the time again to 5% hardly changed the 10% result in fact). It is worth noting that the effect in manufacturing was very small. So clearly for service industries this is an area worth examining more.

There are clearly a number of issues that we might want to address in future work. Firstly, the measurement of output in financial services is clearly not easy, but the approach here is consistent with National Accounts conventions. Second, we do not have a very good measure of prices in financial services, which might again be examined. Third, to do growth accounting one must assume perfect competition so that factor shares measure the (unobserved) output elasticities. To some extent this does not matter in this exercise, since we are most interested here in how the LPG and TFPG picture changes when one moves from excluding intangible assets to including them. Such a conclusion is not of course affected by the degree of imperfection in competition.

Finally, we clearly need better micro measures to back up the macro assumptions. An extended R&D survey is currently in the field that asks both R&D but also intangible assets questions, the results of which should be available early 2010.

5 Conclusion

We have re-examined innovation, productivity and total factor productivity in financial services. We have done this by calculating knowledge spending taking account of the wider spending on knowledge indicated by detailed studies of financial innovation. These studies suggest spending on software, training, marketing and organisations are integral to financial innovation, as well as copying of innovation from other companies. Using this approach changes TFPG from around 50% of LPG to 31% of LPG, reducing the "measure of our ignorance" but confirming that TFPG is important in financial services, as case studies suggest. It also confirms the relative importance in financial services of ICT (software and hardware spend): they account for twice as much LPG as in manufacturing and retail. Finally, it suggests important contributions from organisational spending and training.

Future work will of course look at many areas in this paper, such as the time spent on research activities and better measurement of TFP in imperfect competition situations. But this paper suggests this intangibles approach is likely to be worth exploring further.

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Table 1: UK Industry Classifications and relation to BERD industry sector classification AD

NACE, A-17	SIC code	Description	BERD sector AD	This paper
	65	Financial intermediation, except insurance and pension	√	Financial services
	66	Insurance and pension funding, except compulsory social security	√	Financial services
J	67	Activities auxiliary to financial intermediation	√	Financial services
	70	Real estate, renting and business act's		
	Of which: 70.1	*Real estate activities with own property*	√	*Business services*
	70.2	*Letting of own property*	√	*X*
	70.3	*Real estate activities on a fee or contract basis*	√	*Business services*
	71	Renting of machinery and equipment	√	Business services
	72	Computer related activities	X	Business services
	73	Research and development	X	Business services
K	74	Other business activities	√	Business services

Notes: the BERD classification covers the indicated SICs where ticked. BERD classification is called "Miscellaneous business activities, technical and testing analysis". In the paper, if we quoted BERD data for a subsector of the AD sector, this is prorated data by employment, where the employment data is taken from EUKLEMS. The 2005 data by SIC and employment is as follows: SIC65, 66, 67, 70, 71, 72, 73 and 74 are 623, 207, 253, 440, 160, 589, 102, 3497.
Source: SIC (2003) and EUKLEMS industry definitions

Table 2 : "Knowledge Occupations in Financial Intermediation"

soc 2000	Description
	Managers
1131	Financial managers and chartered secretaries
1132	Marketing and sales managers
1136	ICT managers
1137 1142	Research and Development managers Customer care managers
1151	Financial institution managers
	Researchers
2423	Management consultant, actuaries, economist and statisticians
2126	Design and development engineers
2321	Scientific researchers
2322	Social science researchers
2329	Researchers n.e.c.
	ICT
2131	IT strategy and planning professionals
2132	Software professionals
	Other Researchers
2431	Architects
3122	Draughtspersons
2433	Quantity surveyors
2434	Chartered surveyors
2122 2125	Mechanical eng Chemical eng
2121 2123	Civil eng Electrical eng
2124	Electronics eng
2128	Planning and quality control eng

2127	Production and process eng
2129	Engineering professional
2112	Biological scientists and biochemists
2113	Physicist,geologist and meteorologist
2111	Chemists
2212	Psychologists
2432	Town planners

Source: ONS, SOC classifications 2000.

Table 3: Employment in ASHE by broad occupational classification

Year	Managers	IT professionals	Researchers	Other researchers	Total
2002	212,082	32,110	20,395	5,884	270,471
2003	272,040	37,024	22,355	6,460	337,879
2004	263,724	38,006	22,166	6,715	330,611
2005	276,790	35,903	24,787	6,938	344,418
2006	255,782	40,660	29,039	6,812	332,293
2007	282,550	43,206	35,421	5,358	366,535
2008	288,224	40,619	33,186	5,042	367,071

Notes: Each column reports the weighted to population figure for the different occupation categories. Please refer to table 2 for the SOC 2000 detailed code.

Source: Authors' computation on ASHE.

Table 4: Knowledge spending in financial services

Year	Researchers	Other researchers	Software	Managers	R&D, DIUS scoreboard	R&D, BERD
investment in £bn						
1990	0.5	0.08	1.1	.		0.004
2000	1	0.1	3.2	3.5		0.006
2004	1	0.2	3.7	4.4		0.017
2006	1.8	0.2	4.1	5.1	0.86	0.019
as a % of sales						
1990	*0.78%*	*0.13%*	*1.73%*			*0.01%*
2000	*0.83%*	*0.08%*	*2.66%*	*2.91%*		*0.00%*
2004	*0.62%*	*0.12%*	*2.31%*	*2.75%*		*0.01%*
2006	*0.94%*	*0.10%*	*2.14%*	*2.67%*	*0.45%*	*0.01%*

Notes: The top panel reports spending (£bn) from different sources. The second panel shows the percentages of R&D financial spending in nominal Gross Output. The first four columns are data based on calculations in this paper, with columns 1 and 2 from the researacher data set out above. Column 3 and 4 are based on respectively official ONS software data and an assumed fraction (20%) of managerial time. Column 5 is the DIUS R&D scoreboard for financial services, which is R&D spend from accounting data (that is, part of software spend) and column 6 is official data from BERD allocated between financial services and other services as set out in the text.

Source: Authors' computations, EUKLEMS, BERD, R&D BIS scoreboard

Table 5: Share of Intangible Investment by industry and asset.

Year	2000		2006	
Intangible assets	Manufacturing	Financial Services	Manufacturing	Financial Services
Software	0.19	0.21	0.15	0.22
Total R&D	0.79	0.07	0.78	0.07
AED	0.33	0.07	0.28	0.07
Brand equity	0.21	0.20	0.17	0.17
Firm-human capital	0.21	0.07	0.13	0.05
Organisational capital	0.25	0.19	0.25	0.19

Notes: Each cell is investment in the particular asset in the indicated industry as a share of total investment of the same asset in the total market sector.

Source: See text

Table 6: Growth Accounting, 2000-2005, excluding intangibles, selected industries

	Excluding intangibles						
	Labour Productivity	Capital Deepening			Labour Quality	Intermed Input Deep	TFPG
		Total	ICT Tangible	Non-ICT Tangible			
Manufacturing	3.79	0.3	0.09	0.2	0.29	2.31	0.89
Retail, Transport and Hotels	3.03	0.56	0.33	0.23	0.22	1.64	0.61
Financial Services	2.94	0.34	0.47	-0.14	0.27	0.93	1.4
Business Activities	1.93	0.51	0.38	0.13	0.3	0.48	0.64

Notes: The table reports selected industries, other industries are Agriculture, Construction, Gas, Electricity and Water. The data are average growth rates per year 2000-2005. The first column is growth in industry gross output per hour. Column 2 is the total contribution of capital services per hour, namely growth in capital services per hour times share of capital in Gross Output (GO). Column 3 is growth in computer capital services times share in GO. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) times share in GO. Column 5 the contribution of labour services per hour, namely growth in labour services per hour times share of labour in GO. Column 6 is the contribution of intermediate inputs per hour, namely growth in intermediate inputs per hour times their nominal share in GO. Column 7 is TFPG, namely column 1 minus the sum of columns 2, 3 and 4.

Source: Authors' computations

Including all intangibles

	Labour Productivity	Capital Deepening										Labour Quality	Intermed Input Deep	TFP
		Total	ICT Tangible	Non-ICT Tangible	Intangible capital	Software	Total R&D	AED	Brand equity	Firm-human capital	Organisational capital			
Manufacturing	3.74	1.21	0.1	0.24	0.87	0.08	0.37	0.12	0.03	0.11	0.16	0.29	1.82	0.42
Retail, transports and hotel	3.06	1.08	0.35	0.26	0.46	0.08	0.02	0.05	0.05	0.16	0.1	0.22	1.46	0.31
Financial Services	2.89	0.75	0.43	-0.08	0.39	0.13	0.03	0.05	0	0.05	0.14	0.27	0.98	0.89
Business activities	2.18	1.32	0.4	0.15	0.78	0.13	0.03	0.18	0.07	0.24	0.13	0.3	0.48	0.07

Notes: The table reports selected industries, other industries are Agriculture, Construction, Gas, Electricity and Water. The data are average growth rates per year 2000-2005. The first column is growth in real gross output per hour. Column 2 is the total contribution of capital services per hour, namely growth in capital services per hour times share of capital in Gross Output (GO). Column 3 is growth in computer capital services times share in GO. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) times share in GO. Column 5 is growth in intangible capital services times share in GO. Columns 6-11 are the breakdown contribution by asset of intangible capital services per hour; respectively the shares in gross output times growth per hour in software, R&D (including for financial services R&D derived from research occupations, as set out in the paper), AED (architecture, engineering and design), Brand equity (investment in marketing and branding), Firm-specific human capital (training financed by firms) and organisational capital (namely investment in management consultants for bought in spending and 20% of managerial time for own account). Column 12 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in GO. Column 13 is the contribution of intermediate inputs per hour, namely growth in intermediate inputs per hour times their nominal share in GO. Column 14 is TFP, namely column 1 minus the sum of columns 2, 12 and 13.

APPENDIX

The table below reports growth accounting decompositions for managerial on own-account organisational capital formation assumed to be 10% of time as opposed to 20% in the baseline results above.

Appendix Table 1: Growth Accounting, 2000-2005, robustness check assuming 10% of managerial time is on organisational capital building

	Including all intangibles													
		Capital Deepening												
	Labour Productivity	Total	ICT Tangible	Non-ICT Tangible	Intangible capital	Software	Total R&D	AED	Brand equity	Firm-human capital	Organisational capital	Labour Quality	Intermed Input Deep	TFP
Manufacturing	3.75	1.12	0.1	0.23	0.79	0.08	0.37	0.12	0.03	0.11	0.08	0.29	1.92	0.43
Retail, transports and hotel	3.05	1.02	0.35	0.26	0.41	0.08	0.02	0.05	0.05	0.16	0.05	0.22	1.48	0.33
Financial Services	2.9	0.67	0.43	-0.08	0.32	0.13	0.03	0.05	0	0.04	0.07	0.27	1.01	0.95
Business activities	2.14	1.25	0.39	0.15	0.71	0.13	0.03	0.18	0.07	0.24	0.06	0.3	0.48	0.11

Notes to table., please refer to note table 7 above.