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Innovation and Intangible Investment in Europe, Japan and the US

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Innovation and Intangible Investment in Europe, Japan and the US*

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Abstract

This paper sets out theory and measurement of how intangible investment might capture innovation and what data on intangibles looks like for the EU, Japan and the US. We also look at complementarities between ICT and intangibles, spillovers from intangibles to growth and policy implications.

*Contact: Jonathan Haskel, Imperial College Business School, Imperial College, London SW7 2AZ, j.haskel@imperial.ac.uk. This paper is prepared for *Oxford Review of Economic Policy*. This draft is based heavily on a longer paper "Intangible Capital and Growth in Advanced Economies: Measurement Methods and Comparative Results", available along with all data used here at www.intan-invest.net. That paper discusses many of the details briefly dealt with here: this paper has updated US results and adds results for Japan. We are very grateful for comments to Steve Nickell, and an anonymous referee and participants at an OxRep meeting in December 2012. We are grateful for financial support from the EU FP7 in developing previous versions of these data and to Kyoji Fukao and Tsutomu Miyagawa for kindly supplying the Japanese data. Errors are our own.

1 Introduction

Everyone seems to think Europe needs some innovation. Innovation to improve a broken financial system, innovation to shore up the Eurozone, innovation to boost economic growth. So we have a profusion of agencies, indices and think tanks competing to offer ideas. The UK produces an innovation index.[1] The EU an innovation scoreboard.[2] The OECD an innovation strategy.[3]

But what exactly is innovation? How is it measured? What policy works and what should be discarded? Among this melee of activity, there seems surprisingly little agreement. The Lisbon strategy set the EU a target of 3% of EU GDP to be spent on R&D by 2010. When this was missed, the target was downgraded to an aspiration. Should policy-makers upgrade the target? Act on universities? Immigration? Improve the internet? Perhaps vested interests are drowning out the good advice of academics. Or perhaps the academic community is still not settled on what it wants to say.

This paper starts in section 2 by reviewing a number of different approaches to innovation. In section 3 its sets out an integrating framework to understand them all. Sections 4-6 implements just one approach, based on intangible assets and sets out just what we know about intangible investment, innovation and competitiveness in the EU. It uses the latest comparable data for Europe, US and Japan, freely available at www.intan-invest.net and suggests how this work might be built upon to answer these difficult questions. A longer discussion of many of the issues herein may be found in Corrado, Haskel, Jona-Lasinio and Iommi (CHJI, 2012).

2 A preview: the many approaches to innovation

In this section we document at least four broad approaches to measuring innovation and show they seem to indicate very different cross-country rankings. We offer a way to interpret them in section 3.[4]

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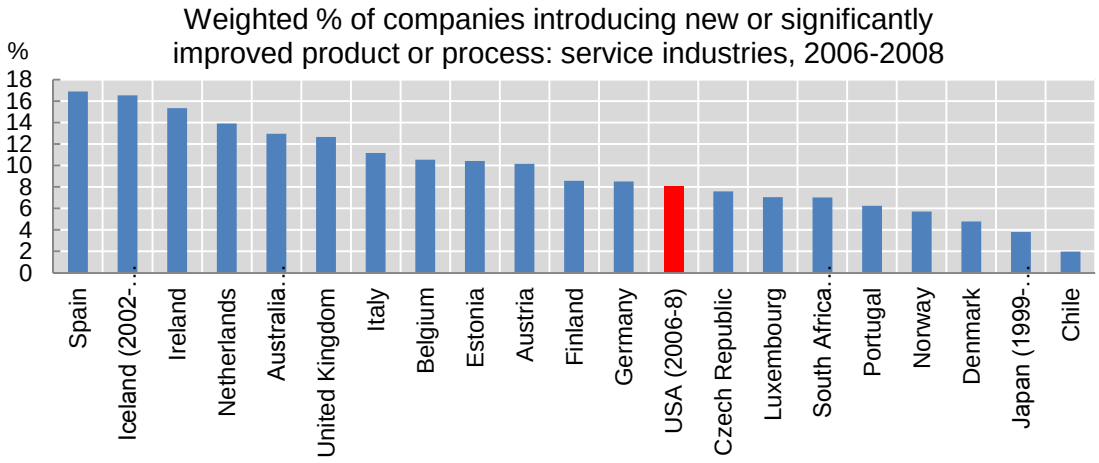
[1] http://www.nesta.org.uk/areas_of_work/economic_growth/the_innovation_index.
[2] http://www.proinno-europe.eu/EIS2008/website/docs/EIS_2008_Final_report.pdf.
[3] http://www.oecd.org/innovation/strategy
[4] Other comparisons can be found in Jensen and Webster (2009) and OECD (2010).

2.1 Innovation output indicators

There are two main approaches here. First, innovation surveys. Eurostat mandates all signatory countries to survey businesses asking them to self-report how innovative they are on the Community Innovation Survey.[5] A typical question on the survey is, for example, *"Over the last three years, did this business introduce (a) new or significantly improved goods? (b) new or significantly improved services*? (this wording is taken from the UK survey).[6] A second approach is to use indicators such as patents, trademarks or copyright as an indicator of innovation output. Other indicators are items such as published scientific articles.

Figure 1 sets out a measure of innovation from innovation surveys, namely the -weighted percentage of service sector companies answering "yes" to the question of whether they introduce a new significantly improved product or process innovation over the three years 2006-8. The most innovative countries according to this measure are Spain and Iceland. Only 9% of US companies replied yes to this question: Japan and Chile are the least innovative (in manufacturing, the typical number is 15%, Ireland and USA are at the top, Germany and Japan at the bottom).

Figure 1. comparative innovation data from cross-country innovation surveys



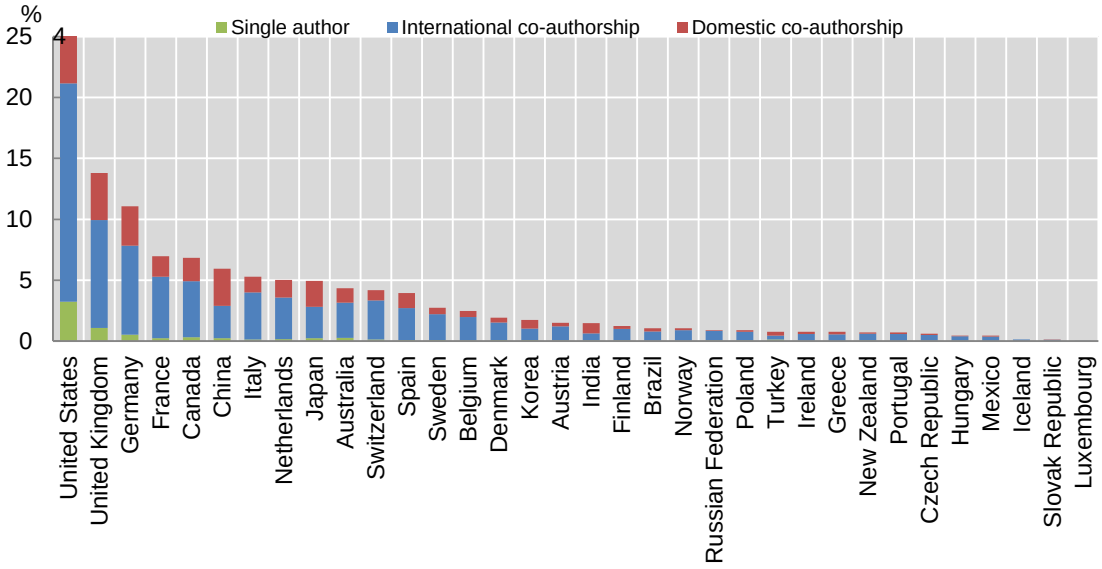
Source: US data: Boroush (2010), Other: OECD (2010), p.26

[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis. Some UK results on this are in http://www.dius.gov.uk/innovation/innovation_nation/~/media/publications/2/21390%20AIR%20Report%20AW%20Complete.

[6] http://www.bis.gov.uk/assets/biscore/corporate/docs/c/cis6-2006-2008-questionnaire.pdf

Figure 2 sets out the authorship of the most cited 1% of published scientific articles, 2006-2008. The innovation leaders here seem to be the US, UK and Germany, with Iceland and Ireland (who are very high in Figure 1) lagging.

Figure 2 Authorship of the most cited 1% of published scientific articles, 2006-2008, for OECD countries



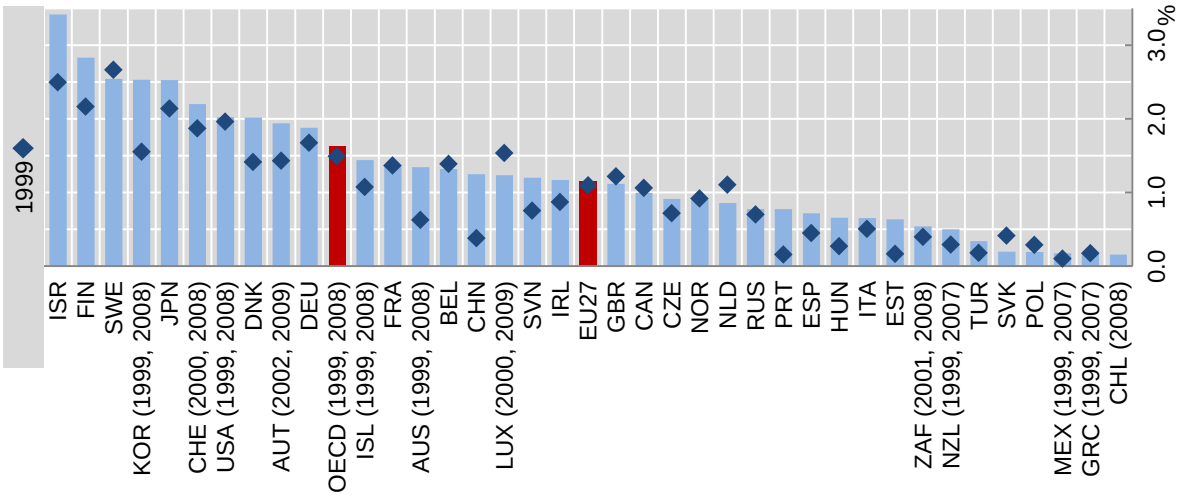
Source: OECD Measuring Innovation, 2010, dx.doi.org/10.1787/836087047406

2.2 Innovation Inputs

The main approach here is R&D spend, which is measured in many countries more or less according to standard accounting rules: typically summing wages of R&D workers and their use of materials and capital (such as laboratories). The latest SNA (2008) mandates countries to capitalise R&D in their national accounts, which will lead to an explicit R&D account.

Figure 3 sets out business investment in R&D as a share of GDP, a measure that puts Israel, Finland, Sweden, Korea and Japan at the top, and Poland, Mexico, Greece and Chile at the bottom.

Figure 3: Business investment in R&D as a share of GDP, 2009, OECD countries



Source: OECD STI Scoreboard, June 2011, Figure 2.7.1

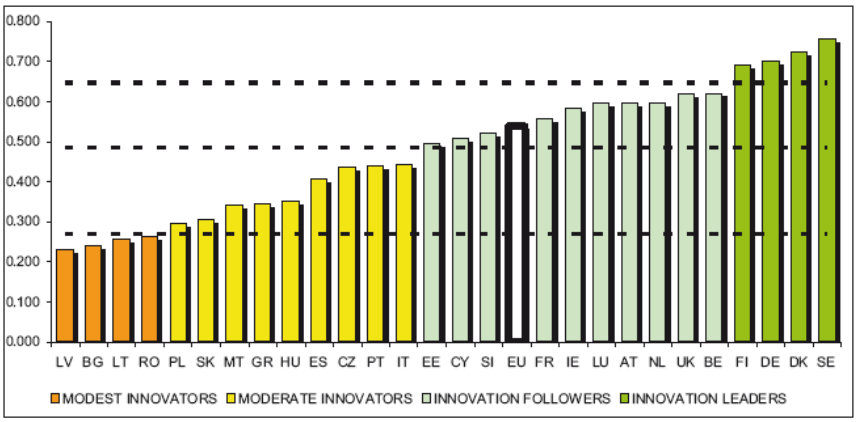
2.3 Innovation inputs and outputs combined: the EU scoreboard method

This method is a kind of multiple indicators method exemplified in the multi-year, multi-country EU innovation scoreboard.[7] It is a weighted average of 24 indicators for each EU country, with the indicators ranging from GDP, R&D spend, ICT spend, exports of high technology products and broadband penetration.

Figure 4 sets out these data. The most innovative countries Sweden, Denmark, Germany and Finland, with Latvia at the bottom.

Figure 4: EU innovation scorecard, 2011

[7] http://ec.europa.eu/enterprise/policies/innovation/files/ius-2011_en.pdf
.



Note: Average performance is measured using a composite indicator building on data for 24 indicators going from a lowest possible performance of 0 to a maximum possible performance of 1. Average performance in 2011 reflects performance in 2009/2010 due to a lag in data availability.

Source: Innovation Union Scoreboard, 2011,

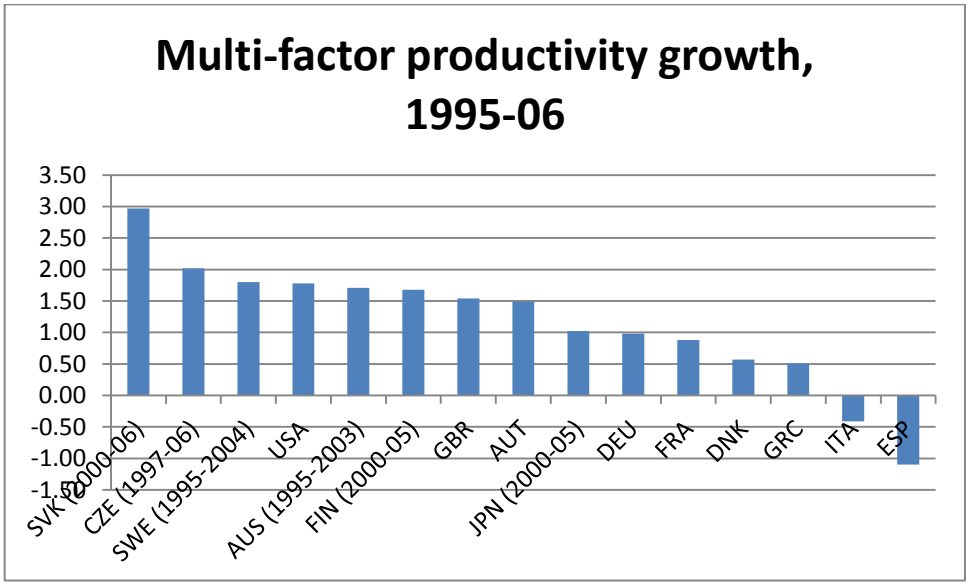
2.4 Growth accounting: outputs net of inputs.

The above methods cover innovation (a) outputs; (b) inputs; or (c) inputs and outputs. A final method employed by many economists is outputs net of inputs, namely multi-factor productivity.[8]

Figure 5 sets out multi-factor productivity growth (excluding the intangible assets that we shall detail below) for a series of countries, 1995-06, with Slovakia, Czech Republic and Sweden uppermost, and Greece, Italy and Spain at the bottom.

[8] To those unfamiliar with the term, the essence of the method is described by Jorgenson (2007). To understand innovation, he argues, start by asking this: how can an economy grow with *no* innovation? It can just add more inputs: airlines use more planes, McDonalds employ more burger flippers, movie companies hire more actors. This is *duplication* of physical or human capital. Innovation is using more ideas i.e. more knowledge capital. So innovation is that part of growth due to using more ideas. Using more ideas is hard to measure, but using more physical capital and machines is easier to measure, and so economists measure innovation as a residual. That is, growth due to ideas is growth net of duplication, or the part of output growth (if any) over and above increased use of physical capital and/or people.

Figure 5: Multi-factor productivity growth, 1996-06, selected OECD countries.



Source: OECD, Science, Technology and Industry Scoreboard, 2011, Figure 1.7.

3 Understanding these approaches: an integrating framework

These approaches come up with very different country rankings. How can we better understand this? This section sets out a simple model which (a) integrates the various approaches to innovation set out above and (b) further integrates innovation into the national accounts to make it measureable.

3.1 Production relations and factor payments

Consider a simplified economy with just two industries/sectors (this model is based on Corrado, Hulten, Sichel, (2005, 2009), and is set out in more detail in Corrado, Haskel, Goodridge, 2011).

(a) an "innovation" or "upstream" sector. This sector produces new finished ideas i.e. it commercializes knowledge.

(b) a "production" or "downstream" sector". This sector uses the knowledge to produce final output.[9]

[9] By "final" output we mean output for sale to consumers or for export or investment (that is, for simplicity this sector does not produce intermediate output).

Assume the following. First, the upstream sector uses ideas for free, e.g. from universities. It then produces "finished" ideas or commercial knowledge: think of a blueprint, which and can be licensed to users. Let the commercialised knowledge have an asset value $P^N N$ and the per period licensing fee users must pay to use the knowledge be PrR (so for example, buying a patent outright costs $P^N N$, whereas renting the knowledge stock R embodied in it costs $P^R R$ per year). This implicitly assumes that the upstream sector can, at least for some period, appropriate returns to its knowledge, and so this model is identical to Romer (1990) (where patent-protected knowledge is sold at a monopoly price to the final output sector during the period of appropriability).

The downstream sector does not produce ideas, but rather consumption and investment goods whose value is given by $P^Y Y_t = P^C C_t + P^I I_t$. We assume however that the downstream sector pays for ideas from the upstream sector to effect this production. The downstream sector is assumed a price-taker for knowledge; by contrast the upstream sector has market power e.g. a patent on knowledge.

With these assumptions in hand, we are in a position to write down the production functions and factor payment equations for the two sectors, they are written as follows:

$$N_t = F^N(L_t^N, K_t^N, R_t^N, t^N); \quad P_t^N N_t = \mu(P_t^L L_t^N + P_t^K K_t^N) \tag{1}$$

And

$$Y_t = F^Y(L_t^Y, K_t^Y, R_t^Y, t^Y); \quad P_t^Y Y_t = P_t^L L^Y{}_t + P_t^K K_t^Y + P_t^R R_t^Y \tag{2}$$

On the left of these equations are the production functions describing how inputs are transformed into outputs. The production functions have three factors of production, stocks of labour (L), stocks of capital (K), and stocks of knowledge (R), superscripted by N or Y depending on sector of usage. The term t captures anything that shifts the production function but is not paid for e.g. free knowledge or inspiration. On the right of these expressions are the factor payment equations that describe the payments to the factors of production. In the factor payment equations, P^L and P^K are competitive factor prices for services supplied, per unit of labour and capital input, respectively

In the upstream factor payments equation, there are no payments to basic knowledge, i.e. $P^R R^N$ does not appear, because its services are assumed free, from universities say, and determined outside the model. The parameter $\mu \geq 1$ measures upstream market power, the

"innovator" markup over competitive factor costs of inputs used up in the innovation process. By contrast, in the downstream payments equation, the downstream sector pays to use the knowledge stock. Thus it "rents" two capital stocks: the *physical* capital stock and the *knowledge* capital stock, for which it pays rental payments $P^K K^Y$ and $P^R R^Y$ respectively. Of course, the downstream sector might in addition be using some ideas that it does not pay for. These will not show up in any factor payments, but rather are "costless" shifts in the production function t^Y. A similar interpretation holds for t^N in the upstream production function.[10]

The stock of commercial knowledge (R^Y) is the accumulated output of upstream production (N), and grows via the perpetual inventory relation:

$$R_t^Y = N_t + (1-\delta^R)R_{t-1}^Y \tag{3}$$

where the term δ^R is the rate of decay of appropriable revenues from the existing stock of commercial knowledge. An analogous equation determines the stock of physical capita

$$K_t^Y = I_t + (1-\delta^K)K_{t-1}^Y \tag{4}$$

The depreciation of knowledge δ^R, is discussed in the case of private R&D by Pakes and Schankerman (1984). As they point out, the deprecation of physical capital δ^K is well established and is commonly thought *physical decay*: that is, a fall in the physical ability of tangible capital to render capital services due to wear and tear. It is then sometimes asked how such a concept can be applied to *intangible* capital, given that it is unlikely to wear out. However, this is not the right interpretation of the term. What is required is a measure of how the value of the usable stock of intangible capital varies over time and it can fall for at least two reasons (a) because new ideas are invented that make old ones obsolescent (or ideas partially "leave" the firm if there are partially embodied in departing workers) and (b) because it might become increasingly difficult for firms to appropriate benefits from knowledge as e.g. knowledge leaks out to competitors (e.g. via patent expiry). Both these considerations might

[10] Corrado, Goodridge and Haskel (2011) discuss how these assumptions can be relaxed. One might also have the upstream sector paying for ideas from universities which would involve another rental term in the upstream equation. Another way to think of the model is to imagine the upstream sector as a platform producer, who then sells versions of ideas downstream (e.g. Microsoft produces Office and then sells successive versions downstream).

make one think that knowledge decays very fast, the polar opposite of the "wear and tear" idea that it does not decay at all.[11] For further discussion see below. [12]

3.2 Value added, growth and innovation predicted by the model

Real value added in the whole economy, Q, is the sum of the outputs of the two sectors, which we denote $P^Q Q$ with real growth rate dlnQ, which are given by

$$P^Q Q = P^Y Y + P^N N = P^C C + \underbrace{P^I I + P^N N}_{\text{Total Investment}}$$
$$d\ln Q = s_Q^Y d\ln Y + (1 - s_Q^Y) d\ln N, \qquad s_Q^Y = \frac{P^Y Y}{P^Q Q} \tag{5}$$

What is the intuition for the top equation in (5)? GDP includes a broad concept of investment, here $P^N N$. 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 value added should be properly treated as *both* the final aeroplanes *and* the machines i.e. one might think of the factory as consisting of both an aircraft factory and also a machine factory. Now suppose the factory also writes its own long-lived software to run the machines. Then we should think of it as *both* an aircraft factory *and* machine factory *and also* a software factory, which is what (5) says.

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[11] This view suggests too that δ varies according to (1) aggregation (e.g. it might be relatively fast for a firm,. but slower for an industry) (2) producer (e.g. it might be zero for the public sector if they are producing basic research not exposed to the competitive process that might make it obsolete) and (3) technology.

[12] For completeness, in the downstream factor payments equation, P^R is the price of renting a unit of the finished knowledge stock (e.g., a license fee for a patent or blueprint or product version). The Jorgenson (1963) user cost expression gives the relationship between P^N, the price of a unit of newly produced finished knowledge (an investment or asset price), and its unit rental price: P^R, $P_t^R = P_t^N (r_t - \pi_t^R + \delta^R)$, where r_t is the net rate of return common to all capital in year t (taxes are ignored) and π_t^R is the expected capital gain (loss) on intangible capital, i.e., the expected rate of change of P^N. The model is completed by an analogous asset price equations for physical capital namely $P_t^K = P_t^I (r_t - \pi_t^K + \delta^K)$.

Aggregating value added inputs across the sectors yields an expression for the sources of growth in value added output as, where s_Q is the share of nominal value added accounted for by payments to the particular factor:

$$d\ln Q = s_Q^{\ L} d\ln L + s_Q^{\ K} d\ln K + s_Q^{R} d\ln R + d\ln TFP \tag{6}$$

where $L = L^Y + L^N;\ \ K = K^Y + K^N;\ \ \text{and}\ R = R^Y \cdot$ and dlnTFP is defined as the growth in Q over and above the growth contributions of L, K and R (which are in turn their growth rates, times their factor payment shares in total value added). The use of factor shares assumes that factors are paid their marginal product so that μ=1 in the upstream sector although the approach can be modified to account for market power (or scale economies) as in Hall (1988). The model written above with u>1 then is a modification that allows only innovators to have market power.

3.3 Understanding the different approaches

Consider (6). This says that value added growth is due in part to growth in L and K. This formalises the idea that growth can be achieved by *duplication* i.e. adding more labour and physical capital.[13] It further says that growth can be due to the increased use of paid for ideas, dlnR, but they have to be paid for to be used, and hence make a contribution to dlnQ of $s_Q^{\ R}$ dlnR. The final term, dlnTFP is the growth impact of everything else, which in this model can only be free ideas used in both sectors (and is in fact a Domar-weighted average of $dlnt^Y$ and $dlnt^N$). Thus in this model, innovation in the sense of use of ideas is also growth net of K and L usage, i.e.

$$Innovation = s_Q^{R} d\ln R + d\ln TFP \ \ = d\ln Q - \left(s_Q^{\ L} d\ln L + s_Q^{\ K} d\ln K \right) \tag{7}$$

This then helps understand the sources-of-growth/outputs net of inputs approach. What of the other approaches?

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[13] In this discussion we abstract from the fact that some part of technical advance is embodied in equipment, or that capital stocks measured in constant quality terms count "better" machines or airplanes as "more" machines or airplanes.

First, surveying firms to ask how innovative they are could in principle get at some of the elements of (7). Recall that firms are asked if their products and services are "new or significantly improved". This could perfectly well capture dlnQ: output of a new drug for example. A well-known issue however is that much depends on how firms understand "significantly" (is the iPhone 5 "significantly" improved?). Much too depends on how firms think of their new capital equipment when answering the questionnaire. In (7) an airline buying new planes is *not* innovation (i.e. dlnK is subtracted out), since the new plane is likely innovation in the aircraft industry and so we don't want to double count it.[14]

To look at how firms treat new capital equipment in answering the questionnaires, Crespi et al (2007) analysed the text replies for a certain UK Community Innovation Survey year where firms were asked to fill in a text description of their "innovations". Many of the replies described an innovation as being the deployment of a new machine (indeed, this tallies with the time series observation that reported innovation rose very strongly during the ICT spending boom of the late 1990s). All this suggests that in innovation questionnaires, firms might be reporting on both dlnQ and also dlnK, which is not what (7) requires and runs the risk of double counting if innovation is counted by the firm producing the new capital and the firm installing it. So, innovation questionnaires may be hard to compare between firms at a point in time (if they interpret "significantly" differently) and hard to compare over time (if innovation includes capital spending which is very cyclical).

Second, what of R&D surveys, that measure wage and capital costs of R&D activities? They are invaluable measures of the upstream innovation process, (1). More work is needed however to find out the effect on growth. When R&D is capitalised into national accounts, as it will be in future years, this effort will be easier but at the moment it is left to the analyst. It is of course worth noting that counting $P^L L^N$ and $P^K K^N$ leave open how to estimate μ. In addition, there may be other knowledge investment besides R&D.

Patents represent of course a potentially very powerful measure of output of the innovation sector (for a very early and prescient discussion, see Kuznets, 1962). In this framework, innovative output N is weighted by its price. In practice the patent price is very rarely observed and so citation-weighted patents (the vast majority of patents are never cited) are

[14] Thus if we survey the *airline* industry and they ordered 5 new innovative planes, we subtract off their dlnK (planes) and ascribe any innovation in airlines only to what airlines do net of this new capital e.g. ticketless boarding, faster turnaround of planes. If we survey the *aircraft* industry and find they produced innovative planes from a very small rise in the number of machines we subtract off their small dlnK (machines) and so correctly ascribe innovation to the *aircraft* industry.

used. In addition, patent citations enable knowledge flows to be traced rather than leaving them, as here to the residual. As is well acknowledged however, patents do not cover all innovations/knowledge investment (in the UK for example software cannot be patented). As Jaffe and Trajtenberg (2002, p.3) say "There are, of course, important limitations to the use of patent data, the most glaring being the fact that not all inventions are patented". An important recent addition therefore to this line of work is the use of trademarks which might be a complementary use of IP to patents or another indicator of novelty (see e.g. Greenhalgh and Rodgers, 2010 for a review and the work in Baroncelli, Fink, and Javorcik, (2005), Gotsch and Hipp (2012) and Jensen and Webster (2009).

In sum, patents are a vital source of important information in areas that the accounting framework does not cover; how much the findings can be generalised to unpatented innovations is yet to be established.

Finally, it will be apparent that the scoreboard mix output and inputs does not sit at all well with the framework here. Indeed, the essence of this approach is to carefully distinguish between output and inputs. A mix of the two might convey some sense of total activity in the economies concerned but not much else. In addition, the scoreboard method suffers from the significant problem of not knowing how to weight the different activities (how does one compare broadband in Italy with the numbers of graduates in the UK?), whereas the weights in this method come directly from market prices (that in turn form the shares, s) so that markets signal relative valuations of different factors.

3.4 The strengths and weaknesses of the intangible/growth accounting approach to innovation

So the TFP approach does have some advantages. First, it is based on a logically consistent framework, which, as we argue below, will help guide measurement of its various parts. Second, it is integrated with national accounts concepts such as GDP, investment etc. and so can bridge the discussion from innovation to familiar and well-established measures. Third, some insight on policy can be gained since the framework lends itself to quantifying spillovers (Griliches, 1988).

There are many disadvantages however. First, the framework places a very heavy burden on measurement. Since dlnTFP leaves no economic footprint, that is, no price or quantity (e.g. how could you measure the price of quantity of information learned over the internet?), it is measured in practice as a residual from (7). Thus mismeasurement of other terms will "land" into dlnTFP.

Second, this framework cannot be readily implemented using current data. At present, much knowledge investment is not counted as investment in the national accounts, but rather as an intermediate (see below for which is and is not counted). For purposes of demonstration assume that no knowledge investment is counted. Thus value added growth will be counted as dlnY and not dlnQ and the following growth accounting relation will hold

$$d \ln Y = s_Y^{\ L} d \ln L + s_Y^{\ K} d \ln K + d \ln TFP^{\ B} \tag{8}$$

where the s terms are shares in $P^Y Y$. So, comparing (8) with (7) we see that

a. The output term is dlnY and not dlnQ
b. The input terms leave out dlnR
c. The share terms are shares of $P^Y Y$ (not $P^Q Q$).

Thus the observed dlnTFP is different.

The two expressions would of course be the same if all knowledge were for free, i.e. the innovation sector provides free commercialise ideas. Put another way, if one calculated the s_Y^K in (8) residually, (i.e. by $s_Y^K = 1 - s_Y^L$) and innovation was not free, it would look like the share of K was very large suggesting large profits accruing to physical capital, whereas this might just reflect that such returns also have to cover payments to knowledge capital as well.[15]

Many innovation studies have attempted to distinguish between *innovation* and *diffusion*, the latter being the spread of new ideas. Questionnaires often attempt to get at this, by asking firms to identify whether their innovation is "new" to the market or country. Patents/trademarks are an attempt to measure innovation since they are supposed to be for something genuinely novel. One very difficult issue in this work is the definition of what is really novel – is for example an iPad novel, or a combination of previously discovered elements such as a touchscreen and software? The intangible/growth accounting approach embodied in equation (7) instead focuses on investment. So in the iPad case, any spending on new knowledge to develop it is investment as long as it is long-lived. . If the ideas come for free, they are, in this framework, counted in TFP growth. So the part of innovation measured by $s_R \Delta \ln R$ is investment in commercialising new ideas and that part measured by $\Delta \ln TFP$ might be regarded as the diffusion of free ideas.

[15] So for example Domowitz, Hubbard and Peterson (1986), use industry data to calculate price cost margins as sales less payroll less material costs (as a proportion of sales, with an inventory adjustment).

4 Measuring investment in innovation

To adopt this approach to innovation then the model suggests we start with measuring intangible investment, $P^N N$. Thus we need (a) a list of intangible assets to be measured and (b) $P^N N$ for each asset type. (In the next section we consider building stocks).

4.1 Asset types to be measured

The first task is to identify all relevant intangible asset types. R&D has been thought of as a knowledge investment for a long time. Software was included as an investment in National Accounts about a decade ago. What other knowledge investments might there be? CHS (2005) choose a list of assets which they grouped in terms of three broad categories: computerized information, innovative property and economic competencies. They populated these categories with nine asset types, with the resulting list similar to that used by, e.g., competition agencies when valuing assets for a company under scrutiny, or tax guides for reporting the value of financial assets following a corporate merger or acquisition [16]. Table 1 shows their list and, in column 1, the National Accounts conventions regarding the assets (see text below for columns 2 and 3).

[16] For example, the UK Competition Commission inquiry on the provision of Home Credit valued: (a) corporate reputation/brand (b) the trained workforce (c) the customer base (d) and IT systems and development. (For details on methods, see the commission's report *Home Credit Inquiry*, 2006, Appendix 3-6 and 3-8). And the US tax code specifies 12 intangible assets to be valued and listed as financial assets following a merger or acquisitions, including the value of the business information base, the workforce in place, know-how (listed along with patents and designs), and customer and supplier bases. (See US IRS *Publication 535*, *Business Expenses*, pp. 28-31).

Table 1: CHS intangible assets, national accounts conventions

Asset	Intang included in Nat Accounts?	Capitalization Factor	Depreciation rate
Computerised Information			
Purchased Software	Yes	1	0.315
Own-Account Software	Yes	1	0.315
Databases	See note	1	0.315
Innovative property			
R&D	Satellite for some	1	0.15
Design	*No*	*0.5*	*0.2*
Mineral Exploration	Yes	1	0.075
Financial Innovation	*No*	1	0.2
Artistic originals	EU yes; JA/US no; see note	asset-specific	asset-specific
Economic Competencies			
Advertising	*No*	*0.6*	*0.55*
Marketing research	*No*	*0.6*	*0.55*
Own-Account Organisational Capital	*No*	1	0.4
Purchased Organisational Capital	*No*	*0.8*	*0.4*
Training	*No*	1	0.4

Note: SNA 1993 recommended capitalization of databases. US BEA plans to include entertainment and artistic originals and R&D as investment in 2013. Capitalisation factors convert data on total spending to investment

Source: Goodridge, Haskel, Wallis, 2012 and CHJI, 2012. The assets set out are of those of CHS, with the addition of details on artistic originals, which is based on the work of Goodridge and Haskel (2011).

Let us review the assets in Table 1. "Computerized information" includes both purchased and own-account software and illustrates an important point in gathering data on intangibles, namely that much of it is likely generated "in-house". Databases are also included. *SNA 1993* recommended capitalizing investments in databases but as a practical matter the issue remains unresolved: national accountants tend to take the view that investments in databases are captured in current software measures.[17] This asset will likely grow in importance with the increased interest in "Big Data".

[17] The *Handbook on Deriving Capital Measures of Intellectual Property Products* (OECD 2010, p. 120ff) reports that a survey of OECD member countries found that, of the 13 countries who responded to the survey, 8 said that they capitalized databases in principle, but that the values were not separately identifiable (OECD 2004).

The second and third broad groups are "innovative property" and "economic competencies". "Innovative Property" is designed to capture a range of assets that may have intellectual property protection associated with them. "Economic competencies" tries to capture a range of knowledge assets that firms invest to run their businesses, but that might have no IP.

These two categories then attempt to capture all other costs of developing and launching new products and services, including for example market research (usually excluded from R&D[18]). The basic idea was to include (1) the non-technological costs of design (industrial and nonindustrial) and services innovation (including investments by financial services firms not captured by R&D surveys), (2) the costs of marketing and launching new products, including ongoing investments to maintain the value of a brand, and (3) organization and human capital management innovations. Given the huge interest at the time in financial services the CHS list included a special category for them.

Artistic originals were included since they are investment in knowledge assets such as books, movies, TV, theatre etc. These are treated as investment in some national accounts systems but not all.

4.2 Nominal investment flows

Having settled upon a list, one then has to match this with data at hand for such spending. This is taken up in detail in CHJI (2012), but to see some of the issues consider software. Purchased assets are generally measured via investment surveys, so when software was capitalized, the existing tangible investment surveys (of machinery, vehicles, buildings etc.) were expanded to include software. This then measures $P^N N$ in (1).

However, much software is produced in house (banks for example write a lot of their own software) and since it is not sold on a market, there is no recorded $P^N N$. Equation (1) then suggests that one tries to measure the labour and capital costs and apply a mark-up. But since none of these data existed, in the first published estimates for software investment in the UK, own-account software spending was assumed equal to a multiple of purchased. . In a subsequent work, own-account software investment was measured using information on employment and wages in software engineering occupations. In terms of (1) then, this was

[18] Practice in the EU and US diverges a bit in this regard. In the United States, all forms of social, market, demographic, and actuarial research, as well as artificial intelligence, management science, and geophysical research were explicitly excluded from the expenditures collected by R&D surveys until 2008. The basis shifted in that year to the same basis used for R&D in company reports, but an instruction to exclude market research remains.

data on $P^L L^N$. A number of decisions then have to be made. First, without data on $P^K K^N$ or μ, some assumption has to be made. Second, not all software workers might be writing new long-lasting software, some might be performing user service and routine maintenance (Chamberlin, Chesson, Clayton and Farooqui, 2006). Thus observed $P^L L^N$ has to be adjusted, a capitalization factor that converts all spending on knowledge to investment (i.e. spending on long-lasting knowledge).

This basic approach to measuring $P^N N$ was implemented by CHS in their attempt to measure $P^N N$ in other intangible assets (and was for the business sector given the measurement problems in the public sector). [19] As above, it used a range of surveys and occupational data. In most cases μ was assumed to be one. When occupational data was unavailable a multiple of purchased was assumed. Purchased organizational capital was assumed to correspond to spending on management consulting and own-account set to 20% of senior managerial wages (i.e. based on $P^L L$ in (8)). Capitalization factors are set out in Table 1 above, second column, those for advertising and management consulting set below 1. Artistic original spending varies by, for example, whether TV production is for news (assumed short-lived) or TV films (assumed long-lived). Further research is clearly needed to improve these assumptions. CHJI (2012) attempt to harmonize methods across countries and amend the existing financial innovation measure. [20]

[19] The pioneering work on Japan (Fukao *et al.* 2009) disaggregated according to manufacturing and nonmanufacturing. Since the emergence of the Japanese work, researchers in other countries have also experimented with disaggregate sector and industry-level estimates of intangibles.e.g., Barnes (2010) and Dal Borgo, Goodridge, Haskel and Pesole (2011). INTAN-Invest industry data are under development and will be available in the near future..

[20] The measurement of each asset is set out in CHJI(2012). Software, artistic originals, mineral prospecting and R&D are all from official statistics. Other data are based on (8). Design and market research are based on purchases from the input/output tables. Advertising is based on final $P^N N$ spending. Bought in organisational capital is a $P^N N$ measure based on sales of management consulting services and purchased is assumed at 20% of senior management salaries. For training, we include both apprenticeship and vocational training. For financial innovation, we follow Hunt (2008) who argued that most of the cost of innovation in the financial service sector consists of compensation of researchers. In related work for the United States, Corrado and Hao (unpublished) identified a group of occupations they called "quantitative finance" occupations that they added to STEM occupations to arrive at an estimate of employment and compensation of workers in financial services whose work activities touched on analytical problem-solving and/or innovation. We therefore assumed that 8 percent of compensation of high skilled workers is a good approximation for the innovation investment in financial industry: a share that mirrors the Corrado and Hao results for the US.

5 Measuring knowledge capital stocks

Before undertaking growth accounting, the capital stocks must be built, following (3). To do this, the $P^N N$ data needs to be deflated to obtain N and then built into a stock using (3). This requires values of the prices P^N and depreciation rates δ^N which are discussed in the remainder of this section. Readers wishing to skip the details can go to section 6.

5.1 The price of knowledge

Intangible investment in real terms—obtaining each N_j —is a particular challenge because units of knowledge cannot be readily defined. Although price deflators for certain intangibles (software, mineral exploration, and artistic originals) are found in the national accounts of many countries, generally speaking, output price measures for intangibles have escaped the statistical net. Thus, other than software and mineral exploration for which deflators are included in the U.S. national accounts, CHS used the overall business output price as the price index for intangible investment and this is the method followed in many papers.

One area where this can potentially be improved is the emerging work on price measures for R&D. The U.S. BEA offered an R&D-specific output price in its preliminary R&D satellite account (Moylan and Robbins 2007; Copeland, Medeiros, and Robbins 2007). A contrasting approach is in a recent paper by Corrado, Goodridge and Haskel (2011), which casts the calculation of a price deflator for R&D in terms of estimating its contribution to productivity. Applying their method to the United Kingdom yielded a price deflator for R&D that *fell* at an average rate of 7-1/2 percent per year from 1995 to 2005—and thus implied that real UK R&D rose 12 percent annually over the same period. This stands in sharp contrast to the science policy practice of using the GDP deflator to calculate real R&D (the UK GDP deflator *rose* 3-3/4 percent per year in the comparable period), and the results of applying the BEA method to the UK data (the UK BEA-style deflator rises 2.1 percent per year).

Regarding software, the EUKLEMS project harmonized *hardware* prices (to quality-adjusted US price indexes) but did not harmonize *software* prices. Since software investment is around three times that of hardware, this is potentially important. In CHJI (2012) we devise a harmonized software index using US quality-adjusted pre-packaged data and taking up the recommendations of the *Handbook on Deriving Capital Measures for IP Products* (OECD 2010) which recommends using a productivity-adjusted cost measure for own-account software and a quality-adjusted measure for pre-packaged and custom software.

5.2 The "depreciation" of knowledge

As mentioned above, the model uses the perpetual inventory model (PIM), to calculate net stock estimates for intangible capital (*R*). In that model, economic depreciation captures two distinct processes, *discards* and economic *decay*. A discard arises if, for example, the commercial value of an idea falls due to competition from another one, or a worker leaves the firm with at least some of the firm's knowledge. The probability that a given asset type will survive in productive use from one period to the next is thus summarized by a stochastic *discard*, or survival, function.

The productivity of an asset as it ages, *conditional on its survival from one period to the next*, is described by a *decay* function. A decay age-price profile can be highly concave (i.e., in the case of, say, certain training investments shown to have long-lasting effects for employees who remain with the investing employer. But when a decay function implying long-lasting productivity conditional on survival is interacted with a discard function with a high early failure rate and age cohorts are aggregated, the end result is a convex geometric-like profile that can be summarized using a relatively fast rate of geometric depreciation δ in the PIM (Hulten and Wyckoff 1981, Schreyer (2001).[21]

Although relatively little is known about depreciation rates for intangible assets, the foregoing discussion implies that their depreciation rates are relatively fast, mainly because of a high rate of "discards" even with little decay (that is productivity of the assets conditional on their continued ownership by, or survival in, the investing firm is long-lasting). On the basis of this thinking CHS set rather high values for δ , especially for the asset types in economic competencies. For example, despite the well-documented fact that advertising campaigns may have long-lasting impacts on a firm's sales and profits, the depreciation rate for brand equity was set to be very fast to account for the fact that some investments in brand result in a

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[21] Oulton and Srinivasn (2003) for example define the real net capital stock of asset *i* at time *t*, $K_{i,t}$, as

$$K_{i,t} = \sum_{t=0}^{T} \frac{f_t}{f_{t=0}} F_{i,t} \frac{IN_{i,t-t}}{p^{A}_{i,t-t,age=0}},$$

where $IN_{i,t}$ is nominal investment in asset *i* at time *t* . Nominal investment is converted to constant quality real investment by dividing by a quality-adjusted investment price index p^A for the new asset at time *t*. *F* describes "discard" or "survival" as the share of assets from time t still in service in each period (i.e., if it equals 1 or 0, all or none of the assets are still in existence). $f_t / f_{t=0}$ is the relative marginal product of the investment of age τ to the marginal product of a new machine, and so captures "economic decay" as a physical quantity concept. Thus a design for example, might exhibit no "economic decay" (that is never "wear out" in a quantity sense), but might be "discarded" as, for example, fashions change. The depreciation rate δ in the PIM captures the net effect of both these terms.

competitor's loss of market share and therefore fail to survive as an asset of the industry or sector. For training and organizational capital, the depreciation rate was set lower than investments in brand to reflect the fact that the average tenure of employees in the United States is between 4 and 5 years. Indeed, average employee tenure could be used to set the service life of employer-provided training, and the depreciation rate for employer-provided training could vary across countries, and, in principle, across time.

Since the CHS study, evidence on service lives of intangible assets has accumulated from two main sources. First, the U.S. BEA, for example, places its central estimate of the depreciation rate for R&D at .15. Soloveichik (2010) produced depreciation estimates for four categories of total artistic originals that also implied rather long service lives. The OECD Handbook on Intellectual Property reviewed national accounting practices on certain intangible assets (software, entertainment and artistic originals, mineral exploration) and states that artistic originals have a 5-10 year lifetime with at least a double-declining balance, implying a geometric rate of depreciation near to CHS.

Direct estimates of life lengths from surveys are a second source of new evidence. Surveys conducted by the Israeli Statistical Bureau (Peleg 2008a, 2008b) and by Awano *et al*. (2010) with the UK Office of National Statistics. These surveys ask about the "life length" of investments in R&D (by detailed industry in Israel) and intangible assets (R&D plus 5 other asset types in the UK). The Israeli survey supports lengthening the service life for R&D, while the UK survey confirms that the very fast depreciation rates CHS assumed for economic competencies are about right. As a result in www.intan-invest.net we use depreciation rates set out in the final column of Table 1 where the rate for mineral exploration is the US BEA rate.[22] The others are as discussed above or the same as CHS, bar R&D which is 15%.

[22] The lifetime of the knowledge created by mineral exploration is the service life of the discovery (a well or a mine). In the Australian national accounts, a service life of 34 years is used whereas the United States uses 12 for oil and gas exploration and 20 for mining. Most U.S. exploration is for oil and gas, and a 12-year life is used for the calculations reported in this paper. Note that investment is mineral exploration is negligible for most EU countries.

6 Some conceptual issues

Finally, two other conceptual issues. First, when analyzing the conduct of R&D in private business, by industry or in the aggregate, the productivity literature and science policy analysis has tended to focus on the performer series. However, in the BEA R&D satellite account, for example, a strong argument for using the funder series, so that, for example, government-funded defence R&D performed in the private sector is treated as public not private assets, in line with how asset ownership is treated in National Accounts. The current treatment regards this form of R&D as producing tacit knowledge in the private sector that depreciates like other such knowledge, and treats the government payments as an addition to private capital compensation i.e. a kind of subsidy. See CHJI (2012) for more discussion.

Second, it is sometimes argued that investment in intangible capital asset X is ultimately investment in human capital. Thus one is "double counting" with human capital. This is not the case. Consider organizational capital, in particular, the internal processes by which a company, say Apple, manages its global supply chain. Although such knowledge may be created and applied by managers within Apple, even when those managers leave the firm, Apple retains a good part if not all of that knowledge. Of course that knowledge may decay in competitive value for other reasons (as the market power is temporary a la the model of section 1 and footnote 5). But the point is that the knowledge involved is, once again, a payment to the intangible capital of a firm (Apple) and not simply a dimension of human capital as conventionally defined.

7 Harmonized estimates

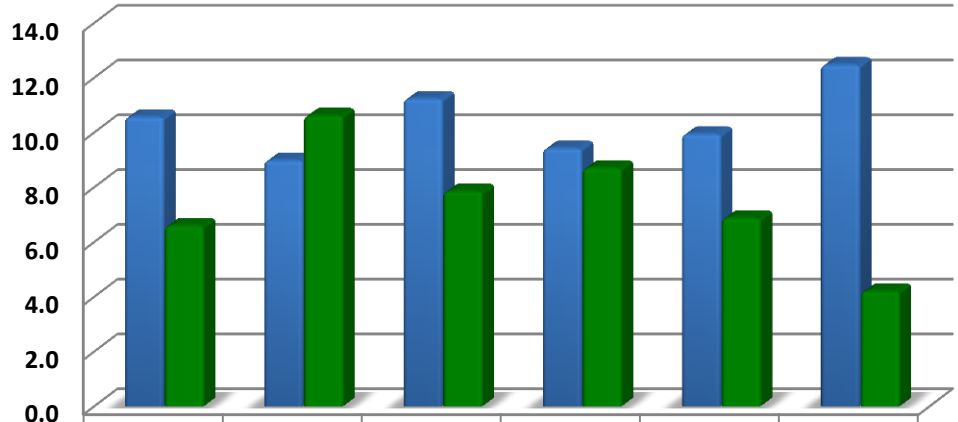
We produce harmonized time series of intangible investment for the EU27 member countries and Norway and the US in 1995-2005, and for the EU15 economies, the US plus Czech Republic and Slovenia we add the years 2006-2009. We include agriculture but exclude rental real estate, which EUKLEMS (2008, and O'Mahony and Timmer, 2009) also omits from its definition of the market sector due to measurement difficulties.[23]

7.1 Results on intangible investment

The updated evidence on intangible investment by the market sector in the EU15 area and in its main groups of member countries from 2005 to 2009 is shown in Figure 6. As previously found (Jona-Lasinio *et al.* 2011; see also van Ark *et al.* 2009), the EU15 shows a lower propensity to invest in intangibles than does the United States. The rates for the U.S., however, are essentially the same as those for the UK, whose propensity to invest in intangibles is the highest in Europe, and like the United States, invests more in intangibles than it does in tangibles.

[23] The market sector in EUKLEMS is NACE sectors A through K (excl. real estate) plus sectors O and P. We exclude sector P (private households) and work with NACE sectors A through K (excl, real estate) plus sector O.

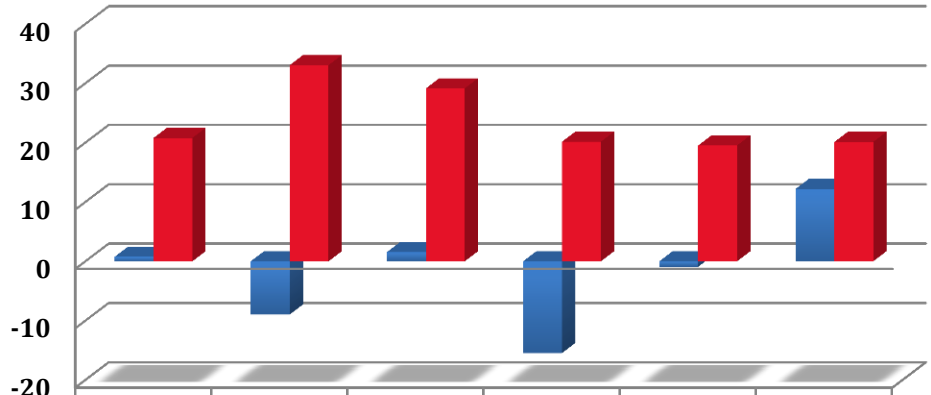
Figure 6. Tangible vs Intangible GDP shares: 1995-2009 (average values)



	EU15	US	Scandinavian (DK, FI, SE)	Anglosaxon (IE,UK)	Continental (AT, BE, FR, DE, LU, NL)	Mediterranean (GR, IT, PT, ES)
Tangibles	10.6	9.0	11.2	9.4	9.9	12.5
Intangibles	6.6	10.62	7.86	8.71	6.89	4.21

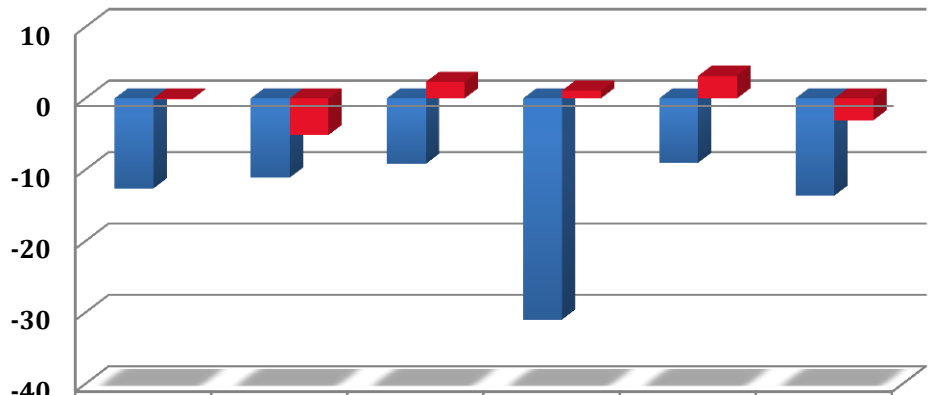
To understand a bit of the dynamics that underlie these cross country differences, the percent change in tangible and intangible investment GDP shares from 1995 to 2007 is shown in the Figure 7a and b. The rate of intangible investment in all EU15 regions increased from 1995 to 2007 while the rate of tangible investment fell or remained about flat (The Mediterranean region is an exception, however.). In the Anglo Saxon countries (an

Figure 7a. Tangible vs Intangible GDP shares: 1995-2007 (percentage changes)



	EU15	US	Scandinavian (DK, FI, SE)	Anglosaxon (IE,UK)	Continental (AT, BE, FR, DE, LU, NL)	Mediterranean (GR, IT, PT, ES)
Tangibles	0.7	-9.0	1.6	-15.5	-0.9	12.2
Intangibles	20.8	33.0	29.1	20.1	19.5	20.1

Figure 7b. Tangible vs Intangible GDP shares: 2007-2009 (percentage changes)



	EU15	US	Scandinavian (DK, FI, SE)	Anglosaxon (IE,UK)	Continental (AT, BE, FR, DE, LU, NL)	Mediterranean (GR, IT, PT, ES)
Tangibles	-12.6	-11.1	-9.2	-31.0	-9.0	-13.6
Intangibles	-0.1	-5.1	2.3	1.1	3.2	-3.1

aggregate dominated by the UK), the slowdown in tangible investment is especially pronounced and is comparable to the US.

The more recent data show that the rate of tangible investment in the EU15 declined sharply from 2007 to 2009 while the rate of intangible investment remained about flat. In the US, intangible investment fell. Across Europe there are small differences by regions, and intangible investment relative to tangibles held up better in recent years on both continents. All told, the shift to intangible investment from 1995 to 2009 is a striking trend.

7.2 Effects on growth

Table 2 sets out our sources-of-growth analysis for 14 EU countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Slovenia, Spain, Sweden, and United Kingdom plus Japan and the United States. We choose the years 1995-2007 (the 2007-09 recession years raise a set of other issues).

The first result from table 2 is the finding originally reported in CHS, that once intangibles have been capitalized, capital deepening (column 2) becomes the dominant source of growth (see the memo items, column 2), being 65.4 percent for the EU (on a weighted average basis), 58.4 percent for the United States, and 42.9 percent for Japan. For the United States, where we have a relatively long time-series (on a EU comparability basis, from 1977 to 2010), the fraction for the sub-period in table 1 is essentially the same as the fraction for the entire period (58.9 percent). That finding would, of course, not necessarily hold for other countries, nor for that matter, for U.S. experience in earlier time periods, but it is useful to note nonetheless.

The second point is that advanced countries differ in interesting ways. Looking at the memo items, the weighted average EU results suggest that the 65.4 percent contribution of capital deepening to labor productivity growth consists of 41.6 percent tangible and 23.8 percent intangible capital deepening, whereas 19.0 percent of the growth in labor productivity is due to MFP. The unweighted averages are 34.3, 23.0 and 26.2 percent, respectively. The unweighted/weighted differences suggest that smaller EU countries rely more on MFP and less on tangible capital deepening. Thus we have the following comparative picture. First, relative to Japan and the US, capital deepening in the EU accounts for a greater fraction of labor productivity growth, mainly as a result of a higher contribution from tangible capital deepening. With regard to intangible capital deepening, its relative importance in explaining labor productivity growth is greatest in the United States and smallest in Japan. Second, in the EU as a whole the rest of growth is split more or less equally between labour composition and MFP, whereas the US relies much more on TFP growth and Japan very much more on improvements in labor quality.

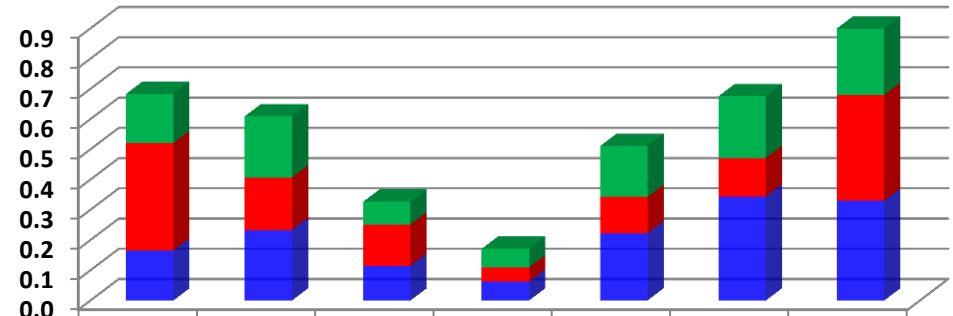
Table 2. Contributions to the growth of output per hour in fourteen EU countries, Japan, and the United States, 1995 to 2007

	Labor productivity growth	*Contribution of components:*				
		Total Capital Deepening	Tangibles	Intangibles	Labor Composition	Multifactor productivity
	(1)	(2)	(3)	(4)	(5)	(6)
Austria	2.4	0.8	.3	.5	.2	1.4
Belgium	1.8	0.7	.2	.5	.1	1.0
Czech Rep	4.2	2.4	1.9	.5	.3	1.5
Denmark	1.4	1.2	.7	.5	.2	-.1
Finland	3.8	.9	.2	.7	.2	2.7
France	1.9	1.0	.4	.6	.4	.5
Germany	1.7	1.0	.7	.3	.0	.8
Ireland	3.8	1.4	.8	.6	.1	2.2
Italy	.6	.7	.5	.2	.2	-.4
Netherlands	2.3	.9	.4	.5	.4	1.0
Slovenia	5.3	1.7	1.2	.5	.7	2.9
Spain	.8	1.0	.7	.3	.5	-.6
Sweden	3.7	1.9	1.1	.8	.3	1.5
UK	2.9	1.5	.8	.7	.4	1.1
Japan	2.1	.9	.7	.2	.8	.5
United States	2.8	1.6	.7	.9	.2	1.0
Memos		*Average percent contribution of component:*				
EU (GDP weight avg)		65.4	41.6	23.8	14.8	19.0
EU (unweight avg)		57.3	34.3	23.0	15.5	26.3
Japan		42.9	33.3	9.5	38.1	23.8
US		58.4	26.8	31.9	7.2	35.7

Source: For EU countries and the United States, authors' calculations based on intangible investment databases developed by the authors and/or partners in previous works. See text for further discussion. For Japan, Fukao, Hisa, and Miyagawa (2012).
Note—For individual countries, figures in column (1) are annual percent changes, and figures in columns (2) through (6) are percentage points. In the memo panel, column 2 is the fraction of column 1 accounted for by column 2, and columns 3 to 6 are the fraction of column 1 that these columns account for. In the memo panel, weights are by the country share of nominal GDP, 1995-2007.

Within intangible capital deepening, figure 8 shows significant differences in the deployment of intangibles by broad type for a sample of countries. For example, the US and UK rely more on economic competencies, relative to Finland who shows a greater contribution of intellectual property, substantially driven by R&D.

Figure 8. Contribution of Subcomponents of Intangibles to Labor Productivity Growth (1995-2007)



	Finland	France	Germany	Italy	Netherlands	UK	US
SFT	0.16	0.20	0.07	0.06	0.17	0.20	0.22
IP	0.36	0.17	0.14	0.05	0.12	0.13	0.35
EC	0.17	0.23	0.12	0.06	0.22	0.34	0.33

Note to figure: SFT=software, IP=innovative property, EC=economic competencies (see Table 1 for definitions of each category).

8 Complementarities and spillovers

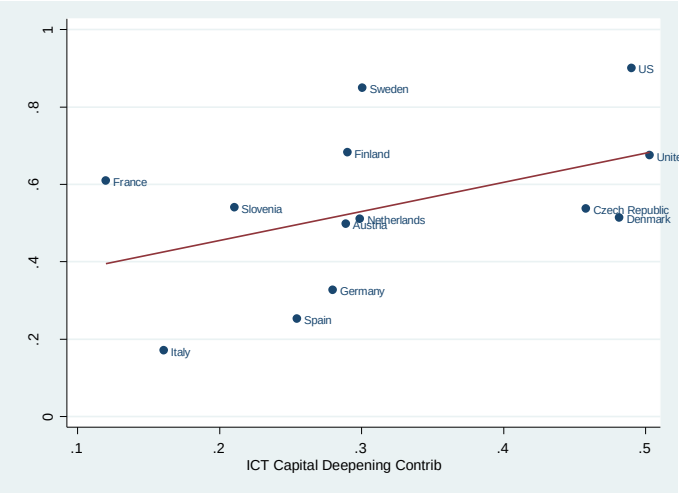
In this section, we use the data to examine: (a) complementarities between factors of production (b) spillovers.

8.1 Complementarities

It has been suggested that intangible assets are assumed to complement ICT capital so that to realize the potential benefits of computerization, investments in additional assets such as new organizational processes and more trained workers are necessary. This mechanism is implicit in, for example, Brynjolfsson and Hitt (2000), who argue that the productivity gains from installing ICT hardware (tangible capital) would only be reaped with organisational change (which in our terms is installing intangible capital). Many other studies analyzed the complementary relation between ICT and other types of intangible assets (R&D, skills training and human capital, brand equity) and suggest productivity growth is higher once the complementary role of intangibles is accounted for (see Basu, Fernald, Oulton and Srinivasan, 2004, for a discussion and references).

Figure 9 lends some support to the complementarity hypothesis showing a broadly upward sloping relation between intangible (non-ICT capital) and ICT capital deepening.

Figure 9: Contributions of ICT and intangible capital deepening, 1995-07, USA and 12 EU countries



Note to figure: ICT capital is defined as computers, communications equipment and software and intangible capital is economic competencies and innovative property. Contribution is share-weighted change in capital stock.

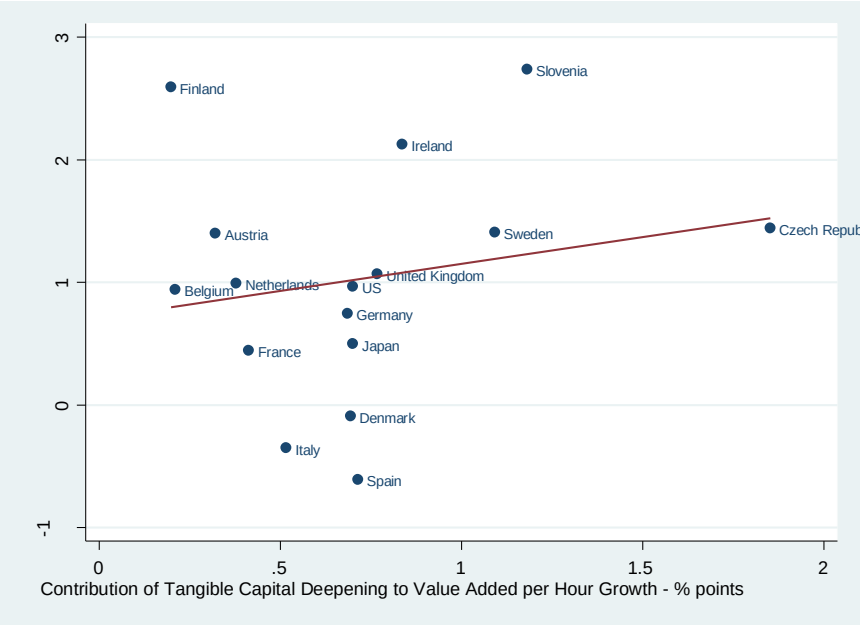
8.2 Spillovers

Turning to spillovers, evidence on tangible capital inputs does not reveal any particularly strong evidence for spillovers due to e.g. plant, buildings and computer hardware (Stiroh, 2002, offers a survey including an earlier literature on equipment investment; an exception here is communications capital, see Corrado, 2011, which likely has network effects). Existing evidence on intangible capital is mostly focused on R&D, and seems to suggest spillover effects, see e.g. Griliches (1998). Spillovers from intangible capital seem a natural hypothesis to the extent that such capital is likely to have public good characteristics. On the other hand, spillovers might not occur if intangible capital is protected by intellectual property rules (copyright, trademarks etc.) or tacit knowledge (internal knowledge of supply chain management for example).

Spillovers from asset X implies that the elasticity of $dlnK^X$ on dlnY exceeds its factor share. Thus the test of a spillover is whether there is any relation between $dlnK^X$ and dlnTFP (since dlnTFP measures the elasticity at the factor share by construction). So, figure 10 plots MFP growth by country against *tangible* capital deepening contribution and shows no clear relation. By contrast, figure 11 shows MFP growth against *intangible* capital deepening contribution, and does appear to show a relation. This is suggestive of spillovers from

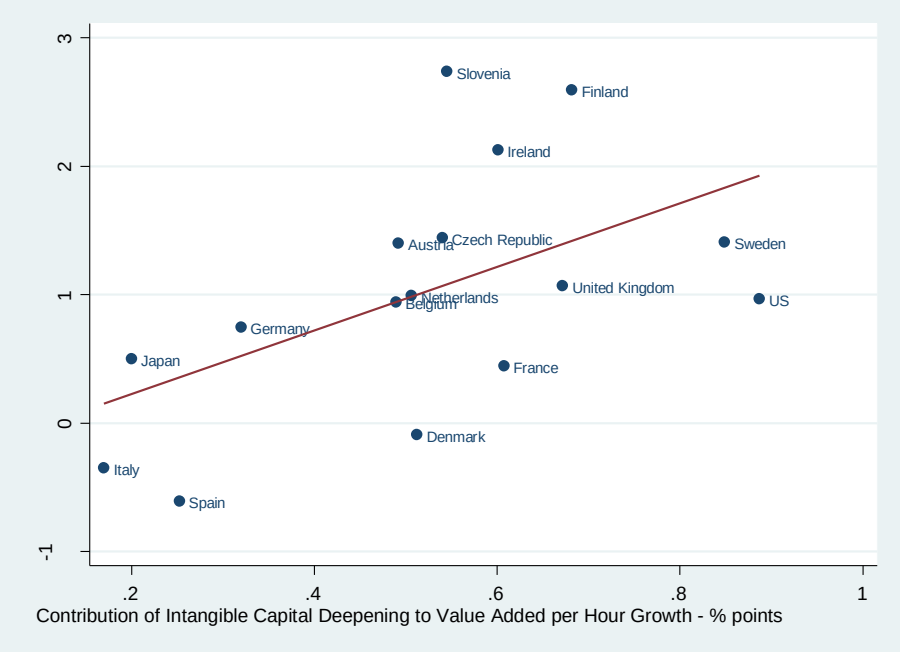
intangible capital, and more extensive regression estimates suggest this to be the case (Corrado, Haskel and Jona-Lasinio, 2012).

Figure 10: MFP growth and tangible capital deepening contribution, 1995-07, USA, Japan and 12 EU countries



Source: Table 2

Figure 11: MFP growth and intangible capital deepening contribution, 1995-07, USA, Japan and 12 EU countries



Source: Table 2.

9 Conclusion

We have set out an approach to innovation measurement and policy, based on intangible investment. We have attempted to distinguish between productivity growth and innovation the latter being made up of investment in the commercialization of new ideas and the use of free ideas. We have implemented the approach by producing harmonized estimates of intangible capital for Europe and the US. The new growth accounting results are the broadest available results for Europe to date.

Drawing this together we have the following. First, the UK, like the US now has more intangible investment than tangible investment, and other EU countries are following. That is to say, future investment will look much more intangible than tangible. Second, this investment is important for growth. In the US, capital deepening is 65% of growth and intangible investment is now 50% of capital deepening. EU countries will be catching up to this level.

Third, is there any role for policy to affect such intangible spending? The arguments over private R&D spillovers are well-known and support for spillovers from public R&D projects is to be found in e.g. Haskel and Wallis (2010) and Guellec and Van Pottelsberghe (2008). This paper suggests there are possible spillover indications that are wider than just R&D. All this suggests that in the future the factors that enable economies to invest in information and monetise new knowledge and discoveries will be key enablers of growth. So, for example, IP policy is likely to be of increasing importance along with broadband/communications equipment. Hargreaves (2011) contains a set of regulatory proposals for IP policy and Corrado (2011) shows the importance of the communications infrastructure.

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