How much does the UK employ, spend and invest in design?*

Fernando Galindo-Rueda
Office for National Statistics and CeRiBA

Jonathan Haskel
Queen Mary, University of London; CeRiBA, CEPR and IZA

Annarosa Pesole
Queen Mary, University of London and CeRiBA

JEL reference: E01, E22, O31
Keywords: design, R&D, intangible investments

July 2008

Abstract

We estimate how much the UK economy employs, spends and invests in architectural and engineering design, both purchased and own account. We provide data for the whole economy and six main industries, 1997-2006. The own-account method follows that used for software in the capitalization of software in the National Accounts. We also provide evidence on the fraction of spending that might be treated as investment in design. Our main results are (a) in 2004 private sector spending on purchased design services was around £17bn, (b) spending on own-account design services about £27bn; (c) investment in design is around half these total and (d) manufacturing accounts for about 50% of total design spending.

---

*Contact: Jonathan Haskel, Queen Mary, University of London, Economics Dept, London E1 4NS, j.e.haskel@qmul.ac.uk. Financial support for this research comes from the FP7 COINVEST collaborative project funded under theme 9, Socio-economic sciences and humanities theme of the European Commission Seventh Framework Research Programme. This work was carried out at CeRiBA (www.ceriba.org.uk) at the Virtual Microlaboratory at the ONS. This work contains statistical data from ONS which is crown copyright and reproduced with the permission of the controller HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. The work builds on earlier work kindly funded by BERR. We alone are responsible for all errors in the paper.

1. Introduction

There has been increased interest in the UK design sector in recent years. This is for a number of reasons. First, UK design is advanced as a dynamic industry in a vibrant creative sector. Second, it is argued that design should be seen as part of the UK's innovation effort.

Our purpose is to contribute to the ongoing effort to better understand design, the creative sector and innovation. Our starting point is that (a) innovation arises from increasing knowledge in the economy and (b) design spending is but one part of the investment in that knowledge stock. The extent to which such spending translates into increased output is an important ultimate aim of this stream of work, but our focus here is on better measurement of expenditure and investment in the design sector.

Design activity can be defined as the process of originating and developing a plan for a product, structure, or component. It is usually considered in the context of the applied arts, engineering, architecture, and other related creative endeavours. By committing resource to design efforts, companies aim to produce valuable new blueprints - in other words, guidance on how to produce goods and services combining a range of aesthetic and functional features. Because such blueprints can be often used repeatedly over time, design activities could be regarded in principle as the production of a potentially lasting economic asset – defined as a good that provides services to its owner over a more than one-year period. Because the economic value of design depends on its originality and novelty, the concepts of creativity, design and innovation are closely intertwined.[1]

This definition of design is wide enough to encompass activities as varied as artistic creation, software design and research and experimental development (R&D). Traditionally, R&D has been considered as the main source of process and product innovation. Whilst few would disagree that R&D, in a generic sense, is a key part of investment in new knowledge, many would take the view that R&D, as measured, does not capture all of this investment. There are two points. First, measured R&D typically refers almost exclusively to investment in scientific R&D (the formal definition of R&D in e.g. the R&D tax credit claims is that R&D spending should aim to "resolve scientific and technological uncertainty"). This then means that sectors, such as financial services, where many feel that innovation is strong, have low values of measured (technological) R&D expenditures. This has led observers to argue that measures should be developed for a broader set of expenditures than just R&D. Second, it is widely argued that R&D spending needs co-investment in

---

[1] The Cox Review (2007) describes design as the link between creativity and innovation. Creativity is often described as the generation of new ideas, in contrast with innovation that refers to the successful exploitation of new ideas. More on the definition of design is set out in DTI (2005).

knowledge production downstream in the innovation process: marketing spending to complement scientific R&D in pharmaceuticals for example.

Both these observations have given rise to various streams of work; the DCMS-sponsored “creative industries” programme, DTI’s “Innovation in services”, and the NESTA work on “hidden innovation” for example[2]. Recent work on innovation and intangible investment (i.e. Corrado, Hulten and Sichel (2005,6) and GiorgioMarrano, Haskel and Wallis (2007)) has brought some streams of this work together, stressing the growing economic importance of investment in “intangible” assets, mostly knowledge assets, as opposed to the traditional focus on investment in tangible assets such as machines, buildings and vehicles. One of the main contributions of this literature is its ability to explicitly relate expenditures in particular activities to the creation of intangible assets which enable companies to produce and deliver improved goods and services. By counting the contribution of these assets, this helps reduce the extent of unexplained productivity changes.

A wide range of design activities can be potentially considered in a similar fashion to R&D that aims to result in knowledge leading to new products and processes. The same applies to software programming, if for example, it leads to code that enable computer users to process information in more efficient ways. What these and related “investment efforts” have in common is that companies undertake them with the objective of producing new “knowledge items” that are valuable in their own right, even if they are not meant to be traded in the marketplace but used in-house. Because knowledge is relatively easy to copy, its economic value largely resides in its originality which then entitles its owner to various forms of protection. Because originality is also often identified with creativity and innovation, many of the various literature strands are actually addressing the same economic issue from different angles.

Throughout this article, we focus on identifying the quantitative significance of more narrowly defined architectural and engineering design (AED) activities. The objective of this article is to estimate: (a) the value of the AED services bought in the marketplace and (b) those which companies produce in-house for internal use. The outcome of design from either source is potentially the source of lasting services to the companies that invested in them and, as a result, would exhibit intangible asset-like properties. Thus we first need to estimate purchased and own account design services. Second, we may then hypothesize how much the UK business sector could effectively be investing in a “design” intangible asset. This, we argue, is the appropriate starting point for addressing the question of what is the contribution of design to UK economic performance and its main drivers are.

---

[2] DCMS, Creative Economy programme http://www.cep.culture.gov.uk; NESTA, The Innovation Gap (2006)

Much of the policy and analytical focus to date has been on the output of the UK design sector, within the wider class that is considered to the "creative sectors" in the economy[3]. It is also well acknowledged that what UK companies purchase from this sector or buy from abroad is only part of the total domestic usage of design services. Companies have in-house design teams and so spend on design on their own account, for example, the man widely credited with the design of the iPod, Jonathan Ive, works for Apple[4]. Under current National Accounts convention that all purchased design services are used up in current period production, it is understandable that official statistics do not collect information on own-account production as accounting for these would not lead to changes in the way GDP or other key statistics are measured.[5] If we adopt instead an alternative view on the nature of these services whereby some design leads to lasting valuable property, it becomes crucial to understand how much companies spend on in-house design activities. This is just the same that would apply to a company building its own machines – it would not expense all related costs in the current period but split those costs over time as the machine delivers its services.

We thus set out a method to illustrate in some detail the full extent of supply and demand of architectural and engineering design services in the UK economy, enabling us to distinguish market and own-account production in a way that is broadly comparable with National Accounts magnitudes and methods used for dealing with computer services and software. The method combines adjustments to published supply-use input-output tables on design services and efforts to identify potential in-house design output based on specialist designer human resources. Our estimates suggest that the UK private sector produces more design services for in-house consumption than it buys in the marketplace. In particular, we estimate that in 2004, UK private sector firms purchased about £17bn worth of architectural and engineering design services, but produced on their own-account about another £27bn worth.

This paper proceeds as follows. Section 2 sets out some initial measures of employment using current industry and occupation definitions. In section 3, we discuss how spending and investment on design might be measured using the supply and use tables. Section 4 sets out our estimates of purchased and own-account design for 1997-2006 for 6 broad UK industry sectors. Section 5 compares our estimates to other estimates. Section 6 discusses the evidence on how much of this spending might be considered as investment and section 7 concludes.

---

[3] See for example Bakhshi, McVittie and Simmie (2008)

[4] See his profile at http://www.designmuseum.org/design/jonathan-ive). As another example Dyson vacuum cleaners report employing 450 designers, engineers and scientists.

[5] In other words, although gross output would be revised up by counting these in-house design services, so would be the level of intermediate consumption by the same amount. Gross value added is the difference between gross output and intermediate consumption, and this would remain unchanged. National accountants refer to this type of in-house activities as "ancillary" to the main market business activity. For example, car design would be seen as ancillary to car manufacturing.

2. Design activity: sectors, products and employment

2.1 Design Industry

Before attempting to quantify the extent of design as an economic activity, it is necessary to understand its distinctive defining factors as well as how these can be operationalised using existing data sources. Distinguishing design from other activities matters because several of design-related activities are already counted in the formation of capital in the National Accounts. Furthermore, there are complementary statistical frameworks which also capture a range of inputs and outputs in the innovation process such as those set out in the OECD Frascati (R&D) and Oslo (Innovation surveys) manuals

Starting with the relationship between design activities and the official measurement of R&D under the Frascati Manual framework, the latter states that if calculations, designs, working drawings and operating instructions are made for the setting up and operating of pilot plants and prototypes, these costs should be included in R&D. However, if they are carried out for the preparation, execution and maintenance of production standardisation (e.g. jigs, machine tools) or to promote the sale of products (e.g. offers, leaflets, catalogues of spare parts), they should be excluded from the definition of R&D.[6]

The System of National Accounts (1993) sets out the convention regarding the treatment of design services. It is that these are fully used up or fully transformed by the production process. This implies two main things: Firstly, purchases of design services are, by convention, treated in most cases as intermediate consumption, not as capital investment. Secondly, the costs of in-house design activities are deemed not to generate an independent output and so not counted as a separate product. As we show below, under the assumption that design is an intermediate input, own-account design services would be exactly offset by intermediate consumption and so would not affect the calculation of gross value added; hence they are not counted in the first place.[7] As a result, innovative design activities, even if they result in valuable long-lasting property such as blueprints

---

[6] The status of design in the official R&D statistics is rather complicated. The instructions for the UK R&D tax credit refer to R&D spending as only that directed at the resolution of scientific and technological uncertainty. The 2007 UK R&D survey firm defines R&D simply as "R&D is characterised by investigation or experimentation, the outcome of which is new knowledge (with or without a specific practical application), enhanced materials, products, devices, processes or services" with no specific extra definition. The 2006 survey data and earlier asked firms to exclude "e. Design costs to meet changes of fashion and artistic design work". However, under the heading defining "Experimental development" the notes to the questionnaire states "This covers the use of the results of basic and applied research directed to the introduction of new materials, processes, products, devices and systems, or the improvement of existing ones. It should include the prototype or pilot plant stage, design and drawing required during R&D and innovative work done on contracts with outside organisations, government departments and public bodies. Firms in the aerospace industry should include expenditure on development batches". Even if firms reported design activities in R&D data, it would still be explained :however we would of course double-counting in tangible spending.

[7] This practice is currently also applied to R&D services although that will be revised following the implementation of the recent SNA Revision 1.

for prefabricated houses or consumption items, are expensed in the current period. The implication from this is an understatement of the value of goods and services, including valuable knowledge, produced in the economy.[8]

To measure design activity we start by looking at those industries where the generation of new designs is one of the main objectives or features of production as implied by the industry description provided in the Standard Industrial Classification (SIC) of economic activities (2003). This classification is intended to guide the classification of business establishments by the type of economic activity in which they are predominantly engaged. Table 1 lists industries with "design" mentioned in their description. Such industries are concentrated in SIC group 74.2 "Architectural and engineering activities and related technical consultancy" and include engineering consulting, quantity surveyors, and technical consulting e.g. on geology services. In addition, there is industry subclass 74.87/2, "Speciality design activities" which include fashion and graphic design, which is a subdivision of group SIC 74.8 "Miscellaneous business activities not elsewhere classified".

It is important to clarify that design activity is not exclusive to business units classified within this SIC. There is a clear distinction between a business unit's predominant activity and the wider range of goods and services (products) it produces for internal use or market sale. Thus a unit could be producing design output and selling it, but is classified to another sector since its predominant activity is not design. In addition, and possibly more importantly, a business unit might produce design activity but not sell it (except as embodied in its final output) which would again not be separately captured in standard measurements.

2.2 Employment and occupations

To try to count in-house or own-account activity, one might turn away from business surveys to labour market surveys and identify the individuals who are classified as being mostly involved in design activities. Although most employees can be expected to perform a range of different tasks in their jobs, the heterogeneity of activity is bound to be lower at an individual than at a business level. The Standard Occupational Classification (SOC) descriptions can be used to identify "designers". Those codes can then be used to estimate the wages earned by designers as potential measure of the direct contribution of design to value added.

---

[8] GVA aims to reflect the value of goods and services produced in the economy, doing so by deducting from the total gross output the value of goods and services fully used up in their production. Thus, the output of the electricity or materials sectors used up by other sectors in their production is netted out to calculate their GVA. When goods and services are used in production but not fully used up in an accounting period, these are described as productive assets. The production of assets used in production is not netted out in the calculation of GVA because the assets continue to deliver services in future periods. Net value added (NVA) statistics reflect the gross value added of a unit or sector netting out the proportion of the asset's value used up in production, which is defined as consumption of fixed capital.

To see this, Table 2 lists not industries but occupations with "design" mentioned in their description. For completeness, it also lists a number of occupations as identified by a number of other studies, typically focusing on aspects of the "creative" economy, namely those by NESTA (2008), Arts Council (2005) and DCMS (2007). As is obvious from the table, these other studies use a broader set of occupations outside of design; compare the first three columns and the last column. We shall however compare our results to these others below, given differences in data sources etc.

Table 3 is a first pass attempt to measure design activity within and outside the design industry, here where activity is measured as employment. It shows a cross-tabulation of SICs and SOCs to examine the incidence of own-account design activity. The first column is the main design SIC identified in Table 1 and shows a total, in 2004, of 55,028 employees. The next six columns are six broad industries chosen for ease of classification in this table and later data.[9] The rows show the design occupations we have chosen as set out in Table 2. Each cell is the number of employees and the data refers to the private sector.[10]

A number of points are worth making. First, the calculation of employment using the ASHE is rather complicated. These numbers are calculated by using ONS-provided weights from the ASHE that are designed to replicate the LFS totals for employees. Second, note that, as discussed below, a substantial number of designers are self-employed and hence the number of people in design occupations is larger than the employment numbers reported here.[11]

In terms of employment then, the following facts appear. First, we estimate here 292,465 employees are in a design occupation in all industries (see penultimate column and penultimate row). Of these, just under 240,000 are in sectors that are not "design" SICs (see last column, penultimate row, suggesting that for every employed designer within the design sector, there are four outside. Second, manufacturing is a major employer of designers, employing close to half of all design employees. Third, the final row shows the wage bill numbers. Comparing the last two columns, we see that for every pound paid to designers in the design sector, around four pounds are paid to designers outside the sector.

---

[9] Fine industry classifications risk disclosure problems. This classification is the most feasible that we have found for this and other intangible assets and covers the market sector as follows (1) Agriculture, Fishing and Mining; (2) Manufacturing; (3) Electricity, Gas and Water; (4) Construction; (5) Wholesale and Retail, Hotels and Restaurants, Transport and Communications; (6) Financial Intermediation and Business Services.

[10] The private sector is defined as "private company", "sole proprietor" and "partnership". These are data only on current workers in these industries. In addition, our industry classification in table 3 excludes sections L(Public Administration), M(Education), N(Health), O(Personal Service), P(Private Household) and Q(Extra-territorial).

[11] In turn this number is different from the number of design jobs, which differs since people can have two jobs and the design labour force which includes unemployed designers.

2.3 How do these numbers compare with other estimates for designers?

Table 6 sets out a number of estimates from related previous studies. The top panel sets out DCMS data. Design is not one of their primary categories, but in breaking down their numbers they do provide data on architects, specifically those employed in the architecture industry and architects employed outside the architecture industry. The upper panel shows, for 2006, employment of architects in these two industries, and in the row below, employment in the creative occupations (not employed in those industries). The numbers in the column heading LFS are those from the Labour Force Survey that DCMS use. In column 2 we set out the comparable data from the ASHE, which is the data set that we shall use in this paper. This shows somewhat lower numbers. We review the reason for these differences below.

The lower panel sets out data from the NESTA (2008) report. Whilst this is about all creative occupations, it also provides some subtotals for design-like activities, based on the decennial Census of Population. Once again, in column 2, we compare these occupational totals with numbers generated from the ASHE and once again, the ASHE numbers are quite substantial under-statements relative to the NESTA numbers, particularly of graphic designers.

Why are these numbers so different? One reason for this is that is different basis of the LFS and ASHE. The LFS includes self-employed, and the self-employment rates are given in the last column. They are quite large, particularly for graphic designers, which would explain understatements in the ASHE. In addition, the LFS relies on self-classification by individuals of their occupation and industry, which the ASHE does not do, and there are typically substantial differences between these. Finally, our ASHE numbers are grossed up to the population of employees using ONS-provided weights.[12]

Finally, the Design Council use LFS data which estimate (which relates to the years 2003-4) 134,000 designers[13] working in the UK (p.10). They suggest however, that LFS data do not include

---

[12] The employment levels of designers are hard to measure. The ASHE samples firms asking about 1% of NI number holders. The problem is that this omits the self-employed and these outside the PAYE system. Also, there may be (systematic) response problems from firms and there are some missing observations due to e.g. incomplete employment years, or workers on training schemes. Thus the ASHE also provides a weight described as "population to LFS total" which according to the documentation is a weight dealing with the 1% sampling and non-response and also the following strata, by gender, three age groups, one digit occupation, 2 work region. The implied total employees in employment sums to around the published total employees, and excludes the self-employed. However, it is suggested that the weights are indicative of totals only, meaning that taking weighted numbers that do not correspond to the strata e.g. numbers by industry, may not correspond to the correct totals. Thus one might go to the LFS for a total, but since the LFS is known to have inaccuracies in reporting industry, then it is not clear that the LFS provides the correct industry totals.

[13] Their definition of designers covers Communication design (Graphics, brand, print, information design, corporate identity); Product and industrial design (Consumer/household products, furniture, industrial design (including automotive design, engineering design, medical products)); Interior and exhibition design (Retail

"designers with supervisory responsibilities, such as design managers in in-house design teams or creative directors in design consultancies". They estimate this number at 51,500 (derived from their own survey of firms which identified these additional people weighted by the LFS numbers). This gives a total of around 185,000 employees.

3. Calculating design output and investment using the supply/use tables.

Table 4 and Table 5 set out, respectively, supply and use tables for an example economy where two activities are undertaken, design activities and car manufacturing. Thus we may define two industries, design and car manufacturing and two products that exist in the economy, design services and car goods. To help motivate what we do below, we suppose that the car industry undertakes its own design activities, but does not sell them in the market. We denote this output Y_{21}^{OA}, which then is shown as an additional entry in the supply table to the quantity Y_{21} which represents the value of design output produced in the car industry and sold to the car industry. It is also an additional entry to the IC section of the use table (we review the case below where Y_{21}^{OA-} adds to GFCF). As the tables show, total supply equals output plus imports, final demand equals intermediate consumption plus investment plus final consumption plus exports and GDP equals output less intermediate consumption.

We may use the tables to review the following examples. First, when a car manufacturer simply buys design services in the marketplace and such services are fully used up in a period, then Y_{12} is simply IC and hence GDP is unaffected. Second, if the car manufacturer produces his own design, Y_{21}^{OA} , and this is treated as IC then again GDP is unaffected. This is the reason why own-account output is typically ignored by National Accounts.

Third, consider now a variant of the first example, where design is bought in, but creates an asset and is so treated as an investment. Thus, from the use table part of IC is re-allocated to GFCF and with a new asset in place GOS rises to represent the payments being made for that asset. Hence GDP rises. Fourth, in a similar variant to the second example, if the own account design creates an asset and is so treated as an investment, then again GFCF, GOS and GDP all rise.

We now need to set out how we are to measure the output of design activities in the car industry. The example above shows that this output consists of that traded in the market-place (and thus recorded in the tables) and that not traded. Thus the main purpose of this section is to describe how to estimate non-traded AED services outside the AED industry.

---

design, office planning/workplace design, lighting, display system, exhibition design); Fashion and textiles design (Fashion, textiles); Digital and multimedia design (Website, animation, film and television idents,digital design, interaction design); Other (including advertising, aerospace design, building design, engineering design, landscape design, jewellery design, mechanical design etc.).

The key to understanding this method is that whilst we do not have data on AED output outside the AED sector, we do have data, from the labour force survey, on the wage costs of specialist designers working outside the AED industry. Thus to obtain output we (a) estimate the output/wage bill ratio of designers in the AED industry, using the cost relations from the use table in the AED industry and (b) multiply this by the wage bill of designers outside the AED sector. We outline first the method and then review the assumptions necessary to implement it.

Consider first then the AED sector, where we need the ratio of output to wage costs of designers in the design firm. The wage bill of designers in the AED industry is not available from the Supply-Use tables since $COE_{I=2}$ refers to all employees in the design industry, which, the labour force data reveals, are not all designers. Thus we calculate wage costs for designers in the design industry, $wN_{I=2}^{O=DES}$ from the labour force data.

What is their corresponding output? One starting assumption might be that it is the output of design products by the design industry which is Y_{22} in the supply table. However, if we used Y_{22} this would assume that in-house AED activities cost the same as those bought-in activities. So, for example, if in-house firms could save on marketing expenditures or some overhead labour then they would save the IC of marketing spending and the COE of shared labour that has to be spent by the design sector. Thus in this case we should apply fractions to IC, COE and GOS to recalculate the industry output. A complication of doing this however is, returning to the use table, that IC, COE and GOS refer to the column sum of costs of producing all products produced by the design industry, namely $Y_{12}+Y_{22}$. Thus we apply the fractions not directly to Y_{22} but to the ratio of IC, COE and GOS to $Y_{12}+Y_{22}$ which we then multiply by Y_{22}. Thus the output of hypothetical firm outside the design sector, Y'_{22} can be written

$$Y_{22}^{'} = \left(\frac{IC_{I=2}}{(Y_{12}+Y_{22})} s_{I=2}^{IC} + \frac{COE_{I=2}}{(Y_{12}+Y_{22})} s_{I=2}^{COE} + \frac{GOS_{I=2}}{(Y_{12}+Y_{22})} s_{I=2}^{GOS} \right) Y_{22} \tag{1}$$

where the *s*'s denote the fractions of each of the expenditures that would be incurred by an out-of-sector firm.

Turning to the car industry, the wage bill of designers in the car industry, denoted $wN_{I=1}^{O=DES}$, is calculated from the labour force data since the COE in the Supply-Use tables, $COE_{I=1}$ refers to all employees. Thus the output of AED in the car industry, Y^*_{21}, is

$$Y_{21}^{*} = \left(\frac{Y'_{22}}{wN_{I=2}^{O=DES}} \right) wN_{I=1}^{O=DES} \tag{2}$$

The final adjustment is that this calculation shows the total AED design output in the car industry and so is the sum of own account and marketed design products, the latter being off-diagonal elements in the supply table. Thus own-account output in the car industry is

$$Y_{21}^{OA} = Y_{21}^{*} - Y_{21} \tag{3}$$

Finally, we wish also to measure purchased design by industry i.e. how much the UK car industry spends on design services. This is a use concept, so we turn to the use table. Since such spending is almost all an intermediate input and very little is final demand then the easiest method would be as (IC_{21}+$GFCF_{21}$) which is readily available from the IO tables.

4. Practical implementation of the framework

4.1 Detail in the supply use tables.

The UK input-output supply-use tables currently provide a detailed specification for a total of 123 different goods and services. The closest product to AED is product 112 defined as "Architectural and engineering activities and related technical consultancy; technical testing and analysis", which is a somewhat wider category than AED services as set out above. This commodity relates to the main activity of units allocated to SIC industries 74.2 and 74.3 (sector SIC74.3 is "Technical testing and analysis"). As Table 7 row 1 shows, in 2004, total supply of the industry 112 (that is the column total) was just above £32bn (that is the vertical sum of the supply table in Table 4). The row sum i.e. total domestic supply of the product 112, was just over £30bn, with 92% of output produced by sector 112 itself, see rows 2 and 3. [14]

4.2 Estimates of AED output outside the design sector

We now wish to measure AED output produced by firms outside the design sector. As discussed above, we have an initial estimate of this, for the existence of off-diagonal elements in the supply

---

[14] This output was broken down in terms of use as follows: £24bn, was attributed to intermediate consumption by producing units, imports were £2bn, £4.5bn were allocated to investment and a much smaller amount (£250m) was deemed to have been used for final consumption by households. Exports accounted for almost £4bn and domestic output of this commodity was approximately £30bn. The fact that some of commodity 112 is treated as investment may seem at odds with the earlier statement that National Accounts treat design purchases as intermediate consumption. This apparent contradiction can be explained by two main factors. Firstly, 112 also includes a number of technical services which are provided by geologists and prospecting companies for mineral exploration purposes. These expenditures are treated as investment in the System of National Accounts and the Oil and Gas industry is one of the main users of commodity 112 for investment purposes. Secondly, the services of architects and engineers are often part of the cost of acquiring assets such as land. Thus, architectural and engineering services can be capitalised when these costs are embedded into the acquisition of a recognised asset. See Appendix 1 for more details.

matrix implies that non-AED industries are supplying AED services. These are however those mediated in the market, so we now wish to measure those produced for in-house use alone.

Following the method above, we start by trying to measure AED output by AED firms. To do this, we need to take a number of steps. First, the SU-tables provide data for commodity 112. As is clear from the definition immediately above, this does not quite correspond to the AED sector we identified from the industry data. Nor does it correspond to AED product, which is a subsector of SIC72.4. Our approach is therefore as follows. We start from the Gross Market Output of product 112 reported in Table 7, row 2, as it is reported in the SU tables. In row 3, we scale down this figure by the percentage of principal product, which tell us the proportion of 112 product output produced by industry 112. Doing this we eliminate any possible side-production in industry 112 and we obtain the Gross Market Output of product 112 by industry112, reported in row 4. We denote this $\tilde{Y}_{22}$, where the tilde refers to the fact that we have a broader design category than in our example. In rows 5 and 6 of Table 7, we start by scaling down this figure by the share of sector 74.2 turnover in the total turnover of sectors 74.2 plus 74.3, which removes SIC74.3 “technical testing and analysis”. This scaling is done using the industry output data from the published ABI tables. Rows 6 and 7 then scale down further this remaining output to remove the subsectors of SIC74.2, such as geology. This second scaling is based on employment data within sector SIC74.2, since a breakdown of output is not provided within industry 74.2. Thus our measure of AED output by AED firms is given by row 7, at about £21.7bn and is denoted Y_{22} :

$$Y_{22} = \tilde{Y}_{22} \cdot \frac{Y^{74.2}}{Y^{74.2} + Y^{74.3}} \cdot \frac{N^{AED}}{N^{74.2}} \tag{4}$$

where $Y^{74.2}$ is the share of industry 112 output imputed to SIC 74.2, $Y^{74.3}$ is the share of industry 112 output imputed to SIC 74.3, N^{AED} is the number of designers in SIC 74.2 and $N^{74.2}$ are all the employees in the SIC 74.2.

We now wish to calculate Y'_{22} from equation (1), where we use Y_{22} from (4) to measure Y_{22} in (1). The unknowns in (1) are the scaling factors, s^{IC}, s^{COE}, s^{GOS}. To recall, because we are interested in Y'_{22}, namely the production costs of AED as relevant to in-house producers, we implement a number of adjustments in order to get to a hypothetical estimate of (1) involving only the necessary costs that would have been undertaken had AED services been produced for in-house use. For example, an in-house producer would likely incur the costs of “core” production of AED services but not the additional marketing and commercialization costs of an external producer. These adjustments, at this stage are a matter of guesswork, but further research should shed light on their accuracy.

To implement this we go through each of the cost elements on the right-hand side of (1) and decide what fraction would apply to in-house production. Starting with intermediate consumption, we use the IO tables to identify the intermediate costs of printing, transport, posts, computer etc. These are set out in Table 8, which shows, in column 1 the proportions of output accounted for by the top 7 cost categories in IC that the IO tables provide. Of these seven, the costs of architectural and technical consulting are the highest fraction, 7%, suggesting extensive use of sub-contracting. In column 3 we assign the fraction of these costs that we think an in-house producer would incur: zero for architectural and technical consulting for example, but 1 for printing and publishing. Again, these ratios are very much guesstimates which we hope future work will improve upon. The total IC that we come up with in this fashion is about 31% of IC for AED firms, see final row of top panel.

The second panel of Table 8 sets out the results for COE. To adjust these data for in-house production we used labour force micro-data (from ASHE) to calculate how the total wage bill in the AED sector breaks down according to the occupational structure of employees in the sector (thus we take the ASHE data for this sector and break the wage bill down by the occupations set out in the Table 2). Thus, for example, managers account for 27% of the total wage bill, professional occupations 39%, of which designers and engineers account for 31% and 34% respectively, and so on. We decided to be conservative and allowed only these occupations are involved in design that likely incur costs for in-house producers; thus the "designer" categories within professional and associate professionals get weights of 1, and engineers a weight of 0.75. All other occupations are given a weight of zero. This gives an overall fraction of 0.23 of the AED COE that we think would be incurred by in-house producers.

Turning to gross operating surplus and mixed income, these combined account for 17% of 112 output. The way to think about this term as a cost is the opportunity cost of the fixed capital used in production plus the opportunity cost of the self-employed AED professionals' time. In the absence of any additional information, we adjust this cost share down by a factor of 75%. Finally, Table 8 shows, "Taxes less subsidies on production". We discount entirely this "cost" component as, unlike the case for R&D, there are no such subsidies for in-house production.

Thus (1) becomes, the hypothetical measure of the costs of AED output that would be incurred by the AED sector if these services were for in-house consumption

$$Y_{22}^{'} = \left(\frac{IC_{I=2}}{(Y_{12}+Y_{22})} 0.31 + \frac{COE_{I=2}}{(Y_{12}+Y_{22})} 0.23 + \frac{GOS_{I=2}}{(Y_{12}+Y_{22})} 0.75 \right) Y_{22} \tag{5}$$

With this measure of Y'_{22} we are now in a position to implement (2), the results of which are set out in Table 9. The first column shows our estimate of Y'_{22}, 7.6bn being the 35% from the bottom row of Table 8 times £21,738m from row 7 of Table 7. The second column shows the wage bills of design occupations in the AED sector and the six others. Note that these wage bills differ from the other wage bills in the earlier tables since they include two important factors. First, they include the wage bill of the self-employed which is, in practice, an important part of the wage bill since there are many small self-employed. Second, the wage bills in all sectors are calculated using the assumed fractions of time that are spent on design activities by the various occupations that are set out in Table 8. Thus column 3 shows the Gross Total AED Output for each non-AED sector. As discussed above, this total potentially includes marketed AED output by the non-AED sector as recorded by the SUT tables (i.e. Y_{21} in our example economy in Table 4). Thus our final adjustment is to subtract the portion of the Gross Market Output sold in the market, see column 5, leaving us with own-account output in column 6 (column 6= column 3 – column 5). The overall total is £27bn, of which almost half is in manufacturing.

5. Comparison with other work

Our final estimates are then about £27bn own-account and £17bn purchased spending. How does this compare with other estimates?

5.1 Design Council (2005)

To the best of our knowledge, the only survey that compares in-house with purchased design is the Design Council (2005). They conducted 2,433 telephone interviews of both design companies (from whom design services would be purchased) but also in-house design teams (to get an idea of own-account design efforts). Their sample included designers in communications (graphics, brand, print, information, corporate identity), product and industrial design, interior and exhibition design, fashion and textiles design, digital and multimedia design (website, animation, film and TV indents, digital design and interaction design) and other (advertising, aerospace design, building, engineering design, etc.). They found (a) a very considerably higher number of firms involved with design than simply those in the IDBR SIC classification 74.87/2 "Speciality Design Services", mainly due to the omission, they find, of 1.77 million partnership businesses and self-employed designers (b) the turnover of design business, to be about £11.6bn and (c) 50% of this figure was bought in services and 50% own-account.

A number of points are worth making. First, this total numbers are clearly lower than ours. One reason for this might be the different definitions of designers; the Design Council survey includes advertising designers but does not include architecture. Second, the fact that they find own-account and purchased expenditures to be about equal is roughly in line with what we find, which is reassuring.

5.2 Community Innovation Survey (CIS)

The EU Community Innovation Survey (CIS) is a survey that asks firms for data on innovation outputs and innovation expenditures. The spending data asks for spending on R&D, design, training and marketing. The main question for our purposes is about innovation expenditure on design where firms are asked to report "spending on design related to new products". Can these data help us either in examining the robustness of the expenditure data above, or in inferring what part of expenditure is investment? A number of points are worth making. First, response rates to the innovation spending data are very low. Second, the total R&D expenditure on CIS (data for 2004) is about £11bn compared to BERD which is about £13.5bn, so there seems to be underreporting of this category at least. Third, turning to design, the CIS number suggests an expenditure of £1.65bn (5% of £33bn), a figure very substantially lower than our purchased figure of £17bn. One possibility is that the response rate for this number is very low and so it might be understated for this reason. Note too that the other reported innovation data on the CIS is understated by around 20%. Furthermore, the CIS respondents are asked for spending on "new design", whereas our data are for total expenditure on all forms of design.

Although design expenditures are quite different in levels, the shares of expenditure over industries show similarities between CIS data and our data. In particular, both this paper and the CIS report the biggest design expenditure share in the manufacturing industry, respectively 38% and 54%. The difference between those percentages seems to be driven entirely by the construction industry, which accounts for 11% in our data and only 2% in CIS data. A possible explanation is that our definition of design occupations includes a wide set of engineers which account for the 78% of all designers in the construction industry. All other industries' shares are alike. Thus the cross-check with shares of design spending seems reassuring that the cross-industry patterns are correct. We use the levels data below.

6. How much design spending is investment?

To answer this question we need to know how much design spending produces an asset that endures for more than a year. Note that as discussed above, ONS already treats some spending on AED services as GFCF and we will not alter this assumption. Thus the question here is, more accurately, how much of currently defined IC spending might produce an enduring knowledge asset?

6.1 Conceptual issues

The SNA definition of an asset is

> *An asset is an entity from which the economic owner can derive a benefit or series of benefits in future accounting periods by holding or using the entity over a period of time, or from which the economic owner has derived a benefit in past periods and is still receiving a benefit in the current period. Because it represents a stock of future benefits, an asset can be regarded as a store of value.[SNA 1993]*

Under this definition, we cannot treat any AED expenditures (market or own account) as AED capital formation because some might be fully used up in current production of other goods and services. It is worth considering the following examples.

(a) *Design of a small kitchen utensil improving its handling and appearance*: The design can be used in the mass production of these utensils over more than a year. It is appropriate to treat the design expenditures as capital formation.

(b) *Design of a clothing range for a particular season*: The design is used in the production of the clothing items (tailored or mass-produced) but only over one period of time. No design asset is created although the design does add value to the clothing items. It is appropriate for them to be treated as intermediate consumption.

(c) *Architectural or engineering design entirely specific to a unique building or piece of transport equipment*: In these examples, it is appropriate to treat all knowledge created as being used up in the production of the final good, which happens to be a tangible asset.

(d) *Architectural or engineering design for a building or piece of transport equipment suitable for mass production*: In these examples, the design is the blueprint which is used to make copies but is not exhausted. Investment is recorded as the buildings / transport equipment items are acquired, but also as the knowledge embodied in the blueprint is created. The cost of the final items reflects the capital services provided by the original design.

Although the conceptual distinction between investment and intermediate consumption is somewhat clear, these general principles are difficult to apply to raw data on architectural and engineering design expenditures. It is an empirical question to establish whether current AED expenditures have an immediate causal impact on market output or whether these expenditures increase market output over a longer period of time. In the latter case, we should observe the market output to decline, everything else constant, once the knowledge embedded in the design becomes obsolete – the way in which intangible assets depreciate over time, see Appendix.

Given the uncertainties, we present different scenarios for establishing how much of AED use corresponds to capital formation.[15]

---

[15] One additional difficulty we have not considered in this exercise relates to the purchase and acquisition of existing AED knowledge. This applies to trade between sectors on intellectual property associated with

6.2 Estimates of how much design spending is investment

Without a clear survey question on this, we use other sources. Here we look at two sources both of which have questions that refer to design expenditure in the production of *new* products. If we wish to distinguish between spending that is on relatively short lasting output and longer lasting, then spending on new products might be an indication.

Our first data set is the Design Council Survey (2004, Table 6.2). They ask *"How is design used in the development of new products /services in your firm?"*; note the use of "new" in this sentence. 14% of firms say that design is not used in the process, leaving 86% of firms saying that it is used to some extent. In turn this breaks down into 16% who say it leads and guides the whole process, 13% used in all stages and 38% in some specific stages, 20% say it is used to a limited extent. However, it should be noted that this question is only asked of those firms who reported having developed a new product or service. Table 6.1 in the Survey reports that this figure is (revenue weighted) 50% of firms[16].

We have then a number of possibilities for the proportion of design spending that is investment. 86% of successful firms have used design at some point in the process that has generated a new product. Of course, this is only the successful firms, but, like R&D, it is perfectly possible that unsuccessful firms also spent but were unlucky. If one confines attention to just successful firms, then the figure is 50% of 86%=43%. A more conservative range for firms using design might be 33% to 66% i.e. the firms who successfully introduced a new product *and* say that design either "leads and guides the whole process (of the development of new products or services) ", or is used in "all" stages or "some specific stages".

Our second data set is the CIS. As we have seen, the raw spending number is £1.65bn for firms who report (likely purchased) spending on design on *new* products. This £1.65bn figure is 9% of the roughly £17bn total spending we have calculated for purchased design above (but if the £1.65bn figure is understated by 20%, as are many of the expenditure numbers in CIS, this would be 11%).

Thus our lower bound is 9% and upper bound is 86%, a range too wide for comfort, but something that we hope future works will narrows. This gives an average of 47.5%, which we shall round to

---

previous AED services, such as registered designs, patents, copyrights and others. Currently, these are treated in the National Accounts as assets that are not produced. Therefore all transactions on these assets do not add to the capital stock if they occur within the country. If we were to treat AED as investment, we should also treat the outright purchase (sale) of AED-related IP from (to) abroad as imports (exports).

[16] The raw data is not revenue weighted, and reports 40% of firms.

50% for convenience. Thus we can take as a starting point that 50% of design spending is on new products.

6.3 Results for 2004 adjusting IO tables for design as investment

We now return to the IO tables and present our estimates of how they differ when at least some part of design is treated as investment. As section 1 showed there are two important differences. First, now that we have measured own account output then we can fill in an extra off-diagonal element in the supply part of the table since industries outside design now produce design services. Second, if we then assume that some fraction of (both purchased and own-account) IC spending on design is investment rather than intermediate consumption, then we need to adjust the IC and investment parts of the "use" table.

The results of this are set out in Table 10. The first row shows the 2004 raw data from the Supply-Use table. Rows 2 and 3 break these data into the two products covering AED and other, as explained in the text. Rows 4 adds the own account data assumed in this row to be intermediate consumption. The final two rows show our estimates of AED market-mediated activity and own-account spending with the assumption that 50% of what was counted as IC is now recorded as GFCF (so note that the activity recorded as GFCF remains, we only reallocate the IC). There are no adjustments to the supply side on the right of the table. The adjustments are to the use side. Total demand and supply are still balanced, but there is an increase in GFCF. In the case of market mediated AED this increase is 7,945=(13,291-5,346) and with own account it is simply 50% of the total spending figure, which is 13,402.

Finally, we may also read off the purchased total from the table, the definition that we adopt being the row sum of IC and GFCF, scaled down by the fraction of output of product 112 that is AED. This gives 17,626 (=9,193+9,680) for AED product.

6.4 Results by industry over time.

The above results can then be split into different industries and repeated for previous years. This is done as follows. For the own account data we simply use the industry-by-industry data in Table 9. For the purchased we compute the sum of IC and GFCF by different industries using the part of the use tables that gives the industry details of the split of IC and GFCF by industries.

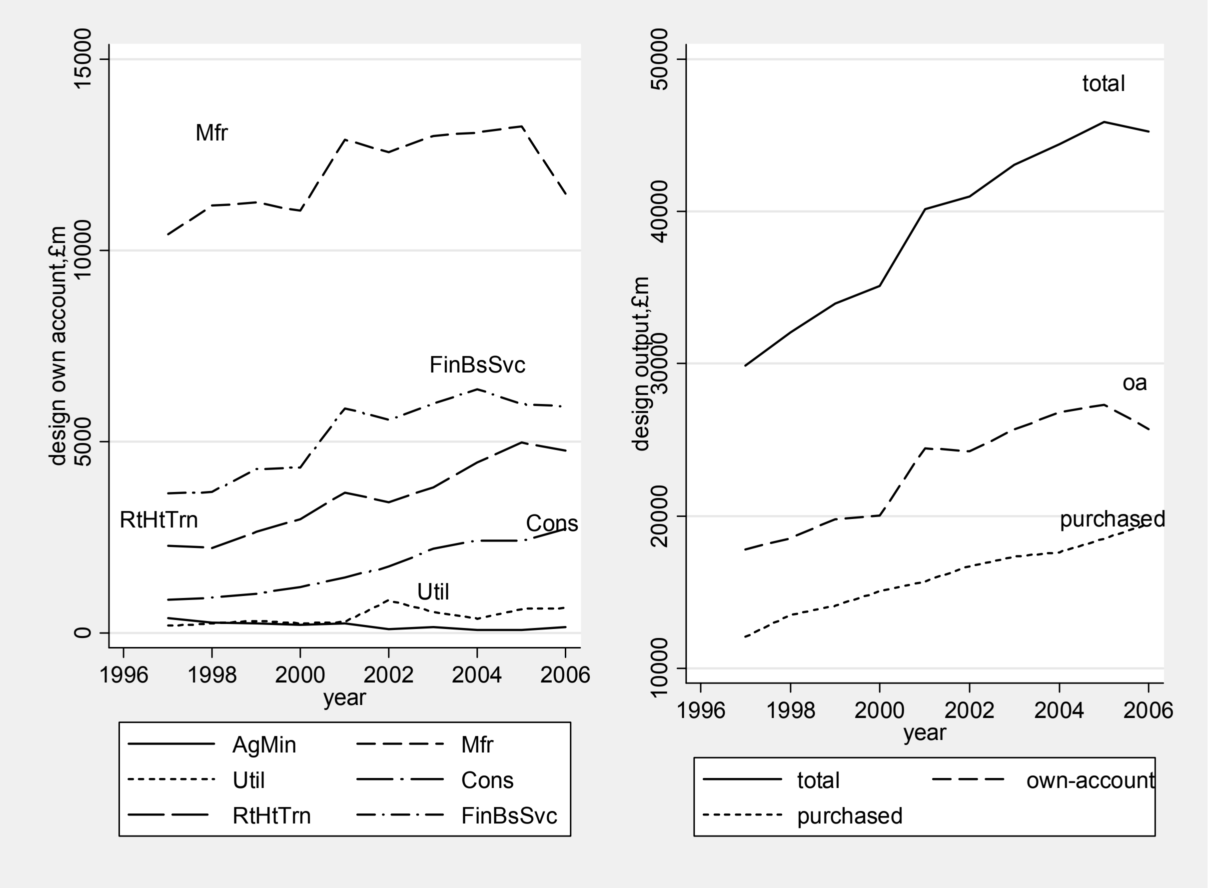
This gives a time series from 1997 to 2006 for the own-account AED output by industry and for the purchased and own account AED output for the whole economy. Note that this is data not on investment but on expenditure on design. This is set out in Figure 1, where the left hand panel shows the own account spending by industry and the right hand panel the spending for purchased and own account in the whole economy. A number of points regarding the figure are worth noting. First, the data for 2005 and 2006 are provisional, being extrapolations of the 2004 data since the 2005 and 2006 IO tables are not available. Second, manufacturing accounts for the lion's share of total spending, although the trend in Finance and Business Services is upward. Figure 2 reports the industry breakdown for the AED purchased output. Again, the data for 2005 and 2006 are extrapolations from 2004 and the Finance and Business Services industry show an upward trend, in addition it is also the industry with the greatest share of total purchased output.

Finally, this number is rather smaller than that quoted in Gil and Haskel (2007). In that paper we used a similar method to infer own-account design, relying on wage bill data in particular industries, although we did not explicitly use the SUTs as we have done here. However, we made a number of different assumptions. First, we used there a much higher output of the design sector (Y_{22}) since we did not reduce the output of the product 112 by as much as we have done here, and so purchased output was much higher. Second, we used that output and the ratio of designer wage bills to infer out-of-sector own account spending. The number are lower in this paper since we have adjusted down the output of the design sector to a hypothetical output (recall this is denoted Y'_{22}) before using the wage bill ratio to try to accommodate the assumption that out-of-sector design units would likely save on a number of overhead costs etc. relative to design sector design units.

7. Conclusion

We have attempted to measure design spending and investment in the UK economy over time for different industries using a framework that is consistent with the UK SUTs and with the method used to capitalise software. Our 2004 data suggests that private sector spending on purchased design services was around £17bn, spending on own-account design services about £27bn and that UK investment in design around half this total, at £23bn. Whilst this approach is based on assumptions and adjustments that aimed to maximize consistency with National Accounts general concepts and available sources, such assumptions clearly warrant further investigation. We think the consultations with parties in the design and related industries would be a valuable step forward.

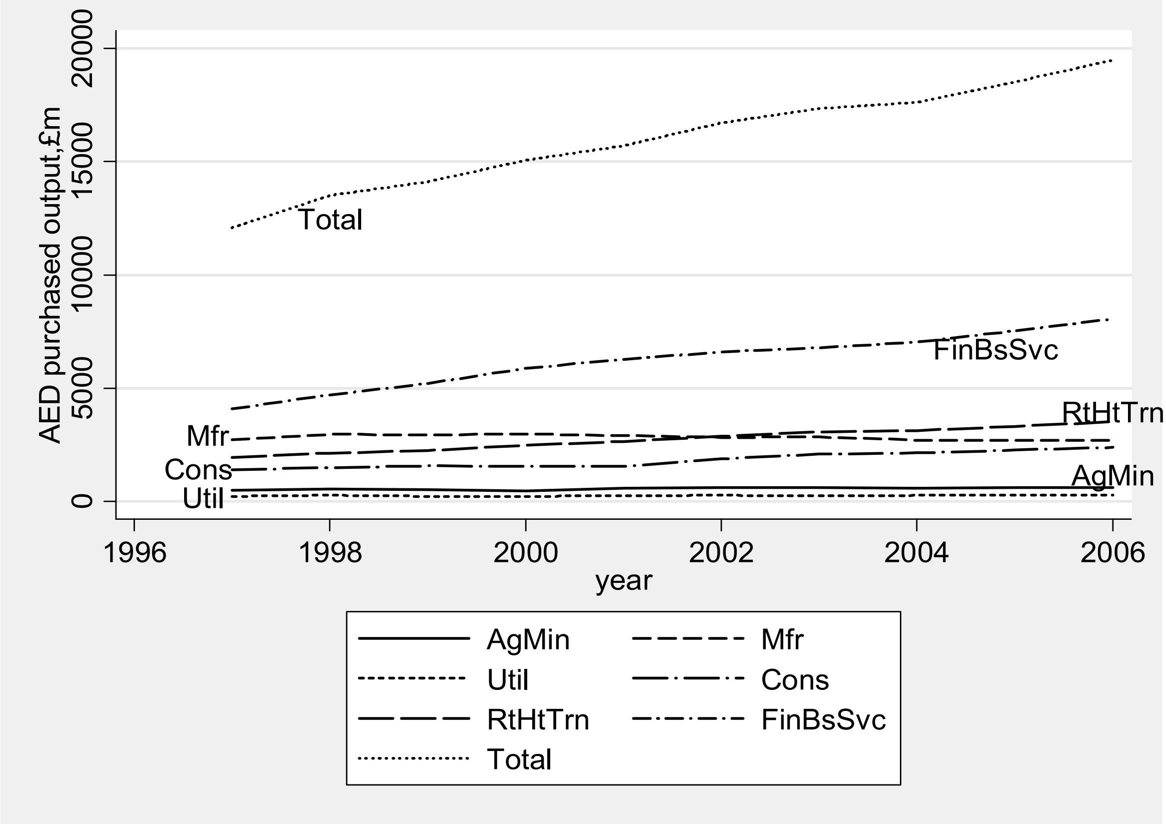
Figure1: Expenditure on AED, by industry, 1997-2006.



Notes: The left-hand side panel illustrates own-account spending by the six industry classification, 1997-2006. The right-hand side panel shows the total own account spending for AED services, total purchased spending and the sum of the two, 1997-2006. The data are based on Input-Output tables 1997-2004 and ASHE dataset 1997-2006. Purchased AED data for 2005 and 2006 are extrapolated using the average annual rate of growth.

Source: Authors' calculations

Figure 2: AED purchased output by 6 industry classification



Notes: The purchased output for product AED is computed as the sum of Intermediate Consumption (IC) and Gross Fixed capital Formation (GFCF). Data comes from IO tables 1997-2004. Data for 2005 and 2006 are extrapolation based on the average annual growth rate.

Sources: Author's calculations

Table 1: Design industries, (SIC2003)

SIC	Title	Description
74.20/1	Architectural activities	This subclass includes: consulting architectural activities: ■ building design and drafting ■ supervision of construction This subclass excludes: activities of interior decoration design cf. 74.87/2
74.20/2	Urban planning and landscape architectural activities	
74.20/4	Engineering consultative and design activities	This subclass includes: advisory and consultative engineering activities and engineering design activities for: ■ the construction of foundations and building structures ■ mechanical and electrical installations for buildings ■ the construction of civil engineering works This subclass excludes: engineering design activities for industrial process and production cf. 74.20/5
74.20/5	Engineering design activities for industrial process and production	This subclass includes: drawing up of preliminary drafts, project development, specification of plans of execution or exact specifications on behalf of the contracting authority for the construction of industrial process and production
74.20/3	Quantity surveying activities	This subclass excludes: research and development activities cf. 73
74.20/6	Engineering related scientific and technical consulting activities	This subclass includes: geological and prospecting activities; weather forecasting activities and geodetic surveying activities. This subclass also includes: activities of technical consultants other than engineers. This subclass excludes other test drilling and test hole boring, activities of computer consultants, research and development activities and technical testing
74.20/9	Other engineering activities	This subclass also includes: integrated engineering activities for turnkey projects
74.87/2	Speciality design activities	This subclass includes: – fashion design related to textiles, wearing apparel, shoes, jewellery, furniture and other interior decoration and other fashion goods as well as other personal or household goods – activities of interior decoration designers – activities of graphic designers This subclass excludes: – machinery and industrial plant design; display of advertisements and other advertising design

Notes: Table 1 report industries with the term design in their description. SIC 74.30 is not included in our definition of design industry and this classification is “Technical testing and analysis”, which includes measuring related to cleanness of water or air, measuring of radioactivity; analysis of potential pollution and testing activities in the field of food hygiene.
Source: own tabulations from directory of SIC numbers and titles

Table 2: Design occupations used by different studies

SOC 2000	Occupation Description	NESTA	ARTS COUNCIL	DCMS	This paper
1134	Advertising and public relations managers	√	x	√	x
1136	ICT managers	x	x	√	x
1225	Leisure and sport manager	x	√	x	
2121	Civil engineers	x	x	x	√
2122	Mechanical engineers	x	x	x	√
2123	Electrical engineers	x	x	x	√
2124	Electronics engineers	x	x	x	√
2125	Chemical engineers	x	x	x	√
2126	Design and development engineers	x	x	√	√
2128	Planning and quality control engineers	x	x	x	√
2131	IT strategy and planning professional	√	x	√	x
2132	Software professional	√	x	x	x
2431	Architects	√	√	√	√
2432	Town planners	√	x	√	x
2451	Librarians	√	√	x	x
2452	Archivist and curator	√	√	x	x
3121	Architectural technologists and town planning technicians	√	x	√	x
3122	Draughtspersons	√	x	x	x
3411	Artists	√	√	√	x
3412	Authors, writers	√	√	√	x
3413	Actors, entertainers	√	√	√	x
3414	Dancers and choreographers	√	√	√	x
3415	Musicians	√	√	√	x
3416	Arts officer, producers and directors	√	√	√	x
3421	Graphic designers	√	√	√	√
3422	Product, clothing and related designers	√	√	√	√
3431	Journalists, newspaper and periodical editors	√	√	√	x
3432	Broadcasting associate professional	√	x	√	x
3433	Public relations officers	x	x	√	x
3434	Photographers and audio-visual equipment operators	√	√	√	x
3543	Marketing associate professional	√	x	√	x
4135	Library assistants\clerks	√	x	x	x
5244	TV,Video and Audio engineers	x	x	√	x
5411	Weavers and Knitters	x	x	√	x
5421	Originators, compositor and print prepares	√	x	√	x
5422	Printers	x	x	√	x
5423	Bookbinders and print finishers	x	x	√	x
5424	Screen printers	x	x	√	x
5491	Glass and ceramics makers, decorator and finishers	√	√	√	x
5492	Furniture makers, other craft woodworkers	√	x	√	x
5493	Pattern makers	x	x	√	x
5494	Musical instrument makers and tuner	x	√	√	x
5495	Goldsmiths, silversmiths, precious stone workers	√	√	√	x
5496	Floral arrangers, Florist	x	x	√	x
5499	Hand Craft occupations not elsewhere classified	x	x	√	x
8112	Glass and ceramics process operative	x	x	√	x
9121	Labourers in building and woodworking trades	x	x	√	x

Notes: The table shows occupations with design or design related in title according to Standard Occupational Classification, 2000. Columns show occupations counted in studies by NESTA(2007), Arts Council (2003), DCMS (2007) and this study. In DCMS study only a proportion of the SOC 9121is included. The NESTA and DCMS papers both focus on what they define creative industries; the Arts Council studies the cultural occupations.

Source: studies cited above and Standard Occupational Classification Occupation.

Table 3: Design employment (as measured by occupations) in design and other industries in 2004

	SIC 74.2	Industry classification						Total Including design industries	Total excluding design industries
SOC		AgMin	Mfr	Util	Cons	RtHtTrn	FinBsSvc		
Civil eng.	14,742	n.r.	6,974	0	12,350	2,398	9,102	45,566	30,824
Mechanical eng.	6,225	n.r.	24,954	n.r.	2,149	5,655	6,547	45,530	49,305
Electrical eng.	4,829	n.r.	6,311	1,994	4,616	4,596	4,483	26,829	22,000
Electronics eng.	0	n.r.	6,521	0	n.r.	3,706	2,587	12,814	12,814
Design eng.	8,705	n.r.	33,640	n.r.	2,199	5,703	8,417	58,664	49,959
Planning eng.	1,702	n.r.	21,535	n.r.	2,293	6,735	4,664	36,929	35,227
Architects	17,208	n.r.	n.a.	0	n.r.	n.r.	3,009	20,217	3,009
Graphic designer	1,617	n.r.	12,754	0	n.r.	3,385	11,193	28,949	27,332
Product designers	n.r.	n.r.	7,417	0	n.r.	6,179	3,371	16,967	16,967
Total	55,028	n.r.	120,106	1,994	23,607	38,357	53,373	292,465	237,437
Wage bill	1,813	n.r.	3,581	73	694	1,239	1,703	9,103	7,290

Notes: Each cell, aside from the last row, shows employment (excluding self employed), the last row shows wage bill (in £ million). The rows are occupations and the columns industries (note that SOC 2125 "Chemical Engineers" is not reported directly due to disclosure). Column 1 is the design industry 74.2 a sub-sector of Finance and Business Services (column 7). Columns 2-7 are the six broad industries that we use in this paper, defined as "Agriculture, Fishing and Mining"; "Manufacturing"; "Electricity, Gas and Water"; "Construction"; "Wholesale and Retail, Hotels and Restaurants, Transport and Communications" and "Financial Intermediation and Business Services". Column 7, Financial and Business Services, excludes 74.2 and 74.87/2 (note that 74.87/2 is not reported directly due to disclosure). The final two columns are then the row sums of these columns, with column 8 including the design industry 74.2 and column 9 excluding it. N.r. stands for not reported due to disclosure.
Source: Authors' calculation on ASHE dataset.

Table 4: Example economy supply table

	Industry		Total Domestic Output	I+M +T-S	Total Supply
	Car	Design			
Product					
Cars	Y_{11}	Y_{12}	$Y_{11}+ Y_{12}$	A	$(Y_{11}+Y_{12})+A$
Design	$Y^*_{21}=Y_{21}+ Y^{OA}_{21}$	Y_{22}	$Y^*_{21}+ Y_{22}$	B	$(Y^*_{21}+Y_{22})+B$
TOTAL OUTPUT	$Y_{11} +Y^*_{21}$	$Y_{12}+Y_{22}$	$(Y_{11}+Y_{12})+ (Y^*_{21}+ Y_{22})$		

Notes: the table illustrates an example supply part of the "supply/use" tables (SUTs) with two industries, cars and design, producing two products, cares and design services. The care industry also produces non-marketed own account design output YOA. The column entitled "I+M+T-S" refers to three separate columns in the SUTs which consist of imports, distributors trading margins, taxes less subsidies

Table 5: Example economy use table

			Total Intermediate Demand	Demand by Household	Gross Fixed Capital Formation		Exports	Final Demand	Total Demand
	Industry								
Product	Car	Design			Car	Design			
Car	IC_{11}	IC_{12}	$IC_{11}+IC_{12}$	$D_{I=1}$	$GFCF_{11}$	$GFCF_{12}$	X_1	$D_{I=1}+GFCF_{11}+GFCF_{12}+X_1$	$TotID_{I=1}+$ Final Demand
Design	$IC_{21}+Y^{OA}_{21}$	IC_{22}	$IC_{21}+IC_{22}+Y^{OA}_{21}$	$D_{I=2}$	$GFCF_{21}$	$GFCF_{22}$	X_2	$D_{I=2}+GFCF_{21}+GFCF_{22}+X_2$	$TotID_{I=2}+$ Final Demand
Total IC	$IC_{11}+IC_{21}+Y^{OA}_{211}$	$IC_{12}+IC_{22}$							
CoE	$CoE_{I=1}$	$CoE_{I=2}$	GVA						
GOS	$GOS_{I=1}$	$GOS_{I=2}$							
Total output	Tot IC+ $CoE_{I=1}+GOS_{I=1}$	Tot IC+ $CoE_{I=2}+GOS_{I=2}$							

Notes: The table shows an example use part of the SUT for an economy with two industries, car and design. IC= Intermediate Consumption; CoE= compensation of employees, GOS= gross operating surplus (payments to capital). The value of total output is total intermediate consumption plus CoE plus GOS. The value of total demand=final demand +total intermediate demand. GVA=CoE+GOS=final demand less imports. The value of total demand for each product equals total supply for each product from the supply table. The value of total output for each industry, here measured by the sum of payments that each industry makes to its productive factors, equals the value of total output supplied by each industry from the supply table.

Table 6: Comparison of ASHE based-employment data with NESTA and DCMS studies

DCMS (2007), data for 2006			
	DCMS (Source: LFS)	Our calculations using ASHE	
Employment in creative industries			
DCMS Architecture sector	82,200	74,072	
DCMS Design sector	3,800	7,260	
TOT	86,000	81,332	
Employment in creative occupations			
DCMS Architecture occupations	29,000	22,613	
DCMS Design occupations	114,900	91,052	
TOT	143,900	113,665	
NESTA (2008),data for 2001			
Employment in creative occupations, not in creative industries (SOC2000)	NESTA (Source: Census)	Our calculations using ASHE	*Memo: Self- employment Rate (NESTA)*
Design and development engineers	62,586	68,434	*11%*
Architects	39,708	25,284	*36%*
Graphic designers	79,854	39,485	*31%*
Product, clothing and related designers	49,604	18,754	*48%*
TOT	231,752	151,957	

Notes: The panels compare the employment data reported in the DCMS (2007) and NESTA (2008) studies with the data from ASHE (the labour force data we use in this paper). The lower right column reports as a memo item the self-employment rates reported in NESTA (2008). The last row reports the total employees in creative occupations as defined by the NESTA work. The NESTA figure includes self-employed, our data excludes them.

Sources: DCMS (2007), NESTA (2008), Authors' calculations on ASHE dataset

Table 7: Estimates of Architectural and Engineering Design (AED) Market Output, (2004)

Row Number	**Description**	**Proportion**	**£m**	**Source / comments**
1	Gross market output of industry 112		32,324	*Supply use input output tables*
2	Gross market output of product 112		30,246	*Supply use input output tables*
3	Proportion of 112 product output produced by industry 112	0.92		*Supply use input output tables*
4	Gross market output of 112 by industry 112		27,826	*Row2*row 3*
5	Sector 74.2 turnover proportion of turnover in sectors 74.2 and 74.3	0.93		*Published sector group turnover from Annual Business Inquiry*
6	Proportion of sector 74.2 employment within AED sub-groups	0.84		*Authors' estimates based on employment in local units using Business Structure Database*
7	Gross market output of AED by AED industry		21,738	*Row4*row5*row6*
8	Gross market output of AED by other indutries		1,890	*Rows (2-4)*row5*row6*

Notes: We assume that all gross output reported in supply use tables is market output i.e. that there are no government owned firms classified to the sector 112. The definition of sector and product 112 is "Architectural activities and technical consultancy". For further explanation see text.
Sources: Supply-Use Tables 2004, the "combined use" matrix table 3.

Table 8: Estimate of AED production costs for own-account production outside the AED sector

	Proportion of Sector 112 Gross Output	Proportion of wage bill paid to employees in the AED sector	Proportion deemed to apply to OA design production	Implied cost components of OA design production
Intermediate Consumption	**0.40**			
For selected product groups				
Printing and publishing	0.01		1.00	205
Transport service	0.01		0.50	161
Postal services and telecommunications	0.01		1.00	400
Computer services	0.03		0.50	535
Market research	0.02		0.50	278
Architectural act. & technical consult.	0.07		0.00	0
Advertising	0.02		0.00	0
Sum of other commodities	0.24		0.32	2,443
			0.31	4,022
Compensation of employees	**0.42**			
Managers		0.27	0.00	0
Professional occupations		0.39	0.00	0
Of which designers		0.31	1.00	1,656
Of which engineers		0.34	0.75	1,362
Associate professional		0.15	0.00	0
Of which designers		0.07	1.00	144
Administrative /secretarial		0.07	0.00	0
Skilled trades		0.08	0.00	0
Personal service		0	0.00	0
Sales and customer		0.01	0.00	0
Operatives		0.02	0.00	0
Elementary		0.01	0.00	0
			0.23	3,162
Gross Operating Surplus	**0.17**		0.75	4,042
Taxes less subsides on production	**0.01**		0.00	0
Gross Output	**1.00**		**0.35**	**11,225**

Notes: The first column shows the fractions of industry 112 output accounted for by IC, COE, GOS and net taxes. The second column refers to the COE panel and shows the fraction of the total wage bill in the AED sector paid to the occupations in the rows. The third column shows, in the body of each panel, the fraction of the row cost that we assume would be incurred by an own-account AED department outside the AED industry advertising in row 8 for example). The final row at the bottom of each panel shows the total share of all IC, COE, GOS and Tax costs that we assume would be incurred by own account design production. The final column shows, in the body of each panel, are the actual reported numbers for industry 112 multiplied by the assumed shares that would be incurred in column 3, and the final row of each panel is the total. The final row then shows that our assumptions suggested that an own-account design department outside the AED industry would incur 35% of the costs within an AED industry, which would be £11,225bn if the 35% was applied to the gross output of the whole 112 industry.

Source: Author's calculations on IO Tables 2004 and ASHE dataset.

Table 9: Calculation of own account AED output by non-AED industries using implied AED unit labour costs, 2004.

Industry	Design sector output, £m	Designer workforce wage bill£m	Gross Total AED output, £m	Share of non-AED industry AED output	Gross Market AED output, £m	AED own account, £m
AED sector	7,608	2,110				
AgMin		n.a.	93	0.00	6.	87.
Mfr		3,920	13,998	0.49	922	13,076
Util		114	408	0.01	27	381
Cons		727	2,598	0.09	171	2,427
RtHtTrn		1,340	4,772	0.17	314	4,458
FinBsSvc		1,910	6,827	0.24	450	6,377
Tot non-AED sector		8,011	28,695		1,890	26,805

Notes: The number in the first column is 35% (from the bottom row of Table 8), times £21,738m (from row 7 in Table 7). In the second column, the wage bill includes self-employed, calculated as a 20% self-employment rate (which is based on a weighted mean of self-employment rate of core designers (0.29) and engineer designers (0.11), source NESTA, 2007). It also included an adjustment for the fraction of time, as in Table 8. The Gross Total AED output is calculated as the industry wage bill in column 2 multiplied by the ratio of AED output to AED industry wage bill (which is row 1 column 1 divided by row 1 column 2). Column 4 reports the share of Out-of-sector output by industry. Column 5 shows the in-house output by each industry sold on the open market, according to the SUT ,and column 6 is own account output for use in-house, namely column 3 less column 5. The Financial and Business services industry excludes the AED industry.
Sources: Authors' calculations on ASHE dataset.

Table 10 Stylized supply use table with additional data on own account output and alternative assumptions on investment.

Product	**Supply**					**Use**								
	Gross output AED sector	**Gross output outside AED**	**imports**	**taxes less subs on product**	**total supply**	**IC by AED sector**	**Total IC**	**GFCF by AED sector**	**Total GFCF**	**Final Consumption**	**Exports**	**Final demand**	**total demand**	**purchased**
Product 112	27 829	2 417	1 688	683	32 618	2 219	20 715	164	2 261	267	3 820	8 652	32 618	
of which														
market AED product	21 740	1 888	1 336	534	25 498	1 702	15 891	126	1 734	0	3 611	5 345	25 498	17 626
Market other 112 product	6 089	529	352	150	7 119	517	4 823	38	526	267	209	1 003	7 119	5 350
Own account AED	0	26 805	0	0	26 805	0	26 805	0	0	0	0	0	26 805	
Market AED product	21 740	1 888	1 336	534	25 498	851	7 946	977	9 680	0	3 611	16 191	25 498	
New own account	0	26 805	0	0	26 805	0	13 402	0	13 402	0	0	13 402	26 805	

Notes: The first row shows the 2004 raw data from the Supply-Use table. Rows 2 and 3 break these data into the two products covering AED and other, as explained in the text. Rows 4 adds the own account data assumed in this row to be intermediate consumption. Rows 5 and 6 show, respectively, the AED data in row 2 and own-account data in row 4. Row 5 and row 6 report the redistribution of IC between 50% and 50% GFCF.

REFERENCES

Advertising Association (2007), "Advertising Statistics Yearbook"

Bakhshi H, McVittie E, Simmie J (2008). "Creating Innovation: Do the creative industries support innovation in the wider economy?**"** *London: NESTA.*
Available at: http://www.nesta.org.uk/assets/pdf/creating_innovation_report_NESTA.pdf

Chamberlin, G., Chesson, A. Clayton, T. and Farooqui, S. (2006), "Survey based measure of software investment in the UK", *Economic Trends*, Office of National Statistics

Chamberlin, G., Chesson, A., Clayton, T. and Farooqui, S. (2007), "New measures of private-sector software investment", *Economic and Labour Market Review*, Office for National Statistics

Corrado, C., Hulten, C. and Sichel, D. (2005), " Measuring capital and technology: an expanded framework", in *Measuring Capital in the New Economy*, edited by Corrado, J.Haltiwanger and D.Sichel, National Bureau of Economic Research Studies in Income and Wealth, *Vol. 65, pp.11-45, The University of Chicago Press,Chicago and London*

Corrado, C., Hulten, C., and Sichel, D. (2006), "Intangible Capital and Economic Growth",NBER *Working Paper, No.11948.*

Davies R., Lindley R. (2003) "Artists in figures. A statistical portrait of cultural occupations" *Arts Council England research report 31.*

Design Council (2005) The business of design. Design industry research 2005

DCMS(2007) Creative Industries Economic Estimates, *Statistical Bulletin.*

DTI(2005), "Creativity, design and Business Performance"

http://www.berr.gov.uk/files/file13654.pdf,

DTI, (2006), Innovation in the UK: Indicators and Insights "Occasional Paper",

http://www.berr.gov.uk/files/file31569.pdf

EU KLEMS Database, www.euklems.net

Hulten C., Wykoff R. (1981) "The estimate of economic depreciation using vintage asset prices" *Journal of Econometrics, vol 15*

HM Treasury (2007) The Cox Review of Creativity in Business

Gil V., Haskel J. (2007), "Industry-level Expenditure on Intangible Assets in the UK" *DTI report, Department for Business, Enterprise and Regulatory Reform (BERR).*

Giorgio Marrano, M., Haskel, J. (2006), "How Much Does the UK Invest in Intangible Assets?, CEPR *Discussion Paper No 6287*.

Giorgio Marrano, M., Haskel, J. and Wallis, G. (2007), "What happened to the Knowledge Economy? ICT, Intangible Investment and Britain's Productivity Record Revisited", *Department of Economics, Queen Mary, University of London*, *Working Paper 603*.

Learning and Skills Council (LSC) (2006), "National Employer Skills Survey 2005: Key findings"

Management Consultancies Association (2005) "The UK consulting industry 2006"

Mandel, M.(2006), " Why The Economy Is a Lot Stronger Than You Think", *Business Week 13 February 2006*.

National Accounts, Concepts, Sources and Methods (2006), available at (http://www.statistics.gov.uk/downloads/theme_economy/Concepts_Sources_&_Methods.pdf)

NESTA (2006) The Innovation Gap.

NESTA (2008) Beyond the creative industries: Mapping the creative economy in the United Kingdom.

OECD (2001). Measuring Productivity OECD Manual, *OECD Paris*.

OECD (2001). Measuring Capital OECD Manual, *OECD Paris*.

OECD (2002). Frascati Manual: Proposed standard practice for surveys on research and development, *OECD Paris*.

OECD (2005). Oslo Manual: Guideline for Collecting and Interpreting Innovation Data, 3rd edition *OECD Paris*.

Office of National Statistics (2006), “Research and development in UK businesses, 2004 (MA14)

Office of National Statistics (2007), “Standard Industrial Classification 2003”

Office of National Statistics (2006), “Standard Occupation Classification 2000”

Office of National Statistics (2007), “United Kingdom National Accounts, the Blue Book.

Okubo, Robbins, Moylan, Sliker, Schultz, and Mataloni (2006), "BEA’s 2006 Research and Development Satellite Account: Preliminary Estimates for 1959-2002; Effect on GDP and Other Measures" available at <http://www.bea.gov/industry/iedguide.htm#rdsa>

Oulton N. and Srinivasan S. (2003) “Capital Stocks, Capital Services, and Depreciation: an integrated framework” *Bank of England, Working Paper no. 192*.

Timmer M.P., O’Mahony M. and Van Ark, B. (2007), “EU KLEMS Growth and Productivity Accounts: An Overview”, www.euklems.net

Triplett J.E. (1997) “Concepts of Capital for Production Accounts and for Wealth Accounts: The Implications for Statistical Programs” *International Conference on Capital Stock Statistics*.

Appendix: Depreciation and deterioration of design

A design cannot deteriorate in the way that a machine experiences "wear and tear". So how are we to account for changes in the design knowledge "capital stock"? The classic method of building capital stocks is to apply the perpetual inventory method (PIM) which accumulates past capital formation and deducts depreciation. But how can we apply depreciation in this case?

To explore this, we need to explain the steps in getting from various definitions of the capital stock to the perpetual inventory model.

1 Productive capital stock & capital services: the quantity side

1.1 Definition

We start with a definition of the "productive capital stock"[17]. It is then typical to assume that this renders a flow of capital services that are directly proportional to the stock, so it is necessary for the estimation of the flow of capital services.

Following OS (2003, equation 10) we define the real productive capital stock of a capital asset at time t, $K^{P}_{i,t}$, as follows:

$$K^{P}_{i,t} = \sum_{\tau=0}^{T} \frac{f_{\tau}}{f_{\tau=0}} F_{i,\tau} \frac{IN_{i,t-\tau}}{p^{A}_{i,t-\tau,age=0}} \tag{6}$$

Where IN is nominal investment in asset i at time t which is converted into constant quality real investment by dividing by a (quality adjusted) investment price index p^A for the new asset at time t. F is a retirement function which describes the share of assets still in service in each period. It takes value one if all the assets are still in existence and zero when all the assets of a particular vintage have been discarded. Finally, $f_{\tau} / f_{\tau=0}$ is the relative marginal product of the investment of age τ, relative to a new machine. The following points are worth making.

First, the intuition behind this expression is that it writes previous investment into new machine equivalents. Second, since the new-machine equivalents are summed, it implicitly assumes that new-machine equivalents are infinitely substitutable with each other. Third, the conditions under

---

[17] Following Triplett (1997) we define the "productive capital stock" as the capital stock measure that contributes to the flow of capital services to production. We distinguish it from the capital stock as a measure of wealth.

which such aggregation over vintages holds are set out in Fisher (1965, see also Hulten, 1972 for a review). Fourth, the practical implementation of the quality adjustment of the price indices is of course difficult. Finally, we may define $f_\tau / f_{\tau=0}$ as an age-efficiency profile outlining the loss in the quantity of capital services as the asset ages.[18]

The common feature of (1) is that all terms are *quantity* concepts, that is, they relate to the quantity of capital or capital services. This is illustrated by considering joint effect of $f_\tau / f_{\tau=0}$ and *F* both of which gives a loss in the quantity of capital services as the capital asset ages. To clarify terms, we will define both these terms as "deterioration" (this is also "wear and tear" as used in the introduction). The loss in efficiency due to the $f_\tau / f_{\tau=0}$ function is sometimes described as "decay" and retirement *F* is sometimes described as "discard". OS also use the $f_\tau / f_{\tau=0}$ to summarise both "input decay" and "output decay".[19] Hence, deterioration measures the change in the *quantity* of capital services provided given a certain input.

Thus all these terms describe the effect of aging on the decline in capital *quantities*. Now, it is quite possible that as capital ages it declines in *value*. This is, under our definitions, related to *depreciation*. Since depreciation is a price concept and not a quantity concept, we defer discussion until later.

This form of expression means that we can write the productive capital stock equivalently as

$$K_t^P = \frac{IN_t}{p^A_{t,age=0}} + \left(\frac{f_\tau}{f_{\tau=0}}\right) K_{t-1}^P \qquad (7)$$

1.1.1 Digression: Triplett example

As a slight digression, a simplified example of measuring capital services is set out in Triplett (1997), who supposes a firm owns a fleet of identical trucks of different ages. Their level of productiveness will differ according to their age. Consider now the case when the firm buys a new truck and we want to measure the firm's productive capital stock. The new trucks will produce one

---

[18] The OCED definition of the productive capital stock of a homogenous asset at time *t*, $K^p i,t$, is:

$$K_{i,t}^P = \sum_{\tau=0}^{T} h_{i,\tau} F_{i,\tau} \frac{IN_{i,t-\tau}}{p^A_{i,t-\tau,age=0}}$$

Where h is the age-efficiency profile. The algebra differs from the OS model since they assume in their model that IN is in efficiency units net of retirement.

[19] As OS say, page 18, note 6, "Output decay occurs when, with unchanged inputs, the output from a given asset declines over time, eg as a result of mechanical wear and tear. 'Input decay' occurs when maintaining output requires increasing other inputs, eg rising maintenance expenditure."

unit of capital services, while a one year old truck will produce (1-D_1) units of capital services, where D_1 is the deterioration between the new and the one year old truck. Given the proportion of deterioration D_t, we can express all the different vintages of capital goods as some fraction of the new one: all ages of trucks can be expressed in terms of a new-truck equivalent.

Once the measure of inputs is comparable, we can define the productive capital stock as the sum of the different vintages of capital goods. In our example, suppose the firm buy a new truck each year for five years. At the end of the 5th year its productive capital stock will equal Λ :

$$\begin{aligned}\Lambda = t_5(1-D_1)(1-D_2)(1-D_3)(1-D_4)(1-D_5)+t_4(1-D_1)(1-D_2)(1-D_3)(1-D_4)+ \\ +t_3(1-D_1)(1-D_2)(1-D_3)+t_2(1-D_1)(1-D_2)+t_1(1-D_1)\end{aligned} \qquad (8)$$

where the D's indicate the deterioration profile for capital goods as they age. Therefore (1-D_t) terms represent the marginal products of different vintages of capital services relative to new trucks. That is we can rewrite (1-D_t) as:

$$(1-D_{t=s}) = \frac{\partial\Lambda/\partial t_s}{\partial\Lambda/\partial t_0} = f_s/f_0 \qquad (9)$$

with f_s being the marginal product of trucks of age *s*, and f_0 the marginal product of new trucks. Equation (3) describes the age-efficiency profile for trucks of different ages.

Now, we can define the productive capital stock at the end of period *t* in terms of the deterioration profile:

$$K_t = I_t + (1-D_t)K_{t-1} \qquad (10)$$

Equation (5) simply writes the productive capital stock at the end of period *t* rather than at the end of all five periods in equation (3).

1.2 Age efficiency profiles

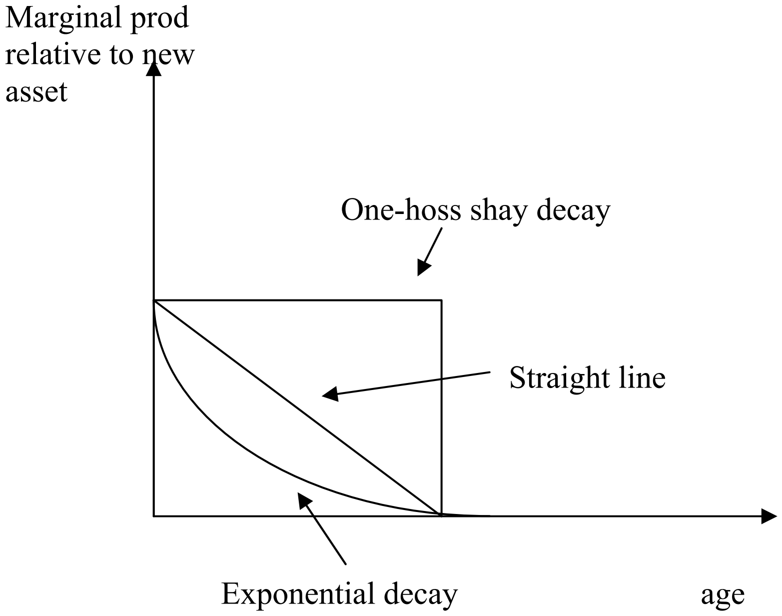
Returning to our main theme, there exist several age-efficiency profiles that could describe the loss in productivity of a capital good:

- The "one-hoss shay" pattern refers to capital goods which no suffer any decay during their life time providing a constant stream of services until the day in which they are retired. An example of capital goods following this pattern is a bridge.

- The geometric pattern involves a loss in the productivity of the capital good at a constant rate each year. The geometric profile implies that the rentals generated by the asset will decrease more in the first period and then decreasing of reducing amounts in subsequent years.
- The linear pattern consists in a fall in efficiency of a constant amount each year.

The evidence on this is discussed by Berndt (2002) for example. If one assumes the one-hoss shay pattern for services, the change in capital services comes about when a vintage is retired. If the time of retirement is stochastic, one can estimate the shape of the distribution of retirements of various durable goods. Figure 1 shows some age-efficiency profiles

Figure 1: Age efficiency profiles



1.3 Choosing the right age-efficiency profile: from quantities to prices

To choose the appropriate age-efficiency profile would seem to the provenance of engineers, since this relates to *physical* decay. However, economic theory suggests that one can do this by deriving the age-*price* profiles that would exist in a competitive economy that are implied by various different age-*efficiency* profiles.

There are two steps to doing this. First, we can derive the relation between the age-efficiency profile and rental prices of goods of different ages. Second, since rental prices are hard to observe, we derive the relation between the rental prices of different ages and initial asset prices.

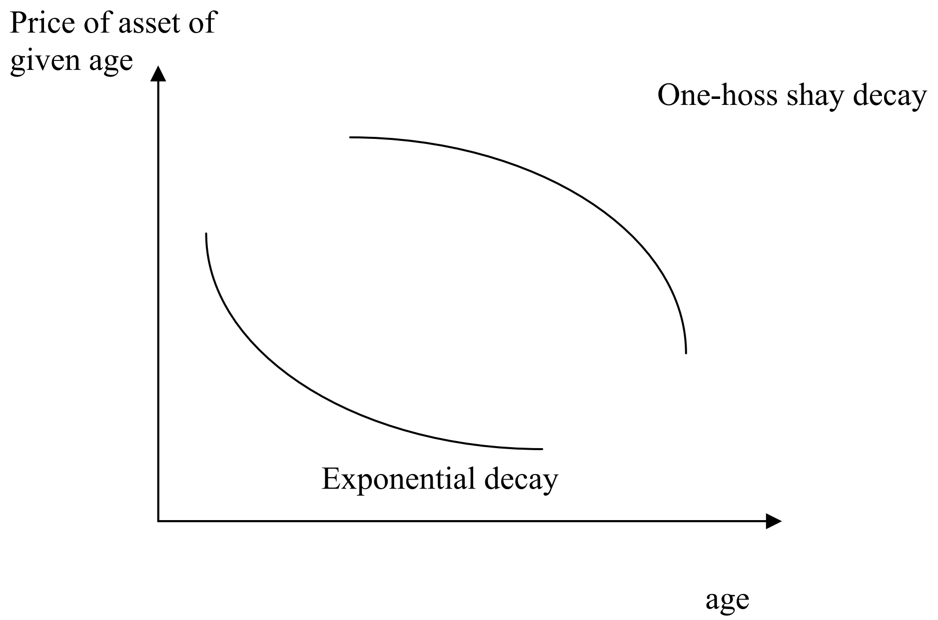
1.3.1 Intuitive explanation

Following Berndt we have the following. The key is that in cost minimising equilibrium the purchase price of a used asset must equal the equal the present discounted value of the stream of revenues expected over the remaining life of the asset.

So suppose the deterioration pattern is one-hoss shay. With discounting, the price that firms would be willing to pay to buy successively older assets would decline slowly at first with age, since the final period, when the asset will be almost retired, will be discounted away. As that final period approaches however, the asset price will fall dramatically. With geometric deterioration, then the asset decays proportionally rapidly at the start of the period and so the age-price profile also does. It can be shown that in this case the age efficiency and age price profiles coincide.

Diagrammatically, we have price of a used asset against age has the following shape.

Figure 2: Age price profiles



1.3.2 Formal explanation

The formal explanation requires two economics assumptions. First, arbitrage: the price of an asset must equal the present discounted value of the stream of contributions to revenues expected over the remaining life of the asset. Second, cost minimisation: a profit-maximising firm will rent machines up to the point where the rental price equals the value of the marginal product from the machines, so the per period rental price equals the per period contribution.

Thus we can write the asset price as equal the present value of the future stream of rental prices

$$p^{A}_{t-1,age=0} = \sum_{z=0}^{n} \left[p^{K}_{t+z,age=z} / (1+r)^{z} \right] \tag{11}$$

Where this refers to a new asset i.e. who has age=0. Now write down the same formula for an asset of age s for times z=0 to n

$$p^{A}_{t-1,age=s} = \sum_{z=0}^{n} \left[p^{K}_{t+z,age=s+z} /(1+r)^{z} \right] \tag{12}$$

We can now derive the relation between the asset prices at time *t-1* of vintage *s* relative to the new vintage and the rental prices at time t-1 of vintage s relative to the new vintage by dividing (12) by (11) giving

$$p^{A}_{t-1,age=s} / p^{A}_{t-1,age=0} = \sum\nolimits_{z=0}^{n} \left[p^{K}_{t+z,age=s+z} / p^{K}_{t+z,age=0+z} \right] * (1+r)^{z} * [p^{K}_{t+z,age=0+z} / p^{K}_{t-1,age=0}] \tag{13}$$

Now, per period cost minimisation gives the equality relationship between the per period rental price and the per period marginal product of capital for any pair of periods

$$p^{k}_{t+z,age=s+z} / p^{k}_{t+z,age=z} = f_{age=s+z} / f_{age=z} \tag{14}$$

so we can define the ratio between asset prices as:

$$p^{A}_{t-1,age=s} / p^{A}_{t-1,age=0} = \sum\nolimits_{z=0}^{n} \left[f_{age=s+z} / f_{age=0+z} \right] * (1+r)^{z} * [p^{K}_{t+z,age=0+z} / p^{K}_{t-1,age=0}] \tag{15}$$

If we now assume that decay is geometric, the relation between the marginal products is:

$$f_{s+z} / f_z = (1-D)^s \tag{16}$$

And substituting (16) into (15) gives that the ratio of the asset prices, the age-price profile, equals the decay factor, the age-efficiency profile:

$$p^A_{t-1,s} / p^A_{t-1,0} = (1-D)^s \tag{17}$$

We now clarify the relationship with *depreciation* which being a price concept we have not yet defined.

2 Depreciation: the price side

2.1 Definition of deprecation

Deprecation has been defined in a number of ways. We define it as

$$\begin{gathered} depreciation = p^A_{t,age=0} - p^A_{t,age=1} \\ depreciation\ rate = 1 - (p^A_{t,age=1} / p^A_{t,age=0}) = \delta \end{gathered} \tag{18}$$

From which the following points are worth noting. First, deprecation is a price concept, involving prices of capital goods. Second, says how at given point in time an old and a new asset price are related. Before proceeding to explain this point more fully, note that (18) and (17) and (16) imply that under geometric depreciation

$$f_{s+z} / f_z = (1-\delta) \tag{19}$$

And so we can write

$$K^P_t = \frac{IN_{t-1}}{p^A_{t-1,age=0}} + (1-\delta)K^P_{t-1} \tag{20}$$

2.2 Depreciation, capital gains and rental prices

We can derive the relation between these three terms in two ways. One is simply to subtract (12) from (11) giving that

$$p^A_{t-1,age=0} - p^A_{t,age=1} = p^K_{t,age=0} - rp^A_{t-1,age=0} \tag{21}$$

This says that a firm holding onto an asset and therefore experiencing the change in the value of the asset over the two periods equals the rental price less the return on the asset. This can be seen otherwise as follows.

Consider a firm that buys a new capital good at the end of period *t-1*, and rents it during period *t* and then gets it back. At the end of period *t*, by definition, the value of the firm's investment will be $(1+r_t)p^A_{t-1,age=0}$, where r_t is the nominal rate of interest during period *t* and $p^A_{t-1,age=0}$ is the asset price paid by the firm for the new asset at the end of period *t-1*, where the first subscript indicates the time at which the asset is acquired, the second is the asset's age. Thus arbitrage will ensure that this value equals the value of renting the asset out, which consists of the rental payment, plus the end of period value of an asset one year older

$$(1+r_t)p^A_{t-1,age=0} = p^K_{t,age=0} + p^A_{t,age=1} \tag{22}$$

Thus from (22) we can derive the rental price at time *t* of a new asset ($p^K_{t,age=0}$) in terms of the asset price (p^A) as:

$$p^k_{t,age=0} = r_t \cdot p^A_{t-1,age=0} + (p^A_{t-1,age=0} - p^A_{t,age=1}) \tag{23}$$

Which says that the rental price of an asset needs to compensate the renting firm for (a) the return the firm could have earned itself on the asset plus (b) any change in the value of the asset.

We can clarify some terms by further considering the second term on the right hand side of (23) and adding and subtracting $p^A_{t,0}$ to the right hand side; giving:

$$p^k_{t,age=0} = r_t \cdot p^A_{t-1,age=0} + (p^A_{t,age=0} - p^A_{t,age=1}) - (p^A_{t,age=0} - p^A_{t-1,age=0}) \tag{24}$$

This separates two distinct effects in the second term on the right hand side of (23). First, we may compare the price, at time t, of an asset that is new (age=0) and old (age=1). Second, we may compare the price, from time t to time t+1, of an asset that was new in time t-1. So, for example, the first effect is to compare, in 2007, a house that is 1 years old with one that it is 2 years old. The second effect is to compare, between 2007 and 2008, a house that was new in 2007. The first effect is depreciation

$$depreciation: p^A_{t,age=0} - p^A_{t,age=1} \tag{25}$$

And the second a capital gain/loss term, namely the difference in prices of new assets in contiguous periods of time, thus the change in value of the asset due to changes in its market price or to obsolescence, independent of the effects of ageing:

$$capital\ gain/loss : p^A_{t,age=0} - p^A_{t-1,age=0} \tag{26}$$

Indeed, while in depreciation we compare in the same period *t* the price of a brand new asset with the price in the second-hand market of a one year old asset, capital gain/loss compares the prices of two new assets in different periods. Thus we have

$$p^k_{t,age=0} = r_t \cdot p^A_{t-1,age=0} + \delta_t p^A_{t,age=0} - (p^A_{t,age=0} - p^A_{t-1,age=0}) \tag{27}$$

A number of points are worth making regarding the second term on the right-hand of (23). First, it is commonly called depreciation, although as stated above, and following Oulton and Srinivasan (2003) we should not call it that here. As OECD Productivity Manual point out, page 66, paragraph 104, it is also sometimes called "consumption of fixed capital". In that publication, they then use deprecation as we do here. They define an alternative term for this as "cross-section deprecation" and define "time-series depreciation" second term on the right-hand of (23).[20] Note that it is not the quantity concept of the loss in productivity/deterioration since it is a price concept.

3 Wealth capital stock: the price side

Finally, we are in a position to define the wealth capital stock, which, following OS, page 26, is current price value of all vintages of surviving investment goods according to the market price at time *t*. It is given by:

$$KN^W_t = \sum_{\tau=0}^{T} p^A{}_{t,\tau} F_\tau \frac{IN_{t-\tau}}{p^A{}_{t-\tau,age=0}} \tag{28}$$

Equation (1) and equation (23) differs only by the first term $p^A{}_{i,t,\tau}$, which is the market price at time *t* of an asset of age τ. This is sometimes called the net capital stock (OECD, p.133) and can be written in terms of the age-price profile $p^A{}_{t,age=\tau} / p^A{}_{t,age=0}$. Replacing it in equation (23) we obtain the measure for the wealth capital stock at constant prices

---

[20] In the Capital stock manual they define deprecation differently as the "the differences in real terms between successive real market values of an asset over its lifetime". See "Measuring Capital", page 20, OECD Manual, 2001.

$$K^{W}_{i,t} = \sum_{\tau=0}^{t} \frac{IN_{i,t-\tau}}{p^{A}_{i,t-\tau,age=0}} \frac{p^{A}_{t,age=\tau}}{p^{A}_{t,age=0}} F_{i,\tau} \tag{29}$$

Comparing (1) and (24) we see that the productive capital stock at constant prices and the wealth capital stock at constant prices will be equal only if the age-price profile and the age-efficiency profile are identical.

3.1 How do intangible assets wear out?

Finally, we are now in a position to better understand how we can have a declining stock of intangible assets even though ideas do not physically "wear out", drawing on the discussion in Oulton and Srinivasan (2003). While physical wear and tear causes tangible assets (buildings, machinery,.etc.) to decay with age, knowledge assets do not exhibit physical decay but are nevertheless discarded early from the market. If we look for example at ICT assets like software, commonly they are replaced though their flow of capital services is unchanged. The cause of this is usually identified as "obsolescence" when newer and better assets enter the market. Although obsolescence is a price concept - it affects only the value of the asset and not the quantity of capital services provided - for an asset to become obsolete will result in a reduction of its life service. For example, a new version of a word processor causes older version not to work so well and so are retired. As it is shown by equation (1), a variation in the retirement pattern will affect the real productive stock through *F*, the retirement function.

There is little international consensus on the degree to which obsolescence occurs. If we assume a geometric age-price profile then this implies an age-efficiency profile. So the rate of obsolescence and the rate of decay coincide and hence we can compute the intangible capital stock through the PIM method above.