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NESTA Making Innovation Flourish

Investing in innovation

Findings from the UK Investment in Intangible Asset Survey

Gaganan Awano (ONS), Mark Franklin (ONS), Jonathan Haskel (Imperial College) and Zafeira Kastrinaki (Imperial College)

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

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Foreword

NESTA's Innovation Index has shown that innovation is the most important source of economic growth in the UK, and offers the best route out of recession.

This report makes a substantial contribution to the evidence base of UK business innovation, identifying in unprecedented detail the investments that they make in intangible assets from R&D to organisational innovation, and the useful life of these investments.

The results will make an important contribution to the Innovation Index, and so will increase our understanding of what drives economic growth in the UK and how to create the right conditions for recovery.

The survey has been designed and administered by the Office for National Statistics and Imperial College London, for whose contribution and insight we are extremely grateful.

As always, we welcome you comments.

Stian Westlake
Executive Director of Policy and Research, NESTA

July, 2010

Executive summary

To support the work on intangible assets and productivity within NESTA's Innovation Index project, this paper reports on a new micro survey of intangible assets. The survey of 2,004 UK private sector firms explored the level of (a) spending and (b) life lengths of private sector investments in intangible assets. The survey draws on a statistically representative sample of UK private sector firms, using the UK business register, and was conducted between October 2009 and January 2010.

This is a new survey, and it has three main innovative features. First, as well as asking about R&D expenditure, the survey asked firms to detail expenditure on a wider range of spending on intangibles: training, software, branding, design and business process. Second, since much spending on intangibles is in-house, the survey specifically asks firms about both purchased and in-house spending. Third, to estimate depreciation rates for intangibles, the survey also asked about the length of time firms expected to benefit from such spending.

The work is therefore distinctive from other surveys, the bulk of which do not ask for all intangibles, but just one, such as R&D or design. With the survey the project team can examine hypotheses such as those in Griliches (1990),[1] who conjectures that other innovation spending, not counted as R&D, is likely important, especially for small firms.

The main survey that does touch on intangibles is (various versions) of the Community Innovation Survey (CIS). However, the CIS does not ask about all intangible categories (business processes for example), does not ask specifically about in-house and purchased (a distinction we find to be very important), and does not look at life lengths. On the issue of life lengths, to the best of our knowledge, the only survey we are aware of is that of the Israeli Statistics Bureau (Peleg 2008a, 2008b).[2] The distinguishing features of the survey therefore provide some innovative micro information to both inform analysis at the micro level and to provide a check against the estimates used at the macro level.

The Investment in Intangible Assets (IIA) Survey was a voluntary postal survey funded by the National Endowment for Science Technology and the Arts (NESTA) and conducted by the Office for National Statistics (ONS). We obtained responses from 838 firms, a 42 per cent rate which is high for a voluntary survey.

Weights were calculated from the UK business register.

The study has two main sets of findings, concerning intangible spending and life lengths.

1. Intangible spending: incidence and amount.

    a. The incidence of non-R&D intangible spending is much more widespread than R&D spend. Eight per cent of UK firms spend on R&D, all of whom also spend on non-R&D intangible spending. But 50 per cent of UK firms spend on non-R&D assets.

    b. The incidence of both non-R&D and R&D intangible spend is more common in large and older firms. But non-R&D spend is much more common in services relative to manufacturing, especially in financial services. Thus much of the incidence of innovation spending in

1. Griliches, Z. (1990) Patent Statistics as Economic Indicators: A Survey. 'Journal of Economic Literature.' Vol. 28, pp.1661-1707.
2. Peleg, S. (2008a) 'Service lives of R&D.' Jerusalem: Central Bureau of Statistics; also: Peleg, S. (2008b) 'Examples of surveys on service lives of R&D.' OECD Task Force on R&D and Other Intellectual Property Products. Paris: OECD.

the service sector, a major part of the economy, is not captured in the R&D statistics.

c. The overall level of intangible spend is considerable, around £39 billion in this survey, of which software is about £11 billion, branding £10 billion, R&D £10 billion, training £7 billion and design and business process improvement £1 billion each. In-house spending is, on average, 55 per cent of this and purchased 45 per cent. Spending as a fraction of turnover (spending intensity) is particularly high in financial services and somewhat weakly higher in small firms.

d. Taking into account differences in definition and timing, these micro numbers compare quite closely with the numbers used in the macro study for the UK Innovation Index (Haskel *et al.*, 2009)[3] for training, software, R&D and branding. The micro numbers here are much lower than those in the macro data for design and business process improvement. This may have to do with sampling (for example according to the Design Council, 85 per cent of designers are in small firms outside the IIA sample) or the recession or inaccuracy of the assumptions upon which the macro numbers are based, all of which needs investigation in future work.

3. Haskel, J. *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project.' London: NESTA.

2. Life lengths

The survey asked firms to report "on average, how long the business expects to benefit from a typical investment in" each of the assets. The main findings are:

a. Average benefit lives for all intangibles were over one year, supporting the idea that intangible investment brings long-lived benefits. Indeed, the lowest of the 95 per cent confidence intervals for all assets were over two years, except for branding which was 1.9 years.

b. R&D had the longest average benefit life of 4.6 years; the average of the others was 3.2 years. In the previous pilot survey respondents were asked, in addition to benefit time, time for development and implementation. Adding these times to the benefit time gives average life lengths of 8.6 years for R&D and five years for other intangibles, with longer life lengths in production than services. On a double declining balance assumption, this gives deprecation rates of 23 per cent for R&D and 40 per cent for other intangibles.

Contents

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

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

Part I: Introduction

Innovation is a key growth driver of modern economies. There are many ways to quantify it, including innovation surveys, patents and measuring spending on innovation such as R&D or design. One approach popular in economics is to study the sources of growth and approximate innovation by TFP growth. The approach is *de facto* a central part of the policymakers' tool kit and central bank analysis, in part because it is integrated with national accounts data. Forecasts for post-financial crisis growth for example depend critically on the assumed path of TFP growth and such forecasts underlie all serious budget projections.

This approach to studying growth has received even more attention following the widely referenced papers by Corrado, Hulten and Sichel (2005, 2008).[4] They suggested treating a wide range of knowledge spending (on R&D, but also software, design, training and business processes) as an investment rather than current practice where it is (with the exception of software) expensed. In order to do this, we require a better understanding of business expenditure on different forms of intangible assets and the rate at which they depreciate.

Existing micro-literature on spending on intangibles is varied. Regarding spending on particular intangibles, there is of course a very large literature on the collection and interpretation of R&D data. Griliches (1990)[5] conjectures that other innovation spending, not counted as R&D, is likely important, especially for small firms, but in general this literature is, quite understandably, devoted to the considerable complications of R&D. For other intangible categories, there are various studies of, for example, training or design, but such studies tend to be much thinner on the ground. For example, aggregate data on UK spending indicates twice as much spending on software than R&D, but there are much fewer micro studies on software spend than R&D.

A few studies have attempted to gather firm-level data on a range of intangibles beyond R&D. The present survey builds upon an earlier pilot exercise of 38 firms, funded by NESTA, reported in Whittard *et al.* (2009).[6] As part of the Innovation Index project NESTA also undertook a survey of around 1,000 firms in particular industries (Roper *et al.*, 2009).[7] In the US, the Kauffman survey has recently included some intangible spending questions. Finally, the EU-wide community innovation survey asks some intangible spending questions, but, as we discuss below, asking about particular assets and for spending only in relation to innovation (defined by the firm).

On the issue of life lengths, to the best of our knowledge, the only survey we are aware of is that of the Israeli Statistics Bureau (Peleg 2008a, 2008b).[8]

The purpose of this paper is to report on the methodology and results of a new micro survey of intangible spending and life lengths. We call this the Investment in Intangible Assets (IIA) survey which was launched in October 2009. The IIA survey is an important element of NESTA's Innovation Index project, a major project and was conducted by the Office for National Statistics (ONS). The survey was a voluntary postal survey. The ONS sampled around 2,000 firms and obtained complete responses from 838. The survey asked about spending, both own-account and bought-in, on training, software, branding, R&D, design and business process improvement. The survey also

4. Corrado, C., Hulten, C. and Sichel, D. (2005) Measuring Capital and Technology: An Expanded Framework. In: Corrado, C., Haltiwanger, J. and Sichel, D. (Eds) (2005) 'Measuring Capital in the New Economy: Studies in Income and Wealth.' Chicago: University of Chicago Press.
5. Griliches, Z. (1990) Patent Statistics as Economic Indicators: A Survey. 'Journal of Economic Literature.' Vol. 28, pp.1661-1707.
6. Whittard, D., Franklin, M., Stam, P. and Clayton, T. (2009) 'Testing an extended R&D survey: Interviews with firms on innovation investment and depreciation.' NESTA Innovation Index Working Paper. London: NESTA.
7. Roper, S., Hales, C., Bryson, J. and Love, J. (2009) 'Measuring sectoral innovation capability in nine areas of the UK economy.' NESTA Innovation Index Working Paper. London: NESTA.
8. Peleg, S. (2008a) 'Service lives of R&D.' Jerusalem: Central Bureau of Statistics; also: Peleg, S. (2008b) 'Examples of surveys on service lives of R&D.' OECD Task Force on R&D and Other Intellectual Property Products. Paris: OECD.

asked about the length of time firms expected to benefit from such spending.

We have two main sets of findings, concerning intangible spend and life lengths.

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   b. The incidence of both non-R&D and R&D intangible spend is more common in large and older firms. But non-R&D spend is much more common in services relative to manufacturing, especially in financial services. Thus much of the incidence of innovation spending in the service sector, a major part of the economy, is not captured in the R&D statistics.

   c. The overall level of intangible spend is considerable, around £39 billion in this survey, of which software is about £11 billion, branding £10 billion, R&D £10 billion, training £7 billion and design and business process improvement £1 billion each. In-house spending is, on average 55 per cent of this and purchased 45 per cent. Spending as a fraction of turnover (spending intensity) is particularly high in financial services and somewhat weakly higher in small firms.

   d. Taking into account differences in definition and timing, these micro numbers compare quite closely with the numbers used in the macro study for the UK Innovation Index (Haskel *et al.*, 2009)[9] for training, software, R&D and branding. The micro numbers here are much lower than those in the macro data for design and business process engineering. This may have to do with sampling (for example according to the Design Council, 85 per cent of designers are in small firms outside the IIA sample) or the recession or inaccuracy of the assumptions upon which the macro numbers are based, all of which needs investigation in future work.

9. Haskel, J. *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project.' London: NESTA.

2. Life lengths

   The survey asked firms to report "on average, how long the business expects to benefit from a typical investment in" each of the assets. The main findings are:

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The rest of the paper is organised as follows. Section 2 describes the survey conduct while Section 3 presents the results. Specifically, Section 3 discusses the response rates of the survey and the weights used. It then presents incidence of expenditure by asset, average and total expenditure by asset, and life lengths of intangible assets. Section 3 concludes with a comparison of IIA survey with other data. Section 4 summarises and concludes.

Part 2: Conduct of survey

The survey was sent in October 2009 to 2,004 UK firms with ten or more employees across the production and service sectors of the economy. The firms were warned in advance of receipt of the survey and reminded by phone in the event of non-response. Checks are also done for outlier returns. Out of the 2,004 firms sampled there were three groups identified: 762 that did not reply at all which also includes a very small number that went out of business between drawing the sample from the register and sampling ("no reply and dead" in what follows), 838 that replied and provided data ("replied") and 404 that replied but said they would not provided data ("refused").

Tables 1 and 2 present sample descriptions. We can thus say that 38 per cent of firms did not respond at all of which some were dead. Twenty per cent of firms responded to say they would not provide information. The remaining 42 per cent of firms (838 firms) provided spending information.

The project team would like to thank all those businesses that completed the survey form, a copy of which is available at www.innovationindex.org.uk

The IIA survey set out to measure two main areas. First, firms' investment in six categories of intangible assets: training, software, R&D, design, reputation and branding and business process improvement. Firms were asked to split their spending on these assets to reflect purchased and in-house investments. The second area of the survey was to determine the benefit life of each category of asset.

The sample frame was drawn from the Inter-Departmental Business Register (IDBR), which is a database of all registered businesses. Firms were selected from a stratified grouping of the population by industry and firm size in terms of numbers of employees.[10] The sample was restricted to the 'market sector' as defined in the growth accounting framework reported in Haskel *et al.* (2009),[11] and to firms with ten or more employees. This is broadly consistent with the sample frame used in the UK Innovation Survey (Robson and Kenchatt, 2010),[12] although the UK Innovation Survey is much larger, with a sample size of 28,000 firms.[13]

Sampling was adjusted to reduce the sample weight on construction, utilities and Sections G (Distribution), H (Transport) and I (Accommodation) of the service sector. This follows UK Innovation Survey findings of below-average levels of innovation in these sectors. By contrast, the sample selection mildly over-sampled engineering-based manufacturing, Section J (Information and Communication) and Section K (Financial and insurance activities).

The final questionnaire used was modified from a template provided by the Central Bureau of Statistics in Israel, with contributions from the Economic Analysis, Methodology and Surveys and Administrative Sources Departments of the ONS, NESTA, and from additional notes from respondents of the pilot survey. We piloted preliminary versions of this survey in summer 2008 to spring 2009.

One point to note is that the costs of employer-funded training should include the opportunity costs of taking workers away from their regular activities while they are undergoing training. Cognitive testing of an initial draft of the survey questionnaire which asked for this information suggested that this was open to misinterpretation. So the

10. The full sample frame is divided into 12 industry groups and four size classes, giving 48 cells in total.
11. In practical terms this means restricting the sample to SIC divisions 05-82 (SIC2007).
12. Robson, S. and Kenchatt, M. (2010) First findings from the UK Innovation Survey 2009. 'Economic and Labour Market Review.' Vol. 4, No. 3, March 2010.
13. The UK Innovation Survey is the UK version of the Europe-wide Community Innovation Survey (CIS).

Table 1: Number of questionnaires sent and different reactions by industry

Industries	Sample	No reply and Dead	Replied	Refused
Agriculture, Mining, Utilities and Construction	212	81	88	43
Manufacturing	551	168	268	115
Hotel, Transport, Retailing	613	269	213	131
Financial Services	195	77	77	41
Business Services	433	167	192	74
Total	**2,004**	**762**	**838**	**404**

Notes: "No reply and dead" are those that did not reply at all and went out of business between drawing the sample from the register and sampling; "replied" are firms who replied and provided full data; "refused" are firms who replied but said they would not provided data.

Table 2: Number of questionnaires sent and different reactions by size band

Industries	Sample	No reply and Dead	Replied	Refused
10-99	1194	438	564	192
100-499	261	86	124	51
500-4,999	292	120	96	76
5,000+	257	118	54	85
Total	**2,004**	**762**	**838**	**404**

questionnaire instead asks for a time-based estimate of the average number of days of training. These estimates are converted to imputed costs of employee time while being trained, using sectoral earnings data, uplifted for sectoral estimates of non-wage employment costs.

A second point is that current results are presented at a relatively high level of aggregation to preserve confidentiality. The project team is, at time of writing, waiting for the latest innovation survey to be made available to us to compare results with that. The current survey dataset has been uploaded to the ONS Virtual Microdata Laboratory (VML), where it can be used for further analysis, subject to usual VML practices.

Part 3: Results

Table 3: Percentage response rate: by firm size

Firm Size	Usable response rate (%)	Positive response (%)
10-99	47	50
100-499	48	68
500-4,999	33	80
5,000+	21	76
Total	**42**	**58**

Notes: Usable response rate is the ratio of responses per size band divided by size band in the sample, while positive response is the ratio of positive spending in one or more intangible assets divided by the total number of firms replied (per size band). Data are not weighted.

Source: Authors' calculation

3.1. Discussion of response rates

Table 3 summarises the breakdown of the sample response rate by employment size bands. The survey obtained higher response rates from smaller firms than for large firms. The total response rate for the survey at the close of the response period in January 2010 was 42 per cent. When analysing respondents who answered positively to spending in any of the intangible asset categories an inverse trend is observed, i.e. relatively more of the larger firms who responded to the survey report spending on intangible assets than smaller firms. Overall the results show 58 per cent of the total respondents' having positive spending on one or more category of intangible assets.

These results are further supported by regression analysis as presented in Tables 4 and 5. As has been seen, out of the 2,004 firms sampled there are three groups: "no reply and dead", "replied", and "refused". We know the size and industry of all these firms from the Business Register and thus ran three regressions of the form:

$$\text{Response Type}_{ji} = \alpha \; 1\text{n}(employment)_i + \beta_k \sum_{k=1}^{6} industry + \varepsilon_{ji} \qquad (1)$$

Table 4: Number of questionnaires sent and different reactions by industry

Variables	Refused	No reply	Replied
Ln(employment)	0.0246 (6.577)	0.0156 (3.369)	-0.0392 (-7.730)
Agriculture & Mining	0.0168 (0.187)	-0.0457 (-0.398)	0.0422 (0.366)
Utilities	-0.0607 (-0.890)	0.0917 (0.975)	-0.00446 (-0.0466)
Construction	-0.00612 (-0.174)	0.115 (2.599)	-0.0804 (-1.874)
Hotels, Transport & Retail	-0.0172 (-0.742)	0.122 (4.170)	-0.116 (-4.005)
Financial Services	-0.0179 (-0.553)	0.0810 (1.950)	-0.0648 (-1.579)
Business Services	-0.0371 (-1.475)	0.0784 (2.461)	-0.0459 (-1.466)
Observations	2,004	2,004	2,004

Notes: z statistics in parentheses. Omitted industry is manufacturing.

Where j is a 1/0 indicator in the categories "no reply", "replied", "refused" response of the i sampled firm, and k=1,…6 accounts for six industries (Agriculture and Mining (AgMin), Utilities (Utl), Construction (Cstr), Hotel, Transport, Retailing (HTR), Financial Services (Fin) Business Services (Bsv) where Manufacturing is used as a benchmark industry) and ε_{ji} is the error term.

The results of estimating (1) are set out in Table 5, where estimation is by using a probit model and we report marginal effects. We found that firms who replied were more likely to be small, whereas firms who refused and did not reply at all were more likely to be large. Thus the sample of respondents will be made up of disproportionately smaller firms. We will of course weight the results, but we might obtain smaller aggregated numbers on this sample if larger firms spend more on intangibles and the weights do not adequately reflect this.

Table 5: Probit estimates of intangible incidence on firm expenditure and industrial sectors, for firms replying to the survey

Variables	Intangible incidence
Ln(employment)	0.0664 (6.820)
Agriculture & Mining	-0.131 (-0.734)
Utilities	0.257 (1.364)
Construction	0.0687 (1.027)
Hotels, Transport & Retail	-0.0487 (-1.053)
Financial Services	0.0219 (0.341)
Business Services	0.0122 (0.257)
Observations	838

Notes: z statistics in parentheses the variable intangible incident is taking 0/1 values indicating zero/positive expenditure in one or more asset category. Omitted industry is manufacturing.

To explore some characteristics of firms who replied they did spend on intangibles, Table 5 presents the estimates of Probit regression of the form:

$$\text{Intangible Incidence}_{\text{i}} = \alpha \; 1\text{n}(employment)_i + \beta_k \sum_{k=1}^{6} industry + \varepsilon_i \qquad (2)$$

Where $\text{Incidence}_{\text{i}}$ takes 0/1 values indicating zero/positive spending on any asset of firm i, ε_i is an error term, α_1 and β_k are coefficients to be estimated, k=1,…6 accounts for 6 different industries (as above). These results further support what Table 3 shows. That is that among firms that have replied to the survey, large firms are more likely to report positive spending to one or more assets than smaller firms.

One explanation for this pattern is that firms do not routinely capture some of the information requested by the survey. For larger firms in particular, completing the survey may therefore be difficult and/or costly; since the survey is voluntary, they elect not to respond. By contrast, it is very easy to complete the survey if the firm carries out no intangible investment.

The response rate among firms in the production sector (SIC groups 05-39) was higher – 48 per cent compared with a response rate of 39 per cent for service sector firms. This is further supported by regression results of Table 4 which shows that firms in different industrial sectors have different propensity to respond. Furthermore, as Table 5 shows, there is no significant difference in the propensity of respondents in different sectors to report positive spending in one or more category of intangible asset.

3.2. Weighting

All subsequent data are weighted to reflect the characteristics of the population from which the sample was drawn and the pattern of responses received. Although the survey sample excludes firms with fewer than ten employees, the population estimates for expenditure scale up to the whole population, using employment weights. This is explained in Appendix A. The weighting method uses ONS procedures which are the following.

In the below results, if the characteristic of interest is an estimate of a population total (e.g. total spending on R&D) it is estimated using a weighted sum of survey responses. Specifically, let y be the value of the characteristic for the ith firm and is the desired population total, then the estimate of Y, $\hat{Y}$, is given by a weighted sum such as:

$$\hat{Y} = \sum_i \alpha_i g_i y_i \qquad (3)$$

where

α_i is the a-weight for firm i,

g_i is the g-weight for firm i,

On the other hand, when interest is on incidence alone, for example how many firms have conducted positive spending on R&D, the weighted sum is calculated as:

$$\hat{Y} = \sum_i \alpha_i y_i \qquad (4)$$

The a-weights depend on the survey design and are also known as design weights. The g-weights are based on the relationship between the characteristic of interest and supplementary information (called auxiliary data) and are also known as model weights (see Appendix A for a detailed description).

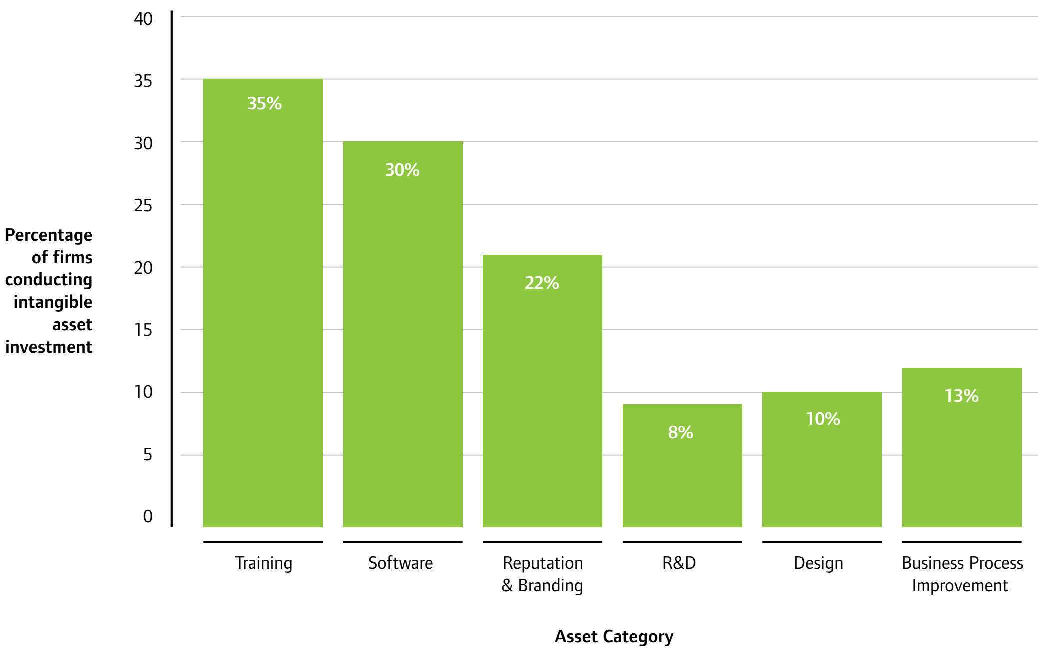
3.3 Incidence of expenditure by asset

Figure 1 shows the incidence of each category of intangible activity; that is, the weighted fraction of firms responding that they have positive intangible spend for each of the six assets. Not surprisingly, employer-funded training has the highest incidence, with just under 35 per cent of respondents reporting some training activity in the last year.[14] R&D had the lowest incidence at around 8 per cent.

This figure confirms that non-R&D intangible spending is much more widespread than R&D spend. In weighted terms, around 50 per cent

14. Our expectation that training would be more prevalent than some other categories was a factor in designing the survey questionnaire with the training questions first.

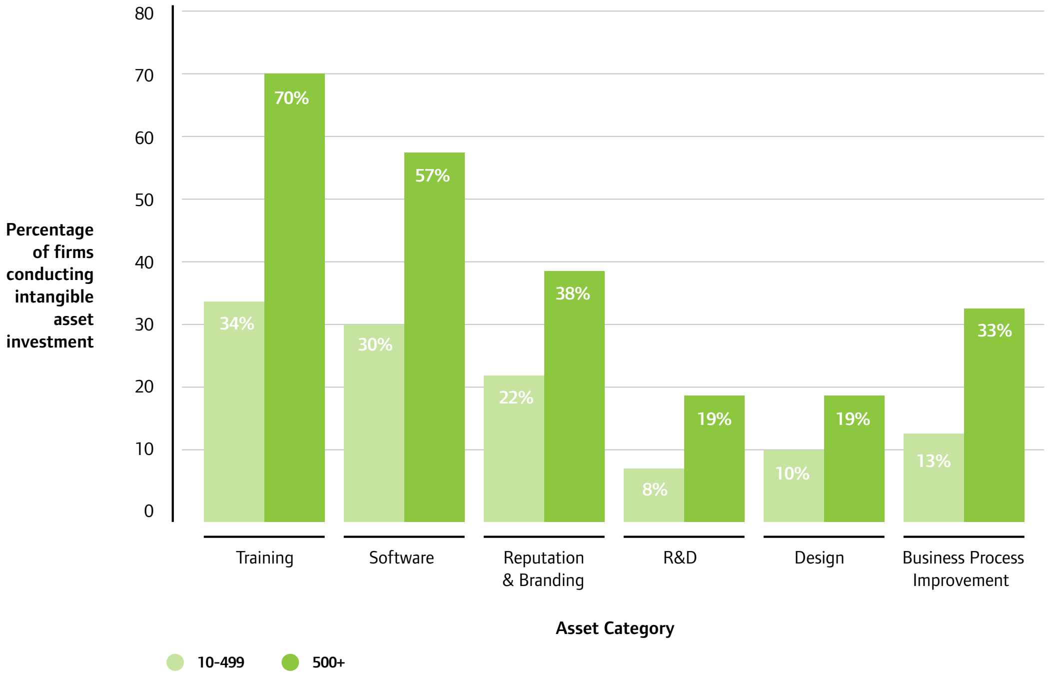
Figure 1: Percentage of firms conducting intangible asset investment by asset category



Notes: The figure shows the percentage of firms saying yes to total (internal plus external) intangible investment by asset category. Data are weighted to be representative of the UK population of firms with ten or more employees.

Source: Authors' calculation based on IIA

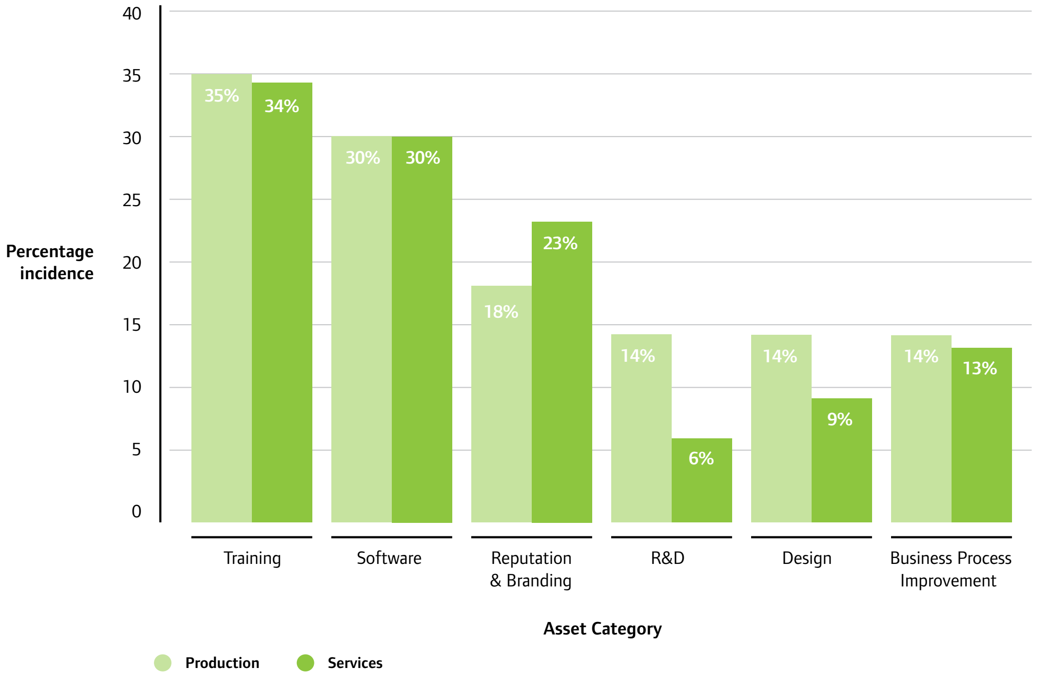
Figure 2: Percentage of firms conducting intangible asset investment by asset category and size band



Notes: The figure shows the percentage of firms in the UK conducting total (internal plus external) intangible investment by asset category and size band.

Source: Authors' calculation based on IIA.

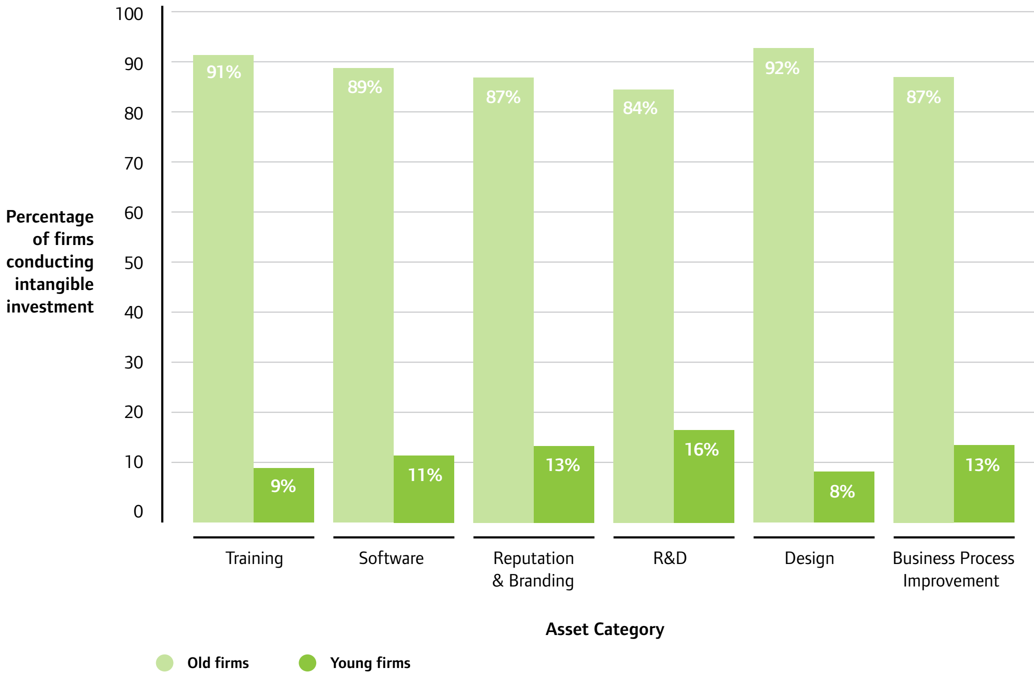
Figure 3: Percentage incidence by broad sector



Notes: The figure shows the percentage of firms in the UK conducting total (internal plus external) intangible investment by asset category and broad sector.

Source: Authors' calculation based on IIA.

Figure 4: Percentage of firms conducting intangible investment by asset category and firm age



Source: Authors' calculation based on IIA.

of firms are active in one or more category of intangible asset including R&D, and almost the same percentage is active in one or more category excluding R&D. That is to say, we find that only a tiny fraction of firms are exclusively active in R&D. Put another way, almost all firms who are active in R&D are also active in one or more other category of intangible asset. But the converse is not true. The survey results suggest that 42 per cent of firms are not active in R&D but are active in one or more other category of intangible spending.

Figure 2 shows the data in Figure 1 broken down by broad size class. This confirms the pattern shown in Table 1, namely that the incidence of intangible investment increases with size band. This is the case for all categories of intangible assets. Around 70 per cent of all firms with 500 or more employees report some employer-funded training, compared with 34 per cent of smaller firms. For business process improvement the respective figures are 33 per cent and 13 per cent.

Figure 3 shows there is little difference in incidence between firms in the production and service sectors for training, software and business process improvement. Firms in the production sector have a higher incidence of investment in R&D and design, while service sector firms have a higher incidence of investment in reputation and branding.

Figure 4 shows incidence of each category of intangible activity broken down by firm age class. Firms are categorised as young if they operate five years or less while old firms are considered to be those with longer lives. Perhaps not surprisingly, old firms have the highest incidence in all intangible assets, accounted for 84 per cent or higher.

To examine this more formally, Table 6 shows probit regression estimates of intangible assets incidence on firms' total employment and industries. That is, we estimate six regressions of the form:

$$Incidence_{ij} = \alpha_1 \ 1\text{n}(employment)_j + \beta_k \sum_{k=1}^{6} industries + \varepsilon_i \qquad (5)$$

where $Incidence_{ij}$ takes 0/1 values indicating zero/positive spending on asset i of firm j, ε_i is an error term, α_1 and β_k are coefficients to be estimated, k=1,…6 accounts for 6 different industries (as above).

Table 6: Probit regression estimates of intangible assets incidence on firm's employment, and industries (dependent variable: incidence of spending by asset)

Variables	Training	Software	Reputation	R&D	Design	Business process
Ln(employment)	0.0904 (9.272)	0.0577 (6.523)	0.0297 (3.917)	0.0198 (3.756)	0.0126 (2.393)	0.0272 (4.506)
Agriculture & Mining	-0.0311 (-0.171)	0.00944 (0.0552)	0.0738 (0.477)	-0.0208 (-0.249)		0.0771 (0.632)
Utilities	0.367 (1.755)	0.155 (0.958)	0.161 (1.142)	0.0401 (0.471)	-0.0209 (-0.267)	-0.0608 (-0.675)
Construction	0.122 (1.759)	0.123 (1.821)	0.0856 (1.365)	-0.0985 (-2.990)	-0.0749 (-2.145)	-0.0247 (-0.532)
Hotels, Transport & Retail	-0.0937 (-1.957)	-0.00140 (-0.0305)	0.0666 (1.591)	-0.0605 (-2.539)	-0.0544 (-2.180)	-0.0474 (-1.508)
Financial Services	0.0803 (1.220)	0.0996 (1.548)	0.0880 (1.478)	-0.0868 (-2.790)	-0.0831 (-2.496)	-0.0286 (-0.655)
Business Services	0.0375 (0.771)	0.0728 (1.553)	0.0677 (1.573)	-0.103 (-4.231)	-0.0472 (-1.859)	-0.0238 (-0.742)
Observations	838	838	838	838	829	838

Note: Marginal effects are reported, z statistics in parentheses. Manufacturing omitted.

These results suggest that all asset categories are affected by firm size. Thus, larger firms are more inclined to undertake any intangible investment than are smaller firms. However, controlling for size, the propensity of different industries to spend on intangible assets varies significantly only for R&D and design, where manufacturing is more likely to spend.

3.4 Average expenditure by asset for firms undertaking positive spending in that asset

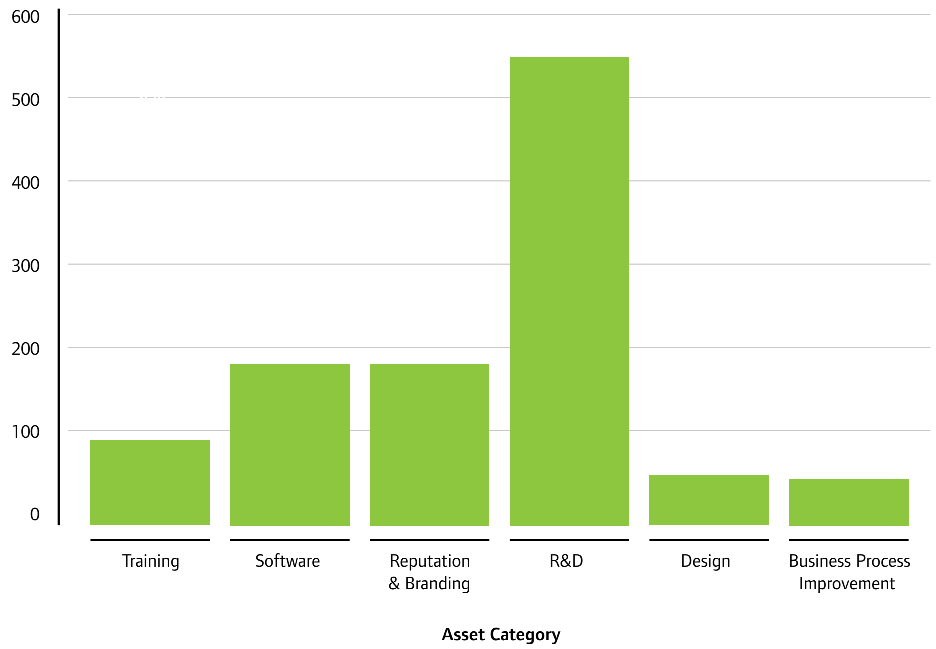
The previous section looked at the incidence of spending. The next section looks at average spending on each asset conditional on reporting positive spending.

There are large differences in the average expenditure on each asset category. Figure 5 shows that R&D has by far the largest average level of expenditure followed by reputation and branding and then software, while average spending on training, design, and business process improvement are relatively smaller.

In Figure 6, the broad industry split reveals that, except for software, firms in the production sector exhibit larger average spending on all other asset categories than firms in the services sector. Average expenditure naturally correlates with the size of the firm. However, the average size of firms in the production and service sectors is almost identical in terms of employment, so this finding would suggest that investment in intangibles – with the exception of software – is more intensive, relative to the size of the firm as measured by employment, in the production sector.

Figure 7 shows the breakdown of average expenditure by asset and employment size class. Not surprisingly, average spending on each asset category increases with employment size (note the log scale on the vertical axis). What this shows is the concentration of R&D spending among a fairly small number of firms,

Figure 5: Average expenditure by asset category (£k), conditional on positive spending on that particular asset

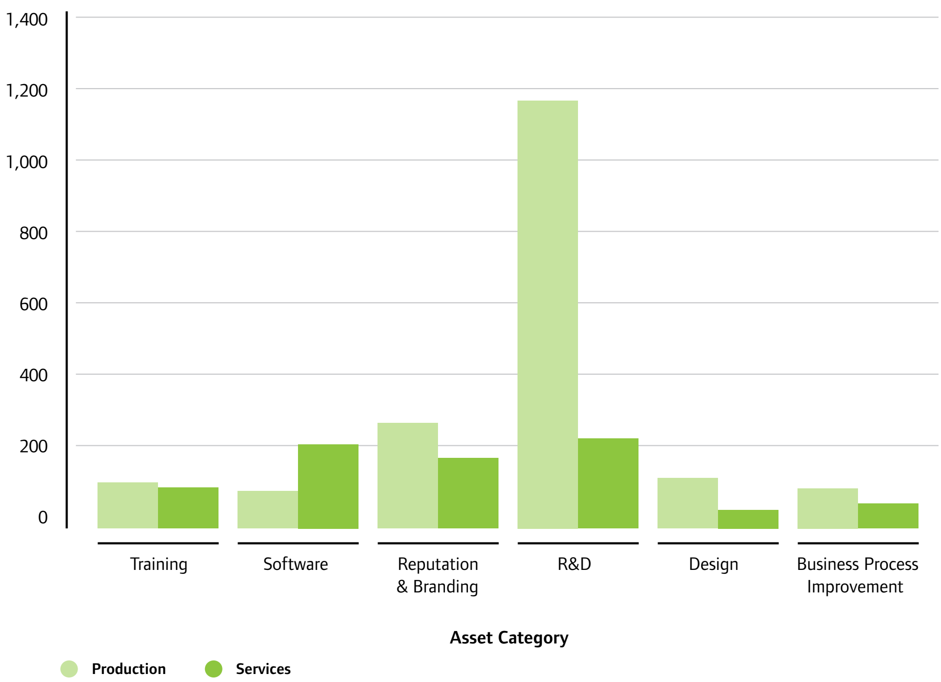


Notes: The figure shows average expenditure of total (internal plus external) intangible investment by asset category in the UK conditional on positive spending for each asset category.

Source: Authors' calculation based on IIA.

15. Training includes imputed costs of employee time during training.

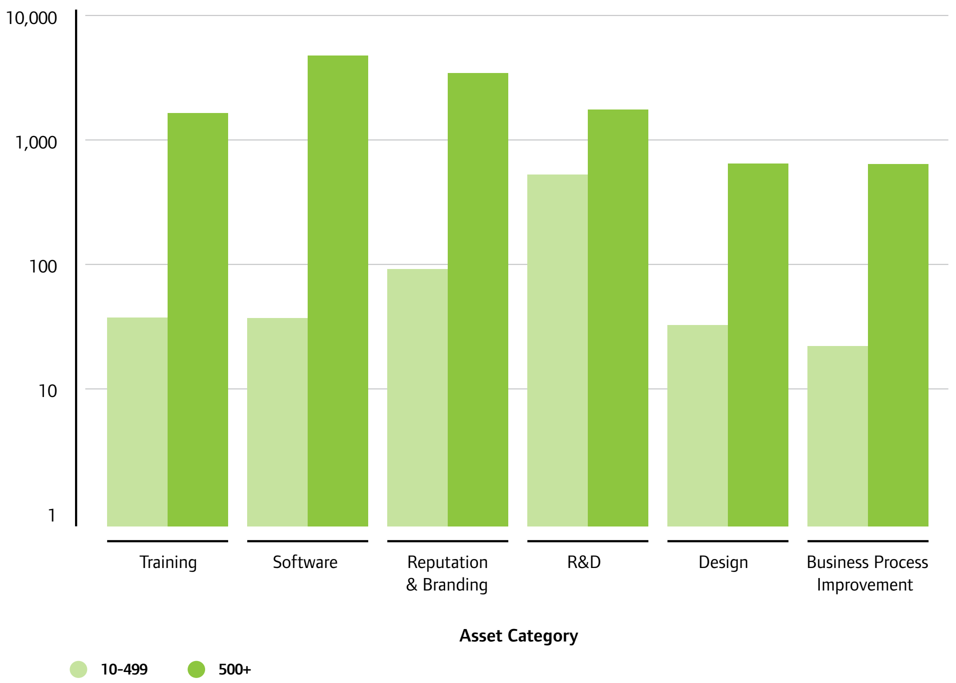
Figure 6: Average expenditure by broad sector (£k), conditional on positive spending on that particular asset[15]



Notes: The figure shows average expenditure of total (internal plus external) intangible investment by asset category and by broad sector in the UK conditional on positive spending for each asset category.

Source: Authors' calculation based on IAS

Figure 7: Average expenditure by size class (£k, log scale), conditional on positive spending on that particular asset



Notes: The figure shows average expenditure in the UK of total (internal plus external) intangible investment by asset category and by size band.

Source: Authors' calculation based on IIA.

Figure 8: Total expenditure by category (£m), weighted to give estimates of UK totals

Notes: The figure shows in-house, purchased and total expenditure of intangible investment by asset category. Training is off-the-job training.

Source: Authors' calculation based on IIA.

with average spending on R&D among smaller firms being an order of magnitude higher than average spending on other categories. Among large firms in general, average spending on R&D is similar to that on training, software and reputation and branding. However, the much greater propensity of smaller firms to invest in these other intangible asset categories, and much lower average spends, lowers the average spending across all firms for these categories of intangible assets.

3.5 Expenditure levels

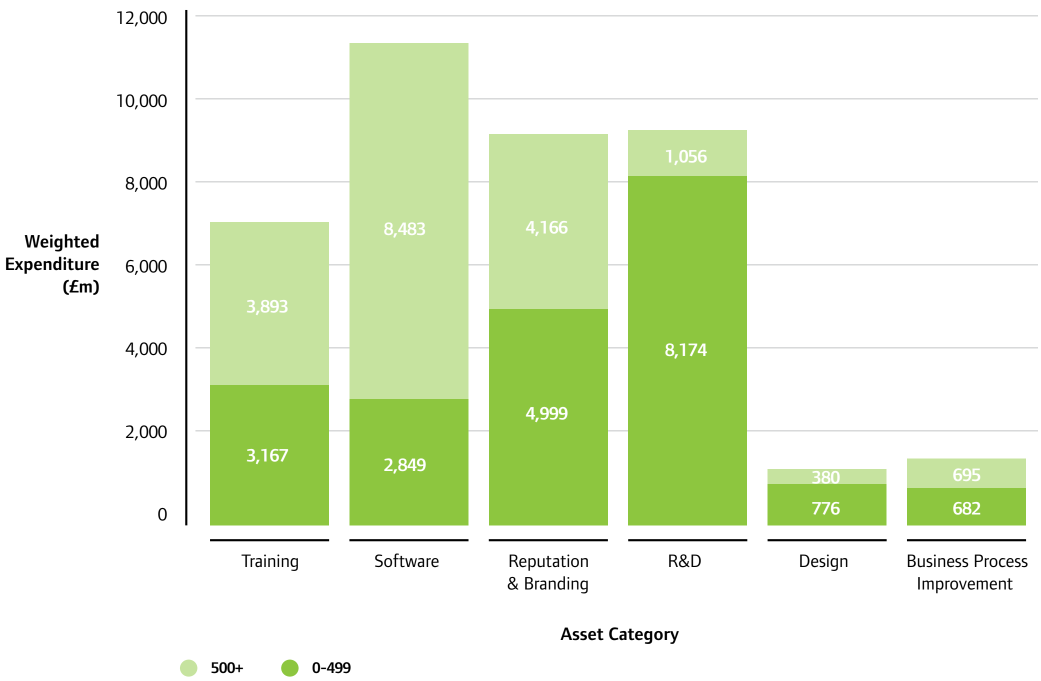
Figure 8 brings together the data on incidence and average expenditure to show weighted overall spending levels by asset category, broken down into purchased and in-house expenditure. Taking all expenditure together, the survey results suggest that software is the largest category, with total scaled expenditure estimated at a little over £11 billion.[16] Total expenditure on R&D and on reputation and branding are both estimated at around £9 billion, with training expenditure estimated at around £7 billion. The remaining categories of design and business process improvement are both estimated at around £1 billion.

Thus the survey results confirm that while R&D is an important component of intangible investment and a source of innovation, it is not the only component. Moreover, the distribution of R&D expenditure differs markedly from the distribution of other categories of intangible investment.

Figure 8 also shows that in-house investment is an important component in all categories, and especially so for design, software and training. The split between in-house investment and purchased investment is around 50:50 for R&D and business process improvement. Only in the reputation and branding category is in-house investment significantly less than half of the total. Taking all six categories of intangibles together, the survey results give an estimate for total investment of around £39 billion, of which around 55 per cent is in-house and around 45 per cent purchased from outside the firm.

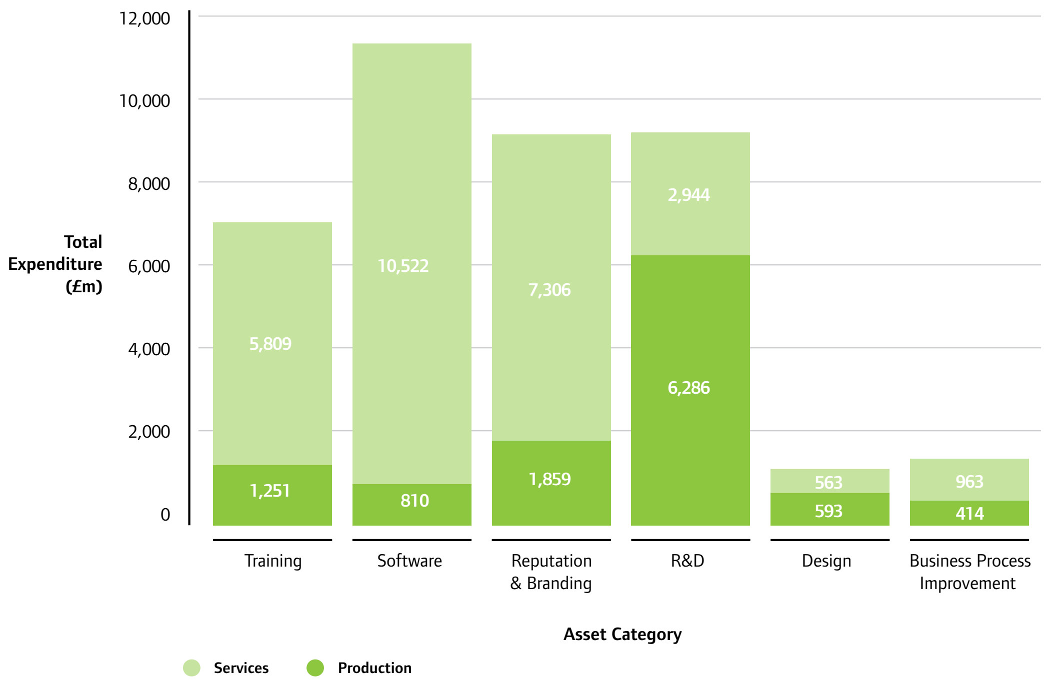
16. Estimates of confidence intervals around the expenditure estimates are provided in a later section of this report.

Figure 9: Weighted expenditure by broad size class (£m)



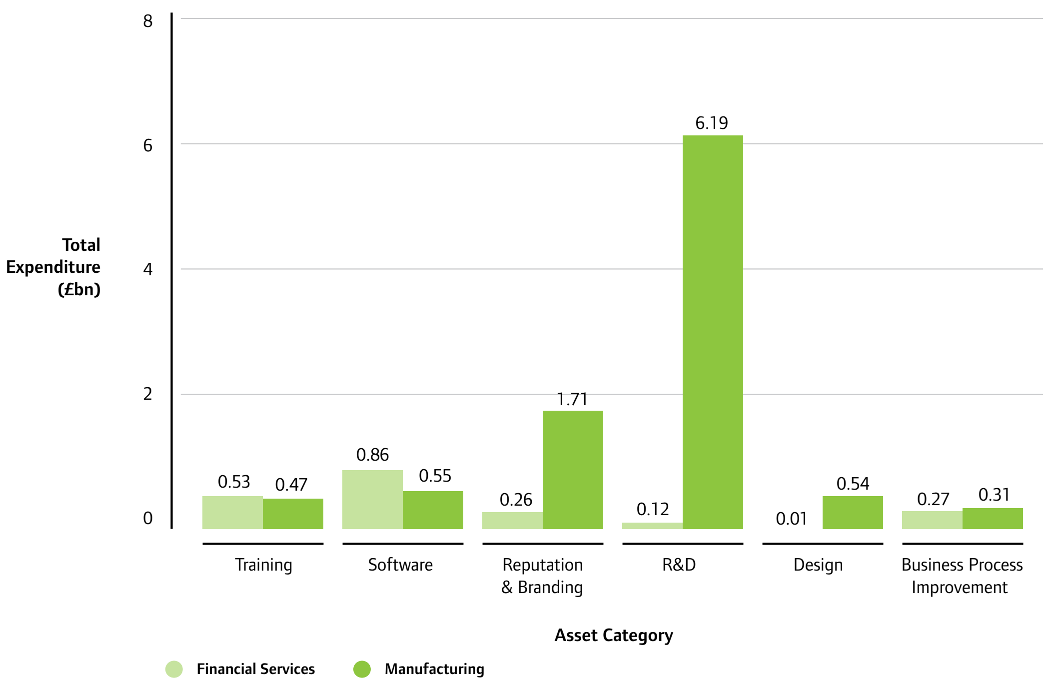
Notes: The figure shows total expenditure of intangible investment in the UK by asset category and by size band.
Source: Authors' calculation based on IIA.

Figure 10: Total expenditure by broad sector (£m)



Notes: The figure shows total expenditure of intangible investment in the UK by broad sector.
Source: Authors' calculation based on IIA.

Figure 11: Weighted expenditure by asset category in Financial Services and Manufacturing



Source: Authors' calculation based on IIA.

Figure 9 shows total expenditure broken down by broad size band. In the population as a whole, employment is split roughly 60:40 between the two categories of 0-499 and 500+.[17] For investment in software and, to a lesser extent, training, there is a bias towards larger firms, whereas R&D and design show a bias towards smaller firms on this categorisation. Taking all intangibles together, the survey results suggest that intangible investment per employee is a little greater in larger firms than in smaller firms.

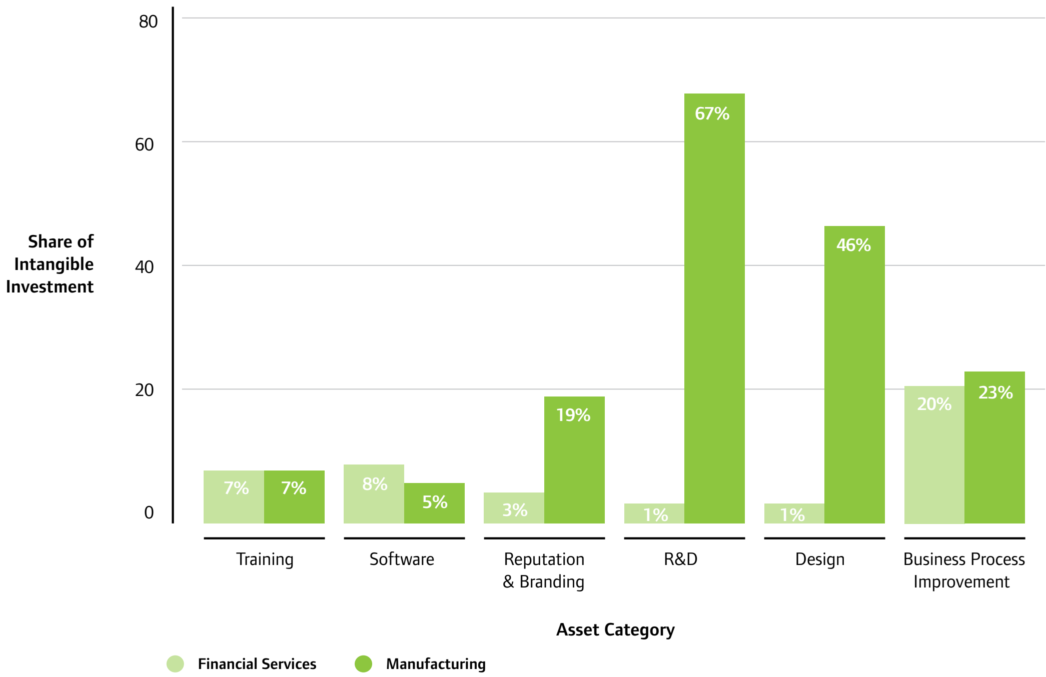
The expenditure split by broad sector is shown in Figure 10. The interesting feature of this analysis is not that expenditure is generally higher in the service sector – which accounts for around 80 per cent of firms in the population, and a similar share of gross value added. But rather that expenditure on R&D and design is higher in the production sector.

Given the outlying characteristics of R&D highlighted by this survey, it is not surprising that the survey results suggest that the breakdown between in-house and purchased investment differs across the broad sectors. The overall share of in-house investment is significantly higher among firms in services than those in the production sector, and there are some marked differences across individual asset categories, although some of these may be due to small sample sizes.

To further get a feel for industry differences, Figure 11 presents total expenditure broken down by asset and by two industrial sectors, financial services and manufacturing. It shows that software has the highest expenditure level in financial services. Furthermore, software in financial services is higher than that in manufacturing. Also, in financial services there are important contributions from training, reputation and business process development spending. Specifically, training and business process development exhibit similar expenditure levels with corresponding spending in manufacturing. On the other hand, R&D and design spending is quite low in financial services but very high in manufacturing. These

17. Note that here the population refers to all firms, including those with fewer than ten employees.

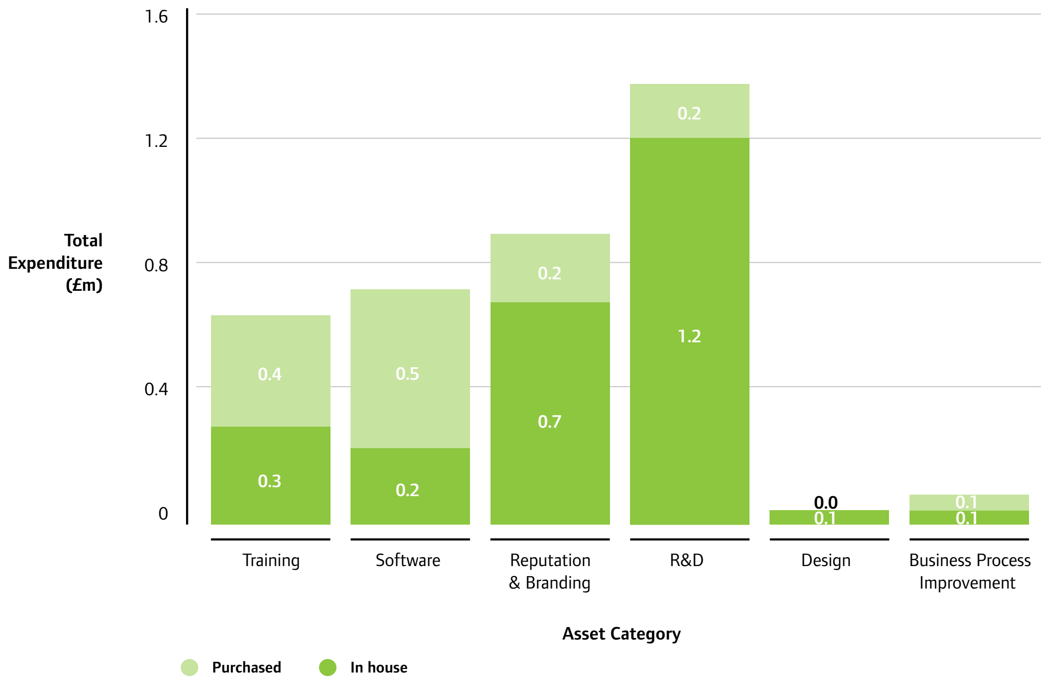
Figure 12: Share of Intangible Investment by Industry (Financial Services and Manufacturing) and Asset



Note: Each column is investment in the particular asset in the indicated industry as a share of total investment of the same asset in the total market sector. Memo note: to give some sense of the relative importance of each sector, employment in financial services and manufacturing is 825,871 and 2,546,806 respectively.

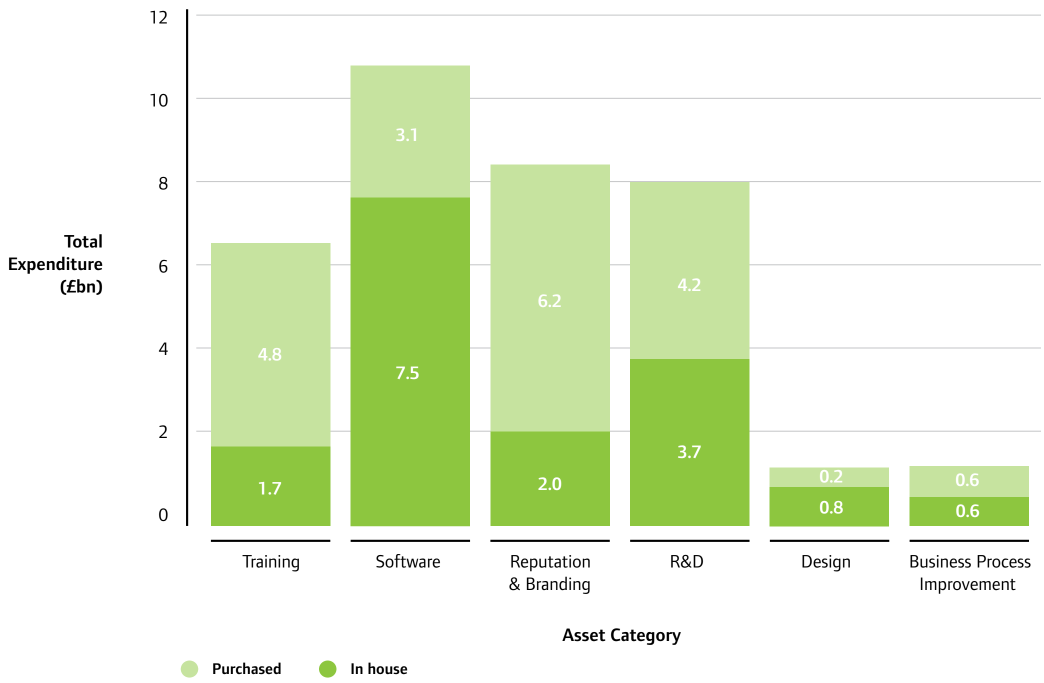
Source: Authors' calculation based on IIA.

Figure 13: Weighted expenditure of young firms by asset category



Source: Authors' calculation based on IIA.

Figure 14: Weighted expenditure of old firms by asset category



Source: Authors' calculation based on IIA.

Table 7: Regression estimates of intangibles intensity on turnover, age, and industries

	Intangibles intensity	t-statistics	Intangible except R&D intensity	t-statistics	R&D intensity	t-statistics
Turnover	0.0000	-0.36	0.0000	-0.31	0.0000	-0.22
Age	-0.0005	-0.7	-0.0002	-0.34	-0.0003	-1.11
Agriculture & Mining	0.02	0.2	0.01	0.14	0.01	0.2
Manufacturing	0.03	1.29	0.01	0.76	0.01	1.67
Utilities	0.02	0.26	0.01	0.17	0.01	0.31
Construction	0.02	0.76	0.02	0.62	0.00	0.51
Hotels, Transport & Retail	0.04	2.01	0.02	1.16	0.02	2.63
Financial Services	0.10	3.86	0.09	3.94	0.01	0.65
Business Services	0.03	1.7	0.02	1.34	0.01	1.3
Number of observations		753		753		753

Note: Intangibles intensity is defined as a firm's total expenditure on all intangible assets as a fraction of its turnover

results indicate the importance of intangible spending in financial services, mainly software, training, and business process development.

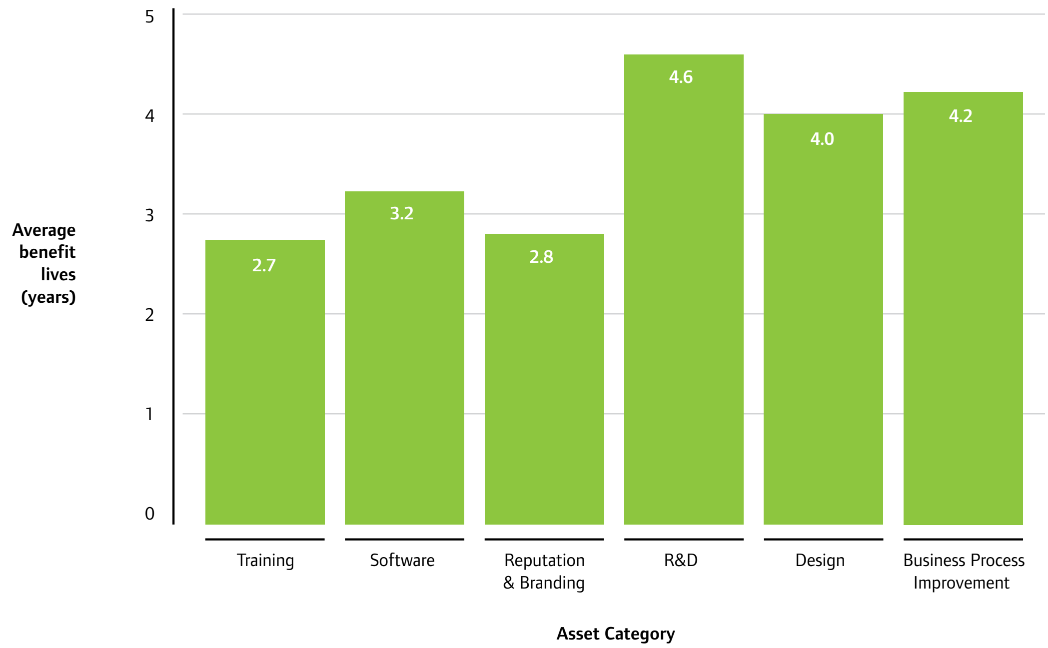
The relative importance of the above intangibles in financial services is also suggested by Figure 12 which shows the share of intangible investment of financial services and manufacturing by asset category. Not surprisingly, manufacturing accounts for 67 per cent of R&D spending, 46 per cent of design, and 20 per cent of business process improving spending. On the other hand, financial services have a significant contribution to other intangible spending such as: software which accounts for 8 per cent, a higher percentage than that of manufacturing; training at 7 per cent; and business process improvement spending at 20 per cent.

We turn now back to the full survey to investigate spending by age. Old firms have the highest share in expenditure levels as Figures 13 and 14 show. Specifically, old firms account for 90 per cent of total intangible spending in the UK. However, total expenditure in intangible investment as a fraction of turnover is found to be 0.17 per cent for the old firms and 3.03 per cent for the young firms. This result suggests that young firms are more intangible-intensive than old firms.

Furthermore, the expenditure split into in-house and purchased investment presented in figures 13 and 14 shows that young firms are more likely to undertake in-house investment while old firms prefer purchased investment. An exception is that of software which follows a reverse pattern: young firms prefer purchased software investment while old firms are inclined to in-house software investment.

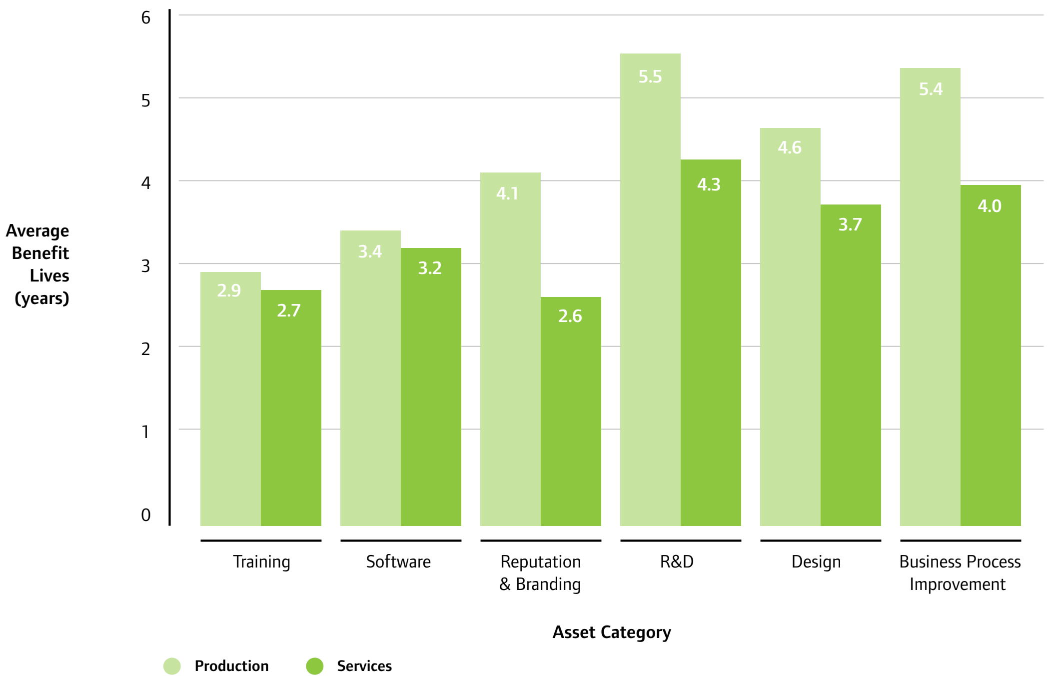
Table 7 shows regression estimates of total expenditure in intangible assets as a proportion of sales on sales (spending intensity), firm age, and industries. As the first column shows, for all intangible spend, intensity does not vary with size, so large firms, who have higher overall spend as we saw above, do not have larger intensity. Nor does intensity vary statistically significantly with age, although the negative term suggests young firms are more intangible-intensive. Hotels and financial services have higher intensities controlling for size and age. The other columns break this into intangibles except R&D and finally R&D. Financial services emerge as being more intensive in non-R&D spend than other industries.

Figure 15: Average benefit lives by asset (years)



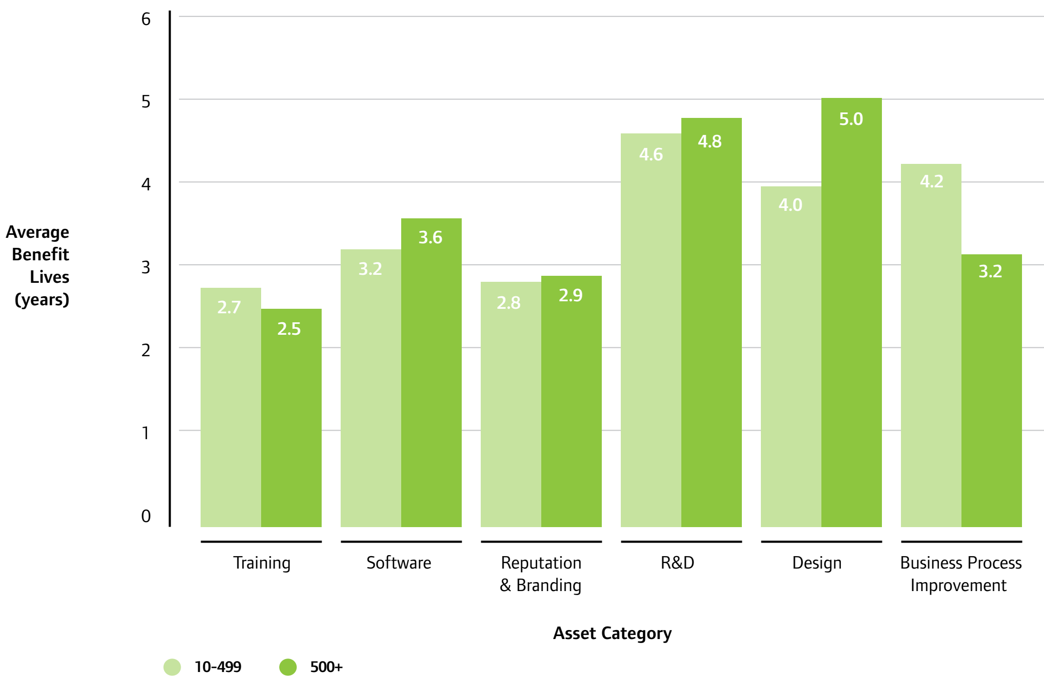
Source: Authors' calculation based on IIA. Weighed by a-weights.

Figure 16: Average benefit lives by broad sector (years)



Source: Authors' calculation based on IIA.

Figure 17: Average benefit lives by broad size class (years)



Source: Authors' calculation based on IIA.

3.6 Life lengths of intangible assets

As well as the magnitude of expenditure, the survey was designed to capture information on the life length of a typical investment in each category of intangible asset. Such information is useful both in forming a judgement as to whether investment in intangibles can be viewed as investment in the context of the national accounts (for which there is a de facto cut-off period of one year) and also in the practical implementation of growth accounting, which requires judgements to be made on depreciation rates of each class of asset.

The survey results for weighted average benefit lives of each asset category are shown in Figure 15. All are comfortably greater than one year, and range from 2¾ years for training and reputation and branding, to around 4½ years for R&D. This quite strongly supports the case for capitalising the assets.

The broad sector split (Figure 16) shows the production sector having longer life lengths in all asset categories compared to the services sector. Significant variations however are on R&D, reputation and branding and business process improvement, where manufacturing sector benefit lives exceed those in the service sector by more than one year.

By contrast, analysing average benefit lives by broad size class shows no clear pattern (Figure 17). For four categories of intangibles – training, software, reputation & branding and R&D – there is little difference in reported benefit lives between small and larger firms. Larger firms report longer benefit lives (by around a year) for design, whereas the reverse is true for business process improvement.

How do these data compare with currently used depreciation rates? The IIA survey asks: "On average, how long does the business expect to benefit from a typical investment in [Training/Software etc]?" We interpret responses to these questions as equivalent to the "life length mean" ($\overline{T}$) in the national accounts framework,[18] where a depreciation rate δ is calculated using the formula: $\delta = d/\overline{T}$ where d is the "declining balance rate", or

Table 8: Comparison of asset life lengths in years

Intangible Asset	Existing estimates in UK National Accounts	IIA	IIA 95% Confidence Intervals
Software*	5	3.2	2.3-4.2
R&D**	10	4.6	2.9-6.3
Training	n.a.	2.7	2.0-3.5
Reputation & Branding	n.a.	2.8	1.9-3.7
Design	n.a.	4.0	2.4-5.6
Business Process Improvement	n.a.	4.2	3.0-5.3

Note: Source of software and R&D existing estimates are *Wallis (2009)[19] and **Galindo-Rueda (2007).[20] R&D used in satellite accounts rather than national accounts.

intuitively, the degree of convexity of the depreciation profile.

Table 9 provides a comparison between IIA estimates of benefit lives with existing assumptions. The first column shows the existing assumptions used for software, currently capitalised in the national accounts and R&D which is in the process of being capitalised. Column 2 shows the average lengths found in the survey with the confidence intervals in the final column.

The first point to note is the paucity of pre-existing information. The existing view on the life of software is taken from US research, in which the empirical evidence is based on IT hardware. The life of R&D is based on patent data. In the absence of any empirical evidence, the assumed life lengths of other intangible assets is taken to be the same as for software.

Secondly, it is apparent that life lengths from the IIA survey are shorter than prevailing estimates. For software, the survey provides an

18. Camus, D. (Ed.) (2007) 'ONS Productivity Handbook: A Statistical Overview and Guide.' London: Office for National Statistics. Available at: http://www.ons.gov.uk/about-statistics/user-guidance/productivity-handbook/index.html
19. Wallis, G. (2009) Capital Services Growth in the UK: 1950-2006. 'Oxford Bulletin of Economics and Statistics.' Vol. 71, No. 6.
20. Galindo-Rueda F. (2007) Developing an R&D satellite account for the UK: a preliminary analysis. 'Economic & Labour Market Review.' Vol. 1, No. 12.

Table 9: Comparison of asset life lengths in years by sector

Intangible Asset	Whittard et al. (2009)	IIA
R&D	**8.6**	**4.6**
Of which		
Production	5.6-12.3	5.5
Services	4.7	4.3
Other Intangibles	**5.0**	**2.7-4.2**
Of which		
Production	4.2-7.5	2.9-5.4
Services	3.2-4.1	2.6-4.0

average benefit life of 3.2 years compared with a prevailing estimate of five years; and for R&D the survey estimate is 4.6 years compared with a prevailing estimate of ten years. The upper limits of the 95 per cent confidence intervals around the survey estimates are also lower than prevailing estimates.

Thirdly, the IIA survey does not collect any direct information on depreciation rates, δ, nor on the profile of depreciation, that is, about d. We therefore do not have an empirical basis for choosing a declining balance rate for converting these life lengths to depreciation rates.

Currently, ONS uses an assumed value of d=2, giving constant depreciation rates of 40 per cent for software and 20 per cent for R&D. For d=2, the IIA survey results imply depreciation of 63 per cent for software and 43 per cent for R&D. To match with currently assumed depreciation rates would imply lower declining balance rates (that is, less convexity to the depreciation profile), namely d=1.28 for software, and d=0.92 (concave to the origin) for R&D.

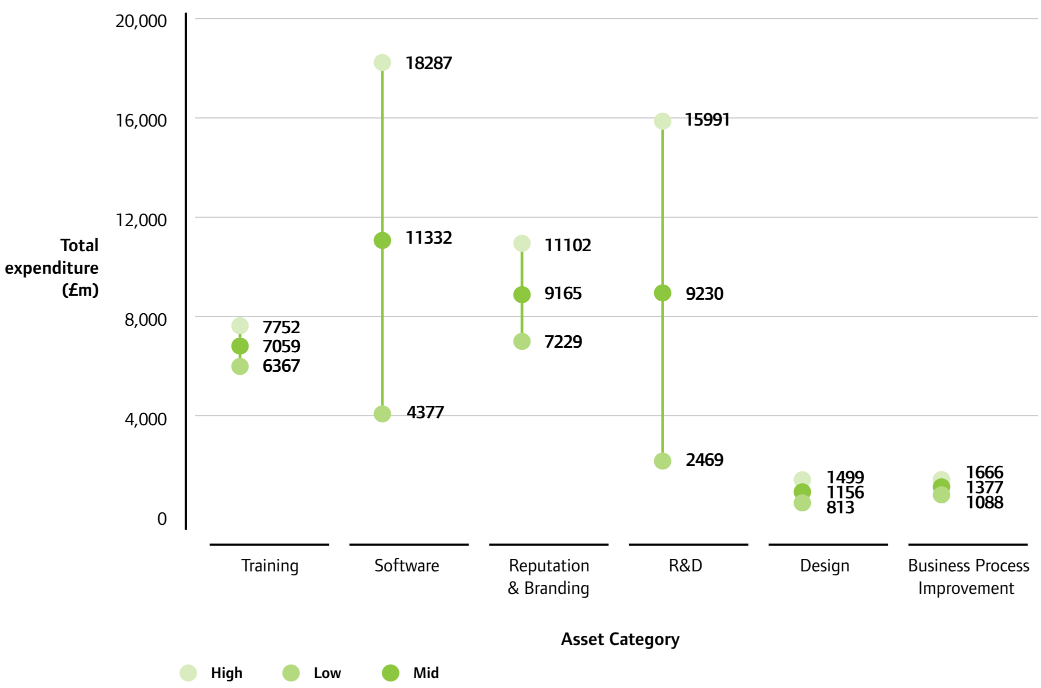
One point is that the IIA survey asks for time of benefit from the investment. In the pilot survey, Whittard *et al.* (2009),[21] we collected data on three phases of project life-lengths - development, transition and use, of which the use phase corresponds to the benefit life questions in the IIA survey. The results of this are set out in Table 8, which shows the sum of time reported for in the development, transition to production and use.

For technical R&D, which corresponds to the R&D asset in the IIA survey, the average (unweighted) life-length for the use phase in the pilot exercise was 8.6 years, considerably longer than the (weighted) figure of 4.6 years from the IIA survey. However, the sectoral split is more consistent, as both surveys point to longer life-lengths in the production sector than in the services sector. There is also a strong bias towards long-length projects in the production sector in the overall average R&D life from the pilot exercise.

Non-technical R&D in the pilot survey on the other hand corresponds to a combination of the other assets (excluding R&D) in the IIA

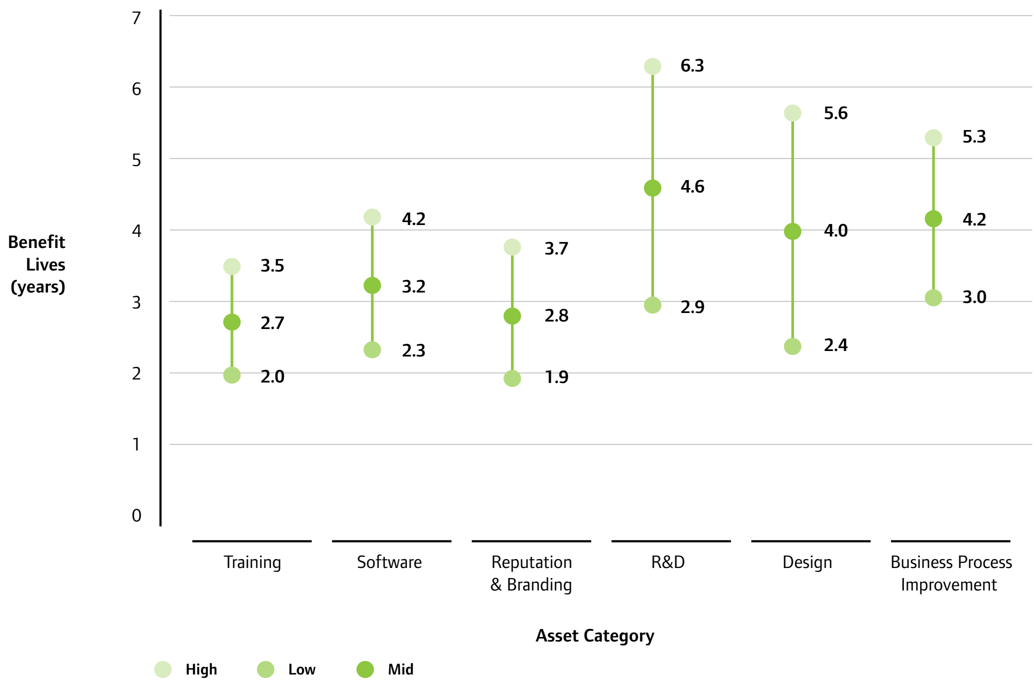
21. Whittard, D., Franklin, M., Stam, P. and Clayton, T. (2009) 'Testing an extended R&D survey: Interviews with firms on innovation investment and depreciation.' NESTA Innovation Index Working Paper. London: NESTA.

Figure 18: Total expenditure by category - 95 per cent confidence intervals (£m)



Source: Authors' calculation based on IIA.

Figure 19: Benefit lives - 95 per cent confidence intervals (years)



Source: Authors' calculation based on IIA.

survey. This category also shows that the range of the IIA survey estimates is shorter than the pilot average of five years, but by a smaller proportion than for technical R&D. Here too, both sources point to longer service lives in the production sector. And again there is some evidence that the pilot average gives undue weight to the production sector.

Lastly, it should be noted that the IIA survey asks for the length of benefit from a typical investment, whereas the pilot exercise focused on projects in their entirety. It is possible that projects that involve expenditures over a number of years would have life-lengths which are longer than the anticipated benefit from expenditure during a single year.

In sum, we regard these estimates as particularly valuable since there are so few other estimates in the literature. The R&D life lengths seem longer than for other assets, and incorporating development, transition and use, we seem to have average project life lengths of around eight and five years for R&D and non-R&D respectively with longer life lengths in production than services.

3.7 Confidence intervals

Estimated confidence intervals are based on the distribution of survey responses in each cell or set of cells in the sample frame (see Appendix A for a detailed discussion).

Figure 18 shows illustrative 95 per cent confidence intervals for total expenditure on each category of intangible asset. It can be seen that confidence intervals around the expenditure estimates vary widely across the different categories. The range of the estimates is relatively narrow for design, training and business process improvement, somewhat wider for reputation and branding, and wider still for software and R&D. Other things equal, the larger the sample size, the narrower the proportionate confidence intervals. Thus we would expect proportionately wider confidence intervals for expenditure sub-aggregates, such as in-house and purchased components of expenditure.

Confidence intervals around the benefit life estimates are shown in Figure 19. The methodology here varies slightly from that

Table 10: Intangible investment, £billion

	IIA survey					CIS07			Haskel et al. (2009)		
				95% confidence intervals							
	Internal	External	Total	Low	High	Internal	External	Total	Internal	External	Total
Training	2.4	4.7	7	6	8	-	-	1	-	-	32
Software	7.7	3.6	11	4	18	-	-	10	10	10	20
Reputation and branding	3	6	9	7	11	-	-	5	-	-	14
R&D	5	4	9	2	16	6.5	1.5	8	-	-	15
Design	0.8	0.3	1	1	2	-	-	1	13	9	22
Business Process Improvement	0.7	0.6	1	1	2	-	-	-	19	7	26

Note: Macro data are investment data adjusted from spending data for design, and reputation. Training data excludes £18 billion on the job training: the IIA survey asks firms to exclude on-the-job training. The IIA training and the macro training both include the opportunity costs of worker time whilst training.

used to estimate confidence intervals for expenditure in that it depends on the number of respondents providing estimates of benefit lives in each category.[22] This, alongside the distribution of the underlying data, is a factor in the fairly wide range for design, where the number of observations on benefit lives reflects the low incidence of this category.

3.8 Comparison with other data

Table 10 shows estimates of spending on intangible assets from three different sources: the IIA, the 2007 CIS and the current macro estimates for 2007 from Haskel *et al.* (2009).[23] The initial impression from the point estimates is that the IIA and CIS are rather similar, with the macro numbers much larger. However, there are a large number of points to be borne in mind in making this comparison.

First, regarding the comparison between the IIA and the macro numbers, there are a number of reasons to expect the IIA numbers to be less than the macro numbers. First, the IIA survey was carried out in 2009, whereas the macro numbers are estimates from 2007. Between 2007 and 2009, ONS nominal software and hardware spending, market sector, fell by 10 per cent and 20 per cent (see latest ONS release of investment data). Since much software is bundled with hardware, we might guess that software spending fell by 15 per cent. If that is indicative of general intangible spending, then we would expect the 2007 numbers to exceed those in 2009.

Second, the IIA is a small, voluntary survey, which excludes firms with fewer than ten employees. Expenditure estimates for the whole population of firms implicitly assume that respondents to the survey are representative of their industry and size class. This would not be the case if, for example, responses are biased because firms who invest in intangibles are less likely to complete the survey, perhaps because they do not routinely capture the information that the survey asks for.

Numerically, small firms are by far the majority of firms. Although the results provide clear evidence that intangible investment is more common among larger firms, this does not mean that intangible investment among the smallest firms is insignificant. For R&D, we know that it is concentrated in large firms. But as we have seen, the incidence of non-R&D intangible spending is much wider than R&D and so the omission of small firms might be significant.

Second, regarding the comparison between the IIA and the CIS, the CIS available at

22. Population estimates of expenditure implicitly assume zero expenditure for respondents who do not engage in intangible investment. However, it would clearly be inappropriate to assume that benefit lives for such respondents was zero, so the population estimate and confidence intervals around that estimate depend only on positive responses.
23. Haskel, J. *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project.' London: NESTA.

Table 11: Comparison of off-the job training expenditures

£billion	NESS07	IIA09
Total	**14.0 (11.0)**	**7.1**
Of which		
In-house	11.0 (8.5)	4.7
External	3.0 (2.3)	2.4
Breakdown of In-house:		
Imputed labour costs	4.8	3.8
Other in-house	6.2	0.9

Notes: Figures in brackets represent NESS07 expenditures excluding health and safety.

time of writing is for 2007; we hope to have contemporaneous data available shortly. In addition, the CIS questions are not the same as those on the IIA. Except for R&D, none of them asks firms about internal and external spending and some questions are ambiguous on what firms should include. Also, the CIS questions all tend to ask about intangible spending in relation to the firm's innovation. The survey asked about all intangible spending, to avoid the interpretation issues around innovation and the possibility of missing firms who are investing in intangibles but have not yet innovated.[24]

Third, as we saw in the response rates analysis above, large firms are less likely to answer the IIA survey.

With these overall thoughts, we turn to an analysis asset-by-asset.

A. Training

Table 10 shows that training is a lower figure on the IIA than in the macro numbers. What might account for this? The IIA excludes on-the-job training, capital items, and the cost of staff time whilst being trained and therefore absent from work. However, the questionnaire asks for a time-based estimate of the average number of days of training. These estimates are converted to imputed costs of employee time while being trained, using sectoral earnings data, uplifted for sectoral estimates of non-wage employment costs. Training, thus, includes imputed costs of employee time during training.

The principal source of the macro training numbers is the National Employer Skills Survey (NESS). NESS07 suggests that, of total training expenditures in the UK market sector of ~£32 billion, on-the-job training accounts for ~£18 billion and off-the-job training accounts for ~£14 billion. This narrows the gap considerably, although it remains an open question whether on-the-job training should be included in the training asset class.

Health and safety training is another factor which may account for variations in the two surveys. About 25 per cent of 'training' in NESS is on health and safety. NESS asks its respondents what proportion of their training is on health and safety and induction. The question is asked separately for on-the-job and off-the-job training. Health and safety accounts for 26 per cent of on-the-job and 23 per cent of off-the-job training in NESS 2007.[25]

In conducting the IIA survey we found some informal evidence that respondents may have omitted training costs associated with health and safety and other 'routine' training on the grounds that they did not consider such activities as falling within the definition of intangible assets, which is on the title page of the survey questionnaire. Since the IIA survey did not specifically request information on health and safety training information, we are unable to quantify this effect, but it could be a factor in the remaining difference, along with reductions in training expenditures between NESS07 and IIA09 due to the economic downturn.

24. The Community Innovation Survey can be found at: http://www.bis.gov.uk/policies/science/science-innovation-analysis/cis
25. Health and safety is the only category they singled out other than the broad on/off-the-job split. Other on/off-the-job questions asked are: a) about the occupation of staff being trained, b) the number of staff trained for each occupation, c) and the number of days each staff member is trained.

Table 12: Comparison of off-the-job training expenditures by sector

	External		In-house			
			Imputed labour costs		Other in-house	
	Production	Services	Production	Services	Production	Services
NESS (£ billion)	0.8	2.2	1.5	3.4	1.3	4.9
IIA (£ billion)	0.4	1.9	0.6	3.1	0.2	0.7
NESS as per cent of IIA	200%	116%	229%	108%	672%	685%

However, we can broadly infer from the NESS figure that factoring this would result in an increase in the difference for training days on one hand, while the difference in cash expenditure for the two surveys would be reduced, bringing off-the-job expenditure for the two surveys closer still.

Table 11 provides more information on the comparison between the off-the-job components of NESS07 and IIA09. This shows that external and imputed labour costs in both surveys are broadly comparable. There is a large difference in other in-house training costs. In NESS, the largest components in this category are training management costs and on-site training centre costs.

We briefly report two further lines of enquiry. First, both NESS and IIA calculate imputed labour costs of training as the product of a volume measure (time spent during training) and a value measure (wages and non-wage labour costs). It turns out that although NESS has a larger estimate of imputed labour costs, the two surveys contain similar estimates of the volume of such training (IIA: ~41m days, NESS: ~39m days). It follows that NESS implicitly uses rather higher figures for wages and non-wage labour costs compared with IIA.[26]

Secondly we have conducted a brief review of the sectoral breakdown of off-the-job training between the two sources, the results of which are summarised in Table 12. For external spending and the imputed labour cost component of in-house spending, the IIA estimates are around half those in NESS for the production sector but broadly comparable for the service sector. For other in-house training, the NESS data are around seven times as large in both sectors.

26. Average imputed costs are around £125/day (NESS) and £93/day (IIA). NESS has higher average wages (~£10/day) and higher non-wage costs (~£16/day). The remaining difference (~£6/day) reflects the distribution of training, which is slanted towards higher wage sectors in NESS relative to the IIA distribution.

Table 13: Comparison of software estimates

£billion	National Accounts (2007)	IIA09
Own-account	**10.5**	**7.7**
Of which:		
Production	2.0	0.3
Services	8.5	7.4
Purchased	**9.9**	**3.6**
Of which:		
Production	1.9	0.5
Services	8.0	3.1

Source: Authors' estimates.

B. Software

Regarding the overall numbers, the decline in software since 2007 means the macro software spending is within sampling error of the IIA numbers (the CIS numbers are not really comparable, since firms are asked about software and machinery investment and it is not clear whether firms have to include in-house software spending).

Thus we regard the software IIA and macro numbers totals as comparable. We may examine the numbers slightly more as follows.

Table 13 shows a comparison of software estimates for the market sector from the National Accounts and the IIA. For own-account software spending, the overall totals are broadly comparable (if one reduces the 2007 figure by 15 per cent). However, the broad sector split suggests more marked differences. In particular, the IIA survey finds much less own account software activity in the production sector than is in the National Accounts, where the figure is based on the distribution of employees who are classified as developers of software. By contrast, the survey estimate for own-account software spending in the service sector is close to the National Accounts data, and the difference is consistent with the effect of the economic downturn.

Turning to the purchased data, there is a larger overall difference between the two sources for purchased software. Here, the National Accounts data are based on consolidated evidence from a number of existing survey sources.[27] For this category, the survey estimate is around one-third that of the National Accounts. The broad sectoral distribution is more comparable between the two sources, although as with own-account software, the survey finds a lower proportion of purchased software in the production sector than in the National Accounts data.

C. Reputation and Branding

Haskel *et al.* (2009)[28] figures come from input-output data on intermediate consumption on advertising and market research for 2007. They exclude all classified advertising and assume that 20 per cent of remaining advertising spending is current spending and not an investment. Now, since they are 2009, if we reduce the total by 15 per cent we obtain total spending of £11.9 billion. The upper part of the confidence interval for the IIA is £11.1 billion.

However, as with training it is conceivable that not all advertising expenditure is intended to "enhance reputation or brand value" (in the words of the survey questionnaire). Indeed, the fact that the average benefit life for reputation and branding is given as 2¾ years would suggest that the expenditure results should be interpreted as reflective of investment, and do not include any element that is expensed. So the macro numbers might be a slight overestimate of the investment content in branding spending. We regard the CIS numbers as too low, likely because they fail to ask about internal and external spending.[29]

D. R&D

The macro numbers, especially if they have fallen, are within the wide sampling error of the IIA survey. Given how skewed R&D spending is the wide errors are not surprising. As noted in ONS (2009),[30] *"R&D surveys pose special problems of survey design and estimation. R&D takes place in only a small proportion of businesses but a comprehensive list of who these are does not exist. A simple random sample of the business population would not be suitable for an R&D survey because many of the sample businesses would not undertake R&D, and many significant R&D performers would be missed in such a sample."* The sample frame in the IIA survey is close to a random sample and therefore it is not surprising that it records lower R&D expenditure than the official R&D survey. Indeed, it could be argued that it is encouraging that the IIA survey gets as close to the official survey as it does.

Similar to theoretical assumptions, the life lengths of non-R&D assets in the survey lie broadly between two to four years. That of R&D was 4.6 years and falls short of the literature benchmark, but is consistent with the idea of being longer than that of other assets.

An attempt to match the intangible survey sample micro data with that of the Business Enterprise Research and Development (BERD) 2007 survey produced 25 overlaps on firm level. On average the level of expenditure reported by these firms is broadly similar and in some cases exactly the same.

E. Design

Turning to design, we have a very considerable gap between the IIA and the macro data, with the IIA numbers looking similar to the CIS07 data. There are a number of possibilities here.

The macro numbers come from two sources. The external data are purchases of design

27. The methodology behind the National Accounts data is described in detail in Chamberlin *et al.* (2007).
28. Haskel, J. *et al.* (2009) 'Innovation, knowledge spending and productivity growth in the UK: Interim report for NESTA Innovation Index project.' London: NESTA.
29. The 2006 survey (http://www.berr.gov.uk/files/file44938.pdf) asks firms for marketing 'expenditures' but does not say internal or external. Looking at the IIA survey, if firms just give external spending, then that is £6.4 billion, close to the CIS figure of £5 billion.
30. ONS (2009) 'UK Business Enterprise Research and Development 2008.' London: Office for National Statistics.

services from the design industry, as recorded in the Input-Output tables. This comes to £9 billion, with the survey giving £0.3 billion. The internal design numbers come from the costs of designers employed outside the design industry (the ratio is around 4:1) and this gives £13 billion. That in-house figure exceeds the purchased, which is in line with the IIA survey, but the overall total is clearly much higher on the macro data.

At the time of writing of this paper, the Design Council produced their 2009 estimate of £15 billion spending on design, both in-house and external.[31] They include some web designers in their survey, but exclude any mechanical and industrial designers. Their numbers are weighted to UK totals, but excluding in-house teams in firms with fewer than 100 employees (that is, they are representative of what would be a UK total excluding all in-house design teams in businesses with fewer than 100 employees). The in-house teams have a budget of £3.8 billion and the rest of the £15 billion is the fee income of freelancers and the design industry.[32]

So the design council figure is much closer to the macro total, and, by sample design, will understate in-house spending.

It is worth recalling that the IIA does not sample below ten employees. One important finding from the Design Council is that 89 per cent of design consultancies and in-house teams have under ten employees.[33] Thus the omission of under ten likely results in a substantial understatement of total spending, with the degree of understatement depending on the share of spending accounted for by those 89 per cent of businesses (which may not be 89 per cent of course, if the smaller businesses account for smaller shares of the total: if the understatement were this, then the IIA figure would be around £11 billion). There is further discussion of this below.

So the particular concentration of small designers would suggest the IIA and CIS both understate design spending. Against this, the IIA does ask specifically for new products which might be less than the overall design totals.

F. Business Process Improvement
There is no CIS information on this and thus we only have the IIA survey. This shows a very large gap with the macro data. The internal macro numbers are from an assumed fraction (20 per cent) of managerial time and the external ones from 80 per cent of management consultancy earnings in sales to the private sector (from the management consulting association, whose data agrees with that in the Supply-Use Tables). Thus these macro numbers do rely on these assumptions. One possibility is that sampled businesses are, in reality, spending very little on such activities given the imperative to keep going in the face of the biggest recession for half a century. Another puzzle is that the purchased question asks firms to include purchased management consultancy services and that the IIA data are very low against management consulting sales. Against this, the respondents might truly be giving an answer to the part of consultancy services that help with long-lived process improvement. Perhaps more detailed case studies are needed to resolve this.

3.9 Further comparison with other data

A. Overall comparison of incidence with latest UK innovation survey.
Whilst this paper was being completed the latest UK innovation survey (UKIS) results were issued.[34] We have not yet been able to compare the micro data but have some comparisons here with the summary results that are in the public domain (Robson and Kenchatt, 2010).[35]

The UKIS is much bigger (14,218 responses, representing a response rate of 50 per cent[36]) and covers three years 2006-2008. The authors note impact of macro downturn from Q2 2008 - e.g. the percentage of firms citing availability of finance as constraint on innovation is up sharply from previous survey.[37]

Looking at the incidence, overall, 45 per cent of respondents reported some innovation-related expenditure in UKIS. This varied only slightly between 45 per cent for smaller firms (10-250 employees) and 48 per cent for larger firms. The comparable (weighted) figure for IIA is 50 per cent for respondents reporting some expenditure on one or more category. We cannot replicate the UKIS size split, but we have 49 per cent for 10-499, and 78 per cent for 500+. Note that the UKIS definition of "innovation-related expenditure" is in some cases wider than IIA survey (e.g. including tangible spend on computer hardware and advanced machinery); in some cases narrower (e.g. training for innovation activities only, no business process improvement.)

The UKIS finds 58 per cent of respondents 'Innovation active' - 13 percentage points

31. This is the combined budget of in-house teams and fee income of others. See second sentence in: http://www.designcouncil.org.uk/Documents/DesignIndustry Research2010 Design IndustryResearch2010_ExecSummary.pdf. And see page 1 of: http://www.designcouncil.org.uk/Documents/Design IndustryResearch2010/DesignIndustryResearch 2010_UKoverview.pdf. The Overall report is here: http://www.designcouncil.org.uk/Documents/Design IndustryResearch2010/DesignIndustryInsights2010.pdf; and definitions here: http://www.designcouncil.org.uk/Documents/Design IndustryResearch2010/DesignIndustryResearch 2010_Methodology.pdf
32. See http://www.designcouncil.org.uk/Documents/Design IndustryResearch2010/DesignIndustryResearch 2010_InhouseDesigners.pdf, page 3.
33. See findings of Design Council survey (upper right table, page 2) at http://www.designcouncil.org.uk/Documents/DesignIndustryResearch2010/DesignIndustryResearch 2010_UKoverview.pdf
34. See http://www.statistics.gov.uk/cci/article.asp?id=2374
35. Robson, S. and Kenchatt, M. (2010) First findings from the UK Innovation Survey 2009. 'Economic and Labour Market Review.' Vol. 4, No. 3, March 2010.
36. This rate refers to firms responded as a fraction of total sample size. However, there are cases where although firms respond they do not provide information on intangibles spending. The IIA response rate is calculated using only firms for whom we had information on their expenditure across all intangible assets.
37. The overall time series results (see their figure 9) sent a rather mixed message. The proportion of firms innovation-active is down from 2007, but still much higher than 2001, which does not chime with the steepness of the current recession. Product and process innovation are both higher then in 2007, but 'wider' innovation is down. One issue is that these are incidence whereas e.g. the official software and R&D data, which are both down since 2007, are spending. All this suggests a problem with time series behaviour on the CIS, as is acknowledged by the surveyors.

Table 14: Design and Intangibles Investment Survey comparison, private sector

	In-house design expenditures	
	Design Survey (£ billion)	Intangibles Investment Survey (£ billion)
All firms (838)		0.8
Only large firms (274)	2.24	0.4

Note: Large firms are defined as having 100 or more employees. Original number in the Design Council survey was £3.8 billion is multiplied by 59% for private sector spending, see text.

Source: Authors' calculation based on IIA, Design Council.

above the share of innovation-related expenditure. Acquisition of computer software for innovation is the most popular activity (37 per cent, compared with 30 per cent in the IIA survey), with training for innovation activities at 23 per cent (IIA: 35 per cent for all training expenditure). UKIS finds internal R&D to be significantly more common (28 per cent) than external R&D (~10 per cent). IIA has no difference between incidence of internal and external R&D spend. It could be that some UKIS respondents reporting internal R&D 'activity' do not report internal R&D spending.

UKIS found 27 per cent of respondents reporting one or more form of 'wider innovation' - defined in the questionnaire as new or changed strategy, management techniques, organisational structure or marketing. This is a lot higher than the IIA survey incidence of expenditure on business process improvement (13 per cent), though again this could reflect the IIA's focus on expenditure versus the UKIS focus on 'change'.

B. Comparison of firms answering other surveys

i) IIA and the Design Survey comparison

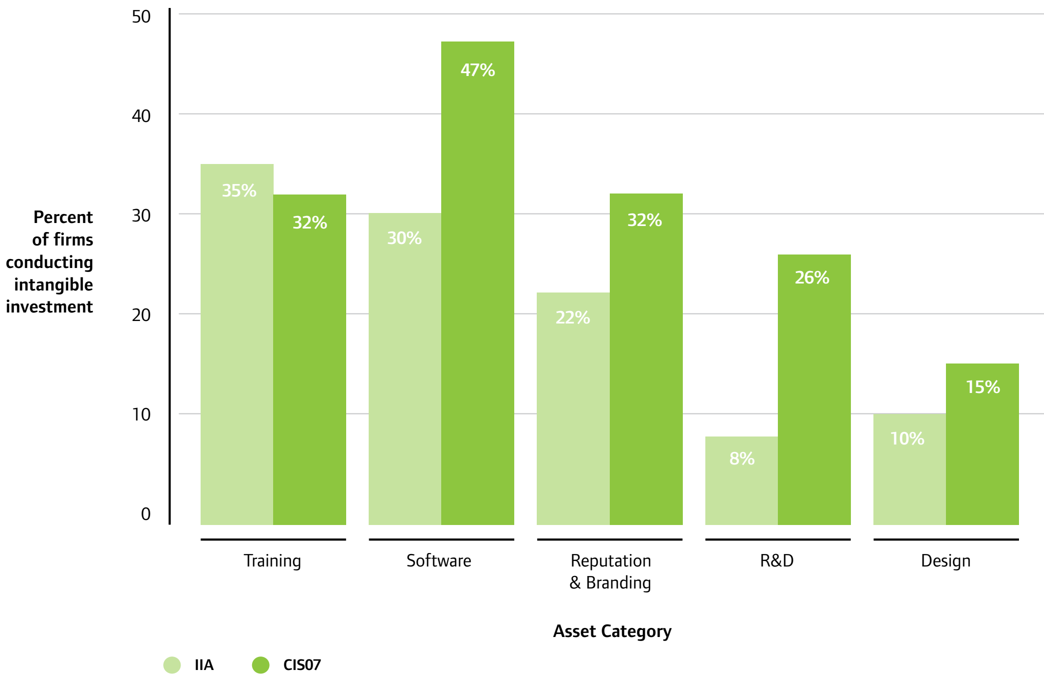
The Design Council has recently completed a survey of design spending. That survey reports results on design expenditures for large firms that have 100 or more employees. The weighted total spending figures for purchased design is £11.2 billion (£7.6 billion for design consultancies and £3.6 for freelancers) and £3.8 billion for in-house. This is not all within the private sector however. For in-house teams it was asked whether they were situated within an organisation that was either public, private or third sector. The responses were as follows: 59 per cent were located within a private sector business; 36 per cent were located within a public sector organisation; 5 per cent were located within a third sector organisation. We could thus calculate in-house design expenditure for the private sector business as: £3.8 billion x 59 per cent = £2.24 billion

Table 15: CIS07 and IIA matched data

	IIA09 survey	CIS07survey (only those matched with IIA09)
Total number of firms	838	89
Average employment (000)	881	3,193
Average turnover (000)	292,021	403,221

Source: Authors' calculation based on IIA.

Figure 20: Per cent of firms conducting intangible investment by asset category, CIS07



Source: Authors' calculation based on IIA.

Table 14 shows a comparison between Design Survey and Intangible Investment Survey as regards in-house design spending. Intangibles Investment Survey reports £0.85 billion total in-house design expenditure. In-house design for medium to large firms, with 100 or more employees, is £0.39 billion. The above numbers are weighted.

It should be noted here that design definition used in the Design Survey is: a) communications (graphics, brand, print, information design, corporate identity; b) product and industrial (consumer/household products), furniture, industrial design (including automotive design, engineering design, medical products); c) Interior and exhibition (retail design, office planning/ workplace design, lighting, display systems, exhibition design); d) fashion and textiles , e) digital and multimedia (website, animation, film and television idents, digital design, interaction design); f) service design defined as an approach concerned with the design of

Table 16: Discrepancies (in activity) between IIA and CIS07

Asset category	Discrepancy between IIA and CIS07 (number of firms)	Matched firms (number of firms)
In-house R&D expenditure	30	81
Purchased R&D expenditure	19	81
Software expenditure	34	81
Business process improvement expenditure	45	81

Note: Column 2 gives the number of firms saying yes/no or no/yes to intangible spending in IIA and CIS07 surveys.
Source: Authors' calculation based on IIA.

services. Services can be both tangible and intangible, and can involve communication, environment and behaviours. Thus this definition incorporates, among others, software design, website, animation, etc. which are grouped as software intangibles in the Intangibles Investment Survey. Specifically, the IIA question on design is: *"the design of products or services to improve their look or performance. Exclude design of scientific prototypes (part of R&D) and design of software"*. So one reason why the Design Council numbers might be higher is that they include such tasks.

ii) IIA and CIS07 comparison
Section 3.9A discusses summary results of the latest UK innovation survey as related to those in IIA. Since we have not yet had access to micro data of this survey we proceed by comparing IIA with the previous innovation survey, i.e. the UK innovation survey of 2007 (CIS07).

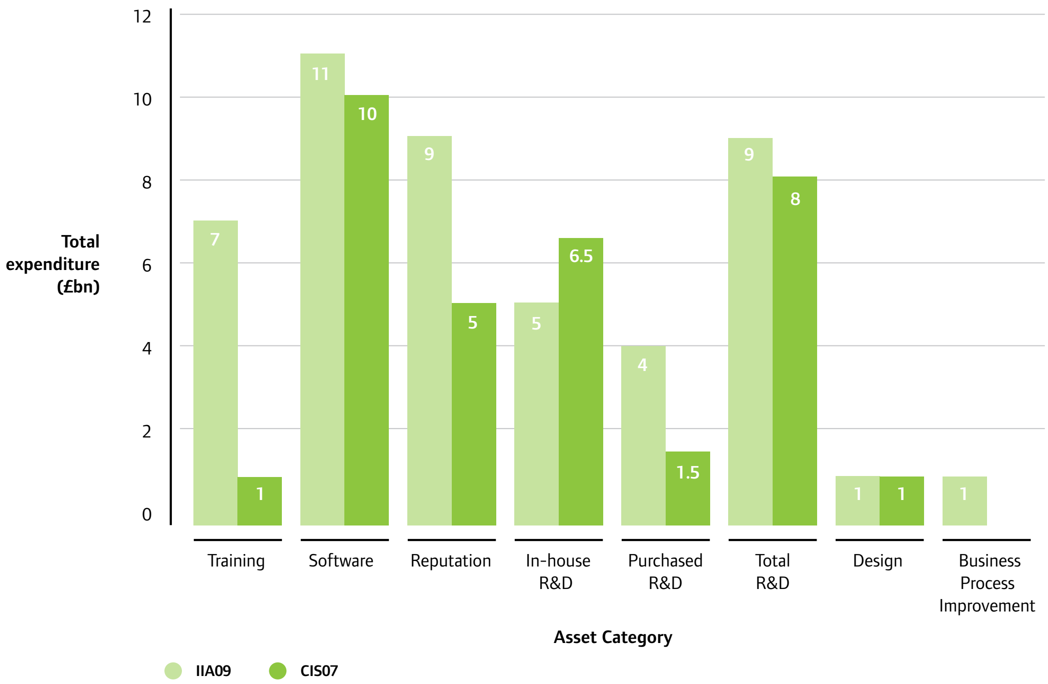
Table 15 shows number and size of firms that are matched between the CIS07 and IIA09 surveys. Only 89 firms have been found to be common in both datasets. Furthermore, these firms are mainly large firms in relation to IIA09 average firm size.

Figure 20 shows that in all cases bar training, the incidence of spending on the IIA is lower than that of the CIS, consistent with the severe downturn. The training question on the CIS is training just for innovation which is narrower than the IIA.

Table 16 reports discrepancies between the CIS07 and IIA data. A common feature among all intangible activities is that quite a few firms had reported an intangible activity in the CIS07 survey while they declared no expenditure in the IIA09 survey. However, only a few firms have a reverse behaviour: saying no to intangible investment in the CIS07 survey but yes to IIA expenditure. Again, such discrepancies can partly be explained by the downturn.

As regards the level of expenditure, Figure 21 brings together total expenditure by asset

Figure 21: Total expenditure by asset category (IIA09 and CIS07 surveys), weighted to give estimates of UK totals



Source: Authors' calculation based on IIA.

Table 17: Correlation coefficients between CIS07 and IIA09 intangible expenditure

	CIS07 internal spending on R&D	CIS07 external spending on R&D	CIS07 software spending	CIS07 spending on training	CIS07 spending on design	CIS07 spending on marketing
IIA internal spending on R&D	0.01					
IIA external spending on R&D		0.97**				
IIA software spending			0.14			
IIA spending on training				0.245*		
IIA spending on design					0.68**	0.13
IIA spending on reputation						0.09

Note: Correlation coefficients are calculated in levels of expenditure (calculations are based on matched micro data). *Significant at 10% significance level. **Significant at 5% significance level.

Source: Authors' calculation based on IIA.

category to show weighted overall spending levels as reported by the CIS07 and IIA surveys. Both surveys suggest that software is the largest category, with total expenditure estimated at £11 billion and £10 billion for the IIA and SIC07, respectively. It is followed by R&D expenditure with a comparable figure between IIA and CIS07 of £9 billion and £8 billion, respectively. However, when R&D is split into in-house and purchased there is much difference between the two surveys mainly because of the different definitions used. For example, in-house R&D in IIA excludes capital items while CIS07 does not, which in turn may explain the higher in-house R&D expenditure reported in the CIS07. Furthermore, training expenditure is much higher in the IIA mainly because it incorporates imputed cost of employee time. If such cost is not included, training expenditure is around £3 billion which is closer to the CIS07 figure. Reputation and Branding is much higher in IIA than in CIS07 which may be due to a wider definition being used by the former. IIA definition refers to every strategy undertaken to enhance reputation or brand values while that of the CIS07 confines itself to marketing expenditures of innovations. Overall, CIS07 reports higher incidence rates per intangible asset while IIA presents slightly higher levels of expenditure in intangibles.

It should be noted that CIS definition of reputation and branding incorporates activities such as changes to product or service design. However, such activities are grouped as design of new or improved products or services in the IIA survey. Indeed, correlation, as reported in Table 16, between spending on reputation and branding (CIS07) and spending on design (IIA09) is 0.13 while correlation of the former with reputation spending of IIA is

Table 18: BERD08 and IIA matched data

	IIA09 survey	BERD08 survey (only those matched with IIA09)
Total number of firms	838	72
Average employment (000)	881	1,780
Average turnover (000)	292,021	314,500

Source: Authors' calculation based on IIA.

Table 19: Discrepancies between IIA and BERD

Asset category	Discrepancy between IIA and BERD08 (number of firms)	Matched firms (number of firms)
Internal spending on R&D	33	72
External spending on R&D	36	72

Note: Column 2 gives the number of firms giving the opposite replies to each survey, that is saying yes/no with no/yes to intangible spending in IIA and BERD08 surveys.
Source: Authors' calculation based on IIA.

only 0.09. However, none of these correlation coefficients are statistically significant. The external spending on R&D exhibits the largest correlation with a value of 0.97, design spending is following with a value of 0.68 while training is 0.25. However, correlation among the other intangible assets has not been found statistically significant.

iii) The IIA and BERD comparison
An attempt to match the IIA survey data with that of the BERD08 produced 72 overlaps on firm level. As Table 18 shows the matched firms are somewhat larger in terms of turnover but not in employment.

Table 19 reports the number of firms that said yes (no) to R&D spending (either in-house or purchased) when asked by the BERD08 survey and no(yes) to the same question when asked by the IIA survey in order to identify the importance of discrepancy between the two. Almost half of them provide different answers to the two surveys, but (not reported due to disclosure) the bulk of these firms answered yes to spending in the BERD and no to spending in the IIA. This last fact is consistent with the time difference between the two surveys (BERD08 refers to the year 2007 while IIA to 2009) and the answers in the IIA have been affected by the economic downturn started at 2008. Note too that BERD is statutory and the IIA voluntary with BERD highly focused on detailed R&D questions: it may therefore be more likely to detect false negatives.

Table 20 shows the correlation coefficients of in-house and purchased R&D. There is strong and significant correlation between the two datasets as regards internal R&D spending. It has to be noted here that BERD definition of in-house expenditure on R&D includes capital expenditure whereas the IIA definition does not. This component was excluded from the calculations in order to have comparable results.

We further matched firms not replying or refusing to reply in the IIA with BERD firms in an attempt to explore R&D spending within the former group of firms. That gave us 120 matched firms. Some 'no reply' and 'refused' firms lie among big R&D spenders as reported by BERD08.

A test statistic of means equality[38] between 'no reply'/'refused' and 'replied' firms suggests that there is no statistically significant difference between these two groups' average R&D spending. This result is an indication that although some big R&D spenders may be excluded from the analysis, the sample does not suffer from selectivity bias against big R&D spenders.

38. A test of means equality with unequal variance was performed.

Table 20: Correlation coefficients between CIS07 and BERD intangible spending

Asset category	Discrepancy between IIA and BERD08 (number of firms)	Matched firms (number of firms)
IIA internal spending on R&D	0.7921**	
IIA external spending on R&D		0.3843**

Note: **Significant at 5% significance level.
Source: Authors' calculation based on IIA.

Part 4: Concluding remarks

This report provides findings of the IIA survey. These are summarised below:

a. The incidence of non-R&D intangible spending is much more widespread than R&D spend. Eight per cent of UK firms spend on R&D, all of whom also spend on non-R&D intangible spending. But 50 per cent of UK firms spend on non-R&D assets.

b. The incidence of both non-R&D and R&D intangible spend is more common among large and older firms. But non-R&D spend is much more common in services relative to manufacturing, especially in financial services. Thus much of the incidence of innovation spending in the service sector, a major part of the economy, is not captured in the R&D statistics.

c. The overall level of intangible spend is considerable, around £39 billion in this survey, of which software is about £11 billion, branding £10 billion, R&D £10 billion, training £7 billion and design and business process improvement £1 billion each. In-house spending is, on average, 55 per cent of this and purchased 45 per cent. Spending as a fraction of turnover (spending intensity) is particularly high in financial services, and somewhat weakly higher in small firms.

d. Taking into account differences in definition and timing, these micro numbers compare quite closely with the numbers used in the macro study for the UK Innovation Index (Haskel *et al.*, 2009) for training, software, R&D and branding. The micro numbers here are much lower than those in the macro data for design and business process engineering. This may have to do with sampling (for example according to the Design Council, 85 per cent of designers are in small firms outside the IIA sample) or the recession or inaccuracy of the assumptions upon which the macro numbers are based, all of which needs investigation in future work.

e. Average benefit lives for all intangibles were over one year, supporting the idea that intangible investment brings long-lived benefits. Indeed lowest of the 95 per cent confidence intervals for all assets were over two years, except for branding which was 1.9 years.

f. R&D had the longest average benefit life of 4.6 years; the average of the others was 3.2 years. In our previous pilot survey we asked, in addition to benefit time, time for development and implementation. Adding these times to the benefit time gives average life lengths of 8.6 years for R&D and five years for other intangibles, with longer life lengths in production than services. On a double declining balance assumption, this gives depreciation rates of 23 per cent for R&D and 40 per cent for other intangibles.

Appendix A: Description of weights and confidence intervals

a-weights

To compute a-weights (more generally known as design weights) we start from the sample design frame, which has 48 cells (12 industry groups, four employment size classes in each). Define N_a, the number of firms in each cell a on the business register (the version from which the survey sample is drawn), and n_a, the number of responses received from each cell. The a-weights are then simply N_a/n_a.

Example: for the fifth cell of the sample design frame, $N=12,035$ and $n=83$, so $a_5=145$. The a-weights are used to generate expansion estimates for the population of firms, excluding cells in the design frame from whom no responses were received and excluding cells that are not sampled at all, such as firms with fewer than ten employees

g-weights

The g-weights (also known as calibration weights) use an auxiliary variable, in this case employment, effectively to estimate a ratio between the auxiliary variable and the variable of interest, which in this case is expenditure on intangible assets. For this reason, population estimates using g-weights (strictly speaking, a*g weights) are referred to as ratio estimates and the effect of weighting by a*g is to calibrate results to known register totals of employment. We chose employment based on a preliminary analysis which shows that expenditure on intangibles is more correlated with employment than with turnover. Another feature of the g-weights is that they provide a route to deal with cells in the sample design frame with no responses and to scale up results to include firms with fewer than ten employees. By merging such cells with adjacent cells, we can estimate expenditure on intangible assets for the missing cells by assuming that the ratio between expenditure and employment is the same as that in the adjacent cells.

G-weights are calculated as follows. First we define a merged sample frame with j cells, by merging cells with nil or very few responses. There is no objectively correct method of merging cells. The primary criterion is that the relationship (between response and auxiliary) does not obviously differ between the strata being merged. In this case we have merged employment classes within industry groups, but it could be equally valid to merge adjacent industry groups of the same size class. Our analysis suggests that the results in terms of expenditure estimates are not particularly sensitive to the design of the merged sample frame.

Define X_j as the population of the auxiliary variable employment in cell j, and $\sum(ax)_j$ as the sum of a-weighted employment of respondents in each cell j. G-weights are then computed as $X_j/\sum(ax)_j$, and expenditure estimates are grossed up by the product of the a and g-weights.

Example: due to low response we merge all four size classes of industry group 64 into a single j cell. According to the business register, total employment in industry 64 is 368k, while the a-weighted employment of respondents is 162k. This gives a g-weight of 2.27. This means that our expenditure estimates for industry 64 are 2.27 times larger than would be the case if we simply used a-weights. In general, g-weights are greater than 1 where the average employment of respondents is below the population average for that cell, and vice versa.

Confidence intervals

The method of computing confidence intervals varies slightly according to the variable in question. Here we outline the method in the case of expenditure estimates.

Define: $\hat{Y}$ the population estimate of the expenditure variable Y for which the confidence interval is to be computed.

R_j	$Sum(ay)_j / Sum(ax)_j$	the ratio of a-weighted expenditure to a-weighted employment in each j-cell.
Compute:	$\hat{S}_a^2 \sum (y - R_j * x)^2 / (n_a - 1)$	for each a-cell
	$Var(\hat{Y}_a) = N_a^2 * (1 - n_a / N_a) * \hat{S}_a^2 / n_a)$	for each a-cell
Then:	$Var(\hat{Y}) = \sum Var(\hat{Y}_a)$	population variance estimate
And:	$SE(\hat{Y}) = \sqrt{Var(\hat{Y})}$	population standard error estimate

The 95 per cent confidence intervals are then +/-1.96 standard errors around the population estimate.

Example: For expenditure on business process improvement, we have a population estimate of £1.38 billion. Following the above steps we compute a standard error around this estimate of £0.15 billion, giving a 95 per cent confidence interval of £1.09-£1.67 billion.

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