Department for **Innovation, Universities** & **Skills**

Design in Innovation

Coming out from the Shadow of R&D

An Analysis of the UK Innovation Survey of 2005

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DIUS Research Report 09 12

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Abstract

This paper is an analysis of the evidence provided by the UK Innovation Survey of 2005 concerning the role of design in the innovation activities of firms. The role of design has attracted increasing interest from policymakers in recent years, but its contribution to innovation is still largely overshadowed by research and development activities. The analysis in this paper shows that relatively few innovating firms engage in design activities outwith research and development, although a significant proportion also appear to invest in design without recognising these as design activities. The evidence also shows that design activities tend to be undertaken by firms with deeper commitments to innovation and/or those innovating at a higher level. In addition, particularly amongst these higher level innovators, investments in design tend to complement other investments, such as investments in R&D and marketing, rather than substitute for them. Firms that invest in combinations of R&D, marketing and design are more likely to innovate, particularly at a high level, than firms that invest in only one of these activities. Also notable is that firms that spend on combinations of R&D, design and other innovation related activities tend to spend more on each activity than firms that spend on only one or two innovation related activities. All told, the analysis suggests that design is an important complementary asset for innovation, particular for high level innovation.

1 Introduction

The UK Government has in recent years recognized that design can be a powerful commercial tool, that can enhance competitiveness at the firm level, and contribute to economic growth at the national level. The contribution of design to enhancing environmental sustainability is also increasingly appreciated. Evidence of the Government's increasing interest in design can be found in the Treasury's commissioning of the Cox Review of Creativity in Business,[1] and the parallel study by the DTI on 'Creativity, Design and Business Performance'.[2] Furthermore, the Government has established the Arts and Humanities Research Council, the activities of which include co-sponsoring with the EPSRC the 'Designing for the 21st Century initiative', which will run from 2005 to 2009.

The present study is an exploration of the evidence provided by the UK Innovation Survey of 2005 on the role of design in innovation. The UK Innovation Survey of 2005 was the UK version of the fourth European Community Innovation Survey (CIS-4). The survey is based on a core set of questions agreed by Eurostat and national governments, and the UK's Office for National Statistics (ONS) administered the UK survey. The survey was postal and voluntary, and the ONS achieved responses from 16,446 enterprises, an overall response rate of 58%.[3]

The UK Innovation Survey of 2005 was not intended as a study of the contribution of design to innovation, and the scope for investigating the role of design in innovation is restricted by the limited nature of the available information. We will discuss this further, and what might be done it in future surveys, in the concluding section of this paper. Although there are difficulties with the available information, we do appreciate that the UK has gone further than many other countries in seeking to include the explicit contribution of design amongst other inputs (such as R&D) to innovation; in most other countries design is included in the miscellaneous category of 'other market preparations' for innovation.

The UK Innovation Survey of 2005 contains three questions which relate directly to design, both as an activity and as an outcome. Firstly, Question 13 on the survey asks the firms whether, during the three-year period 2002-2004, it engaged in the following innovation related activities:

[Below, each activity is first identified, then given a code to be used in this paper, and a definition which is essentially that given on the survey form]:

Intramural (in-house) R&D [IRD]: Creative work undertaken within the enterprise on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes

Acquisition of R&D (extramural R&D) [XRD]: Same activities as above, but purchased by the enterprise and performed by other companies (including other enterprises in the enterprise group or by public or private research organizations

Acquisition of Machinery, Equipment and Software [AME]: Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services production processes or delivery methods.

[1] See http://www.hm-treasury.gov.uk/independent_reviews/cox_review/coxreview_index.cfm
[2] See http://www.dti.gov.uk/files/file13654.pdf
[3] Further details on the survey can be found in Robson, S. and Ortmans, L. (2006), 'First findings from the UK Innovation Survey, 2005', Economic Trends, 628, March, pp. 58-64. See http://www.dti.gov.uk/files/file26156.pdf#search=%22robson%20%22innovation%20survey%22%22

Acquisition of External Knowledge [AEK]: Purchase or licensing of patents and non-patented inventions, know-how and other types of knowledge from other enterprises or organizations

Training [TRA]: Internal or external training for the enterprise's personnel specifically for the development and/or introduction of innovations.

All Forms of Design [DES]: Expenditure on design functions for the development or implementation of new or improved goods, services and processes. Expenditure on design in the R&D phase of product development should be excluded.

Market Introduction of Innovations [MKT]: Activities for the market preparation and introduction of new or significantly improved goods and services, including market research and launch advertising.

It is especially notable that firms are asked to exclude from 'All Forms of Design' any design activities conducted in the 'R&D phase of product development'. This implies that some design activities will therefore be 'hidden' in R&D. This problem of hidden design is one to which we shall return. In sections 2 and 4 of this study we explore the extent to which different types of firms admit to engaging in design, and compare this with their participation in the other activities outlined above.

The second question pertaining to design is Question 14, which asked the firms to estimate their expenditure in each innovation activity for 2004, where the activities were those outlined above and defined in Question 13.[4] This means that expenditures on 'All Forms of Design' (net of expenditures on design in the R&D phase of product development) should have been recorded. In sections 5 and 6 of this study we will examine this expenditures data.

The third question that concerns design, this time as outcome rather than as process, is Question 21, which asked the firms whether (in 2002-2004) they used the following methods to protect their innovations: the **registration of designs**, trademarks, patents, copyrights, confidentiality agreements, secrecy, the **complexity of designs**, and lead-time advantage on competitors. Although design can contribute to patents, trademarks, copyrights and other forms of protection, it is most clearly and explicitly identified in the registration of designs and using the complexity of designs to protect innovations. In Section 3 of this study we will explore the use of design protection amongst firms that did and did not claim to have engaged in design activities.

In the analysis that follows we will divide the overall response to the survey by sector of activity and by level of innovation activity. For sectors, we will for ease exposition mainly divide the sample into four broad sectors: Manufacturing; Financial and Business Services[5]; Trade, Leisure and Transport Services; and Construction, Extraction and Utilities.[6] Some analysis using more detailed sectors of activity will also be undertaken and discussed, with regression models presented in an appendix to this paper.

[4] With the slight alteration that 'Market Introduction of Innovations' became 'Marketing expenditures'.
[5] Including telecommunications services.
[6] This category is actually dominated by construction firms.

For innovation, the survey begins with the following definition:

> *Innovation is defined as major changes aimed at enhancing your competitive position, your performance, your know-how or your capabilities for future enhancements. These can be new or significantly improved goods, services or processes for making or providing them. It includes spending on innovation activities, for example on machinery and equipment, R&D, training, goods and service design or marketing.*

The analysis that follows will be based on the sub-sample of respondents which the DTI has identified as 'innovation active'. To be innovation active in the three-year survey period (2002-2004) firms had to have engaged in one or more of the innovation activities outlined above, and / or have introduced at least one product and / or process innovation, and / or have engaged in ongoing or abandoned innovation activities. The DTI found that, overall, 62% of the responding firms were innovation active; or 57% of firms if the sample is adjusted to reflect the population of firms in the UK in the surveyed sectors. Table 1 shows how the proportion of innovation active firms varies substantially across the broad sectors, being highest amongst manufacturers and lowest amongst construction, extraction and utilities firms.

A binary logistic regression model (shown in Table B of the appendix) shows that larger firms tend to be more likely to be innovation active, as are newly established firms, and firms that are part of a larger group of companies. Relative to manufacturers in the food, drink and tobacco sector, most manufacturing firms are more likely to be innovation active, some substantially more likely, as are some services - such as computer services, but other services (notably wholesale and retail service firms) and utilities firms are less likely to be innovation active (all else equal).

Table 1: Innovation Active Respondents in the 2005 UK Innovation Survey

	Number of Innovation Active Respondents	Innovation Active / All Respondents	Adjusted proportion of Innovation Active Respondents
Construction, Extraction & Utilities	893	48.3%	44.6%
Manufacturing	3,727	75.7%	71.6%
Financial & Business Services	2,995	65.4%	62.7%
Trade, Leisure & Transport Services	2,631	51.7%	48.4%

The survey also asked the firms whether any of their product innovations were new to their markets (rather than just new to the firm itself and therefore essentially imitative of rivals' existing products), and whether any of their process innovations were new to its industry (rather than new to the firm itself and essentially imitative of rivals' existing processes). We can use this information to divide the classification of 'innovation active' firms into three sub-classes:

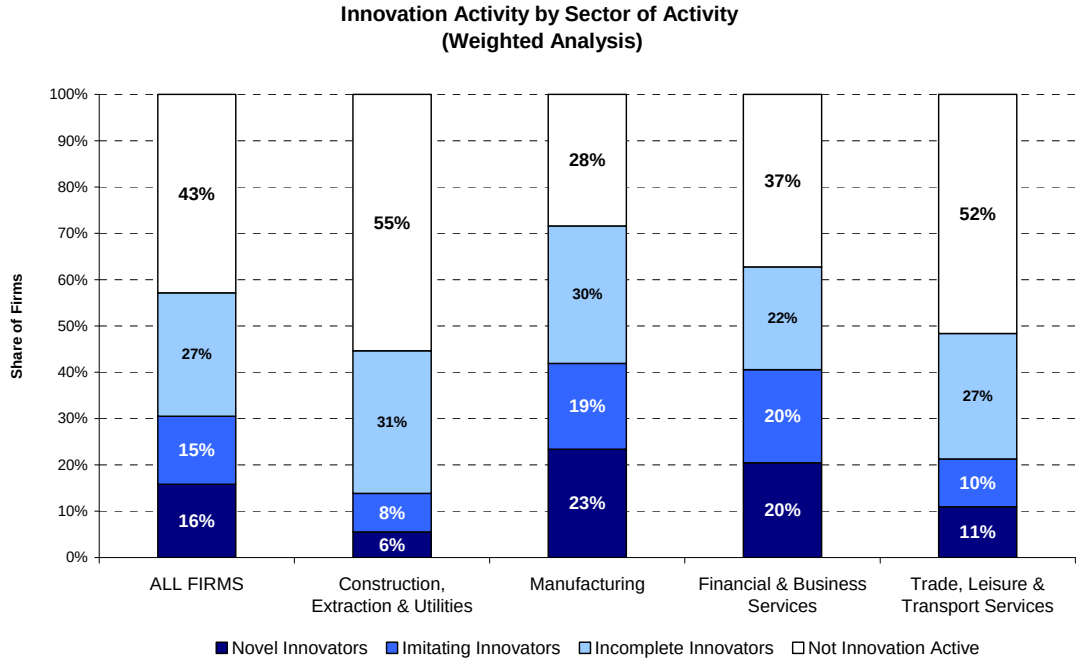
Novel Innovators: are those that introduced at least one new to the market product and/or one new to the industry process. These firms may also have introduced imitative products &/or processes &/or have incomplete innovation activities.

Imitating Innovators: are those not identified as novel innovators that introduced at least one new to the firm product innovation and / or one new to the firm process innovation. These firms may also have had incomplete innovation activities.

Incomplete Innovators: are those not identified above that had engaged in innovation activities but had not introduced a product or process innovation during the survey period.

By the number of respondents, 28% of innovation active firms were classed as novel innovators, 28% as imitating innovators, and 43% as incomplete innovators. Adjusted to the population of firms, the corresponding proportions are 28%, 26% and 47%. Figure 1 shows how the proportion of firms allocated to these categories varied by grand sector of activity.

Figure 1



2 Firms Engaging in Design and Other Innovation Activities

Figure 2 shows the proportion of innovation active firms that engaged in the seven innovation related activities identified earlier (and in Q13 on the survey). The most widespread activity was the acquisition of machinery, equipment and software, followed by training, and then intramural R&D and activities associated with the market introduction of innovations. About a quarter of the innovation active firms recognized that they engaged in design, a slightly higher proportion than that for firms acquiring external knowledge and a significantly higher proportion than firms engaging in extra-mural R&D. The figure also shows that design activities are more common amongst manufacturing firms (as are intra-mural R&D activities) than amongst service and construction firms.

Figure 2

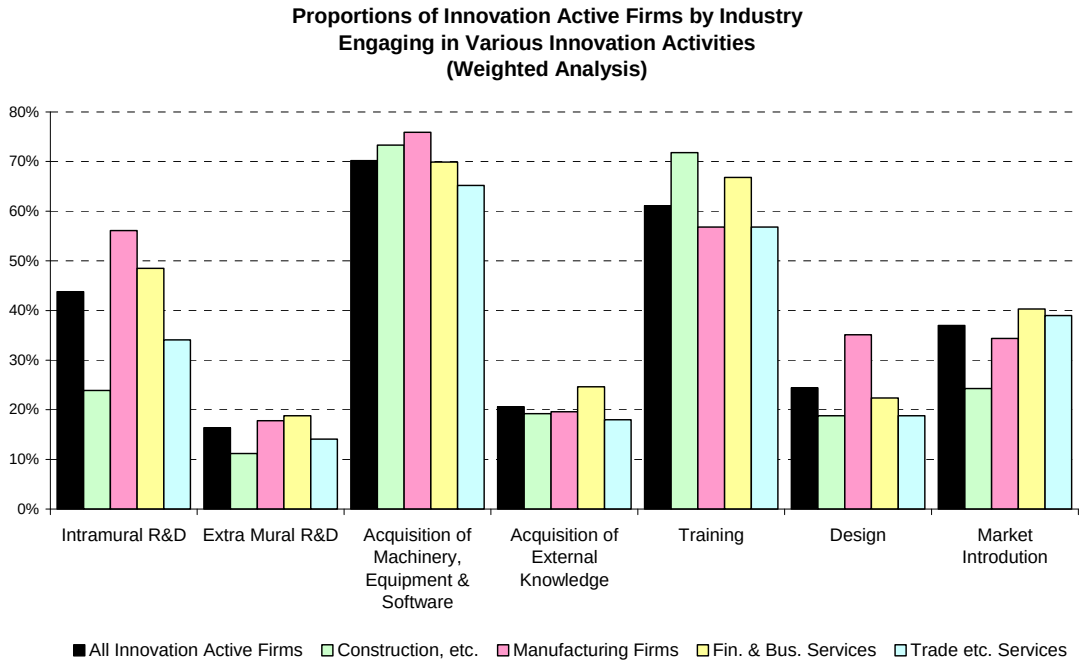
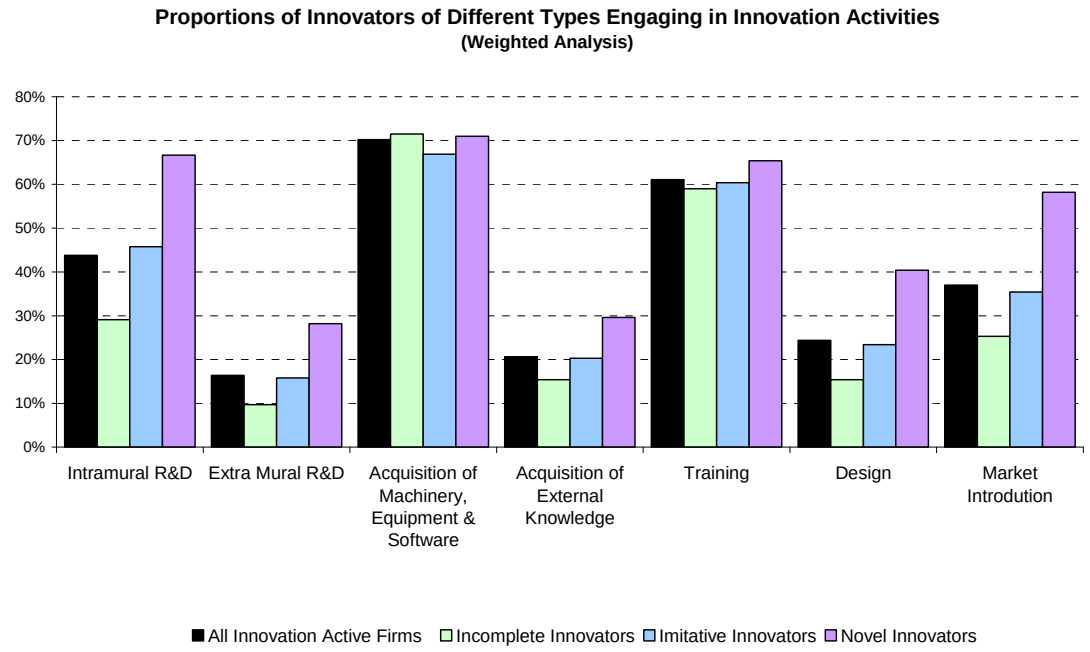


Figure 3 shows that the propensity to engage in design (and other activities bar training and the acquisition of machinery, equipment and software) was markedly greater amongst the novel innovators, compared with the imitating innovators, whilst those with incomplete innovation activities were even less likely to invest in design (and the indeed all the other activities bar training and the acquisition of machinery, equipment and software). This suggests that investing in design tends to be associated with greater commitments to innovation and/or engaging in higher levels of innovation, rather than with low commitments and low levels of innovation. We will see later that there is further evidence to support this conjecture. First, however, we assess the extent to which firms are probably investing in design but failing to report these investments in the survey.

Figure 3


Proportions of Innovators of Different Types Engaging in Innovation Activities
(Weighted Analysis)
80%
70%
60%
50%
40%
30%
20%
10%
0%
Intramural R&D
Extra Mural R&D
Acquisition of Machinery, Equipment & Software
Acquisition of External Knowledge
Training
Design
Market Introdution
All Innovation Active Firms
Incomplete Innovators
Imitative Innovators
Novel Innovators

3 'Hidden Design' and Methods Used to Protect Innovations

One of the problems with studying design is that investments in design are often hidden in other categories. As reported earlier, the 2005 UK Innovation Survey asked firms explicitly not to record under 'All Forms of Design' those design activities that were undertaken within the 'R&D phase of product development'. It follows that some design active firms will have effectively hidden their participation in design within R&D if their design activities were confined to R&D.

We have already seen that about 40% of the novel innovators that claimed to have introduced a new to the market or industry innovation claimed to have engaged in design. Although substantially greater than the corresponding proportions for imitating and incomplete innovators, this proportion is arguably surprisingly low rather than surprisingly high. For arguably all new products and processes need to be designed and thus involve design. And those that are new to an industry or market must surely have involved design activities, even if these were not undertaken by a professional designer.

Table 2: Novel Product Innovators Engaging in Design & In-house R&D

	All Novel Product Innovators*	Extraction, Construction & Utilities*	Manufacturing*	Financial & Business Services*
With Design Activities	54%	40%	63%	45%
No Design, but In-house R&D	35%	41%	29%	42%
Neither Design nor In-house R&D	11%	19%	7%	13%
Total	100%	100%	100%	100%

* Firms that claimed to have mainly developed the innovations by themselves

Table 2 is based on a simple (unadjusted) analysis of the extent to which firms that claimed to have introduced a new to the market product innovation (which they also claimed they had mainly developed themselves) admitted to engaging in design activities, and failing that in-house R&D, or neither design nor in-house R&D. The table shows that over half these firms admitted to engaging in design, with a further third not engaging in design but undertaking in-house R&D (and probably design activities within R&D). A little over one in ten of these firms claimed to have engaged in neither design nor R&D, which seems inconsistent with the claim to have developed internally a new to the market product innovation. The pattern is shown for each of the broad sectors, and is most logical for manufacturing, and least logical for trade, leisure and transport services (closely followed by construction, etc.), amongst which almost one in five of these new to the market product innovators claimed to have engaged in neither design nor R&D: the creative source of their innovations therefore remains something of a mystery.

An indicator that these firms did engage in design even if they failed to recognize this is found in at least some of their answers to the question on how the firms protected their innovations. As mentioned earlier, amongst eight possible methods of protecting innovations, two explicitly mention design: the registration of designs, and using the complexity of designs to inhibit competitors. It is of course possible for firms to use design to develop new products, processes and / or services that are simple, and thus complexity of design is no defence. It is also possible for them to develop products, processes or services which either do not qualify under the registration of designs, or which they choose not to register even if this protection is available to them. In Figure 4 we see that the majority of firms with design activities used the registration of designs and/or the complexity of designs as means of protecting their

innovation activities, and this proportion rises to over 80% amongst the novel innovators. However, we also see that some firms (and in the case of novel innovators, over 40%) that failed to recognise they engaged in design or intra-mural R&D used one or both of these methods to protect their innovations. This implies design is more widespread than shown by the number of firms admitting to engaging in it. We call this the problem of 'hidden', or 'silent' design (Gorb and Dumas, 1987).

Figure 5 shows the extent to which firms in different sectors and by different levels of innovation engage in design. At the bottom of each bar are those firms that explicitly stated they engaged in design (i.e. answered yes to the 'all forms of design' question), above these are firms that did not state that they engaged in design but did engage in intra-mural R&D, and some design activities are likely to have been undertaken within R&D. Above these are firms that did not claim to have engaged in either design or in-house R&D, but which claimed to have used one or both the complexity of designs or the registration of designs to protect their innovations. Finally the top part of each bar shows the proportion of innovation active firms that had none of these indicators of design activity. The figure shows clearly that manufacturers and novel innovators were the most likely to engage in design (even though a great deal of design activity amongst these firms is hidden). Meanwhile, about half the construction, extraction and utilities firms, the trade, leisure and transport services firms, and the incomplete innovators showed no explicit signs of engaging in design.

Figure 4

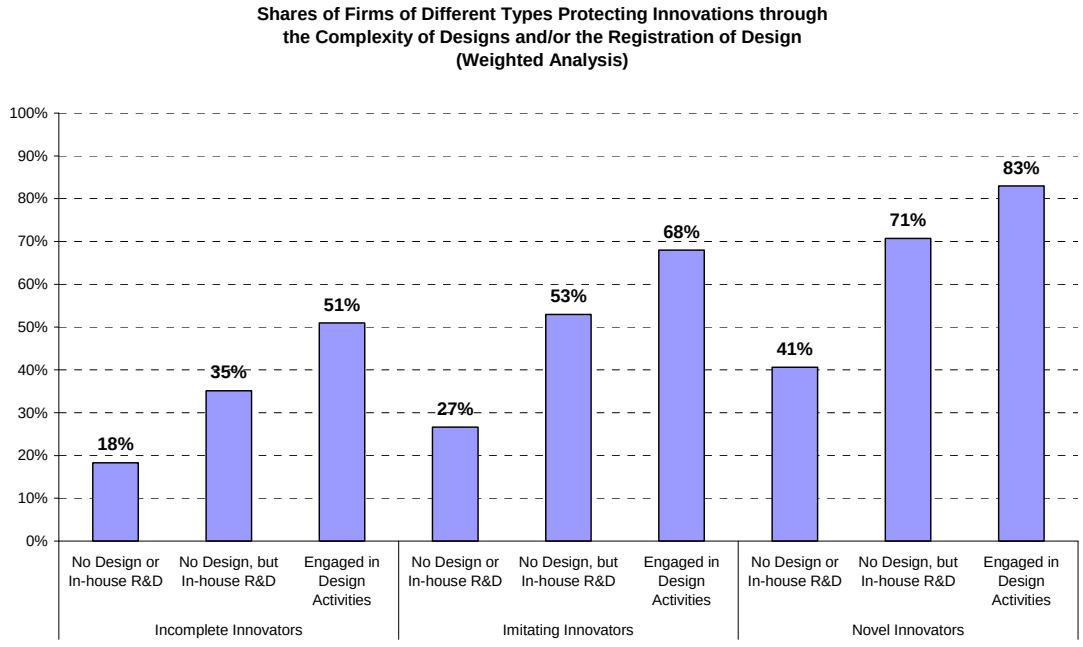
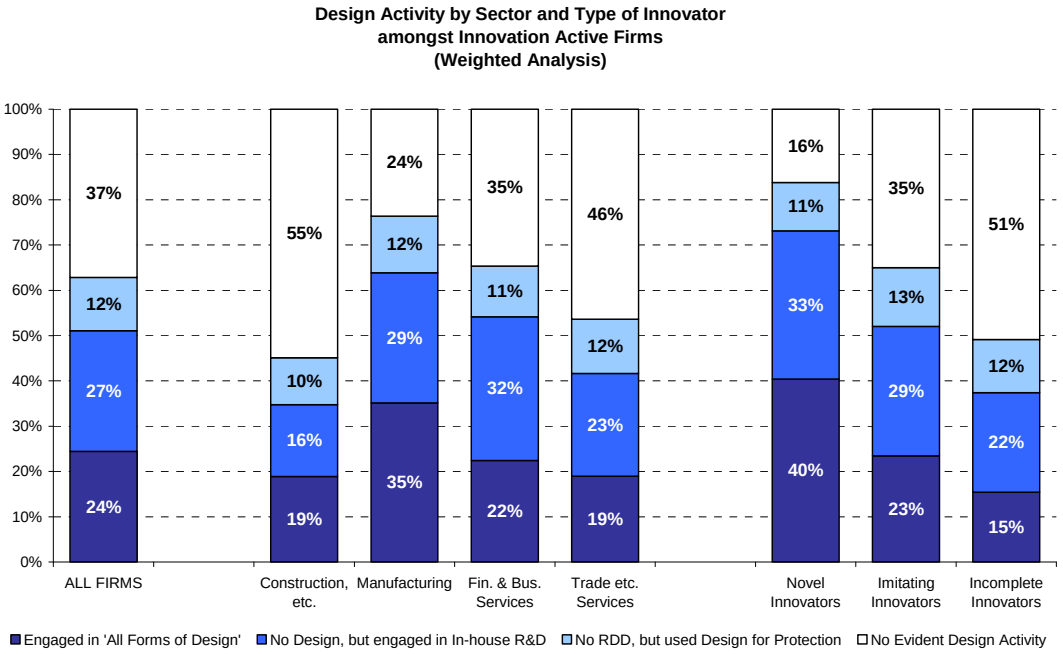


Figure 5



A more detailed analysis of the types of innovation active firms that engaged in explicit, 'hidden' or no (apparent) design activities is revealed by the multinomial logistic regression models reported in Tables C and D in the appendix to this paper. Here, firms with explicit design are innovation active firms that claimed to have engaged in "All Forms of Design"; firms with 'hidden design' are those not identified above but which claimed to have engaged in intra-mural R&D and / or claimed to have used registered designs and/or the complexity of design to protect their innovations; whilst firms not qualifying above are classed as having no apparent design activities.

In Table C in the appendix we model engagement in design by firm size, age, markets, and sector of activity. In Table D we also include in the analysis the types of innovations the firms introduced during the survey period. Technically, the inclusion of the types of innovations is problematic, because these are likely to be outcomes rather than inputs to the decision as to whether and how to invest in design - i.e., these variables are endogenous.

The tables show that larger firms are more likely to engage in design - they are in fact more likely to engage in hidden design than no design, and are more likely still to engage in explicit design. New firms are more likely to invest in design, but with no significant difference between hidden and explicit design. The same is true for firms that are part of a wider company group.

Markets also matter. Firms that engage in international markets are more likely than those that confine their activities to the national market to engage design, whilst those that serve national markets are more likely than those that serve only local/regional markets to engage in design. There is some evidence that firms that engage in international and national markets are more likely to engaged in explicit as opposed to 'hidden' design.

Sector also matters. Compared with the reference sector - the manufacture of food, drink and tobacco, low technology manufacturing sectors tend to be as, or less likely to engage in design, whilst medium and high technology manufacturing sectors (such as machinery, electronics, instrumentation, transport equipment) tend to be more likely to engage in design, and especially explicit design. By contrast, with the odd exception such as computer

services, service sector firms (and construction firms) tend to be much less likely to engage in both explicit design and hidden design.

Finally, innovation outcomes also matters. As mentioned earlier, the inclusion of these variables is problematic due to their being an outcome rather than a true input. These variables might proxy however for firms intentions regarding innovation. The analysis shows, as expected, that firms that introduced goods innovations were more likely to use design, and were more likely to use explicit design than hidden design. The same is true of firms that introduced novel product innovations and, perhaps more surprisingly, for firms that introduced process innovations. The models also show that firms that introduced service innovations were more likely to use design, although not significantly more likely to use explicit than hidden design. Firms that introduced new to the industry process innovations were more likely than other process innovators to use design, especially explicit design.

4 Complementarities between Design and Other Innovation Activities

In this part of the paper we investigate whether there appear to be complementarities between the various innovation activities that the firms engaged in, paying particular attention to any complementarities involving design. On the simple basis of whether or not the firms engaged in each of the activities, we will compute complementarity measures for all seven innovation related activities asked about in Question 13 of the survey. Firms which indicated that they engaged in at least one of the innovation related activities are included in the analysis.[7]

Following Swann (2006), there are two approaches to measuring complementarity between activities. The first and easiest approach, is:

$$P_{AB} = \Pr\{A \text{ and } B \mid A \text{ or } B\} = \frac{A \cap B}{A \cup B} \qquad (1)$$

This is the conditional probability that the firm does A and B, given that it does either or both A and B. This measure is symmetric ($P_{AB} = P_{BA}$) so the complementarity matrix is easy to interpret.

Table 3 presents estimates of equation (1), with the estimates above the diagonal reflecting the data as a simple sample (Unweighted Analysis), and those below the diagonal representing the data adjusted to reflect the population of firms (Weighted Analysis).

Table 3: Complementarities in Innovation Activities
(Probability of Both, conditional on doing either or both)

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100%	31%	43%	25%	44%	39%	42%
XRD	29%	100%	21%	27%	21%	28%	27%
AME	39%	18%	100%	25%	59%	31%	37%
AEK	23%	25%	24%	100%	27%	28%	27%
TRA	40%	18%	55%	26%	100%	32%	42%
DES	34%	25%	26%	25%	28%	100%	38%
MKT	38%	23%	34%	25%	39%	33%	100%

Above the diagonal = Unweighted Analysis; Below the diagonal = Weighted Analysis

Following Swann's (2006) rules of interpretation, we can say that when the matrix element is above 50% the two activities are complementary: if a firm does one or other, it is more likely than not that it will do *both* activities. But when the matrix element is below 50%, we can say that the two activities are not complementary: if a company does one or other, it is more likely than not that it will only do one of the activities, *not both*. In demand theory A and B are considered *substitutes*.

As in Swann (2006), the table has been coloured to ease interpretation. Red cells indicate complementarity (>=50%), whilst dark blue cells imply strong substitutes (<20%): yellow, green and light-blue cells show intermediate scores. The principal diagonal cells are grey, meaning 100%.

[7] This therefore excludes 469 or 4.6% of the 'innovation active' firms (as defined by the DTI) that did not claim to have engaged in any of these seven activities.

Perhaps surprisingly, this analysis finds only one complementarity: that between investments in training and investments in acquired machinery, equipment and software. A complementarity between these activities is of course logical and might have been expected. All other combinations show scores below 50% and indicate that firms are more likely to do one or other of these activities rather than both. The greatest degree of disconnection is found being between investing in external R&D and training, and between investing in external R&D and acquiring machinery and equipment.

Table 4: Complementarities in Activities by Sector and Level of Innovation
(Probability of Both, conditional on doing either or both)

Extraction, Construction and Utilities

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	33%	30%	19%	30%	29%	31%
XRD	35%	100	15%	24%	16%	29%	24%
AME	25%	13%	100	21%	59%	25%	27%
AEK	19%	22%	21%	100	23%	24%	22%
TRA	24%	13%	58%	23%	100	25%	29%
DES	23%	26%	21%	23%	21%	100	33%
MKT	26%	22%	26%	22%	27%	28%	100

Financial and Business Services

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	32%	44%	27%	47%	33%	43%
XRD	31%	100	23%	28%	21%	28%	25%
AME	43%	22%	100	29%	61%	26%	41%
AEK	27%	26%	29%	100	30%	29%	32%
TRA	45%	20%	58%	29%	100	27%	46%
DES	31%	26%	25%	28%	26%	100	35%
MKT	40%	23%	37%	30%	42%	33%	100

Manufacturing

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	31%	51%	25%	50%	47%	46%
XRD	26%	100	22%	28%	25%	28%	32%
AME	45%	18%	100	24%	60%	40%	37%
AEK	22%	24%	21%	100	27%	27%	27%
TRA	44%	20%	56%	25%	100	43%	42%
DES	43%	23%	35%	24%	37%	100	44%
MKT	42%	28%	31%	24%	37%	40%	100

Trade, Leisure and Transport Services

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	31%	33%	23%	37%	30%	35%
XRD	29%	100	18%	25%	18%	28%	22%
AME	31%	17%	100	24%	54%	22%	36%
AEK	21%	25%	22%	100	25%	27%	24%
TRA	35%	17%	51%	23%	100	24%	41%
DES	28%	26%	22%	23%	23%	100	31%
MKT	34%	19%	35%	22%	41%	29%	100

Novel Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	38%	64%	32%	61%	52%	59%
XRD	36%	100	34%	35%	33%	35%	35%
AME	61%	31%	100	35%	68%	48%	56%
AEK	31%	32%	35%	100	35%	35%	35%
TRA	56%	29%	65%	34%	100	47%	58%
DES	46%	32%	43%	33%	42%	100	49%
MKT	55%	32%	54%	34%	57%	44%	100

Imitating Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	30%	47%	23%	48%	36%	39%
XRD	27%	100	22%	24%	20%	26%	24%
AME	42%	19%	100	26%	63%	30%	37%
AEK	21%	23%	25%	100	28%	26%	25%
TRA	45%	18%	60%	27%	100	31%	42%
DES	33%	23%	26%	24%	28%	100	34%
MKT	35%	20%	34%	23%	39%	32%	100

Incomplete Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	23%	26%	16%	28%	24%	24%
XRD	21%	100	11%	18%	12%	18%	16%
AME	23%	10%	100	18%	50%	18%	22%
AEK	16%	17%	17%	100	20%	19%	19%
TRA	25%	11%	47%	19%	100	20%	28%
DES	20%	16%	16%	16%	17%	100	25%
MKT	23%	13%	21%	17%	27%	21%	100

Above the diagonal = Unweighted Analysis; Below the diagonal = Weighted Analysis

To explore these patterns further, we disaggregate the data by sector of activity and by level of innovation activity. The results are shown in Table 4. This shows that whilst there are some differences between firms by sector, the more pronounced differences are found by the level of firms' innovation activities: quite simply firms that had only incomplete innovation projects were more likely to do one or other rather than both of any combination of activities (with the marginal exception of acquiring machinery and equipment and training). By contrast, firms that developed novel innovations were often more likely to have engaged in combinations of activities than to do one or other of these. Interestingly, amongst novel innovators, whilst intra-mural R&D shows complementarity with the acquisition of machinery, equipment and software, with training, and with marketing efforts, it does not quite (in the weighted analysis) show complementarity with design. Design also approaches but does not quite reach complementarity with the acquisition of machinery, equipments and software, training, and activities related to the market introduction of innovations.

The patterns revealed by this complementarities analysis provide the strong suggestion that firms with greater commitments to innovation (or achieving higher levels of innovation) tend to engage in a greater number of innovation related activities than those with low commitments to innovation. This conjecture is confirmed by the patterns shown in Figure 6, which shows the distributions by number of innovation activities engaged in for the three types of innovator in our analysis. More than a third of the incomplete innovators engaged in only one activity, and the median incomplete innovator engaged in only two activities. By contrast, few novel innovators engaged in only one activity, and the median novel innovator engaged in four activities.

Figure 6

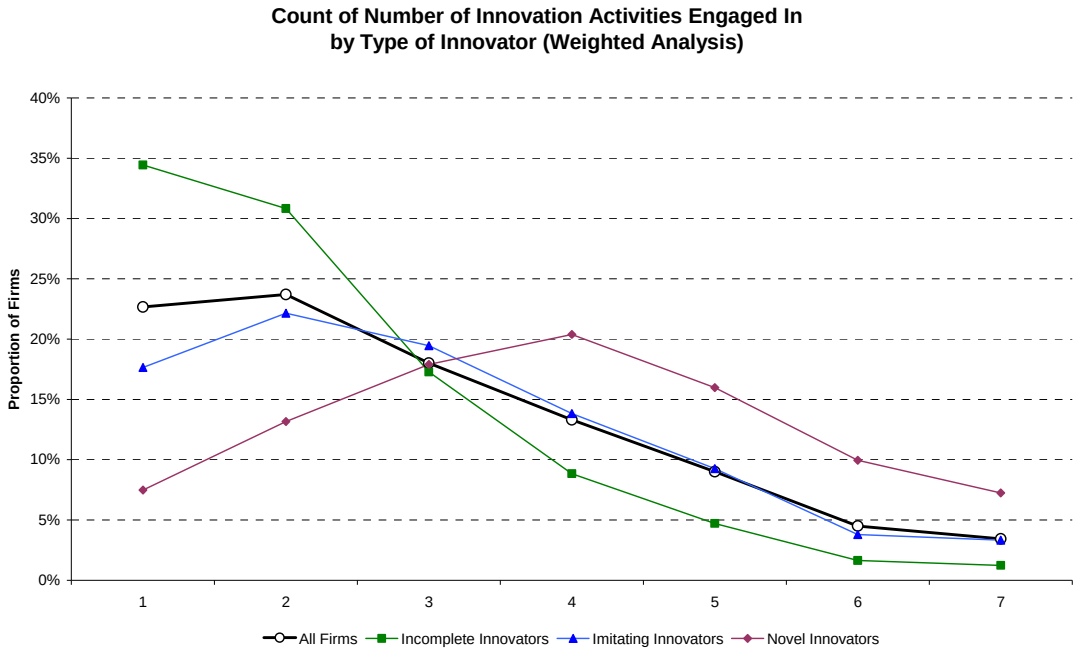
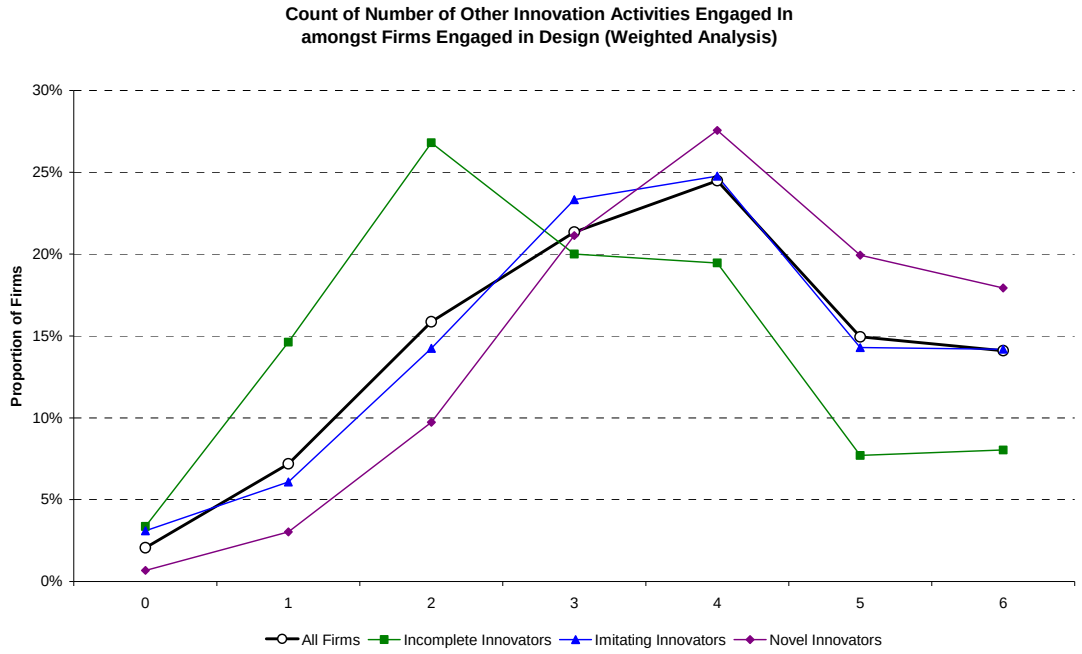


Figure 7 shows the count of the number of other innovation activities engaged in by firms that engaged in "All Forms of Design". The count for the incomplete innovators peaks at two, whilst that for both the imitating and novel innovators peaks at four, indicating that - especially amongst successful innovators - those that engage in design also tend to engage in several other innovation related activities. In other words, when engaged, design is very rarely the only input to successful innovation.

Figure 7



This brings us to the second approach to identifying complementarities between activities (Swann, 2006). his approach requires that we compute two different measures:

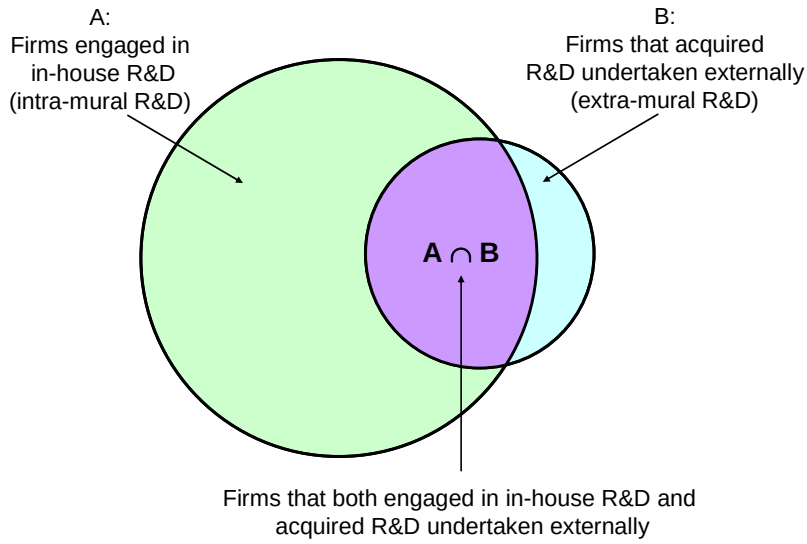
$$P_{A|B} = \Pr\{A \mid B\} = \frac{A \cap B}{B} \qquad (2)$$

$$P_{B|A} = \Pr\{B \mid A\} = \frac{A \cap B}{A} \qquad (3)$$

These are, respectively, the conditional probability that the firm does A given that it does B, and the conditional probability that the firm does B given that it does A. In general (and as we shall see in the matrices below) this measure is ***not*** symmetric ($P_{AB} \neq P_{BA}$). This asymmetry means the matrices contain more information, but they are also more difficult to interpret.

The cells in the matrices below show the conditional probability that a firm engages in the activity identified in the column given that it engaged in the activity identified in the row. Thus, for example, amongst all firms 33% of those that engaged in intra-mural R&D also acquired R&D (extra-mural R&D), but 85% of the firms that acquired R&D also engaged in intra-mural R&D (suggesting that the absorptive capacity (Cohen and Levinthal, 199) provided by internal investment in R&D are normally required to make the most of externally acquired R&D services). This shows the clear asymmetry between the two proportions. The asymmetry is explained by the different propensities to engage in these different activities. Therefore the number of firms doing both A and B relative to the total number doing A can differ greatly from the number doing both relative to the total number doing B, as is shown graphically in Figure 8 with the example of intra-mural R&D and acquired R&D.

Figure 8



As before we colour the cells for ease of interpretation, although because these scores tend to be higher[8] we introduce dark red colouring for cells which indicate high complementarity (>=75%). As before, red cells indicate complementarity (>=50%), whilst dark blue cells imply strong substitutes (<20%): yellow, green and light-blue cells show intermediate scores. The principal diagonal cells are grey, meaning 100%.

Exploring the findings for design, we see that amongst all firms with innovation activities three quarters of those that engaged in design (i.e., “All Forms of Design”) also engaged in intra-mural R&D, whilst over 80% acquired machinery, equipment or software, nearly 80% engaged in training, and two-thirds undertook activities related to the market introduction of innovations. Meanwhile, less than half the firms that engaged in design acquired R&D services, and less than half also acquired other external knowledge. However, whilst less than half the firms that engaged in most other activities engaged in design, half or more of the firms that acquired R&D services and those that acquired external knowledge also engaged in design. This perhaps suggests that design tends to be towards the top of a complex assembly of activities undertaken by the more sophisticated innovating firms. This suggestion is supported by the analysis which breaks the sample down into the three types of innovator: novel innovators engaged in design display stronger complementarities with in-house R&D, acquiring machinery, equipment and software, training and marketing activities, and amongst novel innovators those firms that engaged in any of the other activities have greater than chance than not of also engaging in design. The pattern is very different for the incomplete innovators.

[8] For the obvious reason that whist the numerators remain the same the denominators tend to be smaller as only one rather than both activities are being taken into account.

Table 5: Complementarities in Activities by Sector and Level of Innovation
(Probability of Both, conditional on doing either or both)

Cells show the conditional probability that a firm engages in the activity in the column given that it engaged in the activity in the row. For example, amongst all firms, 33% of those that undertook in-house R&D also acquired R&D.

All Firms

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	33%	75%	29%	71%	44%	53%
XRD	85%	100	83%	46%	77%	55%	64%
AME	50%	22%	100	26%	70%	33%	42%
AEK	64%	40%	86%	100	84%	50%	60%
TRA	54%	23%	79%	29%	100	35%	48%
DES	75%	36%	82%	38%	78%	100	65%
MKT	66%	31%	77%	33%	78%	48%	100

Novel Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	40%	80%	35%	75%	56%	69%
XRD	92%	100	85%	52%	81%	65%	76%
AME	77%	35%	100	36%	79%	53%	65%
AEK	82%	53%	88%	100	84%	65%	77%
TRA	77%	36%	84%	37%	100	53%	69%
DES	87%	43%	85%	43%	80%	100	76%
MKT	81%	39%	80%	38%	79%	58%	100

Imitating Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	28%	73%	25%	72%	38%	46%
XRD	82%	100	85%	43%	73%	47%	55%
AME	50%	20%	100	26%	72%	28%	39%
AEK	57%	33%	86%	100	84%	41%	51%
TRA	55%	19%	79%	28%	100	30%	45%
DES	73%	32%	81%	36%	78%	100	61%
MKT	60%	25%	74%	29%	76%	40%	100

Incomplete Innovators

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	25%	66%	21%	62%	30%	34%
XRD	73%	100	75%	38%	71%	40%	45%
AME	30%	12%	100	18%	61%	19%	25%
AEK	43%	26%	83%	100	79%	33%	41%
TRA	33%	13%	73%	21%	100	21%	31%
DES	56%	25%	77%	30%	73%	100	49%
MKT	45%	20%	72%	26%	75%	34%	100

Extraction, Construction & Utilities

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	36%	79%	26%	75%	39%	43%
XRD	83%	100	84%	47%	87%	60%	56%
AME	33%	15%	100	22%	73%	26%	29%
AEK	41%	32%	84%	100	87%	42%	41%
TRA	33%	16%	76%	24%	100	26%	31%
DES	54%	36%	88%	37%	84%	100	54%
MKT	52%	29%	82%	31%	85%	46%	100

Financial & Business Services

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	34%	74%	32%	77%	37%	56%
XRD	86%	100	85%	50%	80%	48%	64%
AME	52%	24%	100	31%	76%	28%	46%
AEK	63%	39%	86%	100	87%	44%	65%
TRA	54%	22%	76%	32%	100	29%	50%
DES	76%	40%	82%	47%	85%	100	73%
MKT	65%	29%	76%	39%	83%	41%	100

Manufacturing

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	32%	76%	27%	66%	53%	52%
XRD	88%	100	81%	43%	73%	61%	67%
AME	61%	24%	100	25%	67%	43%	41%
AEK	75%	44%	87%	100	79%	61%	59%
TRA	67%	27%	85%	29%	100	50%	49%
DES	81%	34%	83%	33%	75%	100	61%
MKT	81%	37%	80%	33%	75%	62%	100

Trade, Leisure and Transport Services

	IRD	XRD	AME	AEK	TRA	DES	MKT
IRD	100	34%	73%	29%	72%	36%	55%
XRD	78%	100	83%	45%	75%	50%	63%
AME	38%	19%	100	24%	66%	24%	42%
AEK	53%	36%	87%	100	84%	44%	59%
TRA	43%	20%	75%	27%	100	26%	48%
DES	64%	38%	80%	42%	77%	100	70%
MKT	50%	25%	73%	29%	74%	36%	100

The analysis in this table uses the data in an unweighted format.

To explore these issues further we estimated multinomial logistic regressions for both product innovation and process innovation, where the outcomes were: novel innovation; imitative innovation; and no complete innovations. The estimated models are shown in Tables E and F of the appendix to this report. In each of these models we included two sets of interactions between the innovation activities. The first set of interactions concerned whether the firms engaged in intra-mural R&D, marketing activities and design, or each of

the combinations of these. Firms doing none of these were the reference group. The second set of interactions concerned firms with expenditures on machinery, equipment and software, and expenditures on training, both, or neither of these. Expenditure on neither or these was the reference group. Also included as independent variables were firm size, age, group or independent ownership status, markets, and sector of activity.

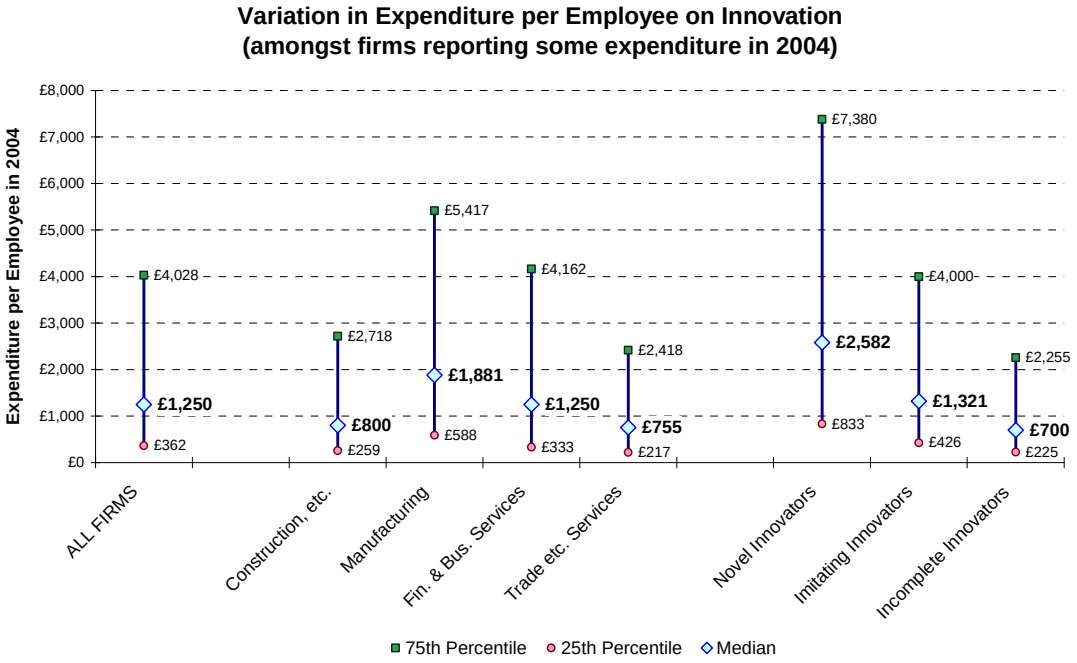
Concerning product innovation, the models show that firms that did only R&D, marketing or design were more likely to innovate than firms that did none of these. However, more powerful effects are found for firms that did combinations of R&D, marketing and design, and especially all three of these activities. For example, other things being equal firms doing all three of these activities were 14 times more likely to than otherwise similar firms to develop a new to the market product innovations. Firms that invested in training or machinery, equipment and software were (strangely) *less* likely to introduce product innovations. These factors aside, new and group firms were more likely to innovate, and especially to introduce novel innovations, as were firms in international markets. Sector also mattered, with most sectors being either as likely, or less likely, to innovate than the reference sector of food, drink and tobacco manufacturing. Interestingly, however, size did not impact on innovation performance once other factors had been taken into account.

Concerning process innovation, the models show that engaging in R&D, marketing and design also impacted positively on process innovation, especially when undertaken in combination. Firms that undertook all three of these activities were six times more likely to introduce novel innovations, and twice as likely to introduce imitative innovations, than otherwise similar firms. Beyond this, firms that invested in both acquired machinery, equipment and software and in training were more likely to introduce process innovations than otherwise similar firms. These factors aside, new and group firms were more likely to introduce novel innovations, whilst being active in international markets also had a positive impact on innovation. Sector also mattered, but the differences were less market than with product innovation. Interestingly, unlike product innovation, size was significantly and positively related to process innovation once other factors had been taken into account.

A problem with the models estimated in Tables E and F is that some of the innovation activities engaged in do not relate to the innovation outputs being considered - for example, firms that invest in acquired machinery, equipment and software may be doing this for process innovation, an outcome which we have not considered in the model on product innovation. To explore this, we estimate a model (using the same specification as above) for the types of innovation engaged in: product, process, both or neither, where innovation is defined as being at least new to the firms. The results are shown in Table G in the appendix to this report (Table H shows the results of a similar model where innovation is defined as new to the market or industry, rather than new to the firm). This shows that firms that engaged in R&D, marketing and/or design were more likely to introduce product and process innovations, or only-product innovations, but not process innovations unless these activities were undertaken in combination. When undertaken in combination firms were much more likely to introduce product and process innovations, or only product innovations. For example, firms undertaking all of intra-mural R&D, marketing and design activities were 11 times more likely to introduce both product and process innovations than otherwise similar firms, and were nearly six times more likely to introduce only-product innovations. They were also more likely to introduce only process innovations, although the effect was smaller. In relation to acquired machinery, equipment and software and training, firms doing only one of these were generally less likely to innovate, especially to introduce product innovations or both product and process innovations. Firms doing both were more likely to introduce either both product and process innovations or only process innovations, but were less likely to introduce only product innovations. Aside from these, larger firms are more likely to introduce both product and process innovations, as are new firms and group firms and those active in international markets. Firms that are part of a larger group of companies and those active in

international markets are also more likely to introduce only product innovations. Sectoral differences can also be seen but are not discussed here.

Figure 5



5 Expenditures on Design and Other Innovation Activities

We now turn to the firms' expenditures on design and other innovation activities. In this section we will use the dataset as a simple sample rather than make adjustments to the national population of firms. This is because the expenditure data is highly variable and it is more doubtful if the responding firms can be regarded as representative of all firms in the population. Figure 9 shows graphically this variation in expenditure amongst firms reporting expenditures on innovation in 2004 (i.e., those with no expenditures are excluded). The expenditure of the median firm in terms of its total expenditure on innovation divided by its number of employees is shown alongside the expenditure levels of the firms at the 25th and 75th percentiles of the distribution: the firm at the 75th percentile spends over 10 times the amount spent by the firm at the 25th percentile. Also shown are these three points in the distributions for novel, imitating and incomplete innovators, and for firms in the four broad sectors.

Table 3 shows the average distribution of expenditures by activity for the firms that reported expenditures on innovation.[9] This simple analysis shows that, on average, explicit spending on design accounts for about 5% of total innovation expenditures. This proportion is higher amongst manufacturing firms (7%) and amongst novel innovators (7%), and lower amongst construction, extraction and utilities firms, trade, leisure and transport service firms, and incomplete innovators (all around 4%). These differences may arise from two sources: a greater propensity amongst manufacturers and novel innovators to engage in design and/or higher average expenditures by manufacturers and novel innovators on design relative to other activities.

Table 3: Average distribution of Innovation Expenditures amongst Activities

	IRD	ARD	AME	AEK	TRA	DES	MKT
All Firms*	18%	3%	44%	3%	15%	5%	12%
Construction etc.*	9%	2%	48%	4%	26%	4%	6%
Manufacturing*	24%	3%	46%	2%	9%	7%	9%
Fin. & Bus. Services*	20%	4%	37%	4%	19%	4%	12%
Trade etc. Services*	10%	3%	46%	3%	16%	4%	17%
Novel Innovators*	28%	4%	32%	4%	10%	7%	15%
Imitating Innovators*	18%	3%	45%	3%	13%	5%	12%
Incomplete Innovators*	11%	3%	51%	3%	19%	4%	9%

* amongst firms reporting innovation expenditures > 0.

Table 4: The Variation & Distribution of Expenditure per Employee on Design

	Share engaging in Design# [Indexed]	25th Percentile*	Median* [Indexed]	75th Percentile*
All Firms*	28.7% [100]	£70	£190 [100]	£568
Construction etc.*	22.2% [77]	£65	£149 [78]	£465
Manufacturing*	40.4% [141]	£85	£220 [116]	£714
Fin. & Bus. Services*	23.5% [82]	£68	£200 [105]	£594
Trade etc. Services*	20.3% [71]	£43	£133 [70]	£385
Novel Innovators*	46.2% [161]	£86	£250 [132]	£833
Imitating Innovators*	27.2% [95]	£66	£158 [83]	£455
Incomplete Innovators*	17.6% [61]	£56	£133 [70]	£400

Unadjusted proportions; * amongst firms reporting innovation expenditures > 0.

[9] In this analysis each firms with any innovation expenditures is given an equal weight. An alternative approach is to use the aggregates by activity, but this is liable to distortion if the very high expenditures reported by some firms are data errors.

From Figure 5 we can see that overall and on average manufacturers and novel innovators spend rather more on innovation than do other innovation active firms, and Table 4 shows how the median expenditure per employee on design varies between sectors and types of innovator. This indicates that both variation in the extent to which firms engage in design and differences in average expenditure influence the greater proportional expenditure on design by manufacturing firms and novel innovators, with the larger part of the difference due to differential participation in design.

Table 5: Expenditure on Design and R&D & Total Expenditure on Innovation[#]

	N.	Median Expenditure* on Design and R&D	Median Expenditure* on All Innovation Activities
All Firms	8,925	£407 [100]	£1,250 [100]
Firms doing Neither R&D nor Design	4,102	None	£730 [58]
Firms doing Design but not R&D	645	£170 [42]	£1,210 [97]
Firms doing R&D but not Design	2,624	£340 [84]	£1,540 [123]
Firms doing both R&D and Design	1,554	£770 [189]	£2,840 [227]
Construction, Extraction & Utilities			
Firms doing Neither R&D nor Design	485	None	£590 [47]
Firms doing Design but not R&D	77	£250 [61]	£1,240 [99]
Firms doing R&D but not Design	161	£160 [39]	£880 [70]
Firms doing both R&D and Design	87	£460 [113]	£1,820 [146]
Manufacturing Firms			
Firms doing Neither R&D nor Design	1,125	None	£1,330 [106]
Firms doing Design but not R&D	237	£190 [47]	£1,980 [158]
Firms doing R&D but not Design	1,134	£420 [103]	£1,760 [141]
Firms doing both R&D and Design	804	£950 [233]	£3,010 [241]
Financial and Business Service Firms			
Firms doing Neither R&D nor Design	1,215	None	£620 [50]
Firms doing Design but not R&D	151	£170 [42]	£920 [74]
Firms doing R&D but not Design	860	£500 [123]	£2,060 [165]
Firms doing both R&D and Design	426	£930 [229]	£3,350 [268]
Trade, Leisure & Transport Services			
Firms doing Neither R&D nor Design	1,277	None	£600 [48]
Firms doing Design but not R&D	180	£130 [32]	£900 [72]
Firms doing R&D but not Design	469	£150 [37]	£890 [71]
Firms doing both R&D and Design	237	£330 [81]	£2,000 [160]
Novel Innovators			
Firms doing Neither R&D nor Design	589	None	£1,460 [117]
Firms doing Design but not R&D	186	£220 [54]	£2,140 [171]
Firms doing R&D but not Design	1,003	£710 [174]	£2,580 [206]
Firms doing both R&D and Design	840	£1,180 [290]	£3,860 [309]
Imitating Innovators			
Firms doing Neither R&D nor Design	1,021	None	£900 [72]
Firms doing Design but not R&D	182	£160 [39]	£1,300 [104]
Firms doing R&D but not Design	788	£330 [81]	£1,470 [118]
Firms doing both R&D and Design	404	£600 [147]	£2,310 [185]
Incomplete Innovators			
Firms doing Neither R&D nor Design	2,492	None	£600 [48]
Firms doing Design but not R&D	277	£150 [37]	£840 [67]
Firms doing R&D but not Design	833	£180 [44]	£780 [62]
Firms doing both R&D and Design	310	£390 [96]	£1,670 [134]

[#] R&D is here confined to intra-mural R&D. * Expenditure per Employee (amongst those reporting expenditures), rounded to the nearest £10.

Table 6: Expenditure on Design and R&D & Total Expenditure on Innovation[#]

	N.	Median Expenditure* on Design and R&D	Median Expenditure* on All Innovation Activities
All Firms		£471 [100]	£1,250 [100]
Firms doing Neither R&D nor Design	3,906	None	£710 [57]
Firms doing Design but not R&D	575	£170 [36]	£1,180 [94]
Firms doing R&D but not Design	2,850	£440 [93]	£1,500 [120]
Firms doing both R&D and Design	1,624	£880 [187]	£2,800 [224]
Construction, Extraction & Utilities			
Firms doing Neither R&D nor Design	477	None	£580 [46]
Firms doing Design but not R&D	68	£260 [55]	£1,240 [99]
Firms doing R&D but not Design	168	£180 [38]	£960 [77]
Firms doing both R&D and Design	96	£540 [115]	£1,690 [135]
Manufacturing Firms			
Firms doing Neither R&D nor Design	1,064	None	£1,300 [104]
Firms doing Design but not R&D	216	£190 [40]	£1,820 [146]
Firms doing R&D but not Design	1,195	£500 [106]	£1,780 [142]
Firms doing both R&D and Design	825	£1,040 [221]	£3,070 [246]
Financial and Business Service Firms			
Firms doing Neither R&D nor Design	1,155	None	£600 [48]
Firms doing Design but not R&D	132	£170 [36]	£900 [72]
Firms doing R&D but not Design	920	£570 [121]	£2,000 [160]
Firms doing both R&D and Design	445	£1,120 [238]	£3,780 [302]
Trade, Leisure & Transport Services			
Firms doing Neither R&D nor Design	1,210	None	£600 [48]
Firms doing Design but not R&D	159	£130 [28]	£910 [73]
Firms doing R&D but not Design	536	£180 [38]	£840 [67]
Firms doing both R&D and Design	258	£410 [87]	£1,950 [156]
Novel Innovators			
Firms doing Neither R&D nor Design	537	None	£1,330 [106]
Firms doing Design but not R&D	159	£240 [51]	£2,170 [174]
Firms doing R&D but not Design	1,055	£870 [185]	£2,600 [208]
Firms doing both R&D and Design	867	£1,450 [308]	£3,800 [308]
Imitating Innovators			
Firms doing Neither R&D nor Design	969	None	£880 [70]
Firms doing Design but not R&D	160	£160 [34]	£1,250 [100]
Firms doing R&D but not Design	840	£400 [85]	£1,460 [117]
Firms doing both R&D and Design	426	£710 [151]	£2,310 [185]
Incomplete Innovators			
Firms doing Neither R&D nor Design	2,400	None	£590 [47]
Firms doing Design but not R&D	256	£170 [36]	£830 [66]
Firms doing R&D but not Design	925	£200 [42]	£,750 [60]
Firms doing both R&D and Design	331	£430 [91]	£1,670 [134]

[#] R&D here includes both intra-mural and extra-mural R&D. * Expenditure per Employee (amongst those reporting expenditures), rounded to the nearest £10.

6 Complementarities and Expenditures on Design, R&D and Innovation

We have already seen that the amount firms report spending on innovation in general, and design in particular, varies widely (even after controlling for firm size by dividing through by the number of employees). In this part of the paper, we explore whether firms that spend on design and / or R&D tend to spend more or less on innovation, both in total, and on design and R&D.

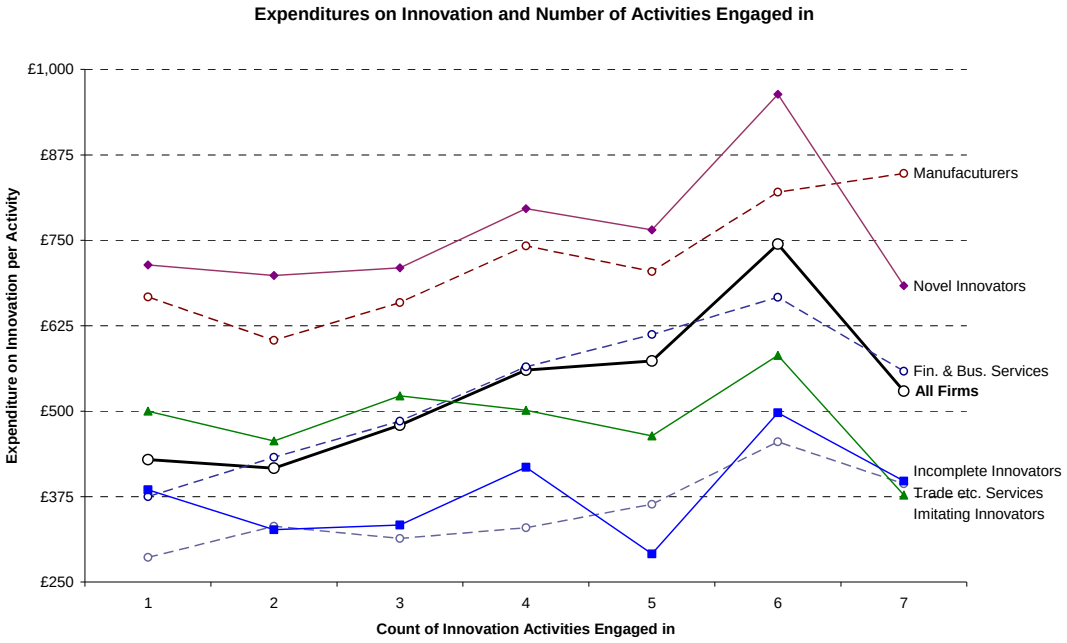
Alongside median total expenditures per employee on innovation, Table 5 shows the median expenditure per employee on design and R&D, where R&D is confined to intra-mural R&D. This is shown for firms in the four broad sectors, and for the three levels of innovation, with these categories divided between firms that spent only on design, only on R&D, neither of these activities, and both of them. Indexed figures are shown alongside the actual levels of expenditure. For total spending (per employee) on innovation the index is based on the median expenditure amongst all firms reporting any expenditure. For expenditure on design and / or R&D the index is based on the median expenditure (per employee) by firms that had spending on one or both of these activities. Table 6 then repeats the analysis but extends engaging in R&D to include extra-mural R&D.

These tables shows that firms that only spent on design tend to spend less on this than firms that only spent on R&D. This finding is consistent across the broad sectors and levels of innovation with the exception of construction, extraction and utilities firms, amongst which spending on design exceeds spending on R&D amongst firms engaged in only one of these activities. The second notable finding is that those firms that spent on both design and R&D tend to spend more on these activities than the sum of the spending by firms that did only one or other of these activities (i.e., median expenditure on design and R&D by firms doing both of these is greater than the median expenditure of firms only spending on design plus the median expenditure of firms only spending on R&D). Also of note is that firms that spent on both design and R&D tend to spend proportionally more on all innovation activities. In other words, spending on both design and R&D does not tend to reduce expenditure on other activities but rather is associated with higher expenditures elsewhere.

This raises a broader question, which is whether firms that do several innovation activities tend to spend less, or more, or about the same, on each of these activities than firms that spend on only one or two activities. Figure 6 shows for all firms and for three of the four sectors (Construction, etc. is excluded due to inadequate data) as well as for the three levels of innovation, the medians of the total expenditure per employee on innovation divided by the number of innovation related activities engaged in by the firms. This is then plotted against the number of activities engaged in, from one to seven.

If, for each set of firms, the line is downward sloping (from left to right), this implies that firms that spend on several activities tend to spend less on each of these than firms that spend on only one or two activities. An upward sloping line implies average spending on innovation per activity tends to increase as firms engage in more activities, whilst a horizontal line implies that average spending per activity is not affected by the number of activities the firms engaged in. Figure 6 shows that the line for all firms is clearly upward sloping (but drops considerably amongst firms engaged in all seven activities). The lines by sector tend to be upward sloping, as is the profile for novel innovators. The profiles for imitating and incomplete innovators are much flatter. This appears to show that firms that spend on multiple innovation activities tend to spend more on these additional items than firms that spent on only one or two activities.

Figure 6


Expenditures on Innovation and Number of Activities Engaged in
£1,000
£875
£750
£625
£500
£375
£250
Expenditure on Innovation per Activity
1
2
3
4
5
6
7
Count of Innovation Activities Engaged in
Manufacturers
Novel Innovators
Fin. & Bus. Services
All Firms
Incomplete Innovators
Trade etc. Services
Imitating Innovators

7. Conclusions and Recommendations

The analysis in this paper has produced a number of interesting results:

- About a quarter of the innovation active firms in the UK recognised that they had engaged in design (not including those firms whose design activities were wholly confined to R&D). This proportion was higher for manufacturers (about a third of firms) and lower for service and construction firms (around one in five firms).

- Fewer innovation active firms recognised that they had engaged in design than in R&D or marketing activities related to the introduction of innovations. Amongst manufacturers fewer firms engaged in design than R&D, but a similar proportion engaged in design as engaged in marketing activities. Service firms were less likely to engage in design than either R&D or marketing.

- Firms that introduced new to the market product innovations and / or new to the industry process innovations were more likely than those that had introduced new to the firm innovations to have engaged in design. About 40% of these 'novel innovators' had engaged in design. Meanwhile, firms that had not introduced any innovations and that had only incomplete innovation activities were the least likely to engage in design: only about 15% of these firms had engaged in design.

- It is likely, however, that some firms did engage in design, even though they did not register this in the survey. Indirect indications that firms engaged in design are found in their registration of designs and / or their use of complexity of designs to protect their innovation activities. 40% of the novel innovators and over a quarter of the imitating innovators (those that introduced new to the firm innovations) which claimed not to have engaged in either design or R&D had used one or both of these methods to protect their innovations, suggesting that they did actually engage in design even if they failed to recognise this. Thus the real extent of design amongst the innovating firms is greater than that reported above. The remainder of the results relate, however, to those that recognised they had engaged in design.

- An analysis of the complementarities between innovation related activities showed that overall firms were more likely to engage in design *or* other innovation activities (such as R&D, marketing, the acquisition of machinery, equipment and software) rather than both design and other activities. However, this either or approach was much more widespread amongst firms that only had incomplete innovation projects, whilst those that had introduced novel innovations were more likely to have done design and other activities.

- In fact, firms that introduced novel innovations were likely to have engaged in a number of innovation related activities, whilst more than half of those that had only incomplete innovation activities engaged in just one or two innovation related activities. Those that engaged in design typically engaged in several other innovation related activities.

- An analysis of the asymmetric complementarities between activities showed that amongst firms that did engage in design the majority also engaged in in-house R&D, the acquisition of machinery, equipment or software, innovation related training and innovation related marketing. Only a minority of firms that engaged in R&D also engaged in design however. Manufacturing firms tended to be more likely to engage in combinations of activities than service and construction firms. Also, firms that introduced novel innovations were more likely to engage in combinations of these activities than were firms that introduced imitative innovations, whilst firms that only had incomplete innovation projects were the least likely to engage in both activities.

- Analysis using multinomial logistic regressions shows that firms that engaged in only one of R&D or marketing were more likely to introduce product innovations, or both product and process innovations (but not process innovations alone), than firms that engaged in neither of these activities. Meanwhile, firms that engaged in design but not R&D or marketing were more likely to introduce both product and process innovations but not product or process innovations alone. However, the most notable finding is that firms that engaged in combinations of R&D, marketing and / or design were much more likely than firms that engaged in none or only one of these activities to introduce product and/or process innovations. Firms that engaged in all three of R&D, design and marketing were 11 times more likely than firms that engaged in none of these activities to introduce both product and process innovations, nearly 6 times more likely to introduce only product innovations, and 50% more likely to introduce only process innovations. If the definition of innovation is changed to require innovations to be new to the market or industry, rather than new to the firm, then the corresponding figures are 18, 8 and twice as likely. This suggests that design has a particularly significant role to play in innovation when used in conjunction with other inputs, particularly R&D and marketing.

- Finally, we examined firms' expenditures on innovation. The median firm reporting innovation expenditures spent around £1,250 per employee on innovation related activities in 2004. Of this, an average of 5% was spent on design, a proportion considerably lower than that spent on R&D (Intra-mural R&D = 18%; acquired R&D = 3%), on marketing (12%) on training (15%) or on acquired machinery, equipment or software (44%). On average, manufacturing firms, and those that introduced novel innovations, spent rather more on design (£220 and £250 per employee amongst those spending on design, or 7% of the total on average), whilst service firms and those with incomplete innovation activities spent rather less (less than £200 per employee, or 4% of the total).

- The evidence suggests, however, that firms that spent on both R&D and design tend to spend more on the combination of these activities than other firms that spend on only on or the other. Thus spending on design does not appear to substitute for spending on R&D, or vice versa. In fact, for all firms, those spending on design and in-house R&D spent on average nearly twice as much on these two activities as did the average firm with expenditures on either or both these activities. Interestingly, firms that spent on both design and R&D also tended to spend more on other innovation related activities, showing that these greater expenditures were also not made at the expense of spending elsewhere. In short, firms with the confidence to spend on both design and R&D tend to also have the confidence (or possibly recklessness) to spend rather more on all innovation activities. Thus the median innovation expenditure per employee of firms that engaged in both R&D and design was more than double the median innovation expenditure per employee of all innovation active firms.

- In fact, we found there was a wider pattern to these results, which is that firms that tend to spend on several innovation related activities tend, on average, to spend more on each of these than the firms that incurred expenditures on only one or two innovation related activities.

Overall, our findings show the UK Government is right to be taking a strong interest in design. Our results imply that design is a complementary asset to R&D and marketing in the innovation activities of firms. Of course, this does not necessarily mean that design can just be undertaken in-house or bought from a design consultant with the automatic benefit of improved innovation performance. Because innovation tends to involve complementarities between R&D, marketing, design and other activities, these complementarities have to be managed. Arguably this is one of the most difficult aspects of innovation management, and one at which many UK firms are not very accomplished. This is an important issue that requires further research, which cannot be addressed using the UK Innovation Survey evidence alone.

The analysis in this paper suggests that design makes a significant, yet neglected, contribution to innovation in firms. The decision of the UK's Department of Trade and Industry to use the UK version of the fourth European Community Innovation Survey to explore further the role of design in innovation appears vindicated, and should perhaps be repeated in other countries.

Recommendations

We would suggest, however, that some consideration be given in future surveys to all the items in the 'Innovation Activities' question, for arguably considerable design activities are still being overlooked (whilst it is also possible that design activities are being indirectly recognised not only in in-house and acquired R&D, but also in the category for the acquisition of external knowledge). We also consider that it might be useful to know whether the design, marketing and training activities undertaken for innovation were undertaken in-house and/or externally (it seems odd that currently only information on whether R&D was conducted internally and / or externally is gathered).

In light of this, we would suggest an alternative categorisation to that currently used in the survey. This would distinguish between research,[10] which few firms are likely to undertake, and design and development,[11] which is likely to be much more widespread. Ancillary design, not directly related to developing new or improved products or processes could also be enquired about - particularly as this is closely related to the Oslo Manual's concept of marketing innovation.

Hence, we suggest the survey ask about the following activities:

Research - i.e., experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts. It may or may not be directed towards a specific practical application or objective.

Design and Development - i.e., systematic creative or experimental work, carried out on an occasional or regular basis, that draws on knowledge from research and / or experience, that is directed to producing products (including materials and services), to installing new processes and systems, or to improving substantially those already produced or installed.

[10] Ideally, one would want to distinguish between basic research (which the Frascati Manual defines as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view") and applied research (which the Frascati Manual defines as "also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective"), but given that few firms are likely to engage in research, and the need to save space, as single category for research is probably more practical.

[11] The definition of which is adapted from the Frascati Manual's definition of experimental development: i.e., "Experimental development is systematic work, drawing on knowledge gained from research and practical experience, that is directed to producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed."

Ancillary Design - i.e., design activities engaged in to support the introduction of product or process innovations. This includes product styling, the design of promotional material and packaging, and the design of any web-sites intended to support innovations. Ancillary design activities undertaken within experimental design and development should not be included.

Training of personnel directly related to innovation activity.

Marketing of Innovations - i.e. activities other than those identified as ancillary design aimed at the introduction of your enterprise's innovations. Marketing activities include market research and advertising of new innovations, but exclude routine marketing activity.

For each of these, firms could be asked to identify one of four possible answers: the activity was undertaken both in-house and externally for the firm; the activity was only undertaken internally; the activity was only undertaken externally; and the activity was not undertaken at all.

Beyond this, further questions should ask about the acquisition of machinery, equipment and software (perhaps divided between information technologies and other machinery and equipment) and the acquisition of other external knowledge or technologies not included in acquired R&D or design. It may also be desirable to know whether or not the firm employed (internally or externally) any professional designers.

References

Cohen, W. M. & Levinthal, D. A. (1990) ‘Absorptive Capacity - A New Perspective on Learning and Innovation’, *Administrative Science Quarterly*, 35(1), 128-152.

Gorb, P., Dumas, A. (1987) “Silent design”. *Design studies,* 8 (3) 150-156.

Swann, G. M. P. (2006) ‘Innovators and the Research Base: An Exploration using CIS4’, mimeo, Nottingham University Business School, University of Nottingham (Draft: 30th June, 2006)

Appendix

Results of Regression Models

Table A Variables used in Regression Analysis

Variable	Description
ln_empt	Firm Size – Ln(Employment)
new_firm	New firms (established after 1st Jan 2000) (dummy variable)
group_firm	Firms that are part of a larger group of firms (dummy variable)
mkt_nat	Firm is active in the national, but not international markets (dummy)
mkt_int	Firm is active in international markets (dummy variable)
sic_1014	Firms active in SIC 10 - 14: Mining & Quarrying (dummy variable)
sic_1719	Firms active in SIC 15 & 16: Food Drink & Tobacco (dummy variable)
sic_2021	Firms active in SIC 17 to 19: Textiles, Clothing & Leathers (dummy)
sic_22	Firms active in SIC 20 & 21: Wood & Paper Products (dummy variable)
sic_2324	Firms active in SIC 22: Publishing & Printing (dummy variable)
sic_2526	Firms active in SIC 23 & 24: Chemicals and Fuels (dummy variable)
sic_2728	Firms active in SIC 25 & 26: Plastics & Non-Metallic Mineral Products (d.)
sic_29	Firms active in SIC 27 & 28: Metals & Metal Products (dummy variable)
sic_3032	Firms active in SIC 29 Machinery (n.e.c.) (dummy variable)
sic_31	Firms active in SIC 30 & 32: Office Equip't, Computers & Electronics (d)
sic_33	Firms active in SIC 31: Electrical Goods (dummy variable)
sic_3435	Firms active in SIC 33: Instruments & Process Control Equipment (d.)
sic_3637	Firms active in SIC 34 & 35: Transport Equipment (dummy variable)
sic_4041	Firms active in SIC 36 & 37: Other Manufacturing & Recycling (dummy)
sic_45	Firms active in SIC 40 & 41: Electricity, Gas and Water Supply (dummy)
sic_50	Firms active in SIC 45: Construction (dummy variable)
sic_51	Firms active in SIC 50: Motor Vehicles trade (dummy variable)
sic_52	Firms active in SIC 51: Wholesale trades (dummy variable)
sic_55	Firms active in SIC 52: Retail trades (dummy variable)
sic_6063	Firms active in SIC 55: Hotels & Catering (dummy variable)
sic_6064	Firms active in SIC 60 to 63, excl. 60.24: Transport Services (dummy)
sic_642	Firms active in SIC 60.24 & 64.1: Post, Couriers & Road Transport (d.)
sic_6567	Firms active in SIC 64.2: Telecommunications (dummy variable)
sic_7071	Firms active in SIC 65 to 67: Financial Services (dummy variable)
sic_72	Firms active in SIC 70 & 71: Real Estate & Rental Services (dummy)
sic_73	Firms active in SIC 72: Computer Services (dummy variable)
sic_7414	Firms active in SIC 73: R&D Services (dummy variable)
sic_7423	Firms active in SIC 74.1 & 74.4: Professional Business Services (d.)
sic_745	Firms active in SIC 74.2 & 74.3: Engineering Services, etc. (dummy)
sic_7468	Firms active in SIC 74.5: Labour Provision Services (dummy variable)
goods_in	Firms that introduced a goods innovation (dummy variable)
service_in	Firms that introduced a service product innovation (dummy variable)
novel_prod	Firms that introduced a new to the market product innovation (d.)
process_in	Firms that introduced a process innovation (dummy variable)
novel_proc	Firms that introduced a new to the industry process innovation
R&D only	Firms that engaged in R&D (intra-mural) but not marketing or design (d.)
Mktg only	Firms that engaged in Marketing but not R&D (intra-mural) or design (d.)
Design only	Firms that engaged in Design but not R&D (intra-mural) or marketing (d.)
R&D & Mktg	Firms that engaged in R&D (intra-mural) and marketing but not design (d.)
R&D & Design	Firms that engaged in R&D (intra-mural) and design but not marketing (d.)
Mktg & Design	Firms that engaged in marketing & design, but not R&D (intra-mural) (d.)
All 3 Activities	Firms that engaged in R&D (intra-mural), marketing and design (dummy)
Acquired MES Only	Firms that acquired equipment or software, but did not engage in training
Training Only	Firms that engaged in training but did not acquire equipment or software
Acq'd MES & Tra'g	Firms that both engaged in training and acquired equipment or software

Table B Binary Logistic Regression Identifying Innovation Active Firms

	Estimate	Exp(Est)
Constant	-0.56***	0.57
ln_empt	0.11***	1.12
new_firm	0.13***	1.14
group	0.26***	1.30
mkt_nat	0.34***	1.40
mkt_int	0.86***	2.37
sic_1014	-0.09	0.91
sic_1516	0.59***	1.81
sic_1719	0.23	1.25
sic_2021	0.59***	1.80
sic_22	0.91***	2.48
sic_2324	1.16***	3.19
sic_2526	0.67***	1.96
sic_2728	0.51***	1.66
sic_29	0.70***	2.01
sic_3032	1.10***	2.99
sic_31	0.87***	2.38
sic_33	1.23***	3.42
sic_3435	0.55***	1.74
sic_3637	0.85***	2.35
sic_4041	-1.00***	0.37
sic_45	-0.16	0.85
sic_50	0.12	1.13
sic_51	0.07	1.07
sic_52	-0.41***	0.67
sic_55	-0.32***	0.73
sic_6063	0.07	1.07
sic_6064	0.07	1.07
sic_642	1.15***	3.15
sic_6567	0.58***	1.79
sic_7071	0.10	1.11
sic_72	1.12***	3.06
sic_73	0.80***	2.22
sic_7414	0.09	1.10
sic_7423	0.66***	1.93
sic_745	-0.16	0.85

Valid cases included in the analysis = 15,886, Initial -2LL = 18882.9; Model Chi^2 = 1907.3
Cox & Snell R Square = 0.113; Nagelkerke R Square = 0.155
Reference group is: independent, established firms, serving local/regional markets only, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table C Explicit vs. Hidden vs. No Design Activity: Multinomial Logistic Regression Models excluding Innovation Outcome Variables

	Explicit Design vs. No Design		'Hidden Design' vs. No Design		Explicit Design vs. 'Hidden Design'	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-1.308***	0.27	-0.16	0.85	-1.13***	0.32
ln_empt	0.28***	1.32	0.16***	1.17	0.12***	1.13
new_firm	0.21***	1.24	0.15**	1.16	0.07	1.07
group_firm	0.29***	1.34	0.34***	1.40	-0.04	0.96
mkt_nat	0.36***	1.44	0.16**	1.17	0.21***	1.23
mkt_int	1.08***	2.95	0.88***	2.41	0.20***	1.23
sic_1014	-0.83***	0.43	-0.79***	0.45	-0.04	0.96
sic_1719	0.26	1.30	0.13	1.14	0.13	1.14
sic_2021	-0.07	0.93	-0.50**	0.60	0.43**	1.54
sic_22	-0.49**	0.61	-0.67***	0.51	0.18	1.20
sic_2324	0.75**	2.12	0.74**	2.10	0.01	1.01
sic_2526	-0.37*	0.69	-0.39*	0.68	0.02	1.02
sic_2728	-0.37*	0.69	-0.69***	0.50	0.32**	1.38
sic_29	0.53**	1.70	-0.20	0.82	0.73***	2.07
sic_3032	0.90***	2.46	-0.45	0.64	1.35***	3.85
sic_31	0.77***	2.17	-0.04	0.96	0.82***	2.26
sic_33	0.60**	1.83	-0.38	0.68	0.99***	2.68
sic_3435	0.50**	1.65	-0.13	0.88	0.63***	1.88
sic_3637	0.37*	1.45	-0.14	0.87	0.51***	1.66
sic_4041	0.70	2.02	-0.06	0.94	0.76	2.14
sic_45	-0.99***	0.37	-1.25***	0.29	0.26	1.30
sic_50	-2.51***	0.08	-1.52***	0.22	-0.99***	0.37
sic_51	-1.03***	0.36	-0.81***	0.44	-0.21	0.81
sic_52	-1.03***	0.36	-1.10***	0.33	0.07	1.07
sic_55	-0.65***	0.52	-0.78***	0.46	0.13	1.14
sic_6063	-1.10***	0.33	-1.05***	0.35	-0.06	0.95
sic_6064	-1.83***	0.16	-1.44***	0.24	-0.39*	0.68
sic_642	-0.45	0.64	-0.53**	0.59	0.09	1.09
sic_6567	-0.48**	0.62	-0.39**	0.67	-0.08	0.92
sic_7071	-0.80***	0.45	-0.84***	0.43	0.04	1.04
sic_72	0.49*	1.63	0.63***	1.88	-0.14	0.87
sic_73	-0.41	0.66	0.36	1.43	-0.77***	0.46
sic_7414	-1.67***	0.19	-1.16***	0.31	-0.50***	0.60
sic_7423	-0.26	0.77	-0.49**	0.61	0.23	1.26
sic_745	-2.05***	0.13	-1.50***	0.22	-0.56**	0.57
sic_7468	-1.68***	0.19	-1.22***	0.29	-0.45**	0.64

Valid cases included in the analysis = 10,129 (Innovation Active firms only)
Initial -2 Log Likelihood = 19513.0, Model Chi-Square = 2051.5
Pseudo R-Square: Cox and Snell = 0.183; Nagelkerke = 0.207; McFadden = 0.093
Reference group is: independent, established firms, serving local/regional markets only, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table D **Explicit vs. Hidden vs. No Design Activity: Multinomial Logistic Regression Models including Innovation Outcome Variables**

	Explicit Design vs. No Design		'Hidden Design' vs. No Design		Explicit Design vs. 'Hidden Design'	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-2.11***		-0.56***		-1.54***	
ln_empt	0.27***	1.31	0.16***	1.17	0.11***	1.11
new_firm	0.16**	1.18	0.13*	1.14	0.03	1.03
group_firm	0.21***	1.24	0.28***	1.32	-0.07	0.93
mkt_nat	0.32***	1.38	0.13**	1.14	0.19**	1.21
mkt_int	0.83***	2.30	0.76***	2.14	0.07	1.07
sic_1014	-0.41	0.66	-0.60**	0.55	0.19	1.21
sic_1719	0.49	1.63	0.25	1.28	0.24	1.27
sic_2021	0.16	1.18	-0.35	0.71	0.51**	1.66
sic_22	-0.26	0.77	-0.57***	0.56	0.32*	1.37
sic_2324	0.51	1.66	0.66*	1.94	-0.15	0.86
sic_2526	-0.32	0.72	-0.33	0.72	0.00	1.00
sic_2728	-0.09	0.92	-0.53***	0.59	0.44***	1.55
sic_29	0.76***	2.14	-0.03	0.97	0.79***	2.20
sic_3032	0.67**	1.95	-0.60*	0.55	1.27***	3.56
sic_31	1.05***	2.87	0.13	1.13	0.93***	2.53
sic_33	0.48	1.62	-0.46	0.63	0.95***	2.58
sic_3435	0.71***	2.03	0.00	1.00	0.70***	2.02
sic_3637	0.53**	1.70	-0.05	0.95	0.58***	1.79
sic_4041	1.27	3.56	0.21	1.24	1.06*	2.88
sic_45	-0.54***	0.58	-1.05***	0.35	0.51***	1.67
sic_50	-2.23***	0.11	-1.35***	0.26	-0.88***	0.42
sic_51	-0.96***	0.38	-0.80***	0.45	-0.15	0.86
sic_52	-0.80***	0.45	-1.03***	0.36	0.23	1.26
sic_55	-0.15	0.86	-0.54***	0.58	0.39***	1.48
sic_6063	-0.68***	0.51	-0.92***	0.40	0.24	1.28
sic_6064	-1.36***	0.26	-1.24***	0.29	-0.12	0.89
sic_642	-0.37	0.69	-0.64**	0.53	0.28	1.32
sic_6567	-0.25	0.78	-0.30	0.74	0.05	1.05
sic_7071	-0.51**	0.60	-0.79**	0.45	0.28	1.32
sic_72	0.20	1.23	0.41*	1.50	-0.20	0.82
sic_73	-0.64*	0.53	0.23	1.25	-0.87***	0.42
sic_7414	-1.36***	0.26	-1.04***	0.35	-0.32	0.73
sic_7423	-0.14	0.87	-0.49**	0.61	0.35**	1.42
sic_745	-1.84***	0.16	-1.46***	0.23	-0.39	0.68
sic_7468	-1.57***	0.21	-1.26***	0.28	-0.31	0.73
goods_in	0.82***	2.27	0.39***	1.48	0.43***	1.54
service_in	0.33***	1.39	0.33***	1.39	0.01	1.01
novel_prod	1.12***	3.06	0.74***	2.10	0.38***	1.46
process_in	0.55***	1.73	0.28***	1.32	0.27***	1.31
novel_proc	0.47***	1.60	0.13	1.14	0.34***	1.41

Valid cases included in the analysis = 9,895 (Innovation Active firms only)
Initial -2 Log Likelihood = 20646.3, Model Chi-Square = 2975.4
Pseudo R-Square: Cox and Snell = 0.260; Nagelkerke = 0.293; McFadden = 0.138
Reference group is: independent, established firms, serving local/regional markets only, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table E Product Innovation: Novel vs. Imitative vs. None

	Novel Product Innovation vs. None		Imitative Product Innovation vs None		Novel vs Imitative Product Innovation	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-1.16***	0.00	-0.71***	0.00	-0.45**	0.00
ln_empt	-0.01	0.99	0.01	1.01	-0.02	0.98
new_firm	0.21***	1.23	0.11	1.11	0.10	1.11
group_firm	0.19***	1.21	0.12*	1.12	0.07	1.07
mkt_nat	0.03	1.03	0.18**	1.20	-0.15	0.86
mkt_int	0.55***	1.73	0.38***	1.47	0.16*	1.18
sic_1014	-1.09***	0.34	-1.33***	0.27	0.23	1.26
sic_1719	-0.50**	0.61	-0.52**	0.60	0.02	1.02
sic_2021	-0.68***	0.51	-0.64***	0.53	-0.04	0.96
sic_22	-0.52**	0.59	-0.34	0.72	-0.19	0.83
sic_2324	0.48*	1.62	0.14	1.15	0.35	1.41
sic_2526	-0.09	0.91	-0.22	0.80	0.13	1.14
sic_2728	-0.57***	0.56	-0.49**	0.61	-0.09	0.92
sic_29	-0.29	0.75	-0.27	0.76	-0.01	0.99
sic_3032	0.72***	2.05	0.55*	1.74	0.17	1.18
sic_31	-0.40*	0.67	-0.51**	0.60	0.11	1.12
sic_33	0.38	1.46	0.03	1.03	0.35	1.41
sic_3435	-0.22	0.80	-0.16	0.86	-0.06	0.94
sic_3637	-0.35*	0.70	-0.24	0.79	-0.11	0.89
sic_4041	-2.04*	0.13	-0.65	0.52	-1.39	0.25
sic_45	-0.88***	0.42	-0.73***	0.48	-0.15	0.86
sic_50	-0.52**	0.59	-0.50**	0.61	-0.02	0.98
sic_51	-0.15	0.86	-0.85***	0.43	0.71***	2.03
sic_52	-0.46***	0.63	-0.85***	0.43	0.40*	1.49
sic_55	-1.38***	0.25	-0.60***	0.55	-0.78***	0.46
sic_6063	-0.63***	0.53	-0.38*	0.68	-0.24	0.78
sic_6064	-0.75***	0.47	-0.60***	0.55	-0.15	0.86
sic_642	0.19	1.21	-0.27	0.76	0.46	1.58
sic_6567	-0.52***	0.60	-0.15	0.86	-0.37*	0.69
sic_7071	-0.70***	0.49	-0.34*	0.71	-0.37	0.69
sic_72	0.60***	1.82	0.26	1.30	0.34*	1.40
sic_73	0.23	1.26	-0.15	0.86	0.38	1.47
sic_7414	-0.73***	0.48	-0.65***	0.52	-0.08	0.92
sic_7423	-0.25	0.78	-0.48**	0.62	0.23	1.25
sic_745	-0.57**	0.56	0.07	1.08	-0.65**	0.52
sic_7468	-0.07	0.93	0.01	1.01	-0.08	0.92
R&D only	0.70***	2.01	0.30***	1.35	0.40***	1.49
Mktg only	0.87***	2.38	0.50***	1.65	0.37***	1.44
Design only	0.40**	1.49	0.07	1.08	0.33*	1.39
R&D & Mktg	2.16***	8.63	1.14***	3.12	1.02***	2.77
R&D & Design	1.67***	5.32	0.80***	2.23	0.87***	2.38
Mktg & Design	1.56***	4.78	0.55***	1.73	1.02***	2.76
All 3 Activities	2.63***	13.93	1.20***	3.32	1.43***	4.19
Aquired MES Only	-0.86***	0.42	-0.98***	0.38	0.12	1.13
Training Only	-0.78***	0.46	-0.88***	0.41	0.10	1.10
Acq'd MES & Train	-0.65***	0.52	-0.68***	0.50	0.03	1.03

Valid cases included in the analysis = 9,953 (Innovation Active firms only); Initial -2 LL = 19,693.4, Model Chi-Square = 2,639.4; Pseudo R-Square: Cox and Snell = 0.233; Nagelkerke = 0.269; McFadden = 0.132; Reference group is: independent, established firms, serving local/regional markets only, doing none of R&D, Marketing, or Design, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table F Process Innovation: Novel vs. Imitative vs. None

	Novel Process Innovation vs. None		Imitative Process Innovation vs None		Novel vs Imitative Process Innovation	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-3.83***	0.00	-2.47***	0.00	-1.36***	0.00
ln_empt	0.11***	1.11	0.14***	1.15	-0.03	0.97
new_firm	0.27***	1.31	0.00	1.00	0.27**	1.32
group_firm	0.16**	1.18	0.09	1.10	0.07	1.07
mkt_nat	-0.14	0.87	0.09	1.10	-0.23	0.79
mkt_int	0.20*	1.22	0.16**	1.17	0.04	1.04
sic_1014	-0.57	0.57	0.15	1.16	-0.72	0.49
sic_1719	-0.02	0.98	-0.01	0.99	-0.01	0.99
sic_2021	0.31	1.37	0.02	1.02	0.29	1.34
sic_22	0.19	1.21	0.10	1.10	0.09	1.10
sic_2324	0.63**	1.88	-0.11	0.89	0.74**	2.11
sic_2526	0.17	1.19	-0.11	0.89	0.29	1.33
sic_2728	0.25	1.29	-0.01	0.99	0.26	1.29
sic_29	-0.12	0.88	-0.22	0.81	0.09	1.10
sic_3032	0.22	1.25	0.25	1.28	-0.02	0.98
sic_31	-0.60*	0.55	-0.40*	0.67	-0.21	0.81
sic_33	0.08	1.08	-0.03	0.97	0.11	1.12
sic_3435	-0.10	0.91	-0.13	0.88	0.03	1.03
sic_3637	0.04	1.04	-0.23	0.80	0.27	1.31
sic_4041	-0.11	0.89	0.01	1.01	-0.13	0.88
sic_45	-0.69**	0.50	-0.80***	0.45	0.10	1.11
sic_50	-0.33	0.72	-1.06***	0.35	0.73*	2.08
sic_51	-0.34	0.71	-0.13	0.88	-0.21	0.81
sic_52	-0.15	0.86	-0.50***	0.61	0.35	1.42
sic_55	-1.00***	0.37	-0.65***	0.52	-0.34	0.71
sic_6063	-0.18	0.83	-0.16	0.85	-0.02	0.98
sic_6064	-0.01	0.99	-0.71***	0.49	0.70**	2.01
sic_642	0.06	1.07	-0.31	0.73	0.37	1.45
sic_6567	0.28	1.32	0.23	1.26	0.05	1.05
sic_7071	0.06	1.07	-0.46**	0.63	0.52*	1.69
sic_72	0.66***	1.93	0.17	1.18	0.49*	1.63
sic_73	1.84***	6.30	1.23***	3.43	0.61**	1.84
sic_7414	0.76***	2.14	0.33*	1.39	0.44*	1.55
sic_7423	0.51**	1.66	0.17	1.18	0.34	1.41
sic_745	0.63**	1.88	0.06	1.07	0.57*	1.77
sic_7468	0.51*	1.66	0.10	1.11	0.41	1.50
R&D only	0.37***	1.44	0.27***	1.31	0.09	1.10
Mktg only	0.34**	1.40	0.07	1.07	0.27	1.31
Design only	0.13	1.14	0.05	1.05	0.08	1.08
R&D & Mktg	1.20***	3.31	0.47***	1.60	0.72***	2.06
R&D & Design	1.12***	3.07	0.53***	1.69	0.59***	1.81
Mktg & Design	0.86***	2.37	0.45***	1.56	0.42*	1.52
All 3 Activities	1.79***	6.01	0.73***	2.07	1.07***	2.91
Aquired MES Only	0.10	1.11	0.46***	1.58	-0.35**	0.70
Training Only	-0.03	0.97	-0.02	0.98	0.00	1.00
Acq'd MES & Tra'g	0.74***	2.09	0.82***	2.28	-0.08	0.92

Valid cases included in the analysis = 9,953 (Innovation Active firms only); Initial -2 LL = 16673.2, Model Chi-Square = 1,495.4; Pseudo R-Square: Cox and Snell = 0.137; Nagelkerke = 0.169; McFadden = 0.088.
Reference group is: independent, established firms, serving local/regional markets only, doing none of R&D, Marketing, or Design, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table G Types of Innovation Engaged in

	Both Prod. & Process Innovation vs. None		Product Innovation vs. None		Process Innovation vs. None	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-2.13***		-0.04		-2.18***	
ln_empt	0.10***	1.10	-0.02	0.98	0.16***	1.17
new_firm	0.22***	1.25	0.08	1.08	-0.08	0.93
group_firm	0.21***	1.23	0.14**	1.15	0.11	1.12
mkt_nat	0.17*	1.18	0.01	1.01	-0.16*	0.85
mkt_int	0.57***	1.78	0.41***	1.50	-0.03	0.97
sic_1014	-0.77**	0.46	-1.60***	0.20	0.11	1.11
sic_1719	-0.38	0.68	-0.69***	0.50	-0.16	0.85
sic_2021	-0.41*	0.67	-0.94***	0.39	0.09	1.09
sic_22	-0.25	0.78	-0.44**	0.64	0.33	1.39
sic_2324	0.36	1.43	0.17	1.19	-0.40	0.67
sic_2526	-0.12	0.88	-0.27	0.76	-0.30	0.74
sic_2728	-0.39**	0.68	-0.52***	0.59	0.31	1.36
sic_29	-0.34	0.71	-0.44**	0.64	-0.79**	0.46
sic_3032	0.81***	2.24	0.77**	2.16	0.46	1.58
sic_31	-0.70***	0.50	-0.41*	0.66	-0.49	0.61
sic_33	0.20	1.22	0.17	1.18	-0.54	0.59
sic_3435	-0.24	0.78	-0.22	0.80	-0.20	0.82
sic_3637	-0.35*	0.71	-0.31	0.73	-0.19	0.83
sic_4041	-1.59	0.20	-0.47	0.63	0.97	2.63
sic_45	-0.98***	0.38	-0.80***	0.45	-1.08***	0.34
sic_50	-1.19***	0.30	-0.25	0.78	-0.60*	0.55
sic_51	-0.49**	0.61	-0.29	0.75	0.07	1.08
sic_52	-0.87***	0.42	-0.48***	0.62	-0.13	0.88
sic_55	-1.16***	0.31	-0.81***	0.45	-0.76***	0.47
sic_6063	-0.41*	0.66	-0.51**	0.60	-0.19	0.82
sic_6064	-0.72***	0.48	-0.58***	0.56	-0.60**	0.55
sic_642	-0.11	0.89	0.07	1.07	-0.33	0.72
sic_6567	-0.01	0.99	-0.36*	0.70	0.31	1.36
sic_7071	-0.58***	0.56	-0.38*	0.68	-0.23	0.79
sic_72	0.79***	2.20	0.89***	2.43	1.20***	3.32
sic_73	1.63***	5.11	0.92***	2.51	2.62***	13.68
sic_7414	-0.23	0.79	-0.54**	0.58	0.85***	2.34
sic_7423	-0.06	0.94	-0.06	0.94	0.78***	2.19
sic_745	0.04	1.04	0.01	1.01	0.48*	1.62
sic_7468	0.15	1.16	0.18	1.20	0.51*	1.67
R&D only	0.68***	1.98	0.35***	1.42	0.03	1.03
Mktg only	0.65***	1.91	0.65***	1.92	-0.03	0.97
Design only	0.36**	1.43	0.11	1.11	-0.15	0.86
R&D & Mktg	1.93***	6.86	1.59***	4.90	0.24*	1.27
R&D & Design	1.56***	4.77	1.14***	3.12	0.33**	1.39
Mktg & Design	1.29***	3.63	1.05***	2.86	0.43**	1.54
All 3 Activities	2.41***	11.19	1.76***	5.80	0.42***	1.52
Aquired MES Only	-0.26**	0.77	-1.26***	0.28	-0.12	0.89
Training Only	-0.60***	0.55	-1.03***	0.36	-0.39***	0.68
Acq'd MES & Train	0.28***	1.32	-1.12***	0.33	0.24**	1.27

Valid cases included in the analysis = 10,141 (Innovation Active firms only); Initial -2 LL = 25,577.7; Model Chi-Square = 3251.6; Pseudo R-Square: Cox and Snell = 0.274; Nagelkerke = 0.297; McFadden = 0.125. Reference group is: independent, established firms, serving local/regional markets only, doing none of R&D, Marketing, or Design, and active in SIC 15 & 16 (Food, Drink and Tobacco)

Table H Types of Novel Innovation Engaged in

	Both Novel Product & Proc. Innov. vs. None		Novel Product Innovation vs. None		Novel Process Innovation vs. None	
	Estimate	Exp(Est)	Estimate	Exp(Est)	Estimate	Exp(Est)
Intercept	-4.57***		-1.55***		-3.71***	
ln_empt	0.05	1.05	-0.03	0.97	0.04	1.04
new_firm	0.43***	1.54	0.10	1.11	0.12	1.13
group_firm	0.22**	1.25	0.15**	1.16	0.18	1.20
mkt_nat	-0.02	0.98	0.00	1.00	-0.27*	0.76
mkt_int	0.56***	1.76	0.41***	1.50	-0.12	0.88
sic_1014	-0.98	0.38	-0.70**	0.50	-0.61	0.55
sic_1719	-0.25	0.78	-0.31	0.73	0.15	1.16
sic_2021	0.01	1.01	-0.55**	0.58	0.40	1.49
sic_22	0.01	1.01	-0.51**	0.60	-0.01	0.99
sic_2324	0.88***	2.42	0.33	1.39	0.78	2.17
sic_2526	0.30	1.34	-0.09	0.92	-0.07	0.93
sic_2728	-0.07	0.93	-0.46**	0.63	0.43	1.54
sic_29	-0.07	0.93	-0.23	0.80	-0.26	0.77
sic_3032	0.48	1.62	0.35	1.42	-0.53	0.59
sic_31	-0.55	0.58	-0.16	0.85	-0.42	0.66
sic_3435	-0.07	0.94	-0.19	0.83	-0.25	0.78
sic_3637	-0.16	0.85	-0.26	0.77	0.40	1.49
sic_45	-0.49	0.61	-0.73***	0.48	-0.92**	0.40
sic_50	-0.30	0.74	-0.38	0.68	-0.24	0.79
sic_51	-0.14	0.87	0.15	1.16	-0.55	0.57
sic_52	-0.42	0.66	-0.17	0.85	0.20	1.23
sic_55	-1.19***	0.30	-1.20***	0.30	-1.04*	0.35
sic_6063	-0.27	0.76	-0.58***	0.56	-0.52	0.59
sic_6064	0.22	1.24	-0.84***	0.43	-0.33	0.72
sic_642	0.45	1.56	0.23	1.26	-0.15	0.86
sic_6567	0.05	1.05	-0.65***	0.52	-0.25	0.78
sic_7071	-0.13	0.88	-0.68***	0.51	0.19	1.21
sic_72	0.91***	2.48	0.37**	1.44	0.41	1.50
sic_73	1.26***	3.51	0.14	1.15	1.46***	4.32
sic_7414	0.29	1.34	-0.71***	0.49	0.69*	2.00
sic_7423	0.34	1.41	-0.13	0.87	0.64	1.90
sic_745	0.41	1.50	-0.91***	0.40	0.59	1.81
sic_7468	0.47	1.60	-0.17	0.84	0.37	1.45
R&D only	0.74***	2.09	0.61***	1.85	0.07	1.07
Mktg only	0.70***	2.01	0.73***	2.08	0.16	1.17
Design only	0.62*	1.87	0.34*	1.40	-0.24	0.79
R&D & Mktg	2.15***	8.56	1.73***	5.62	0.68***	1.98
R&D & Design	1.83***	6.23	1.35***	3.85	0.42	1.52
Mktg & Design	1.43***	4.19	1.43***	4.18	0.65**	1.91
All 3 Activities	2.88***	17.88	2.05***	7.76	0.73***	2.08
Aquired MES Only	-0.27	0.77	-0.58***	0.56	-0.08	0.93
Training Only	-0.09	0.91	-0.51***	0.60	-0.20	0.82
Acq'd MES & Train	0.30*	1.35	-0.51***	0.60	0.45**	1.57

Valid cases included in the analysis = 9,738 (Innovation Active firms only); Initial -2 LL = 16530.4; Model Chi-Square = 2193.2; Pseudo R-Square: Cox and Snell = 0.202; Nagelkerke = 0.246; McFadden = 0.131. Reference group is: independent, established firms, serving local/regional markets only, doing none of R&D, Marketing, or Design, and active in SIC 15 & 16 (Food, Drink and Tobacco). Industries SIC 33 and SIC 40-41 have been excluded due to data problems.

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