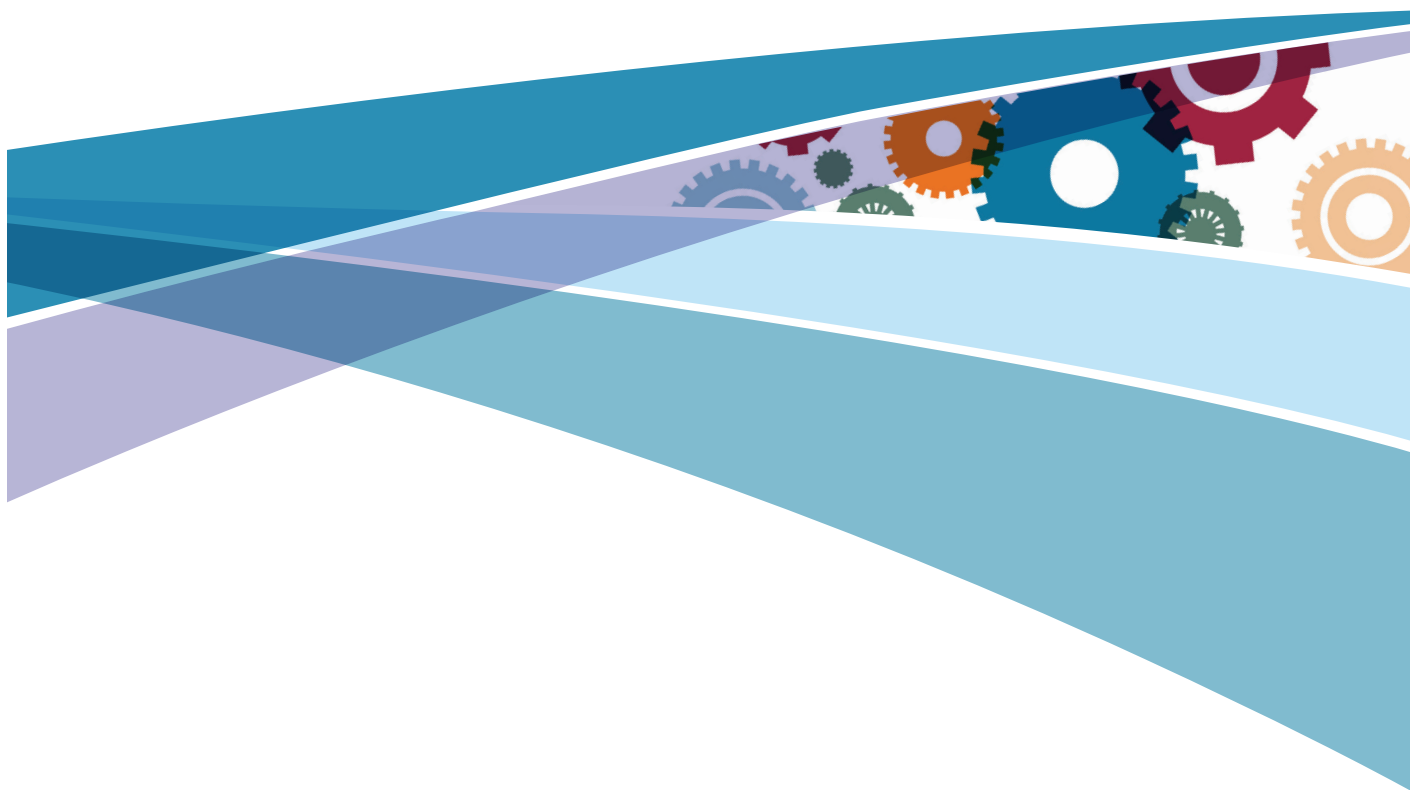# Innovation, Patenting and Licensing in the UK: Evidence from the SIPU survey

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This is an independent report commissioned by the Intellectual Property Office (IPO). Findings and opinions are those of the researchers, not necessarily the views of the IPO or the Government.

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Executive Summary

The IPO commissioned the Survey of Innovation and Patent Use in September 2012 in order to shed light on the factors associated with expenditures on technology in-licensing and the patenting behaviour of firms that had innovated over the 2009-2012 period. The survey was designed by the authors but conducted by the ONS and based on a sampling frame drawn from the Community Innovation Survey (CIS) conducted in 2006-2008.[1] The advantage of this sampling frame was that it gave us information on the antecedent technological behaviour of the surveyed firms. In turn this enabled us to analyse some of the behavioural assumptions/ underpinnings that could explain the observed outcomes on technology in- licensing and recourse to patent use to protect innovations.

Technology in-licensing behaviour

Although "patent licensing" has become prominent in segments such as telecommunications, our study focuses on technology licensing. Patents also play an important role in facilitating such transactions.

Our survey looked at the *demand for technology in-licensing* (defined as the buying of technology whether through the purchase of R&D or technology licensing, including getting a patent license). Although "patent licensing" has become prominent in segments such as telecommunications, our study focuses on technology licensing. Patents also play an important role in facilitating such transactions. Using SIPU data we estimate that expenditure on technology in-licensing was about £6.9 billion a year between 2009-2012. To put this number in perspective, the UK business enterprise R&D spending (BERD) in 2011 was £17.4 billion. Thus, the estimated expenditure on licensing and R&D purchase is about 40% of the total business enterprise spending on R&D.[2]

Although firms that bought R&D service or licensed in technology in 2006-2008 are more likely to do the same in 2009-2012 than the firms that did not buy R&D service or license in technology in 2006-2008, this persistence does not appear very strong. Our analysis thus suggests that spending on in-licensing appears to be more transient than spending on R&D.

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1   For more details of the survey please see Appendix 1 of the main report.

2   See Table 3 of the report for details of how we arrived at this number. U.S. data for 2003 suggest the proportion of technology in-licensing was 44% of R&D expenditures in the U.S.

The factors associated with technology in-licensing are different depending on whether we look at all firms or firms with innovations. A key driver of expenditure on technology licensing is in fact whether the firm introduces an innovation and the firm-level variables that are significant in explaining higher levels of in-licensing such as firm size and R&D, are likely to be proxies for innovative intentions and ability. Within the group of innovators, and particularly for significant innovations, licensing helps firms' catch-up rather than produce truly new to the market innovations, particularly when firms face competition in the product market. It also appears that some industries such as manufacture of non-electrical machinery are more reliant on licensing than others and these are likely to be industries where innovation rates are low. In contrast, in the industries where innovation rates are high, such as manufacture of scientific instrument, firms may be less likely to use licensing when innovating. This may be due to the desire to maintain exclusivity and avoid having to share a technology with competitors indirectly via the licensor. [3]

Patenting and innovation

An important contribution of the report is in providing estimates of patenting propensity for the UK. Although the probability of patenting by any randomly selected firm is low (estimates suggest about 3%), we find that the propensity to patent when conditioned on firms having innovated is considerably higher. Depending on the way we conceptualize patent propensity we estimate that between 28 - 40% of all innovations are patented in the UK. [4] Thus, the UK patent system is relevant to the protection of innovations in the UK.

We also explored the issue of what explains patent propensity, particularly when we conditioned upon innovation. Our main finding is that most of the factors discussed in the literature as influencing patenting actually influence innovation. Innovation specific characteristics are important in explaining patent propensity but on the whole patenting seems to depend upon factors specific to the firm and to the innovation itself. [5] When we take out the influence of the scale of R&D by focussing on the firms' most valuable innovation, and when we control for the characteristics of the industry, we find size does not matter - small firms and large firms are both equally likely to patent an innovation.[6] One implication of these results may be that policy efforts should be focussed on boosting the conditions for innovation generally rather than for patenting in particular.

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3   See estimations reported in Tables 4 and 6 of the report.

4   Please see the more detailed discussion in Section 4 for different notions of innovativeness and how they influence the computed patent propensity.

5   See estimations reported in Table 8 of the report.

6   See estimations reported in Table 9 of the report.

Innovation, Patenting and Licensing in the UK: Evidence from the SIPU survey

1. Introduction

The canonical economics model of innovation is one where firms undertake R&D to create new products and services. In the simplest rendering of the canonical model, R&D produces an invention, which is (sometimes) patented, and the invention is introduced to the market as a product. The pharmaceutical industry best exemplifies this model. However, both the industry and the model have been under strain in recent years as the scale of R&D and the complexity of products have grown.

There are two major elements of the canonical model which violate reality. First, firms do not only rely upon internal R&D – they also buy technology (in the form of R&D services and licenses) from external sources in order to innovate. Second, there is a difference between a patentable invention and a marketable product, and the link between the two is complicated. Innovations produced may or may not be patented. Patents granted to a firm may or may not be embedded in technology products and firms may choose to license out their patents than have exclusive use of them. In short, innovation processes today are far more complex than the simple canonical model would suggest and firms can profit from innovation not only by making technology products but also by licensing their innovations to other firms.

The IPO commissioned the Survey of Innovation and Patent Use in September 2012 in order to shed light on the factors associated with expenditures on technology in-licensing and the patenting behaviour of firms that had innovated over the 2009-2012 period. Appendix 1 describes the achieved sample of the survey in more detail but here we note that the survey was based on a sampling frame drawn from the Community Innovation Survey (CIS) conducted in 2006-2008. The advantage of this sampling frame was that it gave us information on the antecedent technological behaviour of the surveyed firms. In turn this enabled us to analyse some of the behavioural assumptions/underpinnings that could explain the observed outcomes of technology in- licensing and recourse to patent use to protect innovations.

2. Technology In-Licensing Behaviour

Our study focuses on technology licensing. Although "patent licensing" has become prominent in industries such as electronics and telecommunications, these types of licensing arrangements are typically found in complex-product industries where inter-operability of components is important and is sometimes related to standards. Licensing is often in response to litigation or threats of litigation. Access to required patents is sometimes accomplished through cross-licensing arrangements. Sometimes, non-practicing entities are involved in asserting patents. In sum, licensing a patent or patents in order to get "freedom of action" rather than to get access to knowledge or expertise involves issues involving market power and litigation. This topic has been extensively studied by economists, legal scholars and management scholars (see for instance, Shapiro, 2001; Jaffe and Lerner, 2004;Bessen and Muerer, 2008; Rysman and Simcoe, 2008;).

A different form of licensing involves access to technology, including codified technology as well as know-how and other elements. Arora, Fosufri and Gambardella (2001) document the size and extent of markets for technology which comprises of market based transactions for technology. Other scholars have studied the broader phenomenon of what has been dubbed open innovation (Chesbrough, et al. 2008).

Patents play an important role in facilitating such transactions. In their seminal work, which is still relevant for discussions about licensing in the UK, Taylor and Silberston (1973) note that most licensing agreements they studied also included 'know-how' components. Of the 29 firms in their survey 21 reported about half or more of their patent agreements contained know-how provision. 'Know-how' provision is a broad term that includes designs and blueprints, software, R&D services, training and quality control services. The CIS 6 and CIS 7 allow us to track if firms purchased R&D services along with in-licensing.   Of the 1679 firms that had bought licenses in the CIS6, 834 (49.6%) reported that they also bought R&D services. Similarly, in CIS7 of the 858 firms that reported buying licenses, 439 (51.2%) also reported buying R&D. These are unweighted averages[7] of a much underestimated measure of know-how but serve to underline the fact that although patents are frequently involved, the principal objective is getting access to knowledge and expertise that is required for a firm to introduce a new good or service, or to introduce a new production process.

Why should licensing and purchase of R&D services go hand in hand? Arora (1995) argues that licensing agreements typically bundle additional know-how sales because of the complementarities between the codified and tacit elements of knowledge with the former finding their way into licensing contracts while the latter are the subject of additional R&D agreements. Since one is not very valuable without the other, licensing agreements typically occur with R&D agreements. Hagedoorn et al (2009) analyse a large sample of US and European licensing agreements and find that when companies decide to engage in technology transfer through exclusive licensing to other firms, they are more likely to set-up partnership-embedded licensing agreements. They find broader partnership-embedded licensing agreements are preferred to standard licensing contracts with higher levels of technological sophistication of industries, with greater perceived effectiveness of secrecy as a means of appropriability, and when licensors are smaller than their licensees.

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7   The comparable proportions for innovative firms and large firms are closer to the 52 - 55% range.

This previous research suggests disentangling the expenditure on R&D services from technology licensing maybe quite difficult and also not very meaningful. Accordingly, we try to estimate the size of the market for R&D services and licensing together as well as explain the determinants of spending in that market. Our approach is different from that in earlier empirical surveys (e.g., Giuri et al., 2007; Gambardella and Harhoff, 2008; Walsh and Nagaoka, 2009) in two ways: First, our respondents are not the suppliers of technology licenses- they are the ones that demand technology licensing. Second, the focus of our analysis is technology licensing rather than patent licensing.

Table 1 gives a rough idea of the participation in this market conditioned on different characteristics of firms. It also compares the SIPU proportions of firms with those achieved in CIS6 and 7 which also ask firms about their technology acquisition expenditures. Our comparison suggests the proportion of firms undertaking these activities varies lot over time. Thus, although 18% of all firms had bought external technology in 2006–2008 (CIS6) and 10% did that in 2008–2010 (CIS7), 21% had reported the same purchases during the period of 2009–2011 (SIPU). The difference is statistically significant at 5% level. However, these comparisons are contaminated by sampling differences as the CIS employs a rotated sampling policy. Furthermore, Appendix 1 shows that SIPU surveyed more small and medium firms and more innovators than CIS6 and CIS7 did and this may cause the difference between the proportion in SIPU at one hand and in CIS6 and CIS7 in the other hand.

Table 1: Share of firms reporting technology purchase (Purchase of R&D services or technology license)

	Share in all firms of that type in CIS6 (2006-2008)	Share of All firms of that type in SIPU	Share in all firms of that type in CIS7 (2008-10)
All firms[2]	0.18	0.21	0.10
	(0.38)	(0.41)	(0.30)
Small & Medium firms (SME)[3]	0.17	0.19	0.09
	(0.37)	(0.39)	(0.29)
Large firms[2]	0.21	0.34	0.14
	(0.41)	(0.48)	(0.34)
Product Innovators[3]	0.39	0.42	0.34
	(0.49)	(0.49)	(0.47)
Process innovators[3]	0.45	0.39	0.37
	(0.50)	(0.49)	(0.48)
Non-Innovators[4]	0.14	0.09	0.07
	(0.35)	(0.29)	(0.25)

Notes:
1. Standard deviations are in parentheses.
2. Share of all firms of that type in SIPU is statistically different from that of CIS6 and CIS7 at 5% level.
3. Share of all firms of that type in SIPU is statistically different from that of CIS7 at 5% level, but not different from that of CIS6.
4. Share of all firms of that type in SIPU is statistically different from that of CIS6 at 5% level, but not different from that of CIS7.

To explore this inter-temporal variation in technology purchase further we looked for whether firms that bought R&D and technology licenses tended to persist in doing so over time. Since acquisition of external technology is a complement to R&D and R&D expenditures tend to be quite persistent, we expected external technology acquisition also to be persistent. To this end, we focus on the firms in SIPU because we can track their acquisition of external technology in both CIS6 (2006-2008) and SIPU (2009-2012).[8]

Table 2a shows that 56% of the firms surveyed in SIPU did not buy external technology in either survey period. Further, of the 172 firms that did report external acquisition of technology in SIPU, only 103 or about 60% also reported spending on external technology purchase in 2006-2008 (CIS6). Conversely, of the 289 firms that reported acquisition of external technology in CIS6, only 103, or about 35%, report acquisition of external technology in SIPU. Although the chi-square test allows us to conclude the firms that bought R&D service or licensed in technology in the CIS6 period are more likely to do the same in the SIPU period than the firms that did not buy R&D service or license in technology in the CIS6 period, this persistence does not appear very strong. Spending on in-licensing appears to be more transient than spending on R&D.

Table 2a: Number of firms buying of R&D and/or in-licensing technology in CIS6 and SIPU

SIPU / CIS6	Not buying of R&D nor in-licensing technology	buying of R&D or in-licensing technology	Totals
Not buying R&D and/or in-licensing	453 (56%)	69 (8%)	522 (64%)
Buying of R&D and/or in-licensing	186 (23%)	103 (13%)	289 (36%)
Total	639 (79%)	172 (21%)	811 (100%)

Notes:

1.   The numbers in parentheses are the share of the firms in the cells in total.

2.   The Pearson chi-square test rejects the null hypothesis that the row and column are independent with each other at 1% level.

To be sure, the two periods are not the same, and the 2009-2012 period period, which corresponds both the SIPU and CIS7 has lower rates of innovation. Indeed, the share of innovators (which should be related to the share of firms that acquire external technology) drops noticeably between CIS6 and CIS7 (from 27.1% and 21.6%). Consistent with this, we find similar rates of persistence in innovation activity between CIS6 and SIPU. Of the surveyed firms, 58% did not report innovation in either survey period. Of those firms that did report innovation in SIPU, 75% had also reported innovation in 2006-2008 (CIS6).

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8   For a small subset of SIPU sample firms, we can also track activity in CIS7. We do not report those statistics here because the sample size is too small.

Table 2b: Innovation and Technology purchase: CIS6 and SIPU

SIPU	Non-innovators	Innovators	Total
Not buying R&D nor in-licensing	436 (54%)	203 (25%)	639 (79%)
Buying R&D or in-licensing	43 (5%)	129 (16%)	172 (21%)
Total	479 (59%)	332 (41%)	811 (100%)
CIS6			
Not buying R&D nor in-licensing	295 (36%)	227 (28%)	522 (64%)
Buying R&D or in-licensing	65 (8%)	224 (28%)	289 (36%)
Total	360 (44%)	451 (56%)	811 (100%)

Next, in Table 2b, we look at the share of innovators involved in external technology acquisition activities. We look at the SIPU sample and also the activities of the same SIPU firms in CIS6 period before the survey. Table 2b shows that innovators are a heterogenous group, some of whom rely purely upon internal resources while others also purchase technology from outside. In SIPU period, innovators are three times more likely to acquire external technology than non-innovators, whereas innovators are four times as likely to acquire external technology in the CIS6 period. Further, innovators are more likely to rely upon internal sources only in SIPU, CIS6 indicates that innovators were just as likely to acquire external technology as to rely entirely upon internal resources. Overall, we find that in the SIPU sample, acquisition of external technology has gone down from the 2006-2009 period to the 2009-2012. In part, this is because innovators are more likely than non-innovators to acquire external technology and there is a decline in the share of firms innovating between the 2006-2009 period to the 2009-2012 period. In part, however, this is due to the reduction in the share of innovators that acquire external technology.

The SIPU survey also asked firms to report what per cent of their investment expenditure constituted the total value of their purchases on licensing and R&D services. Based on this number and matched investment expenditures (obtained from Company Houses data) we calculated the spending on R&D and licensing for each firm.[9] These totals by broad groups of interest are reported in the penultimate column of Table 3. We use these estimates to generate a value of the overall technology licensing market in the last column of Table 3.

As shown in Appendix A, the SIPU over-sampled innovative firms and small firms in comparison to CIS6. Thus, in order to correct this bias to generate a reasonable estimate of the population spending we need to calculate the expenditure of in-licensing and purchase of R&D service separately for innovative and non-innovative firms and firms with different size. Thus, we in first step divided the number of small, medium and large firms in the UK by the number of the firms of the corresponding categories in the SIPU to attain the weights (see the equation in Table 3). We then multiplied the sum of the expenditure of the firms in each category by the respective weights to estimate the total licensing and R&D purchase expenditure in the UK, which amounts to 6.9 billion pounds a year in the period of 2009–2011.

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9   We also tried to obtain the reporting unit data on investment from the Annual Respondent Database. The match in this case was very poor and we were only able to obtain data for a small fraction (about10%) of the SIPU firms. The discrepancy between reporting unit and company house data are likely to be the largest for group companies but the SIPU survey also indicated that in about 60 % of the cases, parent firms controlled the decisions on patenting and licensing.

To put this number in perspective, the UK business enterprise R&D spending (BERD) in 2011 was 17.4 billion pounds. Thus, the estimated expenditure on licensing and R&D purchase is about 40% of the total business enterprise spending on R&D. By way of international comparison, US businesses reported licensing revenues of $66 billion in 2003, of which approximately $50 billion was from domestic sources (Robbins, 2009). In addition, US businesses reported spending about 20 billion USD on in-licensing from overseas. As a first approximation, we can therefore assume that US business enterprises expenditure on in-licensing technology was about $70 billion. During the same period, US firms reported spending about $10 billion in purchased R&D services. Taken together, US business enterprises reported about $80 billion in licensing and R&D purchases. In this year, US business enterprises spent about $180 billion on R&D, implying that licensing and R&D purchases accounted for about 44% of total business enterprise spending on R&D. In other words, the extent to which UK enterprises rely on outside technology relative to their own internal R&D investments is broadly similar to that in the US. Of course, these calculations are subject to many qualifications because they relate to different years, and the data come from different sources. Even so, they provide us with some confidence that our tentative estimate of the spending on licensing and R&D purchase for the UK is reasonable.

Our estimates suggest that expenditure on external sources of technology, in-licensing and R&D purchase are significant in the UK, comprising about 40% of the expenditure on internal research and development. It therefore makes sense to understand what factors condition the expenditure on licensing and R&D purchase.

Table 3: Value of expenditure on in-licensing and purchase of R&D services

Innovators					
	firms in SIPU	firms in the UK	Weight	Expenditure on in-licensing and R&D purchase in SIPU (£ thousand)	Estimated expenditure on in-licensing and R&D purchase in the UK (£ thousand)
	(1)	(2)	(3)=(2)/(1)	(4)	(5)=(3)*(4)
Small	180	38,994	217	3,816	826,761
Medium	100	8,134	81	4,690	381,497
Large	52	1,635	31	100,790	3,169,056
Non-innovators					
Small	260	110,951	427	2,061	879,581
Medium	147	16,985	116	8,065	931,824
Large	72	2,917	41	18,860	764,083
Total					6,952,802

3. Factors associated with acquisition of external technology

In their recent survey, Arora and Gambardella (2010) point out that much of the literature has focused on the factors that influence whether an inventing firm decides to license its invention to other firms. They also note that we know relatively little about the demand for in-licensing. Theoretical arguments suggest that in- licensing is a mechanism employed to get rapid access to a proven or mature technology while reducing firms' financial exposure and time-to-market (Atuahene-Gima 1993; Chatterji 1996; Roberts and Berry 1985). Thus, it is also a preferred route to complement R&D activities of firms that lie behind the technological frontier or are latecomers to the market. Another view of in-licensing is that it is a reaction to a (temporary) technological shortfall in the licensee (Lowe and Taylor 1998). Lastly, recent literature on fragmented patent rights has suggested that when technology products are complex and many firms hold overlapping patent rights then cross-licensing may be the norm. Firms will seek to build their patent portfolio through in-licensing some patents as a bundle and out-licensing others to the same firm (Cohen et al., 2000).

In order to understand why firms may buy in technology we also conducted a few interviews with patent attorneys. Two of the interviewees had worked with large firms in a variety of sectors (pharmaceutical, chemicals, glass, instrumentation, telecommunications and aerospace) and the third was a solicitor specialised in writing technology licensing contracts for small firms.

The interviews suggested the following set of reasons as lying behind the decision to in-license:

(i)   Small firms often in-license to improve the quality of their product offering and often this may involve in-licensing of brands- for example, the incorporation of a Zeiss lens or an Intel chip to enhance the quality of the product offering by the firm.

(ii)   Among large firms that are licensors there are sharp differences in the in-licensing practices between technology sectors.

Large pharmaceutical firms may buy external technology when their own R&D projects fail to generate the expected outcomes. In this view, in-licensing is likely to be a transient expenditure in the pharmaceutical sector. However, available evidence suggests that large pharmaceutical firms, in particular, regularly in-license compounds in various categories, indicating that for some firms, at least, in-licensing is a regular part of the innovation strategy (Ceccagnoli et al 2013).

In telecommunications where fragmented patent rights and applications around technology standards are commonplace, cross-licensing is the norm as no one firm owns all the patents required to produce a technology product in the sector. In this case, the role of in-licensing is designed to balance the portfolio of patents rights held by the innovating firm.

Thus both the sparse literature and our interviews suggested that in-licensing behaviour occurs among innovating firms and among firms that face bottlenecks or constraints on innovation due to the availability of resources or crucial components of technology. Furthermore, industry specific factors account for a large part of the explanation for differences in the extent of in-licensing activity.

As noted while computing Table 3, the SIPU survey identifies the share of total capital expenditure spent on in-licensing and the buying of R&D services (CapEx) and this is the dependent variable used in our empirical analysis. Firms are asked to tick one of 6 bands for this expenditure viz. less than 1%, 1-5%, 6-10%, 11-25%, 26-50% or more than 50%. We assume that spending in each band is concentrated around the midpoint. Since this question followed another which asked firms whether they bought a license or purchased R&D, we are also able to assume that all those that did not tick any of the bands spent no money on these activities, i.e. had zero expenditure.

We constructed two new variables to proxy for the innovative ability of firms. Based on CIS6 information we created the dummy variable *True Innovator* which takes value 1 when the firm introduced a new to the market product innovation, or new to the industry process innovation in 2006-2008.   As compared to firms that imitated an existing product or process, these firms, as a group, may have greater ability to innovate. We also created a dummy variable *Imitator* which takes value 1 when the firm introduced a new to the firm innovation in 2006-2008 but not new to the market. Both theory and our interviews suggest that both groups are likely to spend on technology in-licensing. We used log transformed *R&D expenditures* and log transformed *employment* as control variables for the level of R&D spending and the size of the firm.

We used factor analysis to extract three groups of factors constraining innovative activities as revealed in CIS6. These factors identified three types of *constraints*. The first factor identifies barriers to innovation due to *costs and financial constraints* such as excessive innovation costs and constraints in financing. The second factor identifies barriers to innovation due to key *resource constraints* such as availability of scientific personnel, lack of information on technology and markets, uncertainties in demand, and the dominance of large firms in the industry. The last group of constraints reflect *regulatory barriers* to innovation.

Given the importance of industry level factors we used a variety of approaches to control for these factors. We first generate two variables to represent the Innovativeness or Imitativeness of industries. The *innovativeness of an industry* is the share of true innovators and *imitativeness* of industry is the share of imitators at two-digit industry level respectively. Secondly, according to the OECD/Eurostat's definition, we define dummy variables for high-tech manufacture, *medium-high-tech manufacture*, *medium-low-tech manufacture*, low-tech manufacture, *knowledge-intensive services* and less-knowledge intensive services to control for the characteristics of these industries. Thirdly, we generate a group of dummy variables to control for characteristics of the two-digit industry which each account for more than three percent of the SIPU sample. These industries include *other business services*, *computer services*, *non-electrical machinery, real estate, scientific instrument, furniture, R&D services, fabricated metal, electrical machinery* and *construction*. Additional details of the construction of variables used in the analysis are provided in the appendix.

The censored nature of the dependent variable suggests a Tobit estimation is appropriate and accordingly Table 4 below reports the marginal effects of each variable on the extent of technology licensing. The first column reports the result of adding the firm level variables alone, the second column shows the effect of adding in the constraints and the third and fourth columns add in the industry controls. The robust result is that both (true) innovators and imitators are likely to spend on technology licensing. The level of spending increases with firm size and R&D expenditures and the sign on the R&D expenditure variable is positive indicating that technology in-licensing is complementary to R&D spending.

Looking next at the role of constraints, we find some evidence that resource constraints are associated with greater technology in-licensing while regulatory barriers are associated with lower spending on technology in-licensing. However, the statistical significance of the coefficient of these constraints becomes weaker once we introduce industry controls. The most interesting result is that the imitativeness of the 2-digit industry has the greatest marginal effect on the extent of technology in-licensing – indeed the marginal effect of this variable increases as we introduce more fine grained industry controls.

As expected, Table 4 shows that innovative firms, i.e., those that had introduced new products and processes in 2006-2009, firms that invest in R&D, and large firms are more likely to in-license than non-innovating firms, non-R&D performing, and small firms respectively. Further firms that claimed to face regulatory barriers to innovation are less likely to in-license. These results, though *prima facie* sensible, raise the question of whether we are mainly uncovering variables that make it likely that a firm introduces a new product or process, and for which, it may also have chosen to acquire external technology.

Table 4: Factors associated with the share of investment expenditure on technology in-licensing (Patent licensing & R&D services): Marginal effects of Tobit estimation

Dependent variable: Share of investment expenditure on technology in-licensing (Patent licensing and R&D)					
	(1)	(2)	(3)	(4)	(5)
True innovator	.01**	.012**	.018**	.011**	.011**
	(.005)	(.005)	(.005)	(.005)	(.005)
Imitator	.015***	.013**	.011*	.012*	.011*
	(.006)	(.006)	(.006)	(.006)	(.006)
R&D expenditures	.0035***	.004***	.003***	.004***	.003***
	(.001)	(.001)	(.001)	(.001)	(.001)
Employment size	.002	.002	.002	.003*	.003**
	(.002)	(.002)	(.002)	(.002)	(.002)
Costs & fin. Constraints		-0.001	-0.001	-0.001	-0.001
		(.003)	(.003)	(.003)	(.003)
Resource constraints		.004	.004	.004*	.004
		(.002)	(.002)	(.002)	(.002)
Regulatory barriers		-0.004*	-0.004*	-0.004*	-0.004
		(.003)	(.003)	(.003)	(.003)
Industry innovativeness			.007	.0182	-0.005
			(.012)	(.014)	(.019)
Industry imitativeness			.027*	.034**	.051***
			(.016)	(.017)	(.019)
OECD industry classification dummies				Yes	Yes
Dummies for 2-digit industries					Yes
Number of observations	759	759	759	759	759
Left-censored observations	611	611	611	611	611
Pseudo R-square	.12	.13	.13	.15	.18

Note: Standard errors are in parentheses. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

The results reported in Table 4 are across the entire SIPU dataset where the majority of firms are non-innovators. It is useful to also see the influences on technology in-licensing when conditioned on innovation. In the SIPU survey, all innovating firms were asked to consider their most significant innovation.[10] These respondents were further asked whether they used any externally purchased technology for the innovation.

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10   Respondents were told, "Of all the new or significantly improved goods or services or processes you brought to market since November 2009, think of the one that accounts for the most turnover"- thus, the most significant innovation is their most valuable one.

There are several benefits to focusing upon in-licensing for a focal innovation. For one, insofar as relying upon an external source of technology implies that the firm's competitor's also have access to the technology, one might expect in-licensing to be related to faster imitation by the firm's competitors.   The correlation matrix reported in Table 5 gives us some clues to the relationship between competition, technology in-licensing and speed of imitation in the case of firms reporting a significant innovation. From the matrix we see that 1) patenting firms have fewer competitors; 2) Firms with more competitors have shorter time period of monopoly- there is a negative correlation with the speed of imitation; 3) the number of competitors or speed of imitation has no relationship with in-licensing. 4) there is no relationship between in-licensing and whether the innovation was patented.

Table 5: Pair wise correlation between patenting and licensing for significant innovation and competition

		1	2	3	4
1	Firm applied for patent for its most significant innovation	1			
2	Firm licensed in technology for its most significant innovation	-0.08 (0.147)	1		
3	Number of competitors	-0.19*** (0.003)	0.10 (0.13)	1	
4	Number of months that other businesses introduced a competing good or service	0.12 (0.17)	-0.07 (0.44)	-0.24*** (0.01)	1

Note: The standard errors are in parentheses.

In Table 6 we report the factors associated with the purchase of external technology (technology in-licensing or purchase of R&D). Column 1 simply reports the factors associated with purchase of external technology. In Columns 2, 3 and 4, we consider whether the firm acquired technology for its most significant innovation, thereby restricting attention to firms that had introduced an innovation in the SIPU period. We add other explanatory variables such as the characteristics of the significant innovation (*innovation is new good, innovation is new service or innovation is new process*) in Column 3 and the nature of competition faced by the firms (proxied by the *number of imitative competitors*) in Column 4. Unlike in Table 4, we use a probit model to estimate the relationship in Table 6 because the question we asked about the buying of technology was a dichotomous one.

The results in Table 6 show that a very different set of factors is important for the technology in-licensing activities of firms when their innovations are valuable. As shown in the column (1), being a true innovator, imitator or a larger firm, or having larger R&D expenditure, a firm in general was more likely to license in technology. However, when focusing on a firm's most significant innovation in column (2), we find that the level of R&D spending, being an imitator firm, being part of an imitative industry and regulatory barriers no longer explain technology in-licensing, once we condition on the firm having innovated. The resource constraints are still weakly significant and so is employment size. However, among firms that have introduced an innovation, those that previously introduced a new to the market innovation (*true innovator*) are less likely to have purchased technology for their most significant innovation relative to those that had imitated existing innovations in the past. Furthermore, finance and cost constraints are positively associated with the decision to license external technology.

Table 6: Factors associated with technology in-licensing (Patent licensing & R&D services) for the most significant innovation: Marginal effects of Probit model

Independent variables	Dependent variable			
	Firm licensed in technology	Firm licensed in technology for its most significant innovation		
	(1)	(2)	(3)	(4)
True innovator	0.08**	-0.01*	-0.11**	-0.17***
	(0.04)	(0.05)	(.05)	(.06)
Imitator	0.07*	-0.04	-0.04	-0.02
	(0.039)	(0.06)	(.057)	(0.07)
R&D expenditures	0.03***	0.003	0.01	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)
Employment size	0.03***	0.03*	0.03**	.040**
	(.011)	(.015)	(0.02)	(0.02)
Costs and financial constraints	-0.01	0.04	0.04	.02
	(0.02)	(0.03)	(.03)	(0.03)
Resource constraints	0.01	0.04*	0.04*	0.06**
	(0.02)	(0.03)	(0.03)	(0.03)
Regulatory barriers	-0.02	-0.03	-0.02	0.02
	(0.02)	(0.03)	(0.02)	(0.03)
Innovation is new good			0.01	0.00
			(0.04)	(0.05)
Innovation is new service			0.11**	0.14***
			(0.05)	(0.05)
Innovation is new process			0.09**	0.06
			(0.04)	(0.05)
Number of imitative competitors				0.01
				(0.01)

Innovativeness of industry	0.09	0.14	0.19	-0.14
	(0.15)	(0.23)	(0.23)	(0.19)
Imitativeness of industry	0.23	0.19	0.21	-0.05
	(0.19)	(0.3)	(0.32)	(0.27)
OECD industry dummies	Yes	Yes	Yes	Yes
Dummies for 2-digit industries	Yes	Yes	Yes	Yes
Number of observations	775	306	306	229
Pseudo R-square	0.12	0.14	0.17	0.18

Notes: Standard errors are in parentheses. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

In column (3), we see that the characteristics of the innovation also matters. Firms whose significant innovations were a new service or a new process were more likely to engage in technology in-licensing. The inclusion of these two variables plus *innovation is new good* does not alter the results that we obtained in column (2).

The sample of observations drops dramatically when we include the variable number of imitative competitors (column 4), because a number of respondents were unable to even estimate the number of competitors likely to imitate the innovation. Although we report these results we should bear in mind that competition is likely to be an endogenous variable. It could well be that in-licensing makes it more likely that all firms will have access to similar technology which in turn would influence the level of competition! Thus, competition and technology in-licensing may be jointly determined.

Taken together, the results in Tables 4 and 6 suggest that a key driver of expenditure on technology licensing is in fact whether the firm introduces an innovation. All the firm-level variables that are significant in Table 4, including firm size and R&D, are likely to be proxies for innovative intentions and ability. Within the group of innovators and particularly for significant innovations (the results reported in Table 6), it is clear that licensing helps firms' catch-up rather than produce truly new to the market innovations, particularly when firms face fierce competition. It also appears that some industries, such as manufacture of non-electrical machinery, are more reliant on licensing than others and these are likely to be industries where innovation rates are low. In contrast, in the industries where innovation rates are high such as manufacture of scientific instrument, firms may be less likely to use licensing when innovating. This may be due to the desire to maintain exclusivity and avoid having to share a technology with competitors indirectly via the licensor.

4. The innovativeness of firms and patent propensity

A number of studies have acknowledged that patents underpin licensing behavior and that patent licensing can serve as a useful mechanism for commercialization of innovations by small firms (Arora & Gambardella, 2010). The Pat Val results as reported in Giuri et al (2007) suggest that small firms have a higher propensity to license their innovations compared to large firms but this is a fact that sits rather oddly with another finding which is that small and medium firms do not use the patenting system very much and that all firms exhibit rather low probabilities of patenting in general (Hall et al 2013). This raises the important question of what is the patent propensity of UK firms and how may we go about explaining the higher or lower patenting probability of firms? In this section we explore this question in more detail.

Patent propensity is the tendency to file for patents for innovations: Given an innovation, what is the likelihood that the firm in question will file for patent protection? Empirically, there are several challenges. First, a firm may file for more than one patent for an innovation. Second, a firm may patent inventions that are not brought to market, and hence, are not innovations. But by far the most important challenge is that it is difficult to measure innovations, particularly by outside observers. Consequently, most of the empirical literature has tended to define patent propensity as the number of patents filed by a firm, normalized by some measure of innovativeness, such as R&D expenditure. There are some notable exceptions. Cohen et al. (2000) asked U.S. R&D performing firms for what share of their inventions the firm had filed for patent protection, distinguishing between product and process inventions, and using size categories. Arundel and Kabla (1998) use a similar approach to estimating patent propensity for a sample of European firms. This approach is well suited when the respondent firms have a large basket of innovations, and the share of innovations for which patent protection is obtained (or sought) is a reasonable measure of the underlying patent propensity. Instead, we focus on the likelihood that a firm files for patent protection for a given innovation, and specifically, for its economically most significant innovation.

To structure our thinking about patent propensity, note that the reference group we consider is likely to be important for definitions of patent propensity.. Firms which do not generate innovations would not apply for a patent. Even among innovating firms, only novel innovations can be patented while imitations cannot. Thus not all firms innovate, and amongst firms that do innovate, not all launch patentable innovations, and of the patentable innovations, not all are patented. We use three concepts "patenting probability", "patenting probability conditional on innovation" and "patenting probability conditional on true innovation" to further illustrate our ideas.

We define "patenting probability" as the probability that a regular UK firm applied for patent. Hall et al. (2013) found that only 3% of the firms surveyed in the CIS3 (1998–2000), CIS4 (2002–2004) and CIS5 (2004–2006) have ever patented. The proportion in CIS6 and CIS7 are in similar range, that is, 2.8% and 2.6% respectively. We argue that the low patenting probability of general firms should be viewed in the backdrop that only 27% and 22% of UK firms surveyed in CIS6 and CIS7 innovated, respectively. Therefore, the low probability should not be considered as evidence of weak patenting activities of UK firms or unimportance of patenting system to the UK industry in general.

In addition, not all innovative firms generate patentable innovations. In Table 7, the firms that reported applying for a patent in 2009-2012 are cross-tabulated against those that reported an innovation in the same period. The patenting probability equals 11% (87/811), but the "patenting probability conditional on innovation", which is the probability that an innovative firm applies for a patent, is doubled to 22% (72/332). (Recall SIPU over-sampled innovative firms, so patenting probability is higher in the SIPU sample than in the CIS6 or CIS7 sample.) However, these 332 innovators are defined by a rather noisy measure of innovation because as we saw earlier they include both true innovators (introducing new-to-market innovations) and imitators (introducing only new-to-firm innovation).

Table 7: Patenting and innovative firms in SIPU

	Non-innovative firms	Innovative firms	Total
Non-patenting firms	464 (57%)	260 (32%)	724 (89%)
Patenting firms	15 (2%)	72 (9%)	87 (11%)
Total	479 (59%)	332 (41%)	811 (100%)

Notes:
1. The numbers in parentheses are the share of the firms in the cells in total.
2. The Pearson chi-square test rejects the null hypothesis that the row and column are independent with each other at 1% level.

Considering the important difference between true innovators and imitators, we introduce a more fine-grained indicator "patenting probability conditional on true innovation". It is defined as the probability that a true innovator applies for a patent. In the SIPU sample 57% of the firms that reported an innovation in the period of 2006–2008 had introduced new-to-market innovations. If we assume that only true innovators can patent and imitators do not, we can derive patenting probability conditional on true innovation which equals 39% (22%/57%). If only those defined as true-innovators have patentable inventions, then nearly two out five such innovators filed for a patent.

One might be tempted to conclude that the underlying patent propensity in the U.K is 39%. However, this conclusion needs further amendment. Whether a firm actually files for a patent depends not only on its underlying patent propensity but also on how many patentable inventions the firm has. For instance, if Firm A has a patent propensity of 0.2 and Firm B has a patent propensity of 0.4, but firm A has 5 patentable inventions a year and Firm B has 1 patentable invention a year, the observed probability that Firm A files for a patent in a year is 67% whereas the corresponding probability for Firm B is only 40%.[11]

There are two ways around this. One is to estimate the number of patentable inventions, for instance, by using the scale and nature of R&D in the firm. The other way is to ask whether a firm filed for patent protection for a given innovation. We use a variant of the second approach by asking if the firm filed for a patent for its most significant (valuable) innovation. We find that 16% of the significant innovations reported in SIPU are associated with patent applications.

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11   If p is the underlying patent propensity and n is the number of potentially patentable inventions, then the probability of observing at least one patent is $1 - (1-p)^n$

The true patent propensity, however, is higher, because not all significant innovations are patentable. Specifically, a minimal requirement for patentability is that the invention be new. However, we do not know what percentage of these significant innovations are first to market, because significant innovation is defined as the innovation that accounts for the most *turnover*. Nevertheless, if we assume that the share of true innovations in the significant innovations is the same as the share of true innovators in general innovators (57%), the patent propensity of significant innovation conditional on true innovation is 28% (16%/57%). In other words, among the most valuable innovations, of those that are new to the market, more than a quarter are patented.

By way of comparison, Arundel and Kabla (1998) report that patent propensity among the larger R&D performing firms in Europe in the early 1990s was 32% for all innovations, and 36% for product innovations. Anecdotal accounts indicate that patent propensity has increased significantly over the last two decades. Further, available evidence shows that patent propensity is higher for larger and more R&D intensive firms. Thus, given that our data are for a more patent intensive period and that we focus on the most significant innovations, but that we include not just large, R&D performing, firms, but also small and medium sized firms, the estimated patent propensity of 28% seems reasonable estimate for patent propensity in the U.K.

To summarize, the importance of patent system to the UK industry is not adequately captured by the finding that only 3% of UK firms have ever applied for a patent. Instead, we find evidence of much higher rates of use. The patent system is to encourage and reward innovators. Only a fraction of the UK firms generated new products and processes, and of these, only half generated truly novel products and processes that were new to the market. Of such innovators, nearly two out of five firms applied for at least one patent.

At the level of the specific innovation, ours is one of the first studies to estimate patent propensity. We find that one in six firms applied for a patent for their most significant innovation. When restricted to the set of firms that had produced new to the market innovation in the past, we find that more than a quarter of the firms had filed for patent protection for their most significant innovation. These estimates are consistent with available prior evidence, and indicate that the patent system is salient for innovation in the U.K.

5. Factors associated with patent propensity

Viewing the firm's patenting behavior as conditional on innovation not only allows us to obtain a true picture of patenting probability but can also reveal new insights regarding determinants of patenting decision of firms. Many of the prior studies that have analyzed the patenting probability of firms point to the role of R&D and firm size in explaining firms' behavior (Levin et al., 1987; Arundel and Kabla, 1998; Arora et al. 2008). However, these are also the factors that most likely to explain innovation. Are the determinants of patenting decisions of firms when it is conditioned on having innovated likely to be different? We examine this question below.

We do so in two steps. In Table 8 below, we investigate this issue at the level of the firm. Following Arundale and Kabla 1998; and Cohen et al., 2000), SIPU respondents were asked to indicate the fraction of their innovations that were protected by patents.

In table 8, we posit a process where firms innovate and also decide on which innovations to patent. We use the sample selection model to delineate this process. In this model, the first stage is always a probit model, regressing whether the firm is an innovator. In the second stage we investigate two possibilities:

- whether the firm applied for a patent (the probit sample selection model is adopted).

- the percentage of innovations associated with patent applications (the Heckman sample selection model is adopted) .

For comparative purposes, we also report the marginal effects of regressions unconditional on innovation in column (1) and (2).   The results conditional on innovation are reported n column (3) and (4).

Table 8: Factors associated with patenting probability and higher patent propensity: Marginal effects

	Unconditional marginal effects		Marginal effects conditional on innovation		1st stage
	Probit	OLS	2nd stage: Probit	2nd stage: Heckman	sample selection Probit
	firm applied for a patent	% innovations with patent application	If firm applied for a patent	% innovations with patent applications	If firm is an innovator
	(1)	(2)	(3)	(4)	(5)
Process innov.	0.04*	0.01	-0.03	-0.01	
	(0.02)	(0.01)	(0.03)	(0.02)	
True Innovator	0.06***	0.04***	0.05	0.05**	
	(0.02)	(0.01)	(0.04)	(0.02)	
Imitator	0.01	-0.01*	-0.05	-0.03	
	(0.03)	(0.01)	(0.05)	(0.018)	
R&D exp	0.02***	0.01***	0.03***	0.01**	0.06***
	(0.01)	(0.003)	(0.01)	(0.01)	(0.01)
Employment	0.01	0.00	0.02*	-0.00	-0.02
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Funding for innovation					0.1**
					(0.05)
Ind. Innovativ.	0.16**	0.02	0.21*	0.04	
	(0.08)	(0.03)	(0.12)	(0.06)	
Ind. Imitative.	0.15	0.07	0.28	0.19	
	(0.15)	(0.09)	(0.20)	(0.18)	
OECD ind dummies	Yes	Yes	Yes	Yes	Yes
2-digit ind. dummies	Yes	Yes	Yes	Yes	Yes
Number of obs	479	479	479	479	479
Censored obs	332	328	332	328	

Notes: Standard errors are in parentheses. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

In column (5), we report the marginal effects of the first stage of the Probit sample selection model. The result of column (5) shows that the firms which received public financial support for innovation activities and had larger R&D expenditure had higher probability of being an innovator. [12]

Comparing the unconditional results in column (1) and (2) and the conditional ones in column (3) and (4), we find that most of the firm level predictors of patenting are largely predicting innovation rather than patent propensity per se. However, R&D expenditure is the most consistent predictor of firm's patenting probability and patent propensity no matter whether we condition on innovation or not. Recalling the earlier discussion, R&D has potentially several different routes through which it conditions patenting. First, R&D expenditures determine whether (and how many) inventions the firm will produce. Thus we see in column (5) that R&D is positively associated with whether the firm is an innovator. Second, R&D expenditures increase the expected number of inventions, and therefore, the likelihood that the firm applies for at least one patent during an observation period, conditional upon innovation. Finally, R&D expenditures may also be related to the characteristics of the inventions (which are not observed by the analyst). Specifically, firms that invest in R&D may produce more patentable inventions and higher value inventions, and thereby be more likely to patent.

The second most consistent predictor is the ability to introduce new to market innovations (*true innovator*). This conditions patent propensity even when we condition on innovation in column (4) although its effect on the probability of patenting vanishes in column (3). This is perhaps not surprising. Since patents reward novel innovations, having the ability to create new innovations is likely to be a factor that explains the propensity to patent (how many innovations are patented). The probability of patenting may depend upon factors other than novelty such as the recourse to patenting within the industry. This is also what we find in column (3) where belonging to an industry where a larger than average fraction of firms introduces novel products or processes (*high industry innovativeness*) is associated with higher patenting probability.

These results suggest that once we control for innovation very little else (that is measurable in innovation surveys) actually explains the decision of firms to patent. Put differently, patenting is idiosyncratic, once innovation has taken place and the determinants of patenting may be more visible in innovation specific characteristics.

To understand these factors more, we look at the probability of patenting the most significant innovation in Table 9. Apart from focusing attention on a single innovation, another advantage of Table 9 is that it takes out the influence of size and the number of innovations on patent propensity. Similar to the regressions presented in Table 8, we use the sample selection Probit model to model the two-stage process. However, the likelihood ratio tests indicate that the outcome and selection equations of the models can be estimated independently, without causing a sample selection bias.

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12   The results of the first stages of Heckman sample selection model are similar to that presented in column (5) and available upon request. The likelihood-ratio test of no correlation between the residuals in the outcome and selection equations rejects the null hypothesis that the two equations can be estimated separately in the model of column (4), but fails to do so in the model of column (3). This justifies our choice of sample selection model in order to control for sample selection bias, but also hints that the outcome and selection equations can be estimated separately in the model (3).

Table 9: Patent propensity of the most significant innovation: Marginal effects

	Unconditional marginal effects	Marginal effects conditional on innovation			
	Probit	2nd stage of sample selection Probit model			1st stage Probit
	If firm applied for a patent	If firm applied for a patent for its most significant innovation			Whether the firm is an innovator
	(1)	(2)	(3)	(4)	(5)
Process innovator	0.039**	-0.031	-0.009	-0.028	
	(0.02)	(0.032)	(0.05)	(0.044)	
True Innovator	0.064***	0.032	.024	.044	0.206***
	(0.023)	(0.047)	(0.076)	(0.047)	(0.041)
Imitator	0.01	-0.094*	-0.123	-0.130*	0.134***
	(0.028)	(0.054)	(0.084)	(0.069)	(0.047)
R&D expenditures	0.020***	0.017**	.017*	0.025**	0.033***
	(0.005)	(0.007)	(0.009)	(0.011)	(0.01)
Employment size	0.012	0.013	0.021	0.035**	0.000
	(0.007)	(0.012)	(0.014)	(0.017)	(0.013)
Innovation is new good			0.138***		
			(0.047)		
Innovation is new service			0.025		
			(0.056)		
Innovation is new process			-0.015		
			(0.052)		
Number of imitative competitors				-0.029***	
				(0.011)	
Funding for innovation					0.057
					(0.049)
Costs and Financial constraints					-0.007
					(0.023)
Resource constraints					0.021
					(0.029)
Regulatory barriers					-0.03
					(0.019)
Innovativeness of industry	0.164**	0.167	0.206	0.353*	0.349**
	(0.081)	(0.117)	(0.212)	(0.199)	(0.138)

Imitativeness of industry	0.148	0.1	0.1	0.472	0.333
	(0.146)	(0.238)	(0.286)	(0.358)	(0.21)
OECD industry dummies	Yes	Yes	Yes	Yes	Yes
2-digit industry dummies	Yes	Yes	Yes	Yes	Yes
Number of observations	811	774	767	689	774
Uncensored observations		316	309	231	316
Chi-square statistic of no correlation between the residuals stage 2 and stage1 (H^0: rho = 0)	0.99	0.86	0.82		

Notes: Standard errors are in parentheses. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

In Table 9, Column 1 reports the unconditional results for whether the firm applied for a patent for its most significant innovation, where we include firms that report such an innovation as well as those that do not. Columns 2, 3 and 4 report the results for firms that report an innovation, where we also correct for the selection into innovation.

We find that firms whose most significant innovations are new goods and firms that had more R&D expenditure or fewer competitors are more likely to apply for patents to protect their most valuable innovations. Consistent with the results in table 8, patenting is associated with future potential imitators. Firms that introduce goods and services that are new to them but are similar to those already introduced by a competitor are less likely to file for patents. Further, R&D expenditures are positively associated with patenting a given innovation, consistent with the idea that firms that invest in R&D are more likely to produce higher value patentable innovations. Finally, innovators in industries with high rates of innovation are more likely to patent. High innovation industries may have more patentable innovations. As well, innovators may use patents as a competitive strategy against other innovators.

In contrast to the unconditional results (column 1), being a process innovator or a true innovator are no longer correlated with patent propensity in the sample selection model conditional on innovation. This is consistent with the reasoning that these factors are associated with patenting outcomes largely because they condition innovation rather than the decision or ability to patent innovations themselves. In other words, conditional on the firm having an innovation (which is associated with characteristics of the firm such as size and the nature of the industry), it is invention specific characteristics that largely determine whether the firm patents. Thus, product inventions are more likely to be patented, as are inventions arising from firms that undertake large R&D expenditures.

6. Summary and Conclusions

In this report we sought to estimate the size of the technology in-licensing market and the patent propensity of firms in the UK economy as well as examine the factors associated with higher levels of both.

Based on estimates generated by the SIPU survey we find that technology in-licensing (including R&D purchase) accounts for about 40% of private R&D expenditures and 3.34% of gross investment in the UK.[13] These ratios are comparable to those obtained for the US, although given differences in data sources and definitions, one must be cautious in such comparisons. We also find that technology licensing is less persistent a phenomenon than R&D and that about a third of the demand for technology in-licensing comes from firms that are not introducing new to the world technologies. Furthermore, this finding also highlights that the users of the patent system are more than the firms that own patents - something IP offices should take cognizance of whilst setting the agendas for IP policies.

Although the probability of patenting by any randomly selected firm is low, we find that the propensity to patent when conditioned on firms having innovated is considerable higher. Depending on the way we conceptualize patent propensity we estimate that between 28 - 40% of all innovations are probably patented in the UK. Thus, the UK patent system is very salient to the protection of innovations in the UK.

A key driver of expenditure on technology licensing is in fact whether the firm introduces an innovation and the firm-level variables that are significant in explaining higher levels of in-licensing such as firm size and R&D, are likely to be proxies for innovative intentions and ability. Within the group of innovators, and particularly for significant innovations, licensing helps firms' catch-up rather than produce truly new to the market innovations, particularly when firms face competition in the product market. It also appears that some industries such as manufacture of non-electrical machinery are more reliant on licensing than others and these are likely to be industries where innovation rates are low. In contrast, in the industries where innovation rates are high, such as manufacture of scientific instrument, firms may be less likely to use licensing when innovating. This may be due to the desire to maintain exclusivity and avoid having to share a technology with competitors indirectly via the licensor.

We also explored the issue of what explains patent propensity, particularly when we conditioned upon innovation. We found that most of the factors discussed in the literature as influencing patenting actually influence innovation. Innovation specific characteristics are important in explaining patent propensity but on the whole patenting seems to depend upon factors specific to the firm and to the innovation itself. One implication of these results may be that policy efforts should be focussed on boosting the conditions for innovation generally rather than for patenting in particular.

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13   Based on the figure for Gross Fixed Capital formation at current prices for 2009 (£207,918 million) reported in the Annual Abstract of Statistics, No. 146, 2010 Edition.

References:

Anthony Arundel and Isabelle Kabla (1998) What percentage of innovations are patented? empirical estimates for European firms, Research Policy, 27 (2):127–141.

Jaffe, A. B., & Lerner, J. (2004). Innovation and its discontents: how our broken patent system is endangering innovation and progress, and what to do about it. Princeton University Press, Princeton, NJ.

Ashish Arora, Andrea Fosfuri and Alfonso Gambardella (2001) Markets for Technology. MIT Press.

Ashish Arora, Alfonso Gambardella, (2010). The Market for Technology, In: Bronwyn H. Hall and Nathan Rosenberg, Editor(s), Handbook of the Economics of Innovation, North-Holland, 2010, Volume 1: 641-678.

Arora, Ashish, (1995). Licensing tacit knowledge: intellectual property rights and the market for know-how. Economics of Innovation and New Technology 4: 41-60.

Kwaku Atuahene-Gima (1993) Determinants of inward technology licensing intentions: An empirical analysis of Australian engineering firms, Journal of Product Innovation Management, 10(3) : 230-240.

Bessen, James, and Michael James Meurer (2008) Patent failure: How judges, bureaucrats, and lawyers put innovators at risk. Princeton University Press, Princeton, NJ.

Marco Ceccagnoli, Matthew J. Higgins, Vincenzo Palermo (2013) Behind the Scenes: Sources of Complementarity in R&D. NBER Working Paper No. 18795.

Wesley M. Cohen, Richard R. Nelson, John P. Walsh (2000) Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). NBER Working Paper No. 7552.

Gambardella, Alfonso, Dietmar Harhoff, and Bart Verspagen, (2008) The value of European patents. European Management Review 5, (2): 69-84.

Giuri, Paola, Myriam Mariani, Stefano Brusoni, Gustavo Crespi, Dominique Francoz, Alfonso Gambardella, Walter Garcia-Fontes et al. (2007) Inventors and invention processes in Europe: Results from the PatVal-EU survey. Research Policy 36, (8): 1107-1127.

John Hagedoorn, Stefanie Lorenz-Orlean and Hans van Kranenburg (2009) Inter-firm technology transfer: partnership-embedded licensing or standard licensing agreements? Industrial and Corporate Change 18 (3): 529-550.

Bronwyn H. Hall, Christian Helmers, Mark Rogers, Vania Sena (2013), The Importance (or not) of Patents to UK Firms. The Importance (or not) of Patents to UK Firms. NBER Working Paper No. 19089.

Julian Lowe and Peter Taylor (1998) R&D and technology purchase through licence agreements: complementary strategies and complementary assets, R&D Management, 28 (4): 263–278.

Nagaoka, Sadao, and John P. Walsh. (2009) Commercialization and other uses of patents in Japan and the US: Major findings from the RIETI-Georgia Tech inventor survey. Research Institute of Economy, Trade and Industry (RIETI).

Roberts E. and C. Berry (1985) Entering New Businesses: Selecting Strategies for Success, Sloan Management Review, 26 (3).

Robbins, Carol A. (2009) Measuring payments for the supply and use of intellectual property. In: Marshall Reinsdorf and Matthew J. Slaughter, editors. International trade in services and intangibles in the era of globalization, pp. 139-171. University of Chicago Press, 2009.

Rysman, Marc, and Timothy Simcoe.(2008) Patents and the performance of voluntary standard-setting organizations. Management Science 54, (11): 1920-1934.

Carl Shapiro (2001). Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting. Innovation Policy and the Economy, Volume 1. Adam B. Jaffe, Josh Lerner and Scott Stern, editors. MIT Press, Cambridge, MA.

Christopher Taylor and Aubrey Silberston, (1973). The Economic Impact of the Patent System. Cambridge University Press, Cambridge.

Appendix A: Comparing the SIPU and CIS datasets

As noted in the Introduction to the report, the main advantage of the SIPU sampling frame was the access to information in CIS 6 which helped to understand the antecedent technological behaviors of firms. Here, we compare the sample achieved by SIPU to that of CIS6 and CIS7 in three dimensions.

First, we examine size. As Figure 1 below shows, SIPU over-sampled the small and medium firms but under-sampled large firms in comparison to CIS6 and CIS7.

Figure 1: Size distribution of firms in SIPU sample compared to CIS6 and CIS7
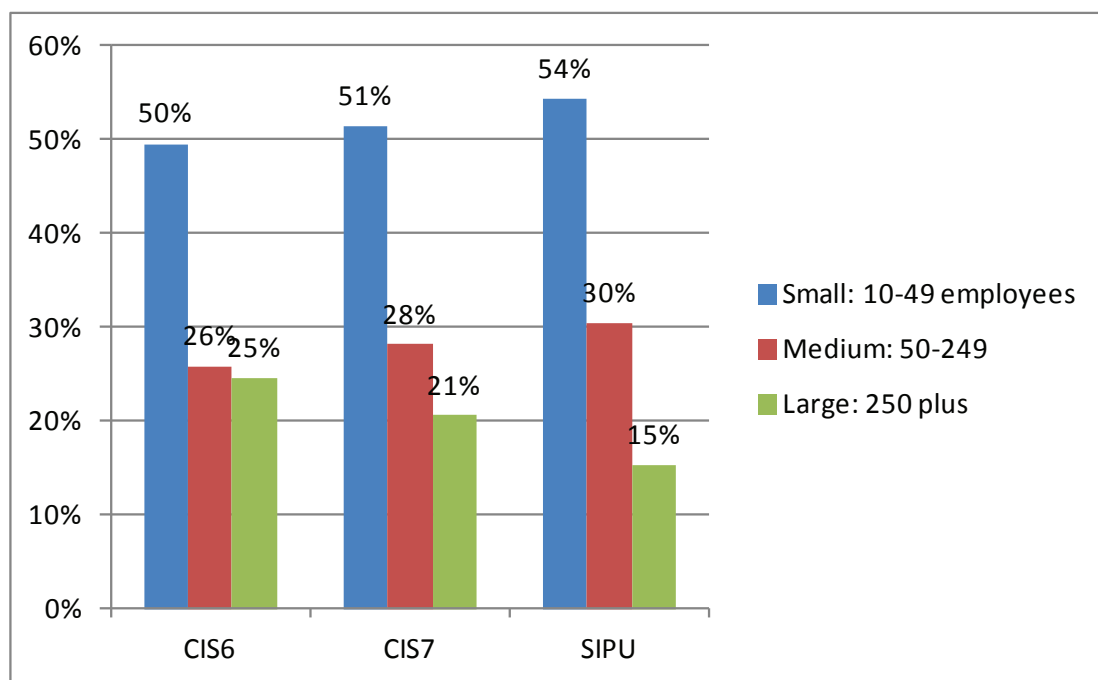
Second, we look at the proportion of innovators in the three samples. As Figure 2 below shows, SIPU over-sampled innovative firms, regardless whether they are product or process innovators vis-à-vis CIS6 and CIS7.

Figure 2: Distribution of innovators in SIPU, CIS6 and CIS7
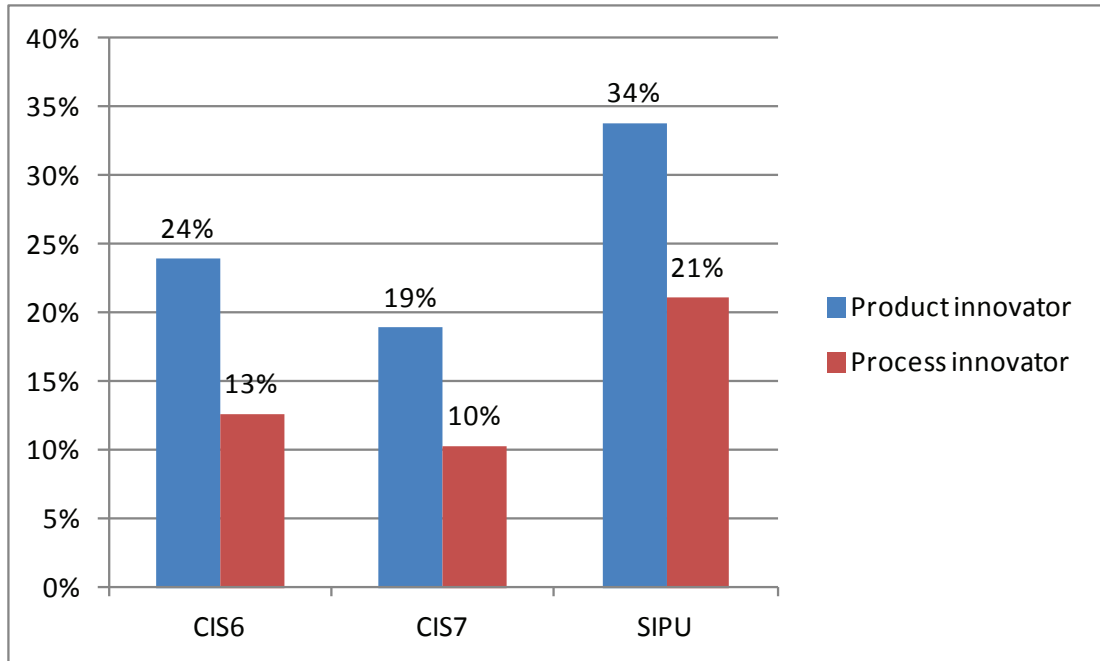
Lastly, we compare the industry composition of SIPU, CIS6 and CIS7 by two-digit industry. We can see from Figure 3 that SIPU over-sampled manufacture of fuels, chemicals, plastics metals and minerals; manufacture of electrical and optical equipment and R&D (natural sciences & engineering) in comparison to CIS6, but it under-sampled construction and hotels & restaurants. This finding is consistent with Figure 2 because the sectors that SIPU over-sampled in comparison to CIS6 are almost all R&D or innovation-intensive ones.

Figure 3: Distribution of achieved sample by industry in SIPU and CIS6
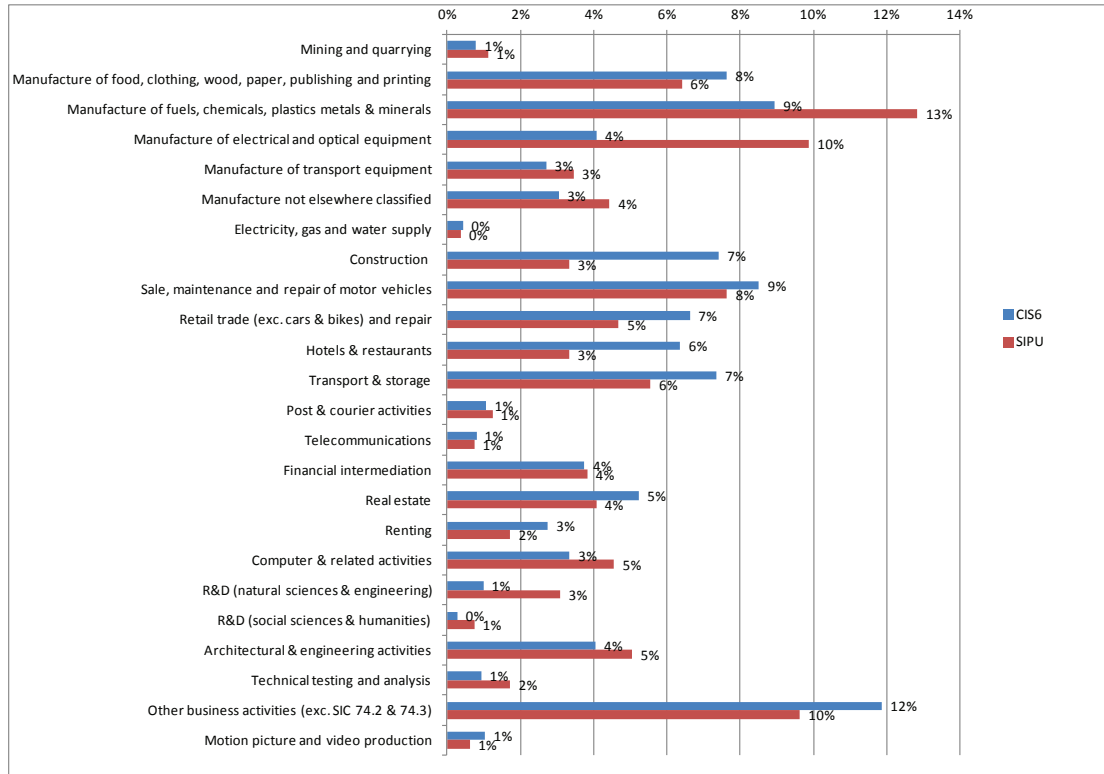
The industry classification used by CIS6 is the UK Standard Industrial Classification of Economic Activities (SIC) 2003. The classification used by CIS7 is different as it is based on UK SIC 2007. Comparing the SIPU and CIS7 samples, we conclude that SIPU oversampled manufacture of fuels, chemicals, plastics metals and minerals; manufacture of electrical and optical equipment; manufacture no elsewhere classified and computer and related activities/ICT, but under-sampled construction, wholesale trade, retail trade, hotels & restaurants and other service not elsewhere classified in comparison to CIS7 (see Figure 4 overleaf).

Figure 4: Distribution of achieved sample by industry in SIPU and CIS7
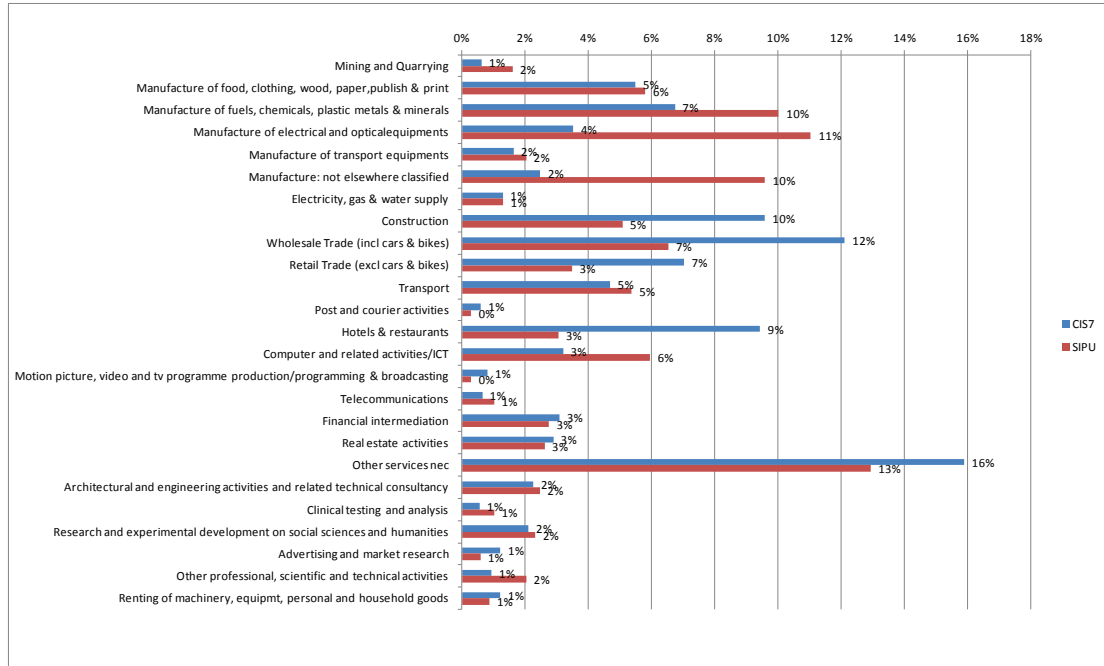
Appendix B: Variable definitions, data sources and descriptive statistics

Table I: Variables used in Tables 4 and 6

Variable name	Definition and note	Data source
Share in investment on technology in-licensing	Midpoint percentage of capital expenditure spent on acquiring external technology through licensing or purchase of R&D services in 2012 or most recent financial years. For example, if the firm ticks the answer "less than 1%", the value of the variable is .5%. If the firm ticks "between 1–5%", the value is 3%.	SIPU
Firm licensed in technology	Dummy. Its value equals 1 if the firm licensed technology from outside the business or enterprise group or purchased R&D services since November 2009, 0 otherwise.	SIPU
Firm licensed in technology for its most significant innovation	Dummy. Its value equals 1 if the firm acquired or licensed technology for its most significant innovation, 0 otherwise.	SIPU
True Innovator	Dummy. Its value equals to 1 if the firm introduced new-to-market products or used new-to-industry process, 0 otherwise.	CIS6
Imitator	Dummy. Its value equals to 1 if the firm introduced only new-to-firm products without introducing new-to-market products or using new-to-industry process, 0 otherwise.	CIS6
R&D expenditures	Ln(intramural R&D expenditure +1)	CIS6
Employment size	Ln(number of employee)	CIS6
Costs and financial constraints	Factor scores generated after factor analysis, representing that the firm's innovation activities were constrained by excessive perceived economic risk, direct innovation costs too high, cost of finance and availability of finance	CIS6
Resource constraints	Factor scores generated after factor analysis, representing that the firm's innovation activities were constrained by lack of qualified personnel, information on technology or markets or market being dominated by established businesses and uncertain demand for innovative goods or services	CIS6
Regulatory barriers	Factor scores generated after factor analysis, representing that the firm's innovation activities were constrained by UK government or EU regulations	CIS6
Innovation is new good	Dummy. Its value equals to 1 if the significant innovation is a new or improved good, 0 otherwise.	SIPU
Innovation is new service	Dummy. Its value equals to 1 if the significant innovation is a new or improved service, 0 otherwise.	SIPU
Innovation is new process	Dummy. Its value equals to 1 if the significant innovation is a new or improved production process, 0 otherwise.	SIPU

Number of imitative competitors	Midpoint number of competitors who have introduced competing goods or services. For example, if the firm ticks "1–3" as the number of competitors, the value of the variable is 2. If the firm ticks "4–5", the value is 4.5.	SIPU
Innovativeness of industry	Average of dummy of true innovator at 2-digit industry level	CIS6
Imitativeness of industry	Average of dummy of imitator at 2-digit industry level	CIS6
High-tech manufacture	Dummy. Its value equals to 1 if the firm belongs to the industries of aerospace (NACE 35.3), pharmaceuticals (24.4), computers, office machinery (30), electronics-communications (32) and scientific instruments (33), 0 otherwise. The classification is in line with that of OECD and Eurostat.	CIS6
Medium-high-tech manufacture	Dummy. Its value equals to 1 if the firm belongs to the industries of electrical machinery (31), motor vehicles (34), chemicals (excluding pharmaceuticals, 24 excluding 24.4), other transport equipment (35.2, 35.4 and 35.5) and non-electrical machinery (29), 0 otherwise.	CIS6
Medium-low-tech manufacture	Dummy. Its value equals to 1 if the firm belongs to the industries of coke, refined petroleum products and nuclear fuel (23), rubber and plastic products (25), non-metallic mineral products (26), shipbuilding (35.1), basic metals (27), and fabricated metal products (28), 0 otherwise.	CIS6
Low-tech manufacture	Dummy. Its value equals to 1 if the firm belongs to the industries of other manufacturing and recycling (36 and 37), wood, pulp, paper products, printing and publishing (20, 21 and 22), food, beverage and tobacco (15 and 16), and textile and clothing (17, 18 and 19), 0 otherwise.	CIS6
Knowledge-intensive services	Dummy. Its value equals to 1 if the firm belongs to the industries of water transport (61), air transport (62), post and telecommunications (64), financial intermediation, except insurance and pension funding (65), insurance and pension funding, except compulsory social security (66), activities auxiliary to financial intermediation (67), real estate activities (70), renting of machinery and equipment without operator and of personal and household goods (71), computer and related activities (72), research and development (73), other business activities (74), education (80), health and social work (85) and recreational, culture and sporting activities (92), 0 otherwise.	CIS6

Less-knowledge-intensive services	Dummy. Its value equals to sale and repair of motor vehicles (50), wholesale trade (51), retail trade (52), hotels and restaurants (55), land transport (60), auxiliary transport activities (63), public administration and defence (75), sewage and refuse disposal (90), activities of membership organization (91), other service activities (93), private households with employed persons (95) and extra-territorial organizations and bodies (99), 0 otherwise.	CIS6
Other business services	Dummy. Its value equals to 1 if the firm belongs to the industry of other business activities (74), 0 otherwise.	CIS6
Computer services	Dummy. Its value equals to 1 if the firm belongs to the industry of computer and related activities (72), 0 otherwise.	CIS6
Non-electrical machinery	Dummy. Its value equals to 1 if the firm belongs to the industry of non-electrical machinery (29), 0 otherwise.	CIS6
Real estate	Dummy. Its value equals to 1 if the firm belongs to the industry of real estate activities (70), 0 otherwise.	CIS6
Scientific instrument	Dummy. Its value equals to 1 if the firm belongs to the industry of scientific instruments (33), 0 otherwise.	CIS6
Furniture	Dummy. Its value equals to 1 if the firm belongs to the industry of furniture (36), 0 otherwise.	CIS6
R&D services	Dummy. Its value equals to 1 if the firm belongs to the industry of research and development (73), 0 otherwise.	CIS6
Fabricated metal	Dummy. Its value equals to 1 if the firm belongs to the industry of fabricated metal products (28), 0 otherwise.	CIS6
Electrical machinery	Dummy. Its value equals to 1 if the firm belongs to the industry of electrical machinery (31), 0 otherwise.	CIS6
Construction	Dummy. Its value equals to 1 if the firm belongs to the industry of construction (45), 0 otherwise.	CIS6

Table II: Correlation matrix for the variables in Table 4 and 6 (except for industry dummy)

	Variable	Mean	Std dev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Share in investment of technology in-licensing	.017	.079	1															
2	Firm licensed in technology	.21	.41	.44	1														
3	Firm licensed in technology for its most significant innovation	.18	.39	.21	.27	1													
4	True Innovator	.32	.47	.05	.17	-.10	1												
5	Imitator	.18	.39	.07	.06	.04	-.32	1											
6	R&D expenditures	1.9	2.2	.09	.30	-.04	.41	.08	1										
7	Employment size	3.9	1.4	.04	.13	.12	.02	-.05	.24	1									
8	Costs and financial constraints	0	1	.03	.03	.10	.13	.11	.18	-.02	1								
9	Resource constraints	0	1	.05	.04	.09	.13	.11	.11	-.09	.56	1							
10	Regulatory barriers	0	1	-.02	.00	.03	.07	.12	.08	-.01	.44	.42	1						
11	Innovation is new good	.62	.49	-.07	-.06	-.14	.11	-.03	.24	-.02	.02	-.04	-.08	1					
12	Innovation is new service	.40	.49	.11	.09	.17	-.04	.08	-.15	-.08	-.03	-.04	-.04	-.28	1				
13	Innovation is new process	.38	.49	.01	-.03	.14	.00	-.11	-.09	-.03	.04	.01	.01	-.29	.03	1			
14	Number of imitative competitors	2.3	2.7	.10	.05	.10	-.16	.13	-.13	-.03	-.07	-.15	-.09	-.07	.06	-.02	1		
15	Innovativeness of industry	.32	.18	.04	.13	-.10	.39	-.05	.37	-.02	.12	.13	.06	.16	-.29	-.03	-.10	1	
16	Imitativeness of industry	.18	.10	.05	.05	.03	-.09	.25	-.01	-.06	.04	.03	.01	-.01	.06	-.03	.24	-.22	1

Table III: Additional variables used in tables 8 and 9

Variable name	Definition and note	Data source
Whether the firm applied for a patent	Dummy. Its value equals 1 if the firm applied for a patent since November 2009, 0 otherwise.	SIPU
Percentage of innovation of the firm associated with patent applications	Midpoint percentage of innovations of the firm since November 2009 being associated with patent applications. For example, if the firm ticks the answer "less than 10%", the value of the variable is 5%. If the firm ticks "between 10–40%", the value is 25%.	SIPU
Whether the firm is an innovator	Dummy. Its value equals 1 if the firm introduced a product or process innovation since November 2009, 0 otherwise.	SIPU/CIS6
Whether the firm applied for a patent for its most significant innovation	Dummy. Its value equals 1 if the firm applied for a patent for its most significant innovation, 0 otherwise.	SIPU
Process innovator	Dummy. Its value equals to 1 if the firm introduced a process innovation since November 2009, 0 otherwise.	SIPU
Funding for innovation	Dummy. Its value equals to 1 if the firm received public financial support for innovation activities from UK local or regional authorities, UK central government or European Union institutions or programs, 0 otherwise.	CIS6

Table IV: Correlation matrix for the variables in Table 8 and 9 (except for industry dummy)

	Variable	Mean	Std dev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Firm applied for a patent	.17	.37	1																		
2	% innovation with patent applications	.045	.16	.66	1																	
3	firm is an innovator	.56	.50	.29	.19	1																
4	firm applied for a patent for its most significant innovation	.16	.37	.68	.59	-	1															
5	Process innovator	.21	.41	.16	.12	.61	-.05	1														
6	True innovator	.32	.47	.26	.24	.30	.20	.18	1													
7	Imitator	.18	.39	-.03	-.06	.05	-.12	.00	-.32	1												
8	R&D expenditures	1.9	2.2	.38	.25	.32	.25	.21	.41	.08	1											
9	Employment size	3.9	1.4	.13	.03	.03	.10	.06	.02	-.05	.24	1										
10	Innovation is new good	.62	.49	.25	.14	-.04	.23	-.17	.11	-.03	.24	-.02	1									
11	Innovation is new service	.40	.49	-.17	-.12	.05	-.09	.07	-.04	.08	-.15	-.08	-.28	1								
12	Innovation is new process	.38	.49	-.04	-.04	.04	-.09	.55	.00	-.11	-.09	-.03	-.29	.03	1							
13	Number of imitative competitors	2.3	2.7	-.07	-.03	.01	-.19	-.14	-.16	.13	-.13	-.03	-.07	.06	-.02	1						
14	Funding for innovation	.20	.40	.20	.15	.17	.13	.15	.22	.01	.31	.07	.06	-.06	.05	-.03	1					
15	Innovativeness of industry	.32	.18	.25	.16	.27	.14	.18	.39	-.05	.37	-.02	.16	-.29	-.03	-.10	.20	1				
16	Imitativeness of industry	.18	.10	-.01	.02	.03	-.02	.00	-.09	.25	-.01	-.06	-.01	.06	-.03	.24	-.06	-.22	1			
17	Costs and financial constraints	0	1	.03	.01	.07	.04	.09	.13	.11	.18	-.02	.02	-.03	.04	-.07	.11	.12	.04	1		
18	Resource constraints	0	1	.03	.06	.10	.03	.08	.13	.11	.11	-.09	-.04	-.04	.01	-.15	.10	.13	.03	.56	1	
19	Regulatory barriers	0	1	.02	-.01	.01	-.03	.04	.07	.12	.08	-.01	-.08	-.04	.01	-.09	.07	.06	.01	.44	.42	1