The Effects of the Emphasis of Firms' R&D on Patenting Behaviour

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Abstract

This paper provides new evidence of firms' patenting behaviour based upon a survey of R&D spenders operating in UK manufacturing. We have explored the relationship between firms' emphasis on either research or development and the way their patents are jointly organised. Although we have observed that neither the focus on research nor the focus on development affects in a different way how patent portfolios are constructed, we have found that the prominence of either activity impacts differently on firms' decision-making as to where, when, and what to patent. In particular, our findings indicate that the enforcement climate is more important to research-oriented firms than to development-oriented firms. Moreover, research-oriented firms need more time to take an invention to the marketplace, and hence make use of follow-up applications more extensively in an attempt to patent each attribute of the final invention. Our findings also revealed that patents of broader scope are more valuable to research-oriented firms than to development-oriented firms.

Introduction

Patents are commonly seen as impediments to the imitative dissipation of rents (RUMELT, 1987), and hence are considered isolating mechanisms that enhance firms' ability to sustain competitive advantage. Patents are also seen as mechanisms of appropriability (TEECE, 1986) whose true benefits are derived from their active use in reaping the returns from innovation (GRANSTRAND, 1999). For example, even if firms do not envisage that they will commercialize inventions they created, and hence were not supposed to patent these inventions, firms may enjoy the benefits of their innovative effort if they engage in cross-licensing. This practice allows them to have access to other knowledge assets that they would not have otherwise or would be much costly to create. In this case, patents play an important role to enable technology negotiations. Thus, there exist different reasons firms pursue patents.

Moreover, as Mansfield, Schwartz and Wagner (1981) observed, the degree of protection is variable. In fact, Levin, Klevorick, Nelson and Winter (1987) detected that the effectiveness of patents as protective devices varies across industrial sectors. As a result, firms may be more inclined to use other ways (e.g., secrecy) of protecting against copying the knowledge they create. Thus, one can observe a large variability in firms' propensities to patent even within individual industries (MANSFIELD, 1986).

Cohen, Goto, Nagata, Nelson and Walsh (2002) have detected that one explanation for firms' variability in patenting behaviour is the distribution of the control of technology in a particular industry. According to the authors, the relatively large number of patentable parts of an innovation implies that the proprietary control of these parts is distributed across firms. So, they need to establish technology negotiations more often than firms in industries whose final innovations comprise relatively few patentable elements.

Although Cohen et al. (2002) confirmed their suspicious to the US, they could not explain for Japan differences in patenting behaviour on the basis of the number of patentable parts of the final innovation. They concluded that country-specific differences in patent law may affect firms' patenting behaviour. This may also explain why Pitkethly (2001) found differences in the management of intellectual property between Japanese firms and British firms. In particular, he observed differences in the extent British firms and Japanese firms use licensing. The author detected that licensing has a larger stake in Japanese firms' intellectual property strategies than in British firms' intellectual property strategies.

The evidence above suggests that British firms might have patent behaviour closer to American firms than to Japanese ones. If this is so, the number of patentable elements of the final innovation may explain British firms' propensity to engage in technology negotiations. However, there has not been any effort to investigate whether the explanation presented by Cohen et al. (2002) for US firms' differences in patenting behaviour also holds for British firms. Even if it holds, it might not be a robust explanation insofar as the authors could not extrapolate that explanation to Japan. So, there might be something else that explains firms' differences in patenting behaviour. As patenting depends on the outcomes of Research and Development (R&D) we conjecture that R&D itself may provide a better explanation to firms' differences in patenting behaviour than does the number of patentable elements, but little is known about the patents-R&D relationship. Jaffe (1986), for example, detected that a higher ratio of patents per R&D outlay takes place in sectors where firms spend more in R&D. However, his work focused on the aggregate of R&D expenses rather than on the proportion of R&D spent on either research or development – also known as *R&D distribution*. Moreover, the author investigated the effects of R&D on the number of patents as opposed to the effects of R&D on the way firms organise their collection of patents (i.e., their patent portfolios).

Therefore, although the literature has drawn attention to the effectiveness of patents (e.g., MANSFIELD, 1986; LEVIN et al., 1987; HARABI, 1995) and the way patents are used (e.g., GRANSTRAND, 1999; PITKETHLY, 2001), as far as we know there has not been any attempt to empirically investigate how firms' R&D distribution affects their patenting behaviour. There is thus a vacuum in our knowledge that this piece of research primarily tries to fill. We follow the approach employed by Cohen et al. (2002) in which two groups of industries are compared according to the number of patentable elements in the final innovation, and we explore the relationship between the distribution of R&D expenses and the way patent portfolios are built. In particular, we focus on the decision-making re where, what, and when to patent. We surveyed manufacturing firms listed in the UK R&D Scoreboard, and after grouping firms according to Cohen et al. (2002) classification we compared both their R&D distribution and patenting behaviour.

The next section reviews the existing literature and states the research hypotheses tested. The third section describes the research method employed and the profile of the sample. The fourth section presents and discusses the empirical findings. The fifth section concludes.

Literature Review and Research Hypotheses

Inventions are ideas which permit to solve, in a practical way, technical problems (WIPO, 1997). Patents (or invention patents) concern technology-based inventions and give holders the right to maintain some control over the utilisation of the invention for a period of time. Originally established to incentivise individual inventors the patent system is now broadly used by corporations. Specifically, a patent is a legal title issued upon application which enables its holder (so called patentee) to enforce, for a limited time (20 years, in general) and geographical area, exclusive rights over an invention by excluding others from making, using or selling it without his/ her authorisation.

Patents are granted insofar as inventions meet the requisites for patentability: i) novelty (i.e., previously unknown), ii) inventive step (i.e., non-obvious to someone with ordinary skills in the technology area the invention fits in), and iii) industrial applicability; deadlines and fees also apply. However, there is an implicit cost to owning a patent because the knowledge to be patented must be disclosed to the world, and it is usually publicly disclosed before a patent is granted[1] (CORNISH, 1999).

Although successful innovating firms have used patents extensively (FREEMAN; SOETE, 1987), little is known about the implications of their investments in R&D to their patent behaviour. This is particular relevant because firms operating in more technology-based sectors are likely to be concerned about appropriability conditions. For those firms patents may be paramount for the economic success of their R&D laboratories (BROCKHOFF, 2003). In turn, firms operating in less R&D-intensive sectors may not value patents as much; reputation as well as know-how is perceived more important than patents as a source of sustainable competitive advantage (HALL, 1993). Moreover, as the returns to R&D depend on the amount of R&D spent *vis-à-vis* other firms (JAFFE, 1986), low returns can be expected if a firm spends less in R&D than its industry counterparts. As Jaffe (1986) observed, higher returns are achieved if a firm has relatively high R&D expenses whereas other firms in the same industry also have high R&D expenses. The author also detected that a higher ratio of patents per R&D outlay takes place in sectors where firms spend more in R&D. However, the author focused on total R&D outlays rather than on the distribution R&D expenses. Moreover, he investigated the effects of R&D on the number of patents as opposed to the way firms construct their patent portfolios, which may play an important role in increasing the returns from innovation as we shall explain later. We conjecture that the distribution of R&D investments might condition firms' decision making on patents. Larger investments in research than in development imply that the output of the former is likely to have a higher technological content as compared to the output of the latter. As a result firms may take different approaches when pursuing the proprietary control of their inventions, and this may help in explaining firms' patenting behaviour variability.

In fact, the empirical literature has documented that both effectiveness and use of patents vary in the marketplace. The latest endeavour in this area has shown that the distribution of the control of technology in a particular industry is a possible explanation (COHEN et al., 2002). The authors drew a comparison between two groups of industries ('discrete' versus 'complex') according to the number of patentable elements in the final innovation. Firms operating in industries where the number of patentable elements held by new commercialized products or processes is relatively high were assigned to the 'complex' industry. In turn, firms whose number of patentable elements held by new commercialized products or processes is relatively low were assigned to the 'discrete' industry. According to the authors, the relatively large number of patentable parts of an innovation implies that the proprietary control of these parts is distributed across firms. Thus, these firms need to establish technology negotiations more often than firms in industries whose final innovations comprise relatively few patentable elements. Hence firms in complex industries use patents mainly as 'bargaining chips' rather than protective devices against copying. Nevertheless, the authors could not find similar pattern in Japan, where Japanese firms from both complex and discrete industries use patents extensively in technology negotiations. Therefore, Cohen et al. (2002) concluded that firms' patenting behaviour variability is a result not only of the number of patentable parts of the final innovation but also of the country-specific patent environment. However, for reasons explained earlier in this paper, we suspect that the distribution of R&D expenses can also explain firms' patenting behaviour variability.

Pitkethly (2001) observed that Japanese firms seem to be more prone to take out patents to use in technology negotiations as compared to British firms. Comparing his results to those of Cohen et al. (2002), one may argue that British firms have patent behaviour closer to US firms than to Japanese ones. However, unless we systematically collect evidence to confirm (or not) this view we cannot say in advance that firms in British and American economies have the same approach to patents. If this is so, we are supposed to find that firms in the UK differ as to the use of patents according to the number of patentable parts of the final innovation. However, as Cohen et al. (2002) could not extrapolate their findings to Japan, we conjecture that an alternative explanation should be sought. Our proposition is that R&D distribution impacts on firms' patenting behaviour, and hence firms' decision-making re where, what, and when to patent should vary according to the focus of their innovative effort on either research or development. Nevertheless, the comparison between two groups of industries (complex and discrete) employed by Cohen et al. (2002) might be particularly useful because a similar approach to a different geographic area (i.e. UK) may support (or not) their findings. In addition, as another explanation is pursued in this paper the new findings may help in consolidating our understanding of firms' patenting behaviour. So, our first hypothesis regards the propensity of firms in complex industries to engage in technology negotiations, that is:

H_1: *The larger the number of patentable elements in the final innovation, the higher the likelihood that a firm will patent with the purpose of engaging in cross-licensing.*

However, as the chief purpose of this paper is to investigate the impact of R&D distribution on patenting behaviour, we should consider the effects of firms' emphasis on either research or development. For example, in general the output of research activities is farther from the market than is the output of development activities. Also, it might be harder to predict the impact of the output of research activities than to predict the impact of the output of development activities. Thus, research activities tend to be riskier than development activities. As a result, in order to justify the risks taken research-focused firms are expected to pursue stronger appropriability for longer periods. So, research-oriented firms are likely to present a more active patent policy (and possibly other appropriation-related actions) in comparison to development-oriented firms. We can then hypothesize the following:

H_2: *The proportion of R&D spent on research has a positive relationship to the extent that patents are pursued.*

At least in theory, firms are supposed to file patent applications in countries where they already do or plan to do business because in formulating their strategy they may have identified either where products will be sold or where growing and likely-to-be-profitable markets are located (KNIGHT, 1996). However, R&D distribution is also expected to impact firms' decision-making on patents because the technological content of the output of R&D may influence firms' perception as to length of protection an invention is supposed to have. Technologically sophisticated inventions are generally associated with higher risks than are inventions of lower technological content. So, research-oriented firms might take the enforcement climate of the geographic area more seriously during their decision-making process when compared to development-oriented firms. Thus, the third hypothesis follows:

H_3: *The proportion of R&D spent on research has a positive relationship to importance of the enforcement climate when choosing a place to patent.*

For most countries, as it is for the UK, the patent system was designed to be a winner-takes-all system. In particular, the UK patent law follows the first-to-file regime, in which a patent regarding the same invention is granted to the applicant who first files a patent (CORNISH, 1999). Thus, it seems logical that patent filings are applied for as early as possible (GRILICHES, 1990), as it is in fact observed in pharmaceuticals (GRABOWSKY; VERNON, 2000). However, research-oriented firms are likely to need more time to produce an innovation and have it ready to be commercialized, and this may impact the timing of the first filing because the output of research activities may not have immediate industrial applicability. So, research-oriented firms are expected to file a patent later than development-oriented firms, though we have no reason to believe so relative to their lead-time.

Whilst patenting can be a sporadic activity (GEROSKI; VAN REENEN; WALTERS, 1997), Granstrand (1999) detected that it is seldom a single event; further patent applications (i.e., follow-ups) may depend upon prior filings. According to Knight (1996) follow-ups can be used to increase the degree of excludability, and hence to provide a stronger protection. Moreover, patents derived from follow-up applications may 'extend' the term of protection of the first patent, especially when applications are made within 18 months of the priority date. This is so because such applications do not have to be inventive over an application that has not yet been published (MIELE, 2000). In turn, follow-up patent applications have a higher risk of being objected to by the patent examiner as to either the novelty or the non-obviousness requirement, and of not being granted because others have filed patent applications in between.

As the subsequent applications are supposed to be an 'improved version' of the first (priority) filing, they will partially incorporate the subject matter of this filing plus something new that will enable the patentee to get stronger or broader property rights. Therefore, when a product is launched it is likely that it will also have incorporated these improvements, and hence the use of follow-ups can enhance the protection. Insofar as the output of research activities is farther from the market and is likely to be perceived as originated from a riskier endeavour, research-oriented firms are supposed to use follow-ups more often than are development-oriented firms, especially because follow-ups can extend to a certain degree the period of enforcement. *Ceteris paribus* the longer the term of protection the longer the period a firm can recoup its expenses with R&D, and hence research-oriented firms should be particularly interested in this possibility for reasons presented elsewhere in this paper. Thus, we state the fourth hypothesis as:

H_4: *The proportion of R&D spent on research has a positive relationship to the number of follow-up applications.*

According to Granstrand (1999), although firms not always have well structured patent portfolios, they on occasions take out patents closely related to existing ones in an ordered fashion. For example, innovating firms can apply for patents that, if granted, will surround their own patents. This raises higher barriers to other firms circumvent the innovator's core invention due to the scope of the patent portfolio. And firms sometimes can hold surrounding patents to the extent that the costs of inventing around may become prohibitive. Moreover, even if firms do not apply for patents with the purpose of surrounding their own existing patents, they may file patent applications in order to deliberately surround patents held by rivals (or other inventors). Eventually that practice leads to technology negotiations if infringements are alleged and the costs of defending property rights in court are much higher than the perceived benefits of enforcement (KNIGHT, 1996).

Based on the paper by Cohen et al. (2002), where the authors found US firms in the complex industry more likely to engage in cross-licensing, one would expect that a firm's behaviour of surrounding other firms' patents would be more likely to be found in the complex industry than in the discrete industry. If R&D distribution explains patenting behaviour one could expect that development-oriented firms are likely to draw more attention to surrounding their own patents than are research-oriented firms since in general the innovative output of the former has a lower inventive step than the innovative output of the latter. Thus, development-oriented firms are expected to have more difficulties in proving validity of what they claim, and hence their ability to hold a broader patent might be low when compared to the ability of research-oriented firms. As a result, patent portfolios of development-oriented firms are likely to be more reliant upon patents surrounding firms' own patents. So, the fifth hypothesis stated is the following:

H_5: *The proportion of R&D spent on development has a positive relationship to the proportion of the patent portfolio filed with the purpose of surrounding patent holder's own existing patents.*

Conversely, due to the reasons presented above research-oriented firms are expected to be able to hold patents which protect many aspects of the original invention. In this case, an array of technical solutions would be protected by a smaller number of patents. As these patents cover a broader technical area, they are not taken out with the purpose of surrounding other patents. So, we can hypothesize the following:

H_6: *The proportion of R&D spent on research has a positive relationship to the proportion of the patent portfolio filed with the purpose of covering an array of technical solutions.*

In covering a larger variety of technical solutions, the scope of patents held by research-oriented firms tends to be broader than the scope of patents held by development-oriented firms. So, research-oriented firms are more likely to hold broader patents than are development-oriented firms. In addition, a larger patent scope enhances the degree to which patent holders can exclude others from a technology area (MIELE, 2000). Thus, one can argue that the broader the scope of a patent the higher its value. In fact, Lerner (1994) identified a positive relationship between scope and market value for biotech companies. Therefore, in comparison to development-oriented firms, research-oriented firms should hold more valuable patents of broad scope. So, the last hypothesis this piece of work will test is:

H_7: *The proportion of R&D spent on research has a positive relationship to the perceived value of broader patents.*

Research Method

In order to collect systematic evidence on firms' R&D profile and patent behaviour we surveyed all manufacturing firms listed in the UK Department of Trade and Industry *R&D Scoreboard*. This research strategy for data collection is generally used to discover facts about a population and/ or to identify probable causes of behaviour or attitudes (BUCKINGHAM; SAUNDERS, 2004). Although other sample frame could be used, such as a list of patent applicants in the UK Patent Office, it would be hard to test the representativeness of the final sample due to the lack of critical information (e.g. R&D expenses). We also focused on R&D spenders since the literature reports they are more likely to apply for patents than are non-R&D spenders (e.g., Scherer, 1983).

The UK *R&D Scoreboard* is produced yearly by the UK Department of Trade and Industry. It contains information on R&D investment, capital expenditure (Capex), sales, profits, employee numbers, and growth of these quantities for UK and international firms, and the information is extracted directly from firms' annual reports and accounts. At the time of the research the UK *R&D Scoreboard* comprised 597 UK-based firms. Our target population was restricted to 395 firms, which were manufacturing firms in operation (i.e. neither in insolvency nor in liquidation) and that did not take part in the pilot-test phase (six firms were used for that purpose); questionnaires were sent to all of them.

At the end of six months of data collection (4 waves of follow-ups were used) the rate of return presented a stationary pattern. Therefore, no further effort was made to collect more information. Seventy two negative responses were received, and seventeen firms were not reached (returned mails). A total of 118 replies were received out of 395 contacts attempted, for which 46 questionnaires were classified as usable, which corresponds to an effective response rate of 12%. We checked for representativeness of our sample by comparing average R&D expenses, available from the UK *R&D Scoreboard*. A comparison between mean scores of the two groups was carried out. The t-test showed that the null hypothesis of equal means could not be rejected ($|t| = 0.18$, $p = .8616$). That is, the average R&D expense of respondents does not significantly statistically differ from the average R&D expense of non-respondents. This result lends support to the idea that the sample is representative of the survey population, though not necessarily representative of all UK manufacturing. Other known characteristics were also explored, namely sales ($|t| = 0.97$, $p = .3384$), profits ($|t| = 0.64$, $p = .5270$), and R&D expenses per employee ($|t| = 1.10$, $p = .2788$). They corroborate the initial findings, i.e., that there exists a high degree of likeness between respondents and non-respondents[2]. Despite the low rate of return achieved, the sample seems to be representative of firms listed in the UK *R&D Scoreboard*, at least for the attributes examined. The sample drawn from the UK *R&D Scoreboard* has the profile described in Table 1. The average size of the sample firms is 8305 employees.

Table 1: Profile of the Scoreboard and Sample Firms

	source	mean	s.e.	median	min	max
R&D (£ M)	Scoreboard	32.57	9.07	2.8	0.02	2526
	Sample	35.13	12.80	5.05	0.28	371
Sales (£ M)	Scoreboard	1339	378	116.5	0	99843
	Sample	3639	2610	70.5	0	99118
Profits (£ M)	Scoreboard	152	57	5	-1113	16678
	Sample	348	335	4	-1113	12328
R&D/ emp.	Scoreboard	14.11	1.76	2.7	0.1	433.3
(£ 000's)	Sample)	22.01	7.76	5.5	0.2	231.1

In order to make our analysis comparable, at least on the basis of industry categories, to the analysis undertaken by Cohen et al. (2002), our comparison of appropriability conditions follows their approach. Thus, our comparison is between two groups of industries ('discrete' versus 'complex') according to the number of patentable elements in the final innovation. Firms operating in industries where the number of patentable elements held by new commercialized products or processes is relatively high were assigned to the 'complex' industry. In turn, firms whose number of patentable elements held by new commercialized products or processes is relatively low were assigned to the 'discrete' industry. Sectors assigned to complex industries were: aerospace, automobiles, construction and building, diversified industrials, electronic and electrical, engineering and machinery, health, household goods, IT hardware, media and photography, software and IT services, and support services. In turn, beverages, chemicals, food processors, forestry and papers, oil and gas, packaging, personal care, pharmaceuticals, steel and metals, and tobacco were assigned to the discrete category. The industrial sectors with the largest number of participants are pharmaceuticals, and engineering and machinery (15.22% each)[3].

On average 4% of firms' R&D expenses were reported to be allocated to basic research, 37% to applied research 43% to design and/or development, and 16% to technical services. Overall, expenses on applied research and design and/or development do not statistically differ ($|t| = 1.14$, $p = .2573$). Although the sample average share of R&D expenses allocated to applied research[4] and design/ development[5] are (statistically) about the same (40%), our results suggest inter-industry variation. Discrete firms said they allocate more resources to applied research whereas complex firms reported to spend more on development (or design) activities. Firms in the discrete industry invest on average 44% of that budget in applied research, while firms in the complex industry invest 29% in similar activity ($|t| = 1.96$, $p = .0508$). Design and/or development account for around 52% of R&D expenses in the complex industry and around 36% in the discrete industry ($|t| = 2.09$, $p = .0436$).

Although our comparison is not across standard industrial sectors, the groups of industries compared were purposefully designed in order to investigate whether R&D distribution may also explain inter-industry differences in patenting behaviour rather than simply relying upon the number of patentable elements in the final innovation. The next section tests the hypotheses stated earlier and discusses the results.

Empirical Findings

Previous survey-based studies have attempted to capture the relative importance of patents by asking either how effective patents are, or for what share of innovations patents are effective in protecting competitive advantage. Although this is certainly of managerial concern, this is unclear as to how the decision-making on the construction of patent portfolios affects their effectiveness. Patent portfolios are not produced only on the basis of a decision to file (or not) an application regarding a particular invention. Several decisions are taken, amongst them at what time a patent will be applied for, where a patent application will be filed, and what is going to be patented (i.e., general and specific attributes of the invention). Moreover, as patents are likely to be dependent on the outcomes of R&D activities, firms' patenting behaviour might be explained at least in part by their own R&D behaviour, but earlier empirical effort has devoted little attention to the patents-R&D relationship. To date we have not come across any study presenting the effects of R&D distribution on firms' patenting behaviour, which our survey explores.

The existing literature (e.g., HALL; ZIEDONIS, 2001; COHEN et al., 2002) suggests that firms in the complex industry are more likely to be mutually dependent than are firms in the discrete industry. As each agent in the complex industry controls only part of the final innovation, they often have to reach agreements for the innovation to be commercialized. Our survey also explores this avenue. In examining that mutual dependence, firms were asked to report the importance (over the last three years) of securing property rights over inventions linked to other firms' inventions[6]. The findings indicate that firms in complex and discrete industries do not differ in their use of patents to provide access to other firms' inventions (chi^2 [1d.f.] = 0.58, $p = .4460$).

Firms were also asked to identify the proportion of their inventions that was a result of deliberately circumventing someone else's patents[7]. However, deliberately inventing around other firms' patents was not detected to be a common practice adopted by firms in either industry[8], and no (statistically) significant difference between industries was observed for product ($|t| = 0.02$, $p = .9872$) or process ($|t| = 1.26$, $p = .2167$) inventions. In addition, firms were asked to report the percentage of their patent portfolios corresponding to patents consciously designed to surround someone else's patents in order to lead to a deal. Neither firms in the complex industry nor firms in the discrete industry seem to devote much attention to that practice. The average share of their patent portfolio built for that purpose is about 8% for both industries ($|t| = 0.07$, $p = .9446$). Our results thus indicate that cross-licensing is not commonly used by our sample firms[9]. And we found no evidence that firms in the complex industry use their patents more extensively to access other firms' inventions than do firms in the discrete industry. Therefore, our sample rejects hypothesis one that the larger the number of patentable elements in the final innovation, the higher the likelihood that a firm will patent with the purpose of engaging in cross-licensing.

We also examined the extent that firms pursue patents. Firms were asked, for example, whether (or not) they had any annual numerical target for patent filings in the last calendar year. About 17% answered yes, with an average target of 49 patent applications[10] per year. Our sample firms reported to hold an average portfolio of 650 patents, 110 of which are registered in the UK. No significant (statistically) difference was found between the size of the patent portfolio of firms in discrete and complex industries. Neither at global level ($|t| = 0.55$, $p = .5847$) nor at UK level ($|t| = 0.72$, $p = .4815$). Our survey data thus suggest that inter-industry differences in the distribution of R&D expenses may not (statistically) significantly impact on total patent numbers. This is also supported by earlier evidence (last section) that total R&D expenses do not statistically differ across-industries.

Firms were asked what best could describe their attitudes with respect to their inventions. Four alternatives were given: i) they do not patent anything, ii) they patent what may be used or market by their company, iii) they patent what may be used or marketed by their company or by their main competitors, and iv) they patent nearly everything. The distribution is shown in Table 2. Although small or medium-sized firms are expected to suffer more from financial constraints, they often reported that patent nearly everything. One justification for their attitude is that they are the most R&D intensive firms[11]. This reinforces our suspicion as to the impact of R&D on patenting behaviour.

Table 2: Patent Policies by Type of Innovation

Patent Policy	**% of Respondents**	
	products	**processes**
Do not patent anything	6.52	17.07
Patent what may be used or marketed by own company	26.09	34.15
Patent what may be used or marketed by own company or by main competitors	47.83	36.59
Patent nearly everything	19.57	12.20

The distribution of firms' policies was compared by industry and type of invention. Overall, firms' policies do not seem to differ that much between complex and discrete industries. The policy of pursuing patent protection for nearly every product invention seems to be more often pursued by firms in the discrete industry (27.3% vs. 12.5%). With respect to process inventions it seems that other firms' potential interest is more often taken into account by firms in the discrete industry (50.0% vs. 23.8%). Firms in the complex industry seem to draw more attention to process inventions that can fulfil their own market interests rather than competitors' (42.9% vs. 25.0%). Thus, our findings indicate that a more active patent pursuit is observed when research as opposed to development is undertaken more extensively, and thus suggest that hypothesis two, that the proportion of R&D spent on research has a positive relationship to the extent that patents are pursued, should not be refuted.

Yet, patent numbers do not necessarily reflect the strength of patent portfolios either. Nor do they reflect the rationale behind patent applications. Our survey explores the latter because even if the extensive role played by patents is recognized in the specialized literature (BOSWORTH; WEBSTER, 2005, SCOTCHMER, 2005), few attempts have been made to address the rationale behind firms' pursuit of patents, especially regarding where, when and what to patent. From the above one can notice that research-oriented firms are keener on patents for appropriation and hence should be more concerned about the enforcement climate where they file patent applications, especially in foreign countries. Our survey asked firms to report the proportion of filings abroad that was motivated by a series of factors[12]. The findings suggest that the chief reason leading firms to apply for patents abroad is their current or future presence in the market (74.5%). Our results are in line with what Bertin and Wyatt (1988) found for multinationals only. Their survey detected that the main reason driving the choice of the country by multinationals was the existing or the prospect of business in the country.

Our results also suggest that a relatively (50.5%) large proportion of filings abroad happens because of the presence of main competitors in the market. The legal environment does not account for a large part (33%) but, in line with our suspicion, this reason is the only one that significantly (statistically) differs across industries ($|t| = 2.34$, $p = .0253$). Other differences between discrete and complex firms in reasons to file abroad are much weaker (statistically). For example, current or foreseeable participation in the market ($|t| = 1.93$, $p = .0618$) and/ or the size of it ($|t| = 1.80$, $p = .0804$) are significant only at levels above 5%. Moreover, no other indication of differences between the two industries was found. As discrete firms in our sample place more emphasis on research than on development, our results indicate that we should not reject the hypothesis (three) that the proportion of R&D spent on research has a positive relationship to importance of the enforcement climate when choosing a place to patent.

Although territorial coverage limits the scope of property rights, scope is also affected by the time a patent is applied for. If, for example, a firm applies for a patent after another firm has applied for, and both applications encompass the same, or nearly the same, invention, either the later applicant will not hold a patent or she will hold a very narrow patent. Timing is therefore an important element of the patenting process (GRABOWSKY; VERNON, 2000). Yet, the patenting process allows the use of further applications that replace the priority (first) filing or complement it depending on either the purpose or the timing of the follow-ups (CORNISH, 1999). Assuming that research-oriented firms create inventions that are farther from the marketplace than are inventions created by development-oriented firms, the former is more likely to use follow-ups because it has a longer time to do so.

Our survey asked firms how long it takes approximately for the main output of their R&D activities (i.e., product or process inventions) to be generated and be ready for commercialization[13]. Moreover, respondents were asked to report how far from market introduction is a corresponding patent application filed. Confirming our suspicion, firms in the complex industry (development-oriented) were found to develop their inventions quicker than firms in the discrete industry (research-oriented). While in the former it takes about 2.1 years, in the latter the innovation development time is around 4.6 years[14].

If discrete firms apply for patents later than complex firms, they might carry out more experimentation and hence have more information available to substantiate the claims in their applications. Nevertheless, our results do not support this idea. Our survey results indicate that firms in complex and discrete industries tend to apply for patents, on average, at about the same moment (proportionately) along the innovation process, that is, around one third of its total length. More specifically, patents were reported to be filed after the corresponding invention has gone through 33% (complex) or 35% (discrete) of the innovation process[15].

Filings that incorporate improvements on the initial conceptual idea and that are applied for before the invention is introduced/ used are defined as follow-ups. Our survey asked how many of them are filed per priority filing[16]. Firms reported how many follow-up applications are filed with respect to both product and process inventions; Table 3 and Table 4 present the results by industry category. According to our survey, follow-up applications were not found to be the norm[17] in UK manufacturing. Although the number of follow-ups was not found to vary according to the type of innovation, the findings indicate that the use of follow-ups varies between the two groups of industries studied. The results also indicate that in both industries the most valuable inventions seem to have more follow-ups than typical inventions.

Table 3: Number of Follow-ups Used by Complex and Discrete Firms for Their Typical and Most Valuable Product Inventions (as percentage of respondents assigning each category)

Number of follow-ups	Product invention			
	complex		discrete	
	typical	most valuable	typical	most valuable
From 1 to 2	82	33	50	30
From 3 to 4	9	56	42	40
From 5 to 6	9	11	0	0
From 7 to 8	0	0	0	10
From 9 to 10	0	0	8	10
More than 10	0	0	0	10

Our survey detected that the complex industry (development-based) accounts for a smaller number of follow-ups when compared to the discrete industry (research-based). In pursuing more follow-ups, firms in the discrete industry, which place more emphasis on research, seem to be more interested in a larger breadth of intellectual property rights. Thus, we should not contest hypothesis four that the proportion of R&D spent on research has a positive relationship to the number of follow-ups.

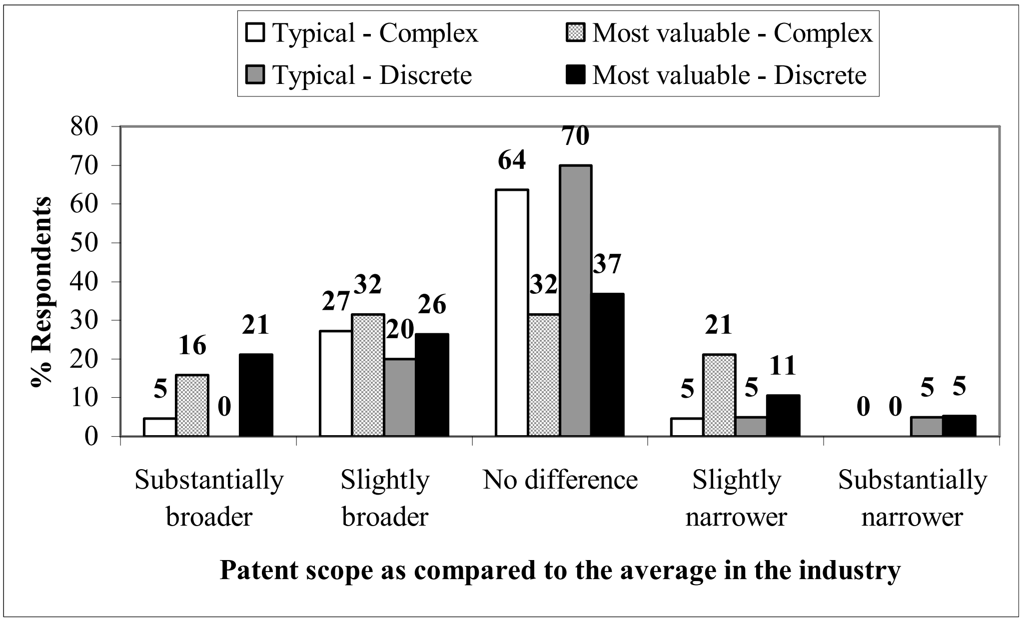
Table 4: Number of Follow-ups Used by Complex and Discrete Firms for Their Typical and Most Valuable Process Inventions (as percentage of respondents assigning each category)

Number of follow-ups	Process invention			
	complex		discrete	
	typical	most valuable	typical	most valuable
From 1 to 2	80	50	60	11
From 3 to 4	20	50	30	44
From 5 to 6	0	0	0	11
From 7 to 8	0	0	0	22
From 9 to 10	0	0	10	0
More than 10	0	0	0	11

Although patent offices rule the extent to which intellectual property rights are granted, patent scope is determined to a large extent by the technological content of the patent itself. So, the scope of protection is also determined by the inventors' own actions either by filing follow-up applications closely related to the priority filing or by filing broader patent applications. This piece of research explored the impact of R&D distribution not only on the former but also on the latter. Our survey asked the proportion of the patent portfolio that is characterized by patents with broad and narrow scope[18]. Respondents answered that they perceive their patent portfolio to comprise mainly patents with broad scope (43%). However, the proportion of narrow patents (34%) does not statistically differ from broad patents ($|t| = 1.45$, $p = .1498$). Moreover, the average proportion of narrow and broad patents do not differ by industry either; $|t| = 0.85$, $p = .4017$, and $|t| = 0.94$, $p = .3535$, respectively. Although R&D distribution does not seem to interfere in the average scope of firms' patent portfolios, it might impact on the most valuable patents.

To understand how the scope changes by industry when comparing an average patent to the most valuable one, respondents were asked to report the scope of most of their patents as well as the scope that best describes their most valuable patents as compared to the average in their industry. They were given five alternatives: substantially broader, slightly broader, no difference, slightly narrower, and substantially narrower. The results indicate that patents with narrow scope are more likely to be valuable in the complex industry than in the discrete industry. In turn, firms in the discrete industry seem to put more value on patents with scope broader than the average (Figure 1). These results suggest that hypothesis seven, that the proportion of R&D spent on research has a positive relationship to the perceived value of broader patents, should not be rejected.

Figure 1: Contrasting Patent Scope Between Typical and Most Valuable Patents by Industry



So far our findings have confirmed that R&D distribution may affect firms' decision-making on patenting. One could argue that size effects as opposed to R&D distribution lead to inter-industry variability. However, we have examined statistically that size and industry are independent, and hence the patenting behaviour variability is indeed more likely to be a result of different R&D distributions. Decisions regarding where to patent, when to patent, and what to patent lead to the construction of patent portfolios whose design can be purposefully elaborated to strengthen firms' appropriability capacity. Certainly not all patent portfolios are consciously designed (or not all patents fit into the wanted design). Neither do patent portfolios have a single structure. So, in order to elucidate the structure of firms' patent portfolios, we asked firms about the composition of their patent portfolios, that is, the percentage of the portfolio that fits into one or more of the categories presented (Table 5).

Table 5: Patent Portfolio Designs

Design	mean	s.e.
Patents that surround their own patent	22.13	3.29
Patents covering an array of technical solutions	19.13	3.29
Patents with prohibitive invent-around costs	16.13	2.88
Unordered patents	15.75	2.50
Patents that surround patents held by other inventors	9.75	1.33

In examining whether the structure of patent portfolios varies according to firms' patent policies presented earlier in Table 2, we found no difference[19]. Our results confirm that it is very unlikely that firms' patent portfolios are structured in a single way; a combination of designs exists. Moreover, Table 5 suggests that innovators' major concern is to preclude others from commercializing their inventions. Their effort to induce others to deal on the basis of overlapping patents seems smaller than the other possibilities. In fact, the average proportion of patents that are developed by surrounding someone else's patents statistically differs from the other categories[20]. So, our findings regarding the design of patent portfolios reinforce that firms' attempt to induce other firms to engage in technology negotiations is not a major concern, at least in the UK.

Our results also indicate that the majority of firms' patent portfolios consist of patents surrounding their own patents and patents covering an array of technical solutions. Both the former ('surrounding') and the latter ('fencing') approaches are to some extent a result of continuous patenting. We detected earlier that continuous patenting is more often found in the discrete industry due to the nature of R&D investments, whose focus on research leads to longer periods to create an invention and to have it ready to be marketed. So, one could argue the opposite to hypothesis five that states that the proportion of R&D spent on development has a positive relationship to the proportion of the patent portfolio filed with the purpose of surrounding patent holder's own existing patents. That is, research-oriented firms should use the 'surrounding' approach more frequently. However, our prior results also revealed that in comparison to the most valuable inventions of development-oriented firms, the most valuable inventions of research-oriented firms tend to be protected by broader patents. This could mean that the share of research-oriented firms' patent portfolios that accounts for patents covering an array of technical solutions should be larger than the share of development-oriented firms' patent portfolios that accounts for the same type of patents (hypothesis six).

In order to investigate whether the rationale behind both hypotheses (five and six) are correct, we examined how the design of patent portfolios varies across industries. But we found no significant (statistically) difference, and hence both hypotheses should be refuted. Therefore, R&D distribution does not seem to affect the structure of patent portfolios. Although this seems contrary to our suspicion on the effects of R&D on patenting, the results are in line with prior arguments that patenting can be part of firms' strategies (GRANSTRAND, 1999; GRAHAM; SOMAYA, 2004), which our results seem to corroborate and also to indicate that the strategic role of patents is beyond an information transmission mechanism (ERNST, 1998). As the design of patent portfolios can take various forms, firms can build their patent portfolios strategically and thus R&D distribution can explain only part of firms' patenting behaviour. Nevertheless, our findings also indicate that the benefits of a stronger patent protection seem to be positively related to a higher degree of technology content of an innovation.

Conclusions

This study empirically explores how R&D distribution affects patenting behaviour. A new survey of UK R&D-based firms was designed and administered. Our findings thus derive from responses to a new questionnaire sent to manufacturing firms listed in the UK *R&D Scoreboard*. In order to allow comparability between our investigation and the study carried out by Cohen et al. (2002), we have followed their approach as to cluster firms according to the number of patentable elements in the final innovation, which the authors found to affect firms' patenting behaviour. One of their salient results was that, at least in the US, the relatively large number of patentable parts of an innovation demanded firms (complex) to establish technology negotiations more often than firms in industries whose final innovations comprised relatively few patentable elements (discrete). We, however, found that this does not apply to our sample firms in the UK. However, we detected that firms' emphasis on either research or development may explain differences in the way firms respond to where, when and what they patent.

Discrete firms of our survey sample spend more on research activities than on development activities. Complex firms, in turn, place more emphasis on development. Due to the nature of R&D activities the former is likely to produce innovations of higher technological content and of higher risks and uncertainties than the latter. In fact, our results confirmed that research-oriented firms differ from development-oriented firms in what concerns i) the attention they draw to the enforcement climate, ii) the number of follow-ups they file, iii) and the scope of their patents regarding their most valuable inventions. In particular, our findings indicate that the enforcement climate is more important to research-oriented firms than to development-oriented firms. Moreover, research-oriented firms need more time to take an invention to the marketplace, and hence make use of follow-up applications more extensively in an attempt to patent each attribute of the final invention. Our findings also revealed that patents of broader scope are more valuable to research-oriented firms than to development-oriented firms.

Although R&D distribution does not fully explain how patent portfolios are organised it explains differences in the decision-making on patenting that directly impact on the extent patents work as isolating mechanisms. A few implications of these results are in order. From a theoretical perspective the findings indicate that the role played by patents as isolating mechanisms depends to a large extent on the appropriability regime firms operate, that is from both the legal framework and the nature of technology. Although the isolating benefits patents provide depend on firms' ability to organize their patents, patent deployment is to a certain degree contingent on the technological content of the innovation. As the effectiveness of patents is related to both the strength of the legal framework and the degree of novelty of the innovation, the use of patents as isolating mechanisms seems to be more beneficial for those firms that are able to produce more sophisticated knowledge.

From a managerial perspective one implication of our study is that firms should not neglect how their R&D budget is allocated because the nature of the activity emphasized may have consequences to firms' patenting behaviour. Our findings indicate that although patent portfolios can be built to some extent purposefully, and this may impact on the strength of firms' proprietary control of technology, the benefits of a stronger protection seem to be positively related to a higher degree of technology content of an innovation. As a result, firms dealing with less sophisticated knowledge to produce their innovations should capture more value from their innovative effort if they place more emphasis on other appropriability mechanisms than they place on patents.

Although our findings suggest the distribution of R&D expenses explains differences in patenting behaviour, they were reliant upon only two groups of industries, according to the number of patentable elements in the final innovation. This is certainly one limitation of this research, needless to mention the sample size. Thus, further investigation on the effects of the distribution of R&D expenses across industrial sectors is needed. In addition, an investigation of the effects of R&D distribution on why (or not) firms patent is welcome.

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[1] At most 18 months after first filing a patent application. The US only started to adopt early disclosure (i.e., before a patent is issued) in 2000.

[2] The assumption of equal variance was relaxed, according to Bartlett's test.

[3] We also detected that in examining industry differences one should not be concerned about size differences because the null hypothesis of independence could not be rejected at 5% either by Pearson chi-square (chi^2=11.14 [6 d.f.], *p* = .084) or by Fisher's exact test (*p* = .070).

[4] Defined as scientific or engineering research with a specific commercial objective.

[5] Defined as technical activity translating research findings into products or processes.

[6] This question relied upon a likert-type scale from 1 (not at all important) to 6 (very important).

[7] Six response categories were given: 1) less than 10%, 2) from 10% to 30%, 3) from 31% to 50%, 4) from 51% to 70%, 5) from 71% to 90%, and 6) more than 90%. The results were calculated by using the mid-points of each category.

[8] Around 10% of inventions are produced in that way.

[9] Our survey also explored why and why not firms apply for patents. One particular result gives further support to the above. We found that induced cross-licensing exerts only a marginal influence on the decision not to apply for a patent. The percentages of product (|t| = 0.50, *p* = .6206) and process (|t| = 0.55, *p* = .5858) inventions that are not patented because of the risks of an induced deal were not found to differ between discrete and complex industries.

[10] Range from 3 to 120.

[11] The proportion of firms' patent policies by firm size band and the average R&D intensity by patent policy can be provided upon request.

[12] i) current or foreseeable participation, ii) size, iii) presence of competitors, iv) enforcement climate, v) world-class technical/scientific competence, vi) territorial proximity, and vii) lower costs.

[13] On average, an innovation was said to take 3.3 years (s.e.=0.46) to be developed and ready to be traded.

[14] They differ statistically (|t| = 2.12, *p* = .0421).

[15] On average a patent was said to be applied for about 2.1 years (s.e.=0.39) before the invention is ready to be in the marketplace.

[16] The first application claiming priority on the invention.

[17] Due to the number of respondents that left the questions blank (about half of the respondents).

[18] The scale was 1) less than 10%, 2) from 10% to 30%, 3) from 31% to 50%, 4) from 51% to 70%, 5) from 71% to 90%, and 6) more than 90%. Their mid-points were used to compute the average.

[19] Analysis of variance was used to check for statistical differences across patent policies in the mean percentage of portfolio characterized by a particular type of design (Sheskin, 2004).

[20] Differences between average share of own patents surrounding third parties' patents and average share of other types of design provided the following statistics from the bottom to the top of Table 5: |t| = 2.12, *p* = .0370; |t| = 2.01, *p* = .0481; |t| = 2.64, *p* = .0100; and |t| = 3.49, *p* = .0008.