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Abstract

Prior literature has revealed firms' motivations to pursue patents but there has not been any attempt to detect whether differences in the distribution of R&D expenses affects firms' perception as to why (or not) they apply for patents. This paper thus reports the results of a new survey on patenting carried out in the UK and which investigates whether firms' motivations to patent differ with respect to their emphasis on either research or development. Our survey provides several insights into firms' motivations to file (or not) patents. Our results suggest that when firms focus more on research than on development patents become more relevant to increase returns from innovation. Moreover, research-oriented firms pursue patents with the purpose of having access to a foreign market more often than do development-oriented firms. Nevertheless, the former is more frequently hampered from patenting due to the amount of information disclosed than is the latter. In turn, development-oriented firms take out patents with the purpose of increasing competitors' inventing around costs more regularly than do research-oriented firms. Our results also revealed that development-oriented firms are more concerned about the ease with which their patents can be invented around and not being valid if contested.

Keywords: R&D, patents, innovation

Introduction

Although prior studies have detected various reasons why firms pursue patents, there has not been any attempt to investigate whether the proportion of R&D outlays spent on either research activities or development activities (i.e. R&D distribution) impacts on firms' motivations to patent. This paper, thus, advances the existing literature by looking at whether the distribution of R&D expenses has a role to play in explaining differences in firms' incentives to patent.

Earlier empirical studies (e.g. LEVIN; KLEVORICK; NELSON; WINTER, 1987; HARABI, 1995; COHEN; GOTO; NAGATA; NELSON; WALSH, 2002) have focused on the effectiveness of patents as a means of appropriating the returns from innovation. Those studies have found that the effectiveness of patents varies across industrial sectors. Although the likelihood of applying for patents increases with an increase in the perceived importance of patents (ARUNDEL; KABLA, 1998), one can observe a large variability in firms' propensities to patent even within individual industries (MANSFIELD, 1986). One explanation for this variability is that firms pursue patents for reasons that have nothing to do with protection from copying, such as their use in technology negotiations. Moreover, as Mansfield, Schwartz, and Wagner (1981) observed, the degree of protection is variable. As a result, firms may be more inclined to use other ways (e.g., secrecy) of appropriating the knowledge they create. Recent work by Cohen et al. (2002) has detected that the variability as to the way and the extent to which patents are used may be dependent on the distribution of the control of technology in a particular industry. 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 cross-license their technologies more often than firms in industries whose final innovations comprise relatively few patentable elements.

Although patenting behaviour can be explained by the number of patentable elements of the final innovation, we conjecture that variability in patenting behaviour also derives from the distribution of investments in Research & Development (R&D) activities. This paper thus reports the results of a new survey on patenting carried out in the UK and which investigates whether firms' motivations to patent differ with respect to their emphasis on either research or development.

The next section gives more detail on earlier studies and presents the research hypotheses tested in this piece of work. The third section describes the research method employed. The fourth section compares motivations for patenting (and not patenting) between the groups of industries of interest. The fifth section concludes.

Literature Review and Research Hypotheses

Patent systems are designed to combat underinvestment in socially desirable inventive activities through the concession of a temporary monopoly over the outcomes of R&D, provided that these outcomes have the requirements specified by law, which are i) novelty, ii) inventive step and iii) industrial applicability (deadlines and fees also apply). The extent to which this reward system satisfactorily plays its role is disputed with conflicting interests and rationales at stake, but this has been so throughout the course of its development. So, although in theory firms pursue patents to stop others from freely copying their inventions (CORNISH, 1999), empirical evidence has shown that patent protection may not be very effective in reaping the economic benefits from innovation (LEVIN et al., 1987). For example, an innovation, even if patented, can be imitated if the legal system of the country where a patent is obtained is not favourable to enforcing of property rights. Moreover, even if the jurisdiction is favourable to enforcing of property rights, a patent, on occasions, can be circumvented. Thus, the effort and time that should be devoted to patent issues are expected to vary.

Mansfield (1986) found in his study of 100 US firms from 12 industries, that there are inter-industry and inter-firms differences on the perception of how useful patents are, and that the incentives patents provide to increase the rate of innovation are very small in most industries studied. Despite that the author found that the bulk of patentable inventions are patented and firms generally prefer to rely on patents than on secrecy. He pointed out some reasons why firms have become more interested in patenting. Firstly, there has been an increase in perceived competition. Secondly, there has been a change in firms' product mixes, with more sophisticated product lines, which are more likely to be patented. Finally, technological paths involving analytical equipment have reached a stage where it is easier for a rival to detect what innovators launch onto the market. However, Mansfield's arguments do not derive from his research findings but rather from his own personal opinion.

As patents can be used as reasonable indicators of inventive performance it might be expected that they are employed and thus applied for as part of incentive structures for research workers (GEROSKI, 1995). In addition, firms can use patents to enter foreign markets where licensing to a domestic firm is required (BERTIN; WYATT, 1988). Furthermore, the ease with which rivals have information about a firm's development decisions may be an incentive for firms to pursue patent protection (MANSFIELD, 1985). Liebeskind (1996), for example, found out that the use of protective mechanisms (namely rules, compensation schemes, and structural isolation) to keep matters secret is both difficult and costly. Thus, by patenting their inventions firms may increase imitation costs because imitators will need to engineer around the patented invention as opposed to simply imitate it (though this does not mean that imitation is costless).

It can also be argued that when firms take out a patent they purchase an option (albeit on an asset the value of which is difficult to estimate but that can be defended in due course if necessary) whose cost is not particularly expensive (GEROSKI, 1995). In purchasing this option they are able to prevent duplication and to secure royalty income (LEVIN et al., 1987). So, patents can be used as assets to trade in technology negotiations (GRANSTRAND, 1999). Moreover, firms may be interested in blocking competitors' attempts to patent closely related inventions, and patents can give some control over a technology path which enables patent holders to settle themselves in a specific market (COHEN et al., 2000). Arora, Ceccagnoli, and Cohen (2000) also argue that the greater the degree to which a firm controls the complementary technologies needed to commercialise an innovation the greater is the incentive to both invest in R&D and apply for patents.

In addition, recent work by Cohen et al. (2002) has detected that the number of patentable elements in the final innovation may influence firms' rationale to patent. The authors distinguish 'complex' innovations from 'discrete' innovations on the basis of the relative number of patentable elements in the final innovation. According to the authors, firms operating in industries where the number of patentable elements in the final innovation is relatively high comprise the 'complex' industry whereas firms in industries where that number of patentable elements is relatively low comprise the 'discrete' industry. They have observed that firms in industries whose final innovations comprise a relatively large number of patentable elements (i.e. complex) engage in cross-licensing of their technologies more often than firms in industries whose final innovations comprise relatively few patentable elements (i.e. discrete). The underlying reason for this behaviour is that when multiple interacting components are what determine the overall system performance, firms may be forced to negotiate because it is unlikely that a single firm will hold all the expertise, and hence IPRs, needed to create and commercialize the final innovation (HALL; ZIEDONIS, 2001).

Firms' innovative effort is another element that may explain differences in patenting behaviour. Firms operating in more technology-based sectors are likely to be more concerned about appropriability conditions, which may be paramount for the economic success of their R&D laboratories (BROCKHOFF, 2003). Conversely, 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). That is perhaps why earlier studies have found a positive (and significant) impact of R&D expenses on firms' propensities to patents (CINCERA, 1997; HALL; ZIEDONIS, 2001).

Mansfield's argument presented earlier is that more technologically sophisticated products are more likely to be patented (MANSFIELD, 1986). As the degree of technological content is a result of firms' effort on either research or development, we suspect that firms' motivations to patent may be influenced by their decisions as to the way they distribute their R&D expenses. However, despite the long list of reasons for patenting, the literature above has not mentioned whether differences in the distribution of R&D expenses may affect firms' perception as to why (or not) they apply for patents. It is this vacuum that this piece of work will primarily try to fill. More specifically, our objective is to detect whether differences in patenting behaviour between the two groups of industries analysed by Cohen et al. (2002) (i.e. complex and discrete) can be explained by R&D distribution. So, our study follows their approach where inter-industry differences mean differences between a group of industries where there is prevalence of complex innovations and a group of industries where there is prevalence of discrete innovations.

Although we conjecture that R&D distribution has a role in explaining variations in patenting behaviour, this may not be conclusive. For example, because of the higher technical risks and uncertainties of research activities, one could argue that research spenders (those who place more effort on research than on development) are more concerned about appropriation than are development spenders (those who place more effort on development than on research). Thus, the proportion of patent filings of research spenders motivated by exclusionary purposes would be larger than the proportion of patent filings of development spenders for the same reason. Nevertheless, for both research spenders and development spenders rents derived from their innovative effort will be dissipated if the innovation produced is easily imitated by competitors. Thus, emphasis on either research or development may not affect the proportion of patent applications filed in order to stop others from copying.

However, because of its own nature, the results of research activities are expected to have a higher degree of novelty as compared to the results derived from development activities. So, the scope of their patents is likely to be higher and hence more difficult to be circumvented (GRANSTRAND, 1999). As a result, research spenders' patents are likely to be more effective in increasing the returns from innovation. As such we hypothesize the following:

H_1: *The proportion of innovations for which patents play a key role in increasing their returns has a positive relationship to the proportion of R&D spent on research.*

As the degree of innovativeness is expected to be lower for the output of development activities, patents held by development spenders are likely to be easier to engineer around. Development spenders are expected to compensate this weakness of their patents by pursuing follow-on patents related to the original invention more often than do research spenders (GRANSTRAND, 1999). In doing so, firms are attempting to increase the costs of competitors to circumvent the original patent. So, development spenders are expected to file a larger share of patent applications with the purpose of increasing competitors' costs to invent around. Thus, we hypothesize the following:

H_2: *The proportion of R&D spent on development has a positive relationship to the proportion of patent applications filed with the purpose of increasing competitors' costs to invent around patents.*

Innovators' attempt to preclude rents from being dissipated due to imitative behaviour is not restricted to national level. As long as all requirements are fulfilled, firms can take out patents in any territory where a jurisdiction on the matter exists. Although applying for patents beyond national boundaries can be of interest to both research spenders and development spenders, the technological content of innovations may be decisive in deciding whether or not a patent application will be filed abroad. Keeping other things constant, inventions with higher technological content are expected to generate higher returns than inventions with lower technological content. As a result, the costs of applying for and holding a patent are more easily justifiable for research spenders than for development spenders. Moreover, due to the higher degree of novelty of the output of research activities it is likely to be more attractive for local firms to either in-license or copy the corresponding invention. Thus, the following hypothesis can be stated:

H_3: *The proportion of R&D spent on research has a positive relationship to the proportion of patent applications filed with the purpose of having access to a foreign market.*

Although the hypotheses addressed so far are related to why firms apply for patents, a similar argument can be used to examine the relationship between the reasons firms do not apply for patents and the distribution of R&D expenses. For example, compared to research spenders, development spenders are more likely to produce inventions easier to imitate. Even if patented, the corresponding patents of inventions created by development spenders are likely to be easier to circumvent than the patented inventions of research spenders. Moreover, patents derived from development activities may be more difficult to prove validity if contested in court due to their lower degree of novelty. Thus, the following hypotheses can be stated:

H_4: *The proportion of R&D spent on development has a positive relationship to the proportion of inventions for which patent applications were NOT filed due to the ease of being invented around.*

H_5: *The proportion of R&D spent on development has a positive relationship to the proportion of inventions for which patent applications were NOT filed due to the possibility of not being valid if contested.*

Unless the one who applied for a patent (applicant) withdraws his/ her application, or simply abandons it, the invention will soon be disclosed. In the UK, an invention is kept secret until the 18^{th} month from the priority date (unless a request is made for earlier publication), and then the patent application is published[1]. Thus, everyone may know what the invention is about. Despite the usual disclosure required, patents do not seem to be very effective in diffusing knowledge. Levin et al. (1987) reported that the use of patent disclosures as a method of learning about competitors' innovation was one of the least effective methods. The firms reported that they relied more on independent R&D and licensing, respectively, to learn about competitor technologies, but in the case of product innovations reverse engineering was the second best alternative. Hall, Oppenheim, and Sheen. (1999) observed that most UK small-medium sized enterprises (SMEs) do not consider patent information relevant for their business. As innovation requires other technical expertise, such as knowledge about how an equipment operates or how technical information can be used, experimentation is always key for firms to acquire knowledge codified in patent documents (GRUBB, 1999). The private cost of patenting due to knowledge spillovers thus does not seem to be so high. However, one can get more than technical information from a firm's patent portfolio. Patent data enables one to trace patentees' technological trajectory and their technology strength (ERNST, 1998). Therefore, due to the nature of their activities, research spenders are likely to be more concerned about information disclosure compared to development spenders. We, then, hypothesize the following:

H_6. *The proportion of R&D spent on research has a positive relationship to the proportion of inventions for which patent applications were NOT filed due to the amount of information disclosed.*

The section that follows describes the research method employed to test the hypotheses addressed throughout this section.

Research Method

Our research strategy for data collection was a survey. Surveys are used to discover facts about a population and/ or to identify probable causes of behaviour or attitudes (BUCKINGHAM; SAUNDERS, 2004). Previous studies on firms' patenting behaviour have adopted this research strategy; in particular when the purpose of these studies was to investigate firms' perceptions of the effectiveness of patents (e.g. LEVIN et al., 1987; COHEN et al., 2002).

The target population was all manufacturing firms listed in the UK Department of Trade and Industry *R&D Scoreboard*. We 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, 414 of which were classified as in manufacturing (using both the internet and the Financial Analysis Made Easy – FAME - database), but six firms were discarded because they had been selected to pilot test the questionnaire. In addition 13 other companies were found to be duplicates or else not in operation (insolvency or in liquidation), and hence were not included in the final survey population. The final list then comprised 395 firms. As the population was relatively small full coverage could be justified and 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 using a t-test, which according to the literature is the most appropriate statistical procedure when the variable is measured in interval or ratio levels, that is, on a continuous scale (SHESKIN, 2004). 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. 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. As observed by Fowler (1993), the more alike are respondents and non-respondents, the lower the rate of return can be. 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). 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 ($p = .070$).

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[3] and design/ development[4] 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).

These results corroborate our initial suspicion as to inter-industry differences in the distribution of R&D expenses. 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.

Results and Discussion

We observed earlier that discrete firms of our survey sample spend more on research than on development activities. Complex firms, in turn, place more emphasis on development activities. In order to understand the importance of patents to our sample firms and to check whether the emphasis on either research or development affects their patenting behaviour, firms were asked to rate the extent to which they agree or disagree with the following statement: "Patents are decisive in increasing the returns from our innovative effort". In a scale from 1 (strongly disagree) to 6 (strongly agree), the median score obtained was 4. However, this median score was not found to differ between complex and discrete industries (chi^2 [1d.f.] = 2.273, p = .1316)[5]. We also asked respondents to report the extent of their agreement with the following statement: "Our most valuable innovations would not bring high returns if they were not patented". The purpose of this question was to draw attention to the skewness in the distribution of the value of innovations. The results indicate that there does seem to exist a difference between complex (median=3) and discrete (median=5) industries with respect to the extent that their most valuable innovations depend on patents to bring higher returns (chi^2 [1d.f.] = 4.880, p = .0272)[6].

We have thus found that patents are equally important in increasing the returns from innovations of complex and discrete industries. However, the most valuable innovations of the discrete industry appear to rely more on patents than the most valuable innovations of the complex industry. It might be therefore that the longer term R&D investments that generate the most valuable innovations in the discrete industry (compared to the complex industry) demand more time to recoup. Thus, the relatively longer monopoly power of patents may be more adequate for the most valuable innovations of that industry, whose investments in their generation are likely to be under higher risks and uncertainties. Therefore, hypothesis 1 that the proportion of innovations for which patents play a key role in increasing their returns has a positive relationship to the proportion of R&D spent on research should not be rejected.

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, few attempts have been made to address the motivations behind firms' pursuit of patents. We asked the proportion of patent applications that were filed according to a number of factors, as shown in Table 2 (scale used: 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%). This approach gives a better visibility of the relevance of the reason and the extent they induce patenting. As there might be more than one reason operating at the same time, the columns in Table 2 do not sum 100%.

Table 2: Reasons Why Firms Apply for Patents

Motivation	(%) Applications	
	mean	s.e.
To preclude others from freely copying inventions	68.98	4.32
To avoid others from patenting a similar invention	55.57	5.17
To prevent others from patenting variations of the invention	53.98	5.35
To increase competitors' costs to invent around patents	36.93	5.16
To enhance the reputation of firm	34.89	5.07
To obtain revenue through licensing-out	28.18	4.87
To get a better bargaining position in standard-setting	21.82	4.30
To have access to a foreign market	20.45	4.22
To get a bargaining position to have access to another patent/ technology	19.89	3.44
To avoid infringement trials	17.95	4.07
To facilitate R&D co-operation with other inventors	16.36	3.30
To incentivise researchers	11.82	2.88
To show the productivity of R&D	11.59	2.31
To signal interest to others	11.36	2.24
To mislead competitors as to the true technological path	7.16	0.93

Although patents can be used to increase the returns from innovation in many ways, they were designed to avoid others freely using inventions without the consent of the original inventor, and thus protection from copying is expected to be the main reason firms seek property rights over their inventions. In fact, firms reported that the major reason why they file patents is to pre-empt others from deliberately copying (and commercializing) their inventions. That is, our findings match the results found by Cohen et al. (2002) for the US and Japan. Although accounting for a lesser proportion ($|t| = 2.55$, $p = .0145$) firms also file patent applications to avoid someone else doing so, which could preclude them from accruing higher returns from the innovation or even not being able to reap any benefit at all. Accounting for approximately the same proportion ($|t| = 0.35$, $p = .7275$) as the previous reason, the objective of preventing others from patenting variations of the invention was also perceived as an important element that has led firms to apply for patents. This protective behaviour is also reflected in the fact that firms seek patents in order to increase competitors' costs of inventing around their patents, though the extent to which this reason impacts on patenting decisions is lower than the previous two ($|t| = 3.43$, $p = .0013$; $|t| = 2.83$, $p = .0071$, respectively). The interest of our sample in holding patents to have access to other technologies seems to be low in comparison to the chief motivation (i.e., to stop copying).

We found that our sample firms are equally likely to patent for most reasons across the two groups of industries. But in line with our expectation, one statistically significant difference between complex and discrete firms was the proportion of patent applications filed with the purpose of increasing competitors' inventing around costs. Our findings indicate that this is to motivate more complex firms than discrete firms ($|t| = 2.06$, $p = .0455$). Hence, hypothesis 2 should not be refuted. That is, the proportion of R&D spent on development has a positive relationship to the proportion of patent applications filed with the purpose of increasing competitors' costs to invent around patents.

Another (statistical) difference between both industries is the proportion of their filings used to access foreign markets ($|t| = 2.01$, $p = .0505$). The discrete industry was detected to have a higher proportion of its patents (about 29%) for that purpose than the complex industry (about 13%). Even if not as robust as the results for inventing around costs, these findings suggest that the proportion of R&D spent on research (i.e., discrete industry) has a positive relationship to the proportion of patent applications filed with the purpose of having access to a foreign market. That is, hypothesis 3 should not be rejected.

Overall, the evidence provided by our survey lends support to our suspicion that the distribution of R&D expenses, on occasions, may explain inter-industry differences in patenting behaviour. Collectively, the findings also suggest that regardless of innovators' R&D distribution they are equally concerned about rivals freely benefiting from their innovative effort. The fact that development spenders pursue patents to increase competitors' costs more often than do research spenders is not conflicting with that argument. The output of research activities is more likely to have a higher degree of innovativeness and thus may be more difficult to replicate. So, inventing around costs is not a driving force for research spenders as they are for development spenders when they file patent applications.

To understand why firms do not patent they were asked to rate the proportion of their inventions (product and process) for which a particular reason contributed to a patent not being applied for (Table 3). In this case, we also compared between product and process inventions since this had not been explored before. Although the influence of each reason on product and process innovations seems to vary, they do not differ statistically, and their influence within each category of invention is not unambiguous either. That is, the results do not allow one to make a clear distinction (statistically) as to whether or not a cause affects one type of invention more than another. Nor do they allow deciding which the main cause hampering the patenting of each type of innovation is.

Although the highest average proportion of product inventions that were not patented seems to be a consequence of the ease with which someone else can invent around a patent, it does not differ (statistically) from the average proportion of product inventions whose patenting was hampered by one of the following: i) the costs of the application process, ii) the difficulty in detecting infringement, iii) the rate of technological progress, and iv) the difficulty in demonstrating patent criteria[7]. The average proportion of product inventions that were not patented due to inventing around risks is, however, different from the average proportion of the same type of inventions that were not patented caused by i) the uncertainty as to the validity of the patent, ii) the amount of information disclosed, iii) the difficulty for other firms to copy the invention, iv) the costs of defending a patent in court, and v) the ease of being induced to cross-licensing[8].

Table 3: Motivation for Not Filing Patent Applications

Reason	Product (%)		Process (%)	
	mean	s.e.	mean	s.e.
Ease patents are legally circumvented	33.56	4.57	33.92	5.25
Costs of application	31.44	5.11	29.87	5.34
Difficulty in detecting infringement	30.22	4.87	41.13	6.01
Technological pace	26.67	4.32	25.38	4.90
Difficulty in demonstrating patentability criteria	24.67	3.75	27.31	4.86
Uncertainty as to the validity of the patent	21.56	3.70	17.56	2.88
Amount of information disclosed	20.33	3.92	28.85	4.97
Difficulty for other firms to copy the invention	19.69	3.21	26.15	4.73
Costs of disputes	16.44	3.35	16.79	3.00
Ease of being induced to cross-licensing	9.78	1.38	9.10	1.35

Table 3 indicates that perhaps what is mainly behind firms' decisions not to patent process innovations is the difficulty of detecting infringement. Clearly, the widespread use of secrecy makes things difficult if a firm is willing to detect infringement against its patented process inventions. The results, however, do not elucidate whether this is really the driving force that hampers the patenting of process inventions. The average share of process inventions that was not patented on account of the difficulty in detecting infringement is not statistically different from the average share resulting from: i) the ease with which patents can be legally circumvented, ii) the costs of prosecuting a patent application, iii) the amount of information disclosed, iv) the difficulty in demonstrating patentability criteria, and v) the difficulty for other firms in copying the invention[9]. The impact of the difficulty in detecting infringement was found to differ from i) the pace of technological change, ii) the uncertainty as to the validity of the patent, iii) the high legal costs of defending a patent in court, and iv) the high probability of being induced to a cross-licensing.

Granstrand (1999) observed that large Japanese corporations are more constrained by the costs of patenting than by the disclosure of information in a patent grant. Harabi (1995) gave more alternatives to his sample of Swiss firms and also addressed a comparison between types of innovation (i.e., product *vs.* process). He found that for both product and process innovations the possibility of rival firms inventing around patents is the major concern of Swiss firms followed by the excessive information disclosed in a patent document, though no option of patenting costs was offered. Cohen et al. (2000) observed that, like Swiss firms, patenting by US firms is hampered mainly by the ease with which patents are invented around. The authors also found that the difficulty in showing the novelty of the invention was reported to be the second most important reason for US firms not to apply for a patent, followed by information disclosure, and costs of patenting. They extended that analysis to Japanese firms and a cross-country comparison identified that patents serve the technical information diffusion function more effectively in Japan than in the US since Japanese firms deem information disclosure to affect their patenting more seriously than US firms judge (COHEN et al., 2002).

Our survey adds to the above by not only providing new evidence for another country but also by providing new findings of factors hampering patenting across innovation type and two groups of industries. Our results for the UK confirm to a large extent the Swiss and US findings that the ease with which a patent is circumvented is the chief factor firms perceive for not pursuing patents, especially if the innovation is a product. Process innovations have shown a different pattern and, as reported earlier, non-applications are to a large extent driven by the difficulty in detecting infringement.

With a few exceptions, for most reasons listed in Table 3 no difference was found between complex and discrete industries. The ease of inventing around patents is one of the few that seems to affect more seriously the complex industry than the discrete one for both product ($|t| = 3.62$, $p = .0008$) and process ($|t| = 2.79$, $p = .0082$) inventions. This means that hypothesis 4 should not be rejected. This evidence that the proportion of R&D spent on development has a positive relationship to the proportion of inventions for which patent applications were not filed due to the ease of being invented around corroborates the result that development spenders (i.e., firms in complex industry) have a larger proportion of their patents filed with the purpose of increasing rivals' inventing around costs.

Along the same lines, uncertainty as to the validity of the patent is statistically different between complex and discrete industries for both product ($|t| = 3.30$, $p = .0025$) and process ($|t| = 2.27$, $p = .0302$) inventions, but the effects on the complex industry were found to be more pronounced. So, hypothesis 5 that proportion of R&D spent on development has a positive relationship to the proportion of inventions for which patent applications were not filed due to the possibility of not being valid if contested should not be rejected. The fact that complex firms are more influenced by the risks of their patent being invalid may have to do with either the technology life cycle (where mature technologies are perhaps more difficult to prove valid if contested due to the extent of the prior art) or the higher risks of litigation in this industry as compared to the discrete one. It could be that, overall, the UK complex industry deals with a more mature technology. However, no inter-industry difference was found as to the fulfilment of the patentability criteria during the prosecution of a patent application, which casts doubt on the life cycle argument. Moreover, the costs of defending patents in court was not found to influence differently complex and discrete firms, and thus the higher risks of litigation argument is unlikely either.

These results, in turn, corroborate our suspicion as to why complex firms are more (negatively) influenced by the risks of their patent being invalid and the ease of inventing around. It is likely therefore that the technological content of the innovations created by discrete firms is higher, and thus their corresponding patents are perhaps more difficult to invent around (due to higher costs) and easier to prove validity. This may also justify why complex firms reported to file a larger share of patent applications in order to increase rivals' inventing around costs.

The last difference observed between both industries, but now only at product level, was the average share of inventions less likely to be patented because of the amount of information that would be disclosed; a concern stressed more by firms in the discrete industry. Thus, hypothesis 6 that states that the proportion of R&D spent on research has a positive relationship to the proportion of inventions for which patent applications were not filed due to the amount of information disclosed should not be refuted. As the information obtained from research is likely to be more valuable than the one derived from development, information disclosed by patents of the output of the former is likely to affect more seriously those who spend more on that activity, i.e. discrete firms.

Conclusions

This study empirically explores how R&D distribution may influence firms' patenting behaviour. Our findings derive from responses to a new questionnaire sent to manufacturing firms listed in the UK *R&D Scoreboard*. The 12% response rate achieved generated 46 usable questionnaires. Our sample, despite being small, has a high degree of match with the survey population (*R&D Score board*) and thus can be considered representative.

Our findings revealed that firms that work in industries where the final innovation comprises several patentable parts (complex industry) were observed to spend more on development activities than on research ones. In turn, firms that work in industries where the final innovation comprises few patentable parts (discrete industry) were observed to spend more on research than on development .One salient result of this study is that this difference in the distribution of R&D expenses may affect firms' patenting behaviour. For example, firms in the development-based sector were found to seek patents with the purpose of increasing inventing around costs more often than firms whose R&D effort is more focused on research.

Development-oriented firms also reported that a larger proportion of inventions, in comparison to research-oriented firms, were not patented because of the risks of the patent not being valid or being invented around. We conjecture that this behaviour mirrors the output of R&D. In spending more on development activities than on applied research, firms in the complex industry are perhaps more likely to generate innovations of lower technological content, which, if patented, are easier to be circumvented or invalidated.

One managerial implication of the results above is that firms should draw attention to how their budget to R&D activities is allocated. This is so not only because of the level of novelty of the output of those activities but also because the technological content of that output may determine the extent competitors can have access to the knowledge embodied in it. In addition, firms that pursue worldwide patent protection should bring under close scrutiny the inventions that will be patented because the degree of innovativeness of these inventions may not justify patenting costs.

Although our findings suggest the distribution of R&D expenses might impact on 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. Thus, further investigation on the effects of the distribution of R&D expenses across industrial sectors is needed, especially because that distribution might not be officially detailed in firms' accountings and respondents might perceive differently what is meant by each activity, even if definitions are provided (as we did). In addition, an investigation of the effects of R&D distribution on other dimensions of firms' patenting behaviour (e.g., when patents are filed and their scope) is welcome.

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[1] This practice has also been adopted by the USPTO since 29th November 2000. Before that date the US used to publish the patent only after it was granted (JOHNSON; POPP, 2001).

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

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

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

[5] As the response scale is in ordinal format, Kruskal-Wallis one-way analysis of variance by ranks was used to test whether the median of the two groups (complex and discrete) are equal (SHESKIN, 2004).

[6] Based on the Kruskal-Wallis one-way analysis of variance by ranks.

[7] $|t| = 0.31$, $p = .7590$; $|t| = 0.50$, $p = .6190$; $|t| = 1.09$, $p = .2766$; and $|t| = 1.5036$, $p = .1364$, respectively.

[8] $|t| = 2.04$, $p = .0446$; $|t| = 2.20$, $p = .0308$; $|t| = 2.48$, $p = .0152$; $|t| = 3.02$, $p = .0034$; $|t| = 4.98$, $p < .0001$, respectively.

[9] $|t| = 0.90$, $p = .3692$; $|t| = 1.40$, $p = .1656$; $|t| = 1.57$, $p = .1196$; $|t| = 1.79$, $p = .0778$; and $|t| = 1.96$, $p = .0541$, respectively.