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Abstract

This paper investigates firms' propensities to patent in manufacturing. Using a unique data set from the UK Community Innovation Survey (CIS) this paper detects the determinants of the importance of patents as a protective device. In addition, this paper explores how patents interact with other appropriability mechanisms. We find that i) the importance of patents varies across industrial sectors and by firm size, ii) a perceived high importance of patents is associated with a higher innovative capacity, iii) competition is to a certain extent conducive to a greater importance for patents, iv) innovation collaborations and government support may increase the importance of patents depending on the agents engaged in these activities, and v) patents seem to work as complements rather than substitutes for other appropriability mechanisms.

JEL Classification: O34; O31; K11; L12

Keywords: intellectual property rights, patents, appropriability, innovation

1 Introduction

This paper investigates how firms' various attributes affect their perception as to the importance of patents and how firms' perception of the relevance of various appropriability mechanisms is related to the importance of patents. Although researchers' interest in firms' propensity to patent is not particularly new (e.g. Scherer, 1965), as far as we know there has not been any effort to detect how firms' perceptions as to the importance of various appropriability mechanisms affect the importance firms assign to patents. Thus, it is this vacuum that this piece of work will primarily try to fill.

There have been many attempts to empirically investigate firms' propensities to patent (Arundel and Kabla, 1998; Blind et al., 2006; Brower and Kleinknecht, 1999; Duguet and Kabla, 2000; Hall and Ziedonis, 2001; Mansfield, 1986; Scherer, 1965, 1983). Most studies look either at the number of patents issued (either total figures or normalized by R&D outlays) or at the proportion of inventions/innovations patented. In many ways this is both their strength and weakness. The strength is that these studies have the merit of encompassing the multi-purpose role of patents (i.e. protection against copying, bargaining chips, signalling, and so on) since this appropaibility mechanism is used not only for protecting inventions against copying (Granstrand, 1999; Pitkethly, 2001) but also for other strategic purposes (e.g. access to other firms' knlowledge base). The weakness is that by looking at patent numbers the results may overestimate how important is the fundamental attribute of patents, that is stopping others from copying.

Our approach in this paper is distinct from prior studies because we focus on the ability that various appropriability mechanisms have in protecting innovations from being freely replicated and commercialized by third parties. In doing so, we shall be able to better understand how patents and other appropriation methods interact, which is an issue that has recently called attention of researchers. However, to date our knowledge is not yet comprehensive for a number of reasons. Firstly, previous studies have focused mainly on how patents are related to secrecy (e.g. Cassiman et al., 2002; Graham, 2003). Secondly, early effort has concentrated upon few industrial sectors (e.g. Graham and Somaya, 2004). Finally, other attempts have not been designed for that particular purpose (e.g. Levin et al., 1987; Sattler, 2003). This paper adds to this emerging literature by looking at firms in UK manufacturing and how patents are related to seven methods of protection.

Our analysis derives from responses of firms to questions in the third UK Community Innovation Survey (CIS 3). The main advantage of the third round of this survey over previous ones is the larger sample size. Of the 8172 total responses gathered, 3440 are from manufacturing. This represents nearly 7.5% of the whole population of manufacturing firms according to the Inter-Departmental Business Register. Further, the design of the questionnaire itself has improved over the years, though some of the more fundamental disadvantages of questionnaire data of this kind might be impossible to overcome.

The paper is organised as follows. In the next section the literature on firms' propensities to patent is reviewed, focusing on definitions used and on empirical findings. In the third section details about both the data set and the framework for data analysis are given. Then, the results are shown and discussed in the fourth section. Finally, conclusions are drawn.

2 Literature review

As there are conditions governing the granting of patents (e.g. patent legislation), one cannot expect that all firms are able to secure property rights. Moreover, although it is intuitive that firms that hold more patents are more innovative, this can be misleading (Schmookler, 1954, 1962). It is misleading because it does not account for the effects of, for example, firms' size (Scherer, 1965), or the industry's competitive structure (Comanor, 1967). Thus, it is fair to say that the interest in firms' propensities to patent emerged largely due to deficiencies that patents per se have as indicators of innovative activity. This line of research has attempted to detect the characteristics of firms that make them more inclined to apply for patents rather than using raw patent numbers to measure firms' level of innovativeness.

There are two main definitions of what is meant by propensity to patent[1]. The first, to the best of our knowledge, dates back to Scherer in 1965. Scherer (1965, 1983) measures propensity to patent as the number of patents per unit of R&D input. His definition may be valuable if one takes into account the availability of such statistics publicly. Nevertheless, Scherer's definition does not allow for possible 'interferences' in the patents-R&D relationship, such as i) the efficiency of R&D, ii) the reasons why firms patent, iii) technological opportunities, and iv) the possible undercounted R&D in small firms. Scherer also used the number of patents as a response variable in estimation models in order to investigate what determines a firm's propensity to patent. This practice seems to have been used more often recently due to advances in the econometrics of count data (e.g. Gourieroux et al., 1984; Hausman et al., 1984).

[1] Arundel and Kabla (1998) revise a broader scope of definitions.

The second main definition of a firm's propensity to patent is based upon the proportion of inventions/innovations that are patented. The first attempt to use this definition was made by Mansfield (1986) who asked US firms the proportion of their patentable inventions that were patented. Mansfield's definition has the merit of avoiding the R&D productivity problem but has the disadvantage of underestimating the value of patents because many inventions do not necessarily become innovations and therefore have little or no economic consequence. In an attempt to overcome this problem many variants of this definition have been used recently (e.g. Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999; Duguet and Kabla, 2000).

The results derived from previous studies on the propensity to patent agree to a certain degree around particular issues. For example, firm size seems to play an important role in determining the number of patents (Brouwer and Kleinknecht, 1999; Scherer, 1965, 1983). R&D outlays are also seen as a major factor in determining a higher propensity to patent (Duguet and Kabla, 2000). Collaborative arrangements, in particular innovation-oriented collaborations, may also increase firms' propensities to patent (Brouwer and Kleinknecht, 1999). However, when joint-effort to foster innovation involves government organisations, the propensity to patent is low (Scherer, 1983). This result may arise from either the presence of well-established firms whose future market position is not particularly dependent on taking out a lot of patents (Griliches, 1990); or because the government supports some industries and insists upon either title or a royalty-free license to any inventions made under its contracts (Scherer, 1983); or the level of uncertainty attached to R&D is very high (Taylor and Silberston, 1973). But according to Scherer (1983) within particular industries that receive government support, the propensity to patent may be high due to the supplementation of the invention-generating potential of company-financed R&D.

Firms' propensities to patent also vary across industrial sectors. Empirical evidence suggests that differences in technological opportunities are thought to be a major determinant of that variability (Scherer, 1983). Moreover, incentives peculiar to individual industries, such as the relevance of patents to different sectors, may help in determining different propensities to patent (Brouwer and Kleinknecht, 1999). Market power, however, seems to have only a modest positive effect on the number of patents, though its intensity may vary by country (Duguet and Kabla, 2000; Scherer, 1983). A higher degree of competition is conducive to a higher propensity to patent (Arundel and Kabla, 1998). Firms with overseas sales also tend to obtain more patents than those with domestic operations only (Scherer, 1983).

Another possible explanation for differences in the propensity to patent lies in environmental factors not related to firm and market structures. These factors constitute what Teece (1986) coined 'regimes of appropriability'. Regimes of appropriability may not only induce firms to pursue patent protection but also to explain when they are not worth using as a protective device. Acccording to Teece (1986) a tight appropriability regime means that technology is relatively easy to protect whereas a weak appropriability regime means that it is almost impossible to protect a technology. These regimes derive, in particular, from the nature of technology and the efficacy of legal mechanisms. By nature of technology Teece means whether it is product or process oriented, and also the extent that the knowledge involved is tacit or codified. By efficacy of legal mechanisms, Teece means the extent that intellectual property rights can be enforced. Nonetheless, one should be cautious when analysing sectoral differences in propensities to patent. Even within individual industries one can observe a large variability in firms' propensities to patent (Mansfield, 1986). An explanation for this variability is that firms also pursue patents for defensive strategic reasons (Blind et al., 2006), such as to avoid hold up (Hall and Ziedonis, 2001).

It is expected and is, in fact, observed that the likelihood of applying for patents increases with an increase in the perceived effectiveness of patents (Arundel and Kabla, 1998). But in concentrating upon patents applied for or issued previous studies may overestimate how important is the fundamental attribute of patents, which is stopping others from copying. It is therefore both of importance and of interest to explore the basic role of the patent system itself (i.e. to incentivise innovation by providing protection against deliberate imitation). This is going to be addressed in this paper by empirically identifying what makes firms assign more (or less) importance to patents as a mechanism of protection. In providing evidence of what firm attributes are related to the perception of a higher importance for patents as a mechanism of protection we hope to advance our current knowledge as to whether patents are serving one of their central purposes.

In addition, there is an emerging literature (e.g. Cassiman et al., 2002; Graham, 2003; Graham and Somaya, 2004; Sattler, 2003) that has attempted to detect whether patents are either complements or substitutes for other appropriability mechnaisms (or vice-versa). But there has not been any attempt to investigate whether the perceived importance of one particular mechanisms is related to firms' perceptions as to the importance of patents. Earlier studies have addressed to a certaing degree this issue as to the relationship between patents and other appropribility mechanisms. For example, Bresnahan (1985), in studying the plain paper copier market after Xerox's monopoly ended, noticed that this firm used patents to complement its leading position in that technology field. Hounshell and Smith (1988) described patents and trade secrets being used concurrently by German dye firms. This preliminary evidence suggests that patents may complement other appropriability mechanisms. In turn, one of the most relevant studies on the use of patents in the US suggests the contrary. The study by Levin et al. (1987) indicates that patents and other mechanisms tend not to be used together. Using factor analysis and cluster analysis techniques the authors deteceted that the studied mechanisms of appropriability could be reduced to two dimensions: i) patents, and ii) other non-intellectual property rights (lead-time, secrecy, learning curve advantages). However, they recognize that this is not robust evidence since the data did not reduce satisfactorily to these two dimensions.

More recently a few studies have addressed this issue. Graham (2003), for example, has investigated the use of submarine[2] patents in the US and has concluded that patents and secrecy can be complements. Another effort that focused on the US software industry has extended that possible complementary role of patents from secrecy to copyrights and trademarks (Graham and Somaya, 2004). Sattler (2003), using an approach similar to Levin et al. (1987) but to study German firms, has detected that patents may complement other forms of intellectual property rights; in particular, design registration. However, his findings indicate that secrecy, complexity of design, long-

[2] This term refers to patents that make use of continuation patent applications to delay patent grants, and hence to prolong the period that patents applications are kept secret. This practice, however, is no longer possible due to changes in the US patent system.

term employment relationships and lead-time are likely to be substitutes to patents in appropriating the benefits from innovation.

To date the results are nor conclusive, and in carrying out this investigation we hope to add to the current knowledge. Thus, this study differs from existing studies for a number of reasons. Firstly, in looking solely at the exclusionary side of patents, distortions caused by several motivations behind patent applications, reflected in patent numbers, are minimized. Secondly, in identifying the attributes that impact on the perceived importance of patents for protection against copying, based upon data and research method accordingly, we hope to avoid distortions caused by not-controlling for important elements affecting that perception (industrial sector, for example). Finally, in investigating the releationship between patents and other appropriability mechanisms the results may help managers, on the basis of their business, assess more clearly whether or not patents should be pursued in tanden with other mechanisms.

3 Data, variables, and analytical framework

3.1 The Dataset

The data source used to examine determinants of the importance of patents as protective devices is the third round of the UK Community Innovation Survey (CIS 3). The Community Innovation Survey is a pan-European effort to gather information on the extent and level of technological innovation activity at firm-level. It produces indicators of innovative output and qualitative information on several innovation related issues, such as the importance of patents.

The CIS 3 was designed in accordance with other EU Member States, and it was administered in the UK by the Office for National Statistics (ONS) on behalf of the

Department of Trade and Industry (DTI). In the UK it was a voluntary survey addressed to firms with more than 10 employees in both manufacturing and services industries. However, the focus of this piece of work is on the former (section D of the UK SIC92) since the output of the innovative activities of the latter are generally not patentable and hence the manufacturing industry is where patents are most extensively used.

The survey was carried out in 2001 and encompasses information on firms' innovative activities during the period 1998-2000. Although one may argue that the information analyzed is outdated, there have not been relevant events for our study that could raise concerns about the stability of the results. To preserve confidentiality no identification of the respondents has been disclosed. Of the 19602 firms drawn from the population of 126775 record of the Inter-Departmental Business Register (IDBR) a final sample of 8172 firms was achieved, of which 3440 from manufacturing.

3.2 Variables

Based upon the literature review, we examined firms' propensities to patent using a base specification model which consists of measures of i) innovative capacity, ii) firm size, iii) degree of competition, iv) government support, v) technological collaborations, and vi) industrial sector. Augmented models incorporate the perceived importance of various appropriability mechanisms. Descriptive statistics of the variables are presented below (Table 1) and detailed information about each variable follows.

Table 1
Descriptive statistics

Variable	**N**	**Mean**	**Median**	**Min**	**Max**
Continuous					
Sales (£'000s)	3440	23 591.21	2662.5	0	3 447 748
R&D (£'000s)	1680	688.92	0	0	323 800
R&D intensity	1669	0.0125	0	0	2.7
Limited continuous					
% Personnel with technical or scientific degree	2814	4.99	1	0	100
Dummies					
Novel product	3440	0.131	0	0	1
Government support	3292	0.118	0	0	1
Innovation partnerships	3313	0.139	0	0	1
Market (Local=1; Regional=2; National=3 International=4)	3383	2.710	3	1	4

3.2.1 Response variable

Importance of patents. The second part of question 15 of the CIS 3 questionnaire poses the following question: *"During the period 1998-2000, please indicate the importance to your enterprise of the following methods to protect innovations"*. The importance of patents served as the response variable in our analysis. The respondents were given four ordinal categories: not used, low, medium, and high importance. We assume that assigning 'not used' means that patents had at most marginal importance over the period 1998-2000, though we are aware that this is no correction for respondent heterogeneity in the interpretation of the rating scales.

3.2.2 Explanatory variables

Innovative capacity. If firms do not innovate they are unlikely to apply for patents, and hence patents would be of no value to them. Conversely, more innovative firms are hypothesised to be more concerned about reaping the returns from their innovative effort, and patents are one of the mechanisms available for this purpose. To examine the effects of firms innovative capacity on the importance firms assign to patents we used both ex-ante and ex-post measures. The ex-ante measures used in different models were R&D expenses, which is a traditional measure of knowledge stock, and percentage of staff holding a scientific/ engineering degree. R&D expenses were used in logarithmic form to linearise the relationship with patents[3], and were also normalized by firm turnover to avoid confounding the effects of the R&D and size variables.

The percentage of firms' staff educated to science and engineering degree level or above was employed to overcome, at least in part, a common criticism of using R&D, that is, smaller firms may under report this cost. In the estimation both variables refer to the year 2000. One can argue that there is a logical lag between innovating and patenting, and hence one would not expect to use contemporaneous values. However, as shown in the literature (Blundell et al., 2002; Griliches et al., 1991; Hall and Ziedonis, 2001), the results of using a lagged structure are roughly the same as the results with contemporaneous levels of R&D. We believe the same applies to percentages of personnel with scientific degree because on average these variables tend to vary marginally over time, and thus the estimates are unlikely to be too inaccurate in a non-lagged structure.

As an ex-post measure of innovative capacity a dummy variable for whether or not a firm introduced a product new to its industry was used. This is a rough guide as to

[3] In models used in this study log values are commonly employed because they tend to result in a better fit (as measured by the log-likelihood) than the gross values (Liao, 1994).

the degree of innovativeness of a firm since it indicates whether the launched product was new not only to the firm. The reason for using this variable is because the ex-ante variables above may not portray the commercial potential of the innovation. Although some firms may put more emphasis on innovativeness than others, they may not necessarily succeed in bring the invention into the market. Moreover, patents are said to be applied for at the beginning of the innovation process (Griliches, 1990).

Firm size. Size may impact on firms' perceptions of the importance of patents because, amongst other things, larger firms are less constrained by the costs of patenting activity. We use the logarithm of firm turnover as a measure of their size. Again, this variable refers to the year 2000. Unlike other variables, this variable was derived from the Inter-Departmental Business Register (IDBR) records[4]. This was mainly to enlarge our sample by avoiding non-response. Five outliers were identified and they were adjusted using the CIS 3 data set. If level of patenting is a good proxy for the importance of patents we would expect, according to previous studies (Scherer, 1983), that the importance of patents is positively associated with firm size. Note however that Taylor and Silberston (1973) could not find such a relationship in the UK.

Degree of competition. The degree of competition may impact on the perception of the importance of patents in a number of ways, but the impact is not unambiguous. For example, a higher degree of competition may show the weaknesses patents have in fully protecting inventions, and hence patents may not be particularly relevant as protective devices. Yet, a high number of patents in an industry might be associated with a high degree of concentration in that industry. Thus, incumbents would enjoy the

[4] The matching (IDBR-CIS) was done by the Department of Trade and Industry. So, that information was available in the original CIS dataset.

benefits of patents as entry deterrents, and the number of newcomers would be only marginal (Levin et al., 1987). In our empirical models an indicator variable representing the firm's largest market is used as a proxy for the degree of competition. The reference market was the national one, and other markets were i) local (situated within approximately 50 miles), ii) regional (situated within approximately 100 miles), and iii) international. We expect firms operating at international/ national level to be in a more competitive environment than those operating at local/regional level.

Government support. A dummy variable was introduced to control for whether firms received government support for innovation-related activities. The literature is not particularly conclusive about the influence of government support on firms' patent behaviour. However, it is expected that governmental support, especially financial support, is given in exchange for, at best, a reduced license fee to be charged if other firms become interested in the innovation (Griliches, 1990). So, patents may become less important for those firms that receive support from the government and hence they would have limited incentives to pursue patent protection.

Partnerships. This (dummy) variable was employed to control for companies which set up innovation co-operation with other organisations. We are particularly interested in firm-university collaborations since universities can be seen as one of the major sources of technical knowledge (Trajtenberg et al., 1997). Thus, innovations derived from these partnerships are likely to be of higher scientific content, and hence likely to be patentable. Moreover, patents may be used as an incentive mechanism for the researchers involved. Even if university researchers deem scientific papers more valuable than patents, firms engaging in this type of partnership may be more concerned about patenting because of the anticipated interest of university researchers in disclosing the results of the joint-project. If they do so before a patent application is filed firms will forfeit their rights, since the application will not fulfil at least one of the patentability criteria: novelty.

Relevance of appropriability mechanisms. The mechanisms of protection derived from the questionnaire and used in our analysis are: registration of design, trademarks, confidentiality agreements, copyright, secrecy, complexity of design, and lead-time advantage on competitors. Although not exhaustive they may provide a comprehensive overview of how patents are related to them. These variables were included in the model in order to investigate how patents interact with other mechanisms of protection (e.g. Cassiman et al., 2002; Graham, 2003; Graham and Somaya, 2004; Sattler, 2003). Should we find that the importance of one mechanism is positively (and statistically significant) related to the importance of patents, these mechanisms are likely to be complements. Conversely, a negative (and statistically significant) relationship between patents and other methods of protection suggests they are likely to be substitutes.

3.3 Analytical framework

As observed above, the dependent (or response) variable is not continuous; it comes from a four-point opinion scale. Therefore, the data available for our analysis are proportions of responses to each category determined by firms with certain attributes (e.g. size, industry), and an appropriate approach for such analysis is needed.

The discrete nature of our response variable demands a model which departs from the simple linear form. We are interested in the probability that a firm with certain attributes will fit in some category of our scale. As probabilities are bounded between zero and one, a model in a linear form may lead to nonsense probabilities, not to mention that the error term will be heteroscedastic (Greene, 2003). Thus, we need to seek models that link the probability of an event to a set of factors.

$$\Pr(\text{event j occurs}) = \Pr(Y = j) = F(x, \beta)$$

So, the estimations were carried out using ordered logit models (Appendix A). These models are estimated using the principle of maximum likelihood, which provides a means of choosing asymptotically efficient estimators for the relating parameters. It aims at determining the value(s) of corresponding parameters that would make a sample most probable to happen. Next section describes the findings from estimations of ordered logit models used in this research and a discussion of the results.

4 Empirical results

4.1 Determinants of the importance of patents

A first look at the importance of patents indicates that patents are relatively unimportant in UK manufacturing as compared to other mechanisms (Table 2). Yet evidence from the literature suggests that even within industries where patents are relatively non-important for protection purposes, one can find firms interested in filing many patent applications (Mansfield, 1986).

Table 2
The importance of appropriability mechanisms in UK manufacturing

Mechanism	N	Mean	SD	Min	Max
Lead-time	2794	1.034	1.193	0	3
Secrecy	2782	0.911	1.155	0	3
Confidentiality agreement	2789	0.903	1.170	0	3
Complexity of design	2772	0.779	1.051	0	3
Trademarks	2776	0.683	1.100	0	3
Patents	2786	0.604	1.075	0	3
Copyright	2757	0.535	0.978	0	3
Registration design	2767	0.496	0.962	0	3

On average, at least in the UK, industries where patents are regarded more important are also industries where patenting activities are more intense (Table 3). There are only a few exceptions[5]. Although this result contrasts with our initial suspicion that the level of patenting may overstate the importance of patents (for protection purpose), this is not totally unsurprising. In examining German firms Blind et al. (2006) detected that the main reason those firms pursue patents is for protection purpose. Thus, their findings suggest the more effective patents are perceived to be the more extensively they will be pursued, and our results seem consistent with this. However, raw patent numbers say little about firms' various attributes that lead to a more extensive pursuit of patent protection and whether firms use patents and other mechanisms interchangeably. It thus seems worth pursuing what factors are likely to impact on the importance firms place on patents and whether other methods of protection interact with patents.

[5] For example, firms in the office and computing industry regard patents less important than firms in the electrical equipment industry. However, the former presents a higher average number of patent applications than does the latter.

Table 3
Importance of patents and number of patent applications across industrial sectors

Industry	Importance of patents[a,c]		Number of patent applications[b,c]			
	N	Mean	N	Mean	Min	Max
Basic Metals	60	0.58	64	0.66	0	25
Chemicals, except drugs	85	1.34	92	3.20	0	80
Communication equipments	95	0.95	100	5.30	0	135
Electrical equipments	166	0.81	172	1.79	0	100
Fabricated metal	291	0.34	336	0.30	0	48
Food, beverages and tobacco	211	0.30	225	**0.10**	0	10
Glass, clay and ceramics	71	0.61	79	1.33	0	90
Machinery (except office)	210	1.00	229	1.59	0	47
Medical and precision instruments	152	1.03	156	2.31	0	78
Motor vehicles	178	0.82	183	1.14	0	50
Office and computing equipments	40	0.73	45	2.47	0	70
Other manufacturing	365	0.49	394	0.49	0	50
Other transport equipment	112	0.46	120	0.35	0	10
Pharmaceuticals	17	**1.82**	17	**39.12**	0	300
Printing and Publishing	240	**0.17**	266	0.32	0	30
Refined petroleum products	13	0.62	14	0.57	0	5
Rubber and plastic products	141	0.79	142	1.72	0	50
Textiles and clothing	172	0.34	180	0.24	0	10
Wood and paper	167	0.50	174	0.22	0	6

[a] Scale from 0 (no importance) to 3 (high importance).
[b] 1998-2000.
[c] Numbers in bold are column maximum and minimum values.

In order to investigate whether a set of factors determine the importance firms assign to patents, we run ordered logit models where two different variables for innovative capacity are used. The purpose of this differentiation in what measures innovative capacity was not a mere sample enlargement due to more responses to the question on the amount of technical staff than to the question of how much R&D was spent. The objective was to identify the impact of non-reporting of R&D on the results. It was expected that firms reporting R&D were, on average, larger than those not reporting R&D since smaller firms may undertake innovative activities in a less structured way, and therefore may not necessarily report this cost. Thus, by relying solely upon R&D as a measure of innovative capacity the results could be affected by sample selection bias. In fact, both the average sales and number of employees of models (1) and (2) in Table 4 were compared. On average, both sales and number of employees are higher for the sample in model (1) than for the sample in model (2). The estimation results of model (1) come from a sample which presented in 2000 average sales of 50 million pounds and 321 employees, whereas the results of model (2) derive from a sample with average sales of 20 million pounds and 181 employees in that year.

Table 4
Estimates of ordered logit models for patent importance[a,b]

Explanatory Variables	**Importance of patents (1)**	**Importance of patents (2)**
R&D intensity (Log)	0.181***	
	(0.070)	
% Science/Engineering Staff		0.017***
		(0.005)
Sales (Log)	0.467***	0.421***
	(0.064)	(0.038)
Novel product	0.434**	0.972***
	(0.191)	(0.132)
Local market[c]	-0.344	-0.937***
	(0.590)	(0.254)
Regional market[c]	-0.348	-0.967***
	(0.459)	(0.233)
International market[c]	0.124	0.433***
	(0.214)	(0.127)
Government support	-0.269	0.351**
	(0.214)	(0.142)
University partnerships	0.608**	0.506***
	(0.250)	(0.189)
Industry dummies	Yes	Yes
N	492	2258
Log-Likelihood	-553.0	-1661.8
Model Chi-square	113.88***	467.40***
Pseudo-R^2	0.1044	0.1691
AIC	2.366	1.498

[a] Robust standard errors in parentheses.
[b] * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
[c] The reference market is the national one.

A clear picture that emerges from Table 4 is that size[6] and partnership with universities present persistence across models. But before we move on to the interpretation of the results a few remarks should be made about the performance of the estimated models. Firstly, as the chi-squares of the models are all significant at 1% level the hypothesis that all coefficients equal zero can be rejected. Secondly, the model using percentage of personnel with science/ engineering degree to control for innovative capacity seems to outperform, in terms of goodness of fit, the model using R&D intensity for the same purpose. However, a degree of caution should be exercised when examining this because these models differ as to their sample size due to non-responses. It would be more sensible to compare estimation models using the same sample. So, if the models are limited to the same sample, the one which uses R&D to control for innovative capacity performs slightly better than the one using percentage of technical staff[7]. However, as R&D poses restrictions on our analysis, model (2) is preferable. Finally, the proportional odds assumption was checked comparing the log likelihood of the estimated models with their binary counterparts, that is, pooling a number of binary models equal to the number of categories minus 1 (three in our case). For both models the assumptions made could not be rejected[8]. That is, the impact of each variable is the same on each category of the response variable.

It is not a surprise that larger firms apply for a larger number of patents than smaller firms do. In fact, previous studies have shown firms' propensities to patent to be positively associated with firm size (Scherer, 1965, 1983). As patenting activity demands availability of resources for the application and enforcement of patents it is

[6] These results were not different when firm size was controlled using firms' number of employees.
[7] Sample size=413; model (1): pseudo-R^2=0.1063, AIC=2.380; model (2): pseudo-R^2=0.0989, AIC=2.399.
[8] Model (1): p-value=0.5482; model (2): p-value=0.2900.

likely that larger firms have an advantage over smaller firms. Besides, economies of scale may apply to this type of activity. So, larger firms are likely to incur relatively lower costs as compared to smaller firms. Our results add to prior evidence for it also shows that larger firms are more likely than smaller firms to consider patents as of high importance. Our actual findings could not be totally expected because even if smaller firms do not have the financial resources to secure a large portfolio of patents, they could regard patents as important as larger firms.

On the basis of the data set used, there is no proper explanation to justify why larger firms are more likely to perceive patents to be more important than are smaller firms. Although the pre-empting power of patents is said to be marginal (Gilbert and Newbery, 1982; Levin et al., 1987), and patents are not priority when UK firms set up their strategies to compete against incumbents and newcomers (Singh et al., 1998), patents may add sufficient value at the margin (Cohen et al., 2000). Yet, it seems that more value is added to larger firms than to smaller ones. In addition, the existence of well defined personnel to deal with patent matters is more likely to be found within larger firms than within smaller firms. Thus, the presence of a more formal structure to deal with patent issues may not only enable firms to more easily monitor their rivals' patents but also give them a better perception of the role played by patents in their competitiveness. Nevertheless, a broader spectrum of smaller firms could be motivated to use the patent system if more attention from policy makers was devoted to post-patenting issues such as renewal, out-licensing, and especially litigation (Kingston, 2001).

Although size effects may raise concerns to policy makers this finding should not be interpreted in isolation from other estimation results. Innovative capacity, for example, was found to be positively related to the importance of patents. That is, the more innovative firms regard patents more important than the less innovative ones do (at least according to the metrics used in this study). Thus patents might be playing their role in fostering innovation. We also estimated our models replacing the introduction of new products by another variable representing whether or not a firm had introduced a new process to the industry[9]. Again, the importance of patents was detected to be positively associated with a higher degree of innovativeness. However, we should interpret these last results carefully. First, because the variable was not significant when R&D was controlled for[10]. And second, because being a process innovator does not preclude a firm from being a product innovator. In fact, in our sample half of process innovators are also product innovators[11]. In line with previous studies (e.g. Levin et al., 1987), the perceived importance of patents seem to be smaller to process innovations than to product innovations.

Regarding competition, it is noticeable (model (2)) that patents are judged more important by those operating in more competitive environments. Taking the national market as a point of reference, the likelihood that patents will be regarded highly important as opposed to medium, low or not important decreases for less competitive markets (local and regional) and increases for a more competitive market

[9] We attempted to estimate models with variables for both product and process innovations simultaneously but we could not avoid collinearity and hence they were discarded.
[10] The estimates for the introduction of novel process innovations are the following when we control for R&D and for technical skills, respectively: i) 0.218 (Wald test= 0.91; p-value=0.364), and ii) 0.546 (Wald test=3.43; p-value=0.001).
[11] Of the total number firms in our full sample (N=3440) 271 reported to have implemented a process new to their industry, 137 of which also reported to have introduced new products to the industry. The total number of firms reporting introduction of new products (regardless of whether or not introduced new processes) was 451.

(international). This, however, does not hold in model (1). This is because the sample in this model comprises on average larger firms, as was described earlier. So, even if the major markets are local and regional, for example, they might be part of a group of companies which has a patent policy dictated by the head office. Another possible explanation for the degree of competition not being significant when R&D is taken into account is that R&D intensity itself may reflect competition. So, effects of competition may be embedded in the R&D variable. These arguments however are unlikely to apply to the proportion of personnel educated in science and engineering.

The results also indicate that the relationship between the importance of patents and the support received by the government is positive and significant. However, the estimate for government support in model (1) is not only insignificant but also goes in the opposite direction of the coefficient of model (2). The sub-set of firms that declared to have received support in model (1) consists of 56% of small, medium-sized firms (less than 250 employees) and 44% of large firms (250 employees or above). In turn, the group of firms that reported to have received government support in model (2) is composed of 75% of small, medium-sized firms and 25% of large firms. Thereby, perhaps a larger proportion of smaller firms receiving support from the government is conducive to a higher likelihood of assigning more importance to patents (holding other things constant).

Another result from this study is that partnerships with universities seem to influence the perceived importance of patents. Firms which set up partnerships with universities are more likely to regard patents as more important than firms that do not establish this type of partnership. This result could be expected to a certain degree since firms may wish to avoid losing proprietary control over the output of this type of partnership. Especially, because it is well known that an important element of university researchers' reputation building process is the sharing of their work with their peers. If they do so before a patent is applied for, property rights will not be secured. Hence, firms engaged in this type of collaboration will be better off if they seek patent protection before the invention is publicly disclosed somewhere else. The question that arises is whether this would also hold for other types of partners.

Table 5
Effects of the innovation partner on the importance of patents

Type of partner	Variants of model (1)			Variants of model (2)		
	Coeff.[a]	**Wald test**	**p-value**	**Coeff.**[a]	**Wald test**	**p-value**
Within group	-0.029 (0.255)	-0.11	0.909	0.142 (0.179)	0.79	0.428
Suppliers	-0.221 (0.246)	-0.90	0.370	-0.013 (0.175)	-0.07	0.941
Customers	-0.034 (0.244)	-0.14	0.888	-0.158 (0.179)	0.88	0.378
Competitors	-0.359 (0.438)	-0.82	0.413	0.015 (0.294)	0.05	0.959
Universities	***0.608 (0.250)***	***2.43***	***0.015***	***0.506 (0.189)***	***2.68***	***0.007***

[a] Robust standard errors in parentheses.

To understand whether the nature of the partner causes any change in the perceived importance of patents, parallel models were estimated investigating how the estimates for partnership differed across types of partner. More specifically, four other partners were studied: firms within own group, suppliers, clients, and competitors. The results are reported in Table 5[12] and indicate that for no other partnership is the importance of patents increased. That is, only joint-innovation projects with universities seem to be conducive to a higher likelihood of firms assigning a higher importance to

[12] The same sort of results was achieved in models (3) and (4).

patents. This might be a surprising result because a previous study of Brouwner and Kleinknetch (1999) indicates that R&D collaborations increase firms' propensities to patent. We should then expect a positive (and significant) impact of the estimates of innovation partner variable on the importance of patents.

Relationships amongst researchers are built over time and are dependent on successful and trustful exchanges (Bouty, 2000). Regarding intellectual property rights (IPRs) issues, Hagedoorn et al. (2003) have found that the number of joint-patents is positively associated with previous experience in sharing this type of property rights and is not associated with previous R&D alliances. So, it may be that firms have learned to share property rights with universities more quickly than with other partners. In addition, universities have increasingly seen collaborations with industries as an important source of revenue and income (Panagopoulos, 2003), which means that they need to fulfil industries' expectations if a successful relationship is aimed. Certainly, an important issue regards intellectual property rights, especially because of the nature of the university researchers' profession described earlier (i.e., scientific publications).

On the basis of the findings presented earlier, one cannot reject the hypotheses that i) the importance of patents varies by firm size, ii) patents are more important for firms with greater innovative capacity, iii) competition is to a certain extent conducive to a greater importance for patents, and iv) innovation collaboration and government support may increase the importance of patents depending on the agents engaged in these activities. However, this exercise has neglected the effects of other contingencies on the appropriation process, which are presented next.

4.2 The relationship between patents and other mechanisms

So far our empirical effort has concentrated upon identifying firms' various attributes that make them more or less prone to pursue patents. Yet, firms may decide whether (or not) to use patents when choosing how to appropriate the returns from innovation because there might be other mechanisms more suitable for that purpose. To date few studies have considered this issue, which is pivotal to our understanding of firms' strategic behaviour regarding appropriability. In order to depict at least in part this phenomenon we have estimated how firms' perception of the importance of patents varies according to the importance they assign to other appropriability mechanisms.

The estimates concerning each appropriability mechanism are presented in ascending order of importance from top to bottom and the baseline was the non-importance of each mechanism (Table 6). The picture that emerges from our estimations is that the likelihood of regarding patents highly important as opposed to medium, low or not important increases whenever another appropriability mechanism is also ranked highly important. Our findings suggest that the use of a particular mechanism does not preclude the use of patents. Thus, the mechanisms investigated in our analysis are more likely to work as complements rather than substitutes for patents in protecting the returns from innovation. Our results therefore are in line with prior findings by Graham (2003), and by Graham and Somaya (2004).

Our results lend support for the theoretical proposition by Anton and Yao (2004) who suggest that firms do not decide to use either patents or secrecy, rather what a firm has to decide is how much knowledge will be disclosed. So, the use of patents and other mechanisms depend on the degree of appropriability of the knowledge created, and some mechanisms are more suitable to protect the codified part of knowledge and others to protect the tacit part of knowledge. For example, Arora (1997) posits that the tacit part of the knowledge is better protected by secrecy whilst the codified part by patents.

In addition, the degree of appropriability tends to fall over time because more agents become able to codify the innovators' tacit knowledge and transform this codified knowledge on their own tacit knowledge (Saviotti, 1998). Also, the process of codification is demanded by innovators themselves because knowledge has to be communicated in order to be embodied into innovations and hence there is a risk of knowledge disclosure even if patents are not applied for. Thus, sooner or later other agents become able to interpret the tacit knowledge held by the innovator as long as they have access to its embodied form, and hence alternative modes of appropriability are needed. As it is particularly difficult to detect the extent rival firms are able to absorb the new knowledge, innovators seem to deploy various mechanisms simultaneously.

Table 6
Effects of the importance of appropriability mechanisms on the importance of patents[a,b]

Appropriability Mechanisms	Estimation Results						
Conf. Agreements	1.914***						
	(0.181)						
	2.516***						
	(0.184)						
	3.132***						
	(0.198)						
Copyright		1.977***					
		(0.152)					
		2.552***					
		(0.173)					
		3.106***					
		(0.241)					
Design Reg.			2.529***				
			(0.159)				
			3.008***				
			(0.179)				
			4.127***				
			(0.256)				
Trademarks				2.431***			
				(0.172)			
				2.963***			
				(0.176)			
				3.817***			
				(0.215)			
Design Complexity					2.046***		
					(0.161)		
					2.090***		
					(0.169)		
					2.517***		
					(0.200)		
Lead-time						1.797***	
						(0.180)	
						1.795***	
						(0.172)	
						2.373***	
						(0.176)	
Secrecy							1.822***
							(0.177)
							2.295***
							(0.174)
							2.943***
							(0.193)
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2202	2202	2202	2202	2202	2202	2202
Log-Likelihood	-1374.9	-1355.7	-1236.4	-1251.8	-1428.3	-1453.3	-1399.0
Model Chi-square	707.59***	817.37***	858.83***	896.97***	708.85***	622.11***	685.44***
Pseudo R^2	0.2783	0.2884	0.3510	0.3429	0.2503	0.2372	0.2656
AIC	1.278	1.260	1.152	1.166	1.326	1.349	1.300

[a] Robust standard errors in parentheses.
[b] * p < 0.10; ** p < 0.05; *** p < 0.01.

5 Concluding Remarks

Using a unique survey-based dataset this paper detects what firms' attributes affect their perception of the importance of patents. In addition, this paper investigates whether the importance of patents is influenced by the importance of other appropriability mechanisms. We use ordered logit models to analyse firm level data from the UK Community Innovation Survey and our results, to a large degree although not totally, match previous studies of this kind. This suggests that contrary to our expectations patent numbers may be a good proxy for evaluating the importance of patents as a mechanism of protection, but only if firms' other attributes are controlled for. This also suggests that despite the multifaceted role played by patents the main purpose of those who use the patent system is to protect their inventions against copying. However, our results reinforce the view that the use of patents as an innovation indicator needs to be carefully interpreted because they may understate the innovativeness of firms for a number of reasons (e.g., size, industrial sector).

Overall, our findings are that one cannot reject the hypotheses that i) the importance of patents varies across industrial sectors and by firm size, ii) patents are more important for firms with greater innovative capacity, iii) competition is to a certain extent conducive to a greater importance for patents, and iv) innovation collaboration and government support may increase the importance of patents depending on the agents engaged in these activities. One result that deserves further attention regards the effect of innovation collaborations. Brouwner and Kleinknecht (1999) studied propensities to patent in the Dutch manufacturing industry and found that R&D collaborations positively impact on those propensities. Our results corroborate their results only in part; we found that in the UK firms that have established joint innovation collaborations with universities deem patents as of more importance than firms that have not set up this kind of partnership. But, we did not find that the same applies to other types of partnerships. As the estimates of Brouwner and Kleinknecht (1999) are at more aggregate level than ours we do not know to what extent our results really differ. As partnerships and intellectual property appear to have become topical it seems important to ask why different partners impact differently on firms' propensities to patent; an issue that clearly deserves future research.

Our paper also explores the relationship between patents and other appropriability mechanisms. In particular, we look at how patents interact with i) confidentiality agreements, ii) secrecy, iii) copyright, iv) design registration, v) trademarks, vi) design complexity, and vii) lead-time. Our findings indicate that firms tend to combine patents with other appropriability mechanisms to enhance the degree of appropriability over their inventions. Taken as a whole, the results support earlier empirical evidence on the complementary role of patents. Based upon an econometric framework that accounts for some properties of the response variable, and upon a number of mechanisms and industrial sectors, the findings of our investigation have contributed to advance our existing knowledge on whether patents interact with other mechanisms. If knowledge takes the forms of codified and tacit, the information disclosed by patents may not be necessarily damaging if tacit knowledge is retained by the innovator. Thus, the drawbacks of patents as to be circumvented or to disclose technical information seem to be less harmful in many ways than having an innovation reverse-engineered and launched on the market by a competitor.

This study presents limitations that should be borne in mind, needless to say the limitations of survey-based studies. A clear limitation is that appropriation strategies may be a result of so many factors that no single empirical work can explicitly control for them all, and thus further empirical research is needed. Moreover, as the importance of the mechanisms of appropriability may vary throughout the innovation process, our approach may not capture the exact way they interact. Clearly, much else remains to be learned but these are just a few avenues of research that merit further attention.

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Appendix A – Ordered Logit Models Framework

Models for ordered data, also known as ordered polychotomous univariate models, assume that the dependent variable y is generated by a latent variable y* whose values are not observed. It is a function of the vector x, and of the vector β of unknown parameters. It also has a disturbance term which is assumed to be independent and identically distributed, with zero mean and a shared cumulative density function F which is known up to a scaling parameter (Gourieroux, 2000). This latent variable can be considered random and is defined by:

$$y^* = \mathbf{x'\beta} + \varepsilon$$

What we observe is the value of each alternative (y) of the choice set. So, assuming that our first alternative of the choice set is zero (as it is in fact in our case) and the last alternative is *J*, the observed values can be represented as follows:

$$\begin{aligned}
&\mathrm{y} = 0 \quad \text{if} \quad y^* \le \alpha_1 \\
&\mathrm{y} = 1 \quad \text{if} \quad \alpha_1 < y^* \le \alpha_2 \\
&\mathrm{y} = 2 \quad \text{if} \quad \alpha_2 < y^* \le \alpha_3 \\
&. \\
&. \\
&. \\
&\mathrm{y} = J \quad \text{if} \quad \alpha_J < y^*
\end{aligned}$$

Where $\alpha_1 < \alpha_2 < ... < \alpha_J$ are the threshold parameters. Then, from the above we can define the following probabilities using logistic distribution, which is a monotonic differentiable function that also allows for the probabilities to be bounded between zero and one, that is, $f(z) \ge 0$ and $\int_{-\infty}^{+\infty} f(z)dz = 1$.

$$\Pr(\mathrm{y} = 0 \mid \mathbf{x}) = \mathrm{F}(\alpha_1 - \mathbf{x'\beta}) = \Lambda(\alpha_1 - \mathbf{x'\beta}) = \frac{e^{\alpha_1 - \mathbf{x'\beta}}}{1 + e^{\alpha_1 - \mathbf{x'\beta}}}$$

$$\Pr(\mathrm{y} = 1 \mid \mathbf{x}) = \Lambda(\alpha_2 - \mathbf{x'\beta}) - \Lambda(\alpha_1 - \mathbf{x'\beta}) = \frac{e^{\alpha_2 - \mathbf{x'\beta}}}{1 + e^{\alpha_2 - \mathbf{x'\beta}}} - \frac{e^{\alpha_1 - \mathbf{x'\beta}}}{1 + e^{\alpha_1 - \mathbf{x'\beta}}}$$

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$$\Pr(\mathrm{y} = J \mid \mathbf{x}) = 1 - \frac{e^{\alpha_J - \mathbf{x'\beta}}}{1 + e^{\alpha_J - \mathbf{x'\beta}}}$$

Therefore, generally speaking we have:

$$\Pr(\mathrm{y} = K \mid \mathbf{x}) = \frac{e^{\alpha_K - \mathbf{x'\beta}}}{1 + e^{\alpha_K - \mathbf{x'\beta}}} - \frac{e^{\alpha_{K-1} - \mathbf{x'\beta}}}{1 + e^{\alpha_{K-1} - \mathbf{x'\beta}}}$$

One can notice from the above that the parameters are not linearly related to the dependent variable since we chose a logistic distribution for the disturbance term. In other words, we are assuming that the error terms are independent and identically Gumbel (or type I extreme value) distributed (Ben-Akiva and Lerman, 2000).

The interpretation of the estimates is straightforward. A positive sign of a coefficient indicates an increased chance that a subject with a higher score on the corresponding explanatory variable will be observed in a higher category. Hence, a negative coefficient indicates that the chances that a subject with a higher score on the independent variable will be observed in a lower category (Zavoina and McKelvey, 1975). Unfortunately the same straightforwardness does not apply when measuring the goodness of fit of these models. Unlike ordinary least square regression (OLS), there is no single measure that reflects proportion of the variance accounted for. Overall, a starting point to measure the goodness of fit of this type of model is using the likelihood ratio (LR) test statistic. In order to measure goodness of fit it is commonly employed a transformation of the likelihood ratio, which is the likelihood ration index, also known as pseudo-R2. There exist other possibilities but for our purposes we will use the McFadden's-R2, which varies between zero and 1 but values between 0.20 and 0.40 are considered an excellent fit (McFadden, 1979).

It might be valid to say that a model with a higher likelihood ratio index fits the data better. But this is only true if the models were estimated on the same sample and with the same set of alternatives. If we are estimating models with different covariates, but with the same set of alternatives (i.e. the same response variable), the Akaike's Information Criterion (AIC) might be useful (Akaike, 1973). The smaller the value of the AIC, the better the fit of the model to the observed data. The AIC, unlike the Likelihood Ratio Test, has been used to select among non-nested models.

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