

**Do firms patent to protect or transfer knowledge in support of their innovations?
An analysis of the fourth UK Community Innovation Survey**

Odile E.M. Janne and Marion Frenz
(Birkbeck, University of London)

Paper prepared for the conference on “Intellectual Property Rights for Business and Society”, London, September 14-15, 2006

Abstract

This paper examines the role of patents in relation to the transfer and exchange of knowledge for corporate innovation. Studies on patents have mostly focused on the role of patents as an incentive for the creation of knowledge by offering a way to appropriate returns from innovation investments. However, an explanation for the relevance of patents for firms may be broader than reducing the possibility of copying their innovations. More recently it has been argued that patents may be considered a strategic asset used by a firm to signal its strengths, provide access to its own technology as well as obtain access to the technology of others. This would suggest that patents play an important role in promoting the transfer and exchange of knowledge. In this paper we investigate whether the use of patents to protect innovations and to participate in knowledge exchanges are complementary or substituting strategic activities of firms in their management of innovation. To investigate this, we utilise a comprehensive large-scale survey into firms innovation related activities, the fourth UK Community Innovation Survey. We use regression methods to examine the role of patents for knowledge transfer and exchange; and the impact of patenting, knowledge exchange and the interactions between patenting and knowledge transfer on firms’ innovation performance. Our findings suggest that firms that use patents have a higher propensity to exchange knowledge. Both, patenting and knowledge exchange is positively associated with innovation performance; however, we find only partial evidence for additional effects deriving from a combination of these two strategies.

1 Introduction

The traditional economic debate about a trade-off between providing incentives to innovation through patent systems and a diffusion of innovations is central to the existing patent and associated legal regimes. Here, the assumption is that patents provide a necessary protection of knowledge assets for growth, even if it may be to the detriment of diffusion. However, a growing body of literature in the evolutionary economic tradition and innovation studies has shown the limitations of this trade-off approach. Drawing from this literature, innovation and imitation or dissemination may be seen as complements rather than substitutes, and the tension between innovation and diffusion is argued to have been exaggerated. This is so since the concept of knowledge is more broadly defined to include an important tacit component that is non-codified non-tradable know-how, which cannot be directly or easily communicated because it is acquired via a learning process (Polanyi 1967, Nelson and Winter 1982). Knowledge diffusion and imitation are therefore difficult and costly, as opposed to an easy and fast transfer of information. The codified and non-codified elements of technology may be seen as strictly complementary as the full development and use of any codified knowledge, such as that contained in a patent, will require the previous accumulation of the requisite tacit capability (Cantwell 1994, 1998, Howells 1995). In that context, the role of patents for knowledge diffusion can be discussed not only as providing further codification of the required knowledge, but also potential incentives to develop cooperation between firms for assisted learning of the complementary tacit element needed to benefit from the particular knowledge. In this sense, patents can ensure incentives for R&D and also support and bring about cooperation among firms in exchanging technological knowledge through licensing and others means.

The aim of the paper is to address this creation vs. diffusion debate raised in the literature on patent rights by empirically testing the relevance of the use of patents by firms for the purpose of exchange and transmission of knowledge, as opposed to (traditionally) its protection from and exclusion of others. In an increasingly knowledge-driven economy, the creation as well as exploitation or dissemination of knowledge has become crucial in the generation of wealth, and it becomes increasingly important to understand the driving mechanisms behind these processes. As a consequence, it is argued that more attention should be devoted to the study of the role of patent rights as mechanisms for inciting or hindering firms to innovate and exploit their knowledge. Patents can then be more broadly regarded as a structuring factor of the innovation process, rather than (solely) an incentive for innovation. In particular, this paper investigates the role of patents in relation to the transfer and exchange of knowledge for corporate innovation, while existing studies on patents have largely focused on their role as an incentive for the creation of knowledge.

Although the role of patents in promoting the implementation and diffusion of existing technologies is recognised, this aspect has less been the focus of attention. While patent rights may support the process of knowledge transfer between different industry players and countries, few studies in economics have focused on the role played by patents in facilitating or impeding that process. Instead, patent and patent citations statistics have been used to measure and assess the geographical localisation of knowledge spillovers (Baptista 2000, Jaffe 1986, Jaffe et al 1993, Jaffe and

Trajtenberg 1996, Almeida and Kogut 1997) and analyse the economic effects of academic research (Jaffe 1989). The literature on intellectual property rights (IPRs) and their management has nevertheless pointed out different motivations and use of patents by firms to facilitate knowledge exchanges such as bargaining for joint ventures or license deals (Blind et al 2006, Hagedoorn 2003). Patents may be considered a strategic asset used by a firm to signal its strength, provide access to its own technology as well as obtain access to the technology of others.

In this paper, we analyse the role of patents in relation to technology cooperation and innovation in the UK. To investigate this, we utilise a comprehensive large-scale survey into firms innovation related activities, the fourth UK Community Innovation Survey, 2002-2004. We use regression methods to examine the role of patents for knowledge transfer and exchange; as well as the impact of interaction terms between patenting and knowledge exchange of firms on their innovation performance. Our findings suggest that firms that use patents are more likely to engage in cooperative agreements with other organisations. However, these combined strategies do not clearly translate into innovation performance as far as our sample is concerned.

We address the questions of:

- (1) Whether the use of patents to protect innovations and to participate in knowledge transfers and exchanges (i.e. pure technological spillovers and purposeful inter-organisational exchanges) are complementary or substituting strategic activities of firms in their management of innovation.
- (2) Whether the use of patents for firms to protect their innovations in relation with their benefit from knowledge spillovers and exchanges depends on the characteristics of their industrial environments; i.e. is industry-specific.
- (3) Whether firms that use patents and benefit from technology exchanges/spillovers are more innovative than the others (those firms which only use patents and not benefit from knowledge exchange and spillovers; or do not use patents but benefit from knowledge exchange and spillovers; or have neither patents nor knowledge exchange)

Section 2 discusses the literature on the motives of firms to use patents that emphasise the role of patents for knowledge diffusion; and implications for the role of patents in different industries. Section 3 develops our hypotheses. Section 4 presents our methodology. Section 5 our results. Conclusions are discussed in the last section.

2 Patents, innovation and knowledge diffusion

Innovation studies on patents have by and large focused on the role of patents as incentives for the creation of new knowledge. In mainstream economics, arguments for patents start from an assumption on the public good nature of knowledge, and use of the patent system to address related issues of appropriation and market failure. Although there is contention about the actual effects of the patent system, it has been economically justified as providing an incentive mechanism to invest in new ideas, invent and innovate, and to participate in a dynamic competitive environment (Andersen 2004). In this context, the rationale for patents at the firm level is that firms benefit from increased protection of inventions and ability of appropriating the returns

from their innovation investments. While founded on the potentially public characteristic of knowledge, concerns over the appropriability of returns on investments in knowledge creation have been a key focus of technology policy on patent rights in industrialised countries, emphasising the need for a temporary restriction on the diffusion of new technical knowledge.

Increased information spillover is another economic rationale for patents when IPRs provide incentives to inventors for disclosing their ideas and sharing them in trade instead of keeping them secret; offer information on science and technology matters; and reduce transaction costs to information spillovers in technological development and trade (Andersen 2004). The arguments for patents as incentives for spillovers, i.e. promoting technology diffusion, have largely focused on their positive impact on transaction costs for the transfer of scientific and technological information, supporting in principle a more efficient and wider market for knowledge. However, these arguments rest on a narrow definition of knowledge as information good, and have therefore limitations when analysing the role of patents for knowledge diffusion overall.

Empirical studies of patent effectiveness have on the whole focussed on the appropriability aspect of patents as to whether they represent an effective method of protecting the firm's innovations from competitive attacks. Findings have shown that patents are not necessarily effective for firms to secure the appropriability of returns from their innovation and that their effectiveness differs significantly across industries and technological areas (Scherer 1980, Mansfield 1986, Teece 1987). Firms in the pharmaceuticals and speciality chemicals seem to rely critically on patent protection, but in other industries other appropriability mechanisms were identified as more important to firms than patents (Levin et al 1987, Mansfield 1986, Scherer 1980, Teece 1987, Cohen et al 2002). More effective barriers to imitations include for example secrecy, lead times, learning advantages, product complexity and complementary assets. Pakes and Schankerman (1984) showed that the average value of a patent right may be quite small and that the annual returns to patent protection decay rather quickly over time. In this context, patents are considered as not contributing significantly to the firm's competitive advantage, as they may not be effective to prevent imitation and are often of little value.

By contrast to the alleged declining effectiveness of patents, firms keep their interest in applying for patents (Mansfield 1986) and there has even been an important increase in US patenting over the last decade which cannot be attributed to a strengthening of US patent rights (Hall and Ziedonis 2001, Kortum and Lerner 1999). If so, the question of why firms patent for a substantial portion of their innovations was investigated. In addition, IPRs are being reinforced and expanded over time both in their scale with the Trade Related Aspects of the Intellectual Property (TRIPS) section of the World Trade Organisation and the European Patent Office (EPO), and scope with their application to a wider basis of knowledge (e.g. software, human genome) and actors (e.g. universities).

Following an evolutionary economic approach and innovation literature, it has been suggested that the appropriability issue of returns to innovation has been overemphasised if one considers that the firm's ability to initiate, assimilate and exploit innovations depends strongly on tacit, specific and cumulative capability. In

this context, imitation is difficult and costly even in the presence of publicly available knowledge. Innovation is seen as a systemic and dynamic learning process, which is context-specific, grounded in its specific institutional environment (Nelson and Winter 1982).

Technology transfer plays a central role when firms increasingly rely on external knowledge and technology sources for their innovation. On the one hand, firms organise and initiate innovation in interaction with (often local or national) institutions given the interactive nature of the innovation process (Freeman 1991, Hagedoorn 2002, Mowery 1999). Corporate external networks for innovation have been related to innovation performance and the UK CIS2 and 3 data has been used to this effect (e.g. Frenz and Ietto-Gillies 2006, Frenz, Michie and Oughton 2005 and Tether 2000). On the other hand, companies increasingly have to develop a wide range of complex and interdependent new technologies to remain market competitive (Kortum and Lerner 1999). This requires, for example, expertise in new areas of technological development in basic sciences (e.g. biology, materials engineering), electronics and communication. Many companies consequently need to gain access to technologies which they require by means of cooperating with other companies or organisations, as they do not have the time, finance or competencies to develop own expertise in all the different technologies.

This view has two related consequences on the interpretation of a firm's R&D efforts and patent portfolio that transcend their conventional purposes in a strict sense, and corresponds with changes in the management of technology. On the one side, the firm's own R&D effort may be seen as a means to enter into the process of knowledge exchange with other firms and to tap into the external environment, i.e. contributing to the assimilation of technology (Cohen and Levinthal 1989). On the other side similarly, patents may be considered as strategic corporate assets from which firms may derive significant competitive advantages (Blind et al 2006, Cohen et al 2002, Parr and Sullivan 1996, Sullivan and Daniele 1996). Patents are increasingly used to obtain access to the technology of others and provide access to one's own technology (Blind et al 2006, Parr and Sullivan 1996).

In Japan particularly, patents are sometimes used to evaluate the results of research departments within firms, as a measure of internal performance (Archibugi 1992, Cohen et al 2002); and the Japanese patent system encourages further diffusion by providing earlier disclosure of inventions and incentives for licensing and cross-licensing agreements, compared to the American system (Ordovery 1991). Findings of broader motives for patenting than strictly to prevent copying a given invention provide an additional explanation of the importance of patenting for firms.

The role of patents for knowledge diffusion therefore includes not only their role in pure knowledge spillovers (providing information through the codification of knowledge), but also their function in intra-, inter-firms and public-private sector interactions and knowledge transfer for innovation, which this paper explores. Patent rights may stimulate a firm's capability to enter into the process of knowledge exchange and cooperation between firms. IPRs, R&D and the possession of advanced technologies may be necessary to benefit from technological cooperation agreements (e.g. joint ventures and strategic alliances) in gaining access to the technology of others.

While patents may be considered as a structuring component of the innovation process, the role of patents for the creation and exploitation of innovation by firms is likely to vary across industries. Indeed, firms have very different incentives to patent their inventions and these will vary across industries. Firms may use patents to block rivals patenting related innovations, prevent patent infringement suits and being excluded from developing own technology in a particular field, enhance their technological image and signal their stature in a particular field, and to extract value from out-licensing and cross-licenses. The propensity to patent of a firm will vary across industries according to the importance of patents as protection against imitation or strategic assets, which may be explained in terms of the industry-specific aspects of the sources, structure and impact of the innovation process (Archibugi and Pianta 1995). The prevalence of the strategic use of patents has particularly been stressed in the semiconductor and electronics industries characterised by rapid technological change and the need for multiple advanced interdependent technologies, thereby facilitating the development of knowledge exchanges (Hall and Ziedonis 2001, Tilton 1971). Cohen, Nelson and Walsh (2000) found that firms typically patent for different reasons in 'discrete' product and 'complex' product industries. In the former, such as chemicals, 'patent blocking' is a common motive to patent. In the later, such as semiconductors or telecommunications, patents are used as a bargaining tool in the negotiation of licensing agreements with competitors. Blind, Edler, Frietsch and Schoch (2006) nevertheless found that no strongly differentiated patterns in the motives to patent can be observed across sectors in Germany.

3 Hypotheses

Based on the discussion above we deduce three sets of hypotheses. The first set of hypotheses is related to the different motives of firms when patenting. More specifically, the relevant hypotheses aim at examining whether or not UK enterprises use patents as a strategic tool to facilitate and participate in knowledge transfer. If this is the case, we expect enterprises that patent to be more likely to engage in external networks.

For the purpose of this paper we measure knowledge transfer through cooperation activities on innovation. If an enterprise declared that it cooperated on innovation with another organisation, it is likely that knowledge relevant to the enterprise's innovation activity is transferred. Furthermore, the relationship between a firm's patenting activity and knowledge transfer is likely to depend on the type of cooperation partner. We distinguish between: (i) suppliers and customers, (ii) competitors and (iii) research organisations. Our first hypothesis states:

H1a: Enterprises that use patents are more likely to engage in cooperation with suppliers/customers, competitors and research organisations.

Furthermore, we expect the use and value of patents for firms to be industry specific, although all sectors may experience increased complexity (Blind et al 2006). The importance of patents as protection against imitation or as a strategic assets used in inter-organizational relationships is expected to vary across industries. Therefore, the second hypothesis states:

H1b: The relationship between the use of patents and knowledge transfer is industry specific.

Our second set of hypotheses is designed to examine the effects of patents and knowledge transfer on the innovation performance of enterprises. First, we expect that the main effect of patenting on innovation performance is positive, because patents act as an incentive to innovate and/or patents may support improved innovation management practices. Therefore, the relevant hypothesis states:

H2a: The use of patents is positively associated with an enterprise's innovation performance.

Moreover, we expect that firms which benefit from knowledge exchange with other organisations to exhibit a higher innovation performance. Though much innovation activities of firms are based on internal sources of knowledge, such as internal R&D and the skill level of the workforce, firms can reap benefits from knowledge which is generated externally and transferred to the firm through external networks. In fact, empirical evidence suggests that firms increasingly seek knowledge to innovate externally (e.g. Hagedoorn, 2002, Mowery, 1999). This relationship has been tested using UK CIS data; Frenz and Ietto-Gillies (2006), Frenz *et al.* (2005) and Tether (2000) all find a positive association between knowledge transfer and innovation performance.

H2b: Knowledge transfer from other suppliers/customers, competitors and research organisations is positively associated with an enterprise's innovation performance.

Our final hypothesis examines if enterprises that use patents and at the same time benefit from knowledge transfers through cooperation are more innovative over and above enterprises which engage in either patenting or cooperation alone. This is based on the complementarity between the creation and diffusion of knowledge and a systemic approach to innovation. Firms that have the capability to use patents and relate to their external environment for innovation are more likely to be innovative firms themselves, and these strategies reinforce their innovative activities. In this context, patents are likely to be used not only to protect and exclude competitors from proprietary knowledge assets, but also to increase the benefits from knowledge exchange; i.e. there is complementarity between the protection and exchange roles of patents. The combination of both may reflect higher innovation management capability. Therefore, the last hypothesis states:

H3: The positive impact of knowledge transfer from other organisations on innovation performance is greater in the case of enterprises that use patents.

4 The data and method

The fourth UK Community Innovation Survey

The data used in this paper is the fourth UK Community Innovation Survey (CIS4) conducted by the Office for National Statistics on behalf of the Department of Trade and Industry. To date the CIS are the most comprehensive and perhaps the most

important surveys into firm level innovation performance. CIS4 is the latest and largest CIS in terms of sample size in a series of EU-wide innovation surveys.

CIS4 was conducted in 2005. The reference period is 2002 to 2004. Respondents were asked, for example, if they introduced a new product during that reference period and to estimate their share of turnover from innovations for the year 2004. Moreover, and relevant with respect to this paper, CIS4 provides information related to the importance of different means of appropriation, including patenting, as well as indicators of cooperation activity.

In the CIS the unit of analysis is the enterprise. An enterprise is the smallest legal unit of a firm that has a certain degree of autonomy. The CIS cover all manufacturing and most private service sectors. They include small and large enterprises. CIS4 has 16,445 observations which were collected using stratified random sampling techniques; stratified by firm size, industry and UK region. For the purpose of this paper we examine the activities of all innovative enterprises, more specifically those enterprises that declared to have introduced a new or significantly improved product during 2002 to 2004 which was new to the enterprises, but not necessarily new to the enterprise's market. This is done because CIS contains a large number of enterprises which are not innovation active and as a result the number of incidents in terms of patenting and cooperation is extremely low in the full sample potentially compromising econometric results. The dataset used in this paper includes 4,790 enterprises.

The variables

With respect to hypotheses 1a and b which examines the impact of patenting on the likelihood that an enterprise engages in knowledge transfer, our *dependent variables* are indicators of cooperation on innovation. We distinguish between three types of cooperation: cooperation with suppliers/customers referred to as vertical cooperation; with competitors labelled horizontal cooperation; and with research organisations referred to as research cooperation. The variables are binary variables coded one if an enterprise cooperated and zero otherwise.

The dependent variables – indicators of innovation performance – used to test hypotheses 2 and 3 are called new-to-market innovator, turnover from imitations and turnover from new-to-market innovations. The first variable is a binary variable. New-to-market innovator is coded one if an enterprise declared that it introduced a new or significantly improved product (goods and services) between 2002 and 2004 that was also new to the enterprise's market and is coded zero otherwise. The variable turnover from imitations is the percentage of turnover that derives from new products new to the enterprise but not new to the enterprise's market. This variable takes values from zero to 100. The variable turnover from new-to-market innovations is a similar percentage referring to the share of turnover from new-to-market products only.

On the side of the *independent variables* two types of variables are used. The first variable is a measure of firms' patent activity. In order to test hypotheses 1a and b, 2a and 3, information on the patent activity of the enterprise is required. We use one variable to measure patenting which is called patents. This variable is based on a questionnaire item which asks if the enterprise has used patents to protect its

innovations from imitations in the three year period 2002 to 2004. The variable is a binary variable coded one if the enterprise used patents and zero otherwise.

The second type of independent variables, used to test hypotheses 2b and 3 are the cooperation variables introduced above. In order to explore hypothesis 3 we use the interaction terms between the variable patents and the three cooperation variables.

Control variables used in the analysis are designed to account for heterogeneity across the CIS enterprises. First, we control for R&D activities of the surveyed enterprises. The strong relationship between R&D and innovation in products is well established in the literature (e.g., Acs and Audretsch, 1988, Patel and Pavitt, 1994). A binary variable is used in the analysis which is coded one if an enterprise engaged in internal R&D and zero otherwise.

Second, we include a variable designed to measure effects of enterprise size. Enterprise size is measured as the natural log of the number of employees in an enterprise for the year 2002. Enterprise size assessed through the number of employees may be considered a classic variable used to explain firm level innovation performance (Cohen, 1995). Oligopolies may be less prone to the development of knowledge transfer as the effect of a ‘leak’ of knowledge is more ‘visible’ and has more competitive implications among a small number of competitors (i.e. losing technologies to others).

Third, we control for the main effects that derive through differences in enterprises’ industrial environment through the use of 13 industry dummies. Finally, we control for differences in enterprise innovation performance which are due to differences in the regional environment by including 14 regional dummies.

The method

The method used to examine the relationship between cooperation, patents and innovation performance is multiple regression methods. In the case of binary dependent variables – cooperation and new-to-market innovators – probit models are estimated. In the case of the share of turnover from imitations and new-to-market products, tobit models are used which are left censored at zero. This is done to separate the information of this variable related to innovation vs. non-innovation, i.e. zero observations as opposed to all other observations, from the information on the intensity of innovation activity, i.e. observations greater than zero. These estimation models are standard models used throughout the literature, and specifically in the case of papers based in CIS.

To test hypothesis 1a and b, the following equation is estimated:

$$Y_i = \alpha + \beta_1 \text{patents}_i + \gamma_1 \text{R\&D}_i + \gamma_2 \text{enterprise size}_i + \delta_1 \text{industry}_i + \delta_2 \text{region}_i + \varepsilon_i \quad [1]$$

where Y_i are a measures of vertical, horizontal and research cooperation. β_1 tests hypothesis 1a which states that there is a positive association between cooperation and patenting. γ_1 captures the relationship between internal R&D and γ_2 the relationship between firm size and innovation. δ_1 and δ_2 are two vectors denoting the associations between sectoral environments, regional environments respectively and cooperation

activity. In order to test hypothesis 1b, we repeat the above regression for each individual industry group.

To test hypotheses 2a, b and 3, the following equation is estimated:

$$Y_i = \alpha + \beta_1 \text{patents}_i + \beta_2 \text{vertical cooperations}_i + \beta_3 \text{horizontal cooperations}_i + \beta_4 \text{research cooperations}_i + \beta_5 \text{cooperation research organisations}_i + \beta_6 \text{patents}_i \times \text{vertical cooperation}_i + \beta_7 \text{patents}_i \times \text{horizontal cooperation}_i + \beta_8 \text{patents}_i \times \text{research cooperations}_i + \gamma_1 R\&D_i + \gamma_2 \text{enterprise size}_i + \delta_1 \text{industry}_i + \delta_2 \text{region}_i + \varepsilon_i \quad [2]$$

where Y_i is a measure of innovation performance as discussed in the previous section. β_1 tests hypothesis 2a which states that there is a positive association between patenting and innovation performance. β_2 to β_5 examine hypothesis 2b which suggests that there is a positive association between cooperation and innovation performance. β_6 to β_8 are designed to examine hypothesis 3 which suggests that enterprises which engage in both patenting as well as cooperation have a higher innovation performance over and above enterprises that engage in only one activity.

We report marginal effects (M.E.), because the regression coefficients of non-linear estimations are difficult to interpret. Marginal effects give the slope of the regression line, the change induced in the dependent variable by a change in the independent variable, at the means of the regressors and for changes from zero to one in the case of binary variables. Marginal effects depend on the unit of measurement and thus the discussions in the results section refer to statistical significance, rather than size effects.

Multiple regression methods based on cross-sectional survey data do not prove causality or the direction of causality. The statistical results where significant indicate associations between two or more variables and causality may not be inferred on the grounds of the results. In this paper causality is a theoretical rather statistical issue.

5 Results

This section presents the results of the statistical analysis Table 1 gives the descriptive statistics and Table 2 the inter-correlations between the dependent and independent variables. Table 3 gives the regression results.

Table 1 Descriptive statistics

Variables	N	Mean	Std. Dev.	Min.	Max.
1 Novel product innovation	4,790	0.59	0.49	0	1
2 Turnover from product imitations	4,789	12.87	19.87	0	100
3 Turnover from novel products	4,789	9.21	18.36	0	100
4 Patents	4,781	0.40	0.49	0	1
5 Vertical cooperation	4,790	0.31	0.46	0	1
6 Horizontal cooperation	4,790	0.15	0.36	0	1
7 Research cooperation	4,790	0.17	0.37	0	1
8 Patents and vertical cooperation	4,785	0.15	0.35	0	1
9 Patents and horizontal cooperation	4,786	0.07	0.26	0	1
10 Patents and research cooperation	4,790	0.10	0.30	0	1
11 Internal R&D	4,790	0.65	0.48	0	1
12 Enterprise size	4,787	358.93	1997.98	0	65000

The 13 industry and 14 regional dummies are omitted from the presentations. For the purpose of the regression estimations, we use the natural log of the number of employees in 2002 to normalise the data. Some differences in sample size are caused by missing values, i.e. some enterprises did not respond to all questions in the questionnaire. Where missing values occur observations are dropped from the statistical analysis. 4,778 enterprises answered all relevant questions.

Table 1 shows that 59 per cent of enterprises with some product innovation output declared to have also had a new-to-market product. The mean turnover from product imitations, i.e. products which were not new to the market, is 12.9 per cent and the share of turnover from new-to-market products is 9.21 per cent.

Moreover, Table 1 shows that only 31 per cent of enterprises in our sample engaged in vertical cooperation, i.e. cooperated with either suppliers or customers, 15 per cent engaged in horizontal cooperation and 17 per cent cooperated with research cooperations. 65 per cent of enterprises carried out in-house R&D and the average enterprises size is 359 employees.

Table 2 First order inter-correlations between variables

<i>Variables</i>	1	2	3	4	5	6	7	8	9	10	11	12
1 Novel product innovation	1.00											
2 Turnover from product imitations	-0.12	1.00										
3 Turnover from novel products	0.43	-0.07	1.00									
4 Patents	0.20	-0.03	0.09	1.00								
5 Vertical cooperation	0.13	0.00	0.09	0.10	1.00							
6 Horizontal cooperation	0.08	0.01	0.05	0.08	0.57	1.00						
7 Research cooperation	0.15	-0.02	0.11	0.17	0.59	0.51	1.00					
8 Patents and vertical cooperation	0.15	-0.01	0.10	0.38	0.43	0.27	0.39	1.00				
9 Patents and horizontal cooperation	0.10	-0.01	0.05	0.25	0.27	0.48	0.32	0.60	1.00			
10 Patents and research cooperation	0.14	-0.02	0.10	0.31	0.34	0.29	0.58	0.68	0.56	1.00		
11 Internal R&D	0.19	-0.02	0.08	0.22	0.17	0.11	0.18	0.13	0.09	0.13	1.00	
12 Enterprise size	0.03	-0.14	-0.10	0.13	0.07	0.06	0.03	0.08	0.06	0.06	0.10	1.00

The inter-correlations between the independent variables are sufficiently low to allow for the use of multiple regression methods.

Table 3 Regression results: equation [1]

Dep. Var.	VERTICAL COOPERATION	HORIZONTAL COOPERATION	RESEARCH COOPERATION
Est. Model	PROBIT	PROBIT	PROBIT
Indep. Var.	<i>M.E.</i>	<i>M.E.</i>	<i>M.E.</i>
Patents	0.05*** (3.32)	0.04*** (3.87)	0.08*** (6.60)
Internal R&D	0.14*** (9.52)	0.07*** (5.92)	0.11*** (9.29)
Enterprise size	0.01*** (3.39)	0.01*** (3.15)	0.001 (0.73)
Pr(Y=1 X= \bar{x})	0.30	0.14	0.15
N	4,779	4,779	4,779
Model χ^2 (d.f.)	227.82(28)***	142.30(28)***	380.30(28)***

* p<0.10; **p<0.05; ***p<0.01.

All regressions are estimated with a constant. Marginal effects are given with the z statistics in parentheses. The estimates for the 13 industry and 14 regional dummies are omitted from the table.

There is strong support for hypothesis 1a, which states that enterprises which use patents are more likely to engage in cooperation with suppliers/customers, competitors and research organisations. The effect is strongest in the case of vertical cooperation and research cooperation (M.E.=0.06; p<0.001), and smallest in the case of horizontal cooperation (M.E.=0.04; p<0.001). With respect to the control variables we find that firms which carry out in-house R&D have a higher propensity to engage in cooperation activities. Enterprises size is positively associated with cooperation in the case of cooperation with suppliers/customers and competitors, however, it is unrelated to cooperation with research organisations. The industry dummies indicate that the propensity to cooperate differs across sectors, with technology intensive industries, including chemicals, machinery and scientific instruments as well as financial and business services exhibiting a higher propensity to engage in cooperation. No statistical differences in cooperation activities across UK regions were found.

The following section looks at the differences in the strength of relationship between cooperation and patenting by industry. We report the marginal effects of patents only and omit all control variables and test statistics.

Table 4 Summary of the marginal effects of patents on cooperation based on equation [1] by industry

Dep. Var.	VERTICAL COOPERATION	HORIZONTAL COOPERATION	RESEARCH COOPERATION
Est. Model	PROBIT	PROBIT	PROBIT
Indep. Var.: patents	<i>M.E.</i>	<i>M.E.</i>	<i>M.E.</i>
FOOD AND BEVERAGES	0.13**	0.05	0.08*
TEXTILES	-0.004	0.07*	0.10**
CHEMICALS	0.15	0.22**	0.25**
NON-METALLIC PRODUCTS	0.04	0.07**	0.06
MACHINERY	0.06	0.04	0.08**
COMMUNICATION EQUIPMENT	0.16**	0.04	0.20***
MANUFACTURING N.E.C.	0.04	0.04	0.03
SALE , WHOLESALE AND RETAIL	0.07*	0.03	0.08***
HOTELS AND RESTAURANTS	-0.02	0.02	0.01
TRANSPORT SERVICES	-0.02	0.08	0.09
FINANCIAL SERVICES	0.01	0.05	0.03
RESEARCH SERVICES	0.39***	0.13	0.27***
OTHER BUSINESS ACTIVITIES	0.001	-0.002	0.05**

* p<0.10; **p<0.05; ***p<0.01.

Only marginal effects of patenting on cooperation are reported. All other information is omitted.

There is support for hypothesis 1b, which suggests that the size effects of the relationships between cooperation and patents differ depending on the industry specific environment.¹ The relationship between patenting and cooperation is particularly strong in the case of research services, chemicals and communication equipment. This is broadly in line with Hall and Ziedonis (2001) who find that exchange motives in the use of patents are particularly relevant in computer and telecommunication equipment industries. In contrast to the results in Table 4, Cohen et al (2002) find that firms in the chemical sector use make strategic use of patents to a much lesser extent compared to electro-technical and automotive industries.

¹ It may be worthwhile noting that at least to some extent the results in Table 4 are influenced by the fact that enterprises in low technology and knowledge intensive industries have a low rate of positive incidents in terms of both cooperation and patenting; meaning that in low tech sectors very few enterprises cooperated or patented. This is likely to have influenced the results.

Table 5 Regression results: equation [2]

Dep. Var.	NEW-TO-MARKET INNOVATOR	TURNOVER FROM IMITATIONS	TURNOVER FROM NEW-TO-MARKET INNOVATIONS
Est. Model	PROBIT	TOBIT	TOBIT
Indep. Var.	<i>M.E.</i>	<i>M.E.</i>	<i>M.E.</i>
Patents	0.06*** (8.18)	-0.01 (-0.92)	0.04*** (6.41)
Vertical cooperation	0.02*** (2.79)	0.004 (0.59)	0.02** (2.52)
Horizontal cooperation	-0.003 (-0.43)	0.01** (2.27)	-0.003 (-0.42)
Research cooperation	0.02*** (2.63)	-0.01* (-1.92)	0.01** (2.11)
Patents and vertical cooperation	0.01 (0.88)	0.003 (0.66)	0.01 (1.09)
Patents and horizontal cooperation	-0.002 (-0.30)	-0.001 (-0.25)	-0.004 (-0.88)
Patents and research cooperation	0.01** (2.04)	-0.003 (-0.71)	0.005 (1.10)
Internal R&D	0.15 (9.40)	0.006 (0.41)	0.11*** (7.77)
Enterprise size	-0.002 (-0.83)	-0.01*** (-7.48)	-0.01*** (-5.94)
Pr(Y = 1 X = \bar{x})	0.57	-	-
Pr(Y a < x < b)	-	0.60	0.45
N	4,779	4,778	4,778
Model χ^2 (d.f.)	461.98(34)***	99.92(34)***	375.36(34)***
No of left censored observations	-	1,586	2,408

* p<0.10; **p<0.05; ***p<0.01.

All regressions are estimated with a constant. Marginal effects are given with the z statistics in parentheses. The estimates for the industry and regional dummies are omitted from the table.

There is support for hypothesis 2a which states that patenting is positively associated with an enterprise's innovation performance; in the case of novel product innovation (M.E.=0.06; p<0.001) and turnover from new-to-market innovations (M.E.=0.04; p<0.001). Furthermore, there is support for hypothesis 2b, which states that cooperation is positively association with innovation performance. Vertical cooperation is associated to novel product innovation (M.E.= 0.02; p<0.01) and turnover from new-to-market innovations (M.E.= 0.02; p<0.05), horizontal cooperation is positively associated with turnover from imitations (M.E.=0.01; p<0.05) and cooperation with research organisations is positively associated with novel product innovation (M.E.=0.02; p<0.01) and the share of turnover from novel products (M.E.=0.01; p<0.05). There is some indication for a negative association between an enterprise's turnover from imitations and cooperation with research organisations (M.E.=-0.01; p<0.10).

From Table 5 it emerges that there are clear differences in the predictors of new-to-market innovators and turnover from new-to-market innovations compared with turnover from imitations. Imitations appear to be based on horizontal cooperation (M.E.=0.01; p<0.05), with no increased performance through patents. There is also some indication that enterprises with a large share of turnover from imitations are less likely to engage in cooperation with research organisations (M.E.=-0.01; p<0.10).

New-to-market innovations, whether measured as a binary variable or as a percentage of turnover, is positively associated with patenting, vertical cooperation and research cooperation. By contrast, horizontal cooperation is associated with the firms' turnover from imitation that may require some knowledge transfer that is more specific to the industry.

Whereas we find good support for hypotheses 1 and 2, we find relatively only some support for hypothesis 3. Table 5 shows that enterprises which engage in cooperation with research organisations and at the same time engage in patenting activities, exhibit a higher innovation performance over and above enterprises that engage in patenting or cooperation only (M.E.=0.01; $p<0.05$). No statistically significant additional effects are found with respect to patenting and vertical cooperation, though the marginal effects are positive. In the case of horizontal cooperation we, too, find no statistically significant association, but the marginal effects are negative throughout.

With respect to the control variables, innovation performance is highly associated with the R&D activities of enterprises. There is no association between enterprise size and new-to-market innovators; however, there is a negative association between the turnover from imitations and new-to-market innovations and firm size, suggesting that if small firms innovate they tend to generate a larger share of their revenues from new products compared to larger and perhaps more established enterprises. Industry effects are statistically significant; chemicals including pharmaceuticals, scientific instrument are industries exhibiting an environment characterised by high innovation activity, whereas retail, trade and catering are industries with a particularly low innovation activity. The regional dummies are insignificant, except in the case of turnover from new products, where Yorkshire and Humberside, Scotland and Northern Ireland where enterprises exhibit a significantly lower innovation performance.

6 Discussion and conclusion

Our empirical results contribute to the recent debate within the literature as to whether or not firms use patents to obtain and provide access to technology (Blind 2006, Parr and Sullivan 1996). Although the strategic motives of why an enterprise uses patents cannot be directly observed in the CIS data, the relevance of patents for knowledge transfer and exchanges is reflected in the cooperation strategies of patenting firms in the UK CIS. The CIS identifies firms that report to use patents to protect their innovations. Our results confirm that these firms exhibit a higher propensity to cooperate on innovation compared to firms that declared not to use patents. Firms that patent, therefore, do not hold off engaging in external networks driven by a primary motive to circumvent the exchange or spillover of technological knowledge. Indeed, it is likely that these enterprises use their patents strategically in the exchange of knowledge through cooperation with other organisations.

The key point that follows is that patents can be understood as being a strategic instrument used not solely with the aim to protect innovations from competitors but also to encourage and aid knowledge exchanges with other organisations operating

within the firm's external environment. This conclusion remains valid even though the traditional motive of protection in relative terms is likely to remain the main reason for patenting by firms (Blind et al 2006), and only a proportion of firms do collaborate with other organisation for innovation.

This contradicts a creation vs. diffusion trade-off identified in the traditional economics literature on the basis of which current patent regimes are justified and has implications for our understanding of the impact of the patent regime on firms. If for a firm to fully benefit from a patent regime, it needs to develop strong and sophisticated technological capabilities for both knowledge creation and exchange, then some firms may lack capability and innovativeness and be unable to use the system effectively. Thus, the problem for the firm may not so much be to use patents initially to protect the knowledge created by its R&D, but increasingly a potential lack of the (resources and) capability that are required to exploit patents further and to fully appropriate the potential or wider returns on own research. As a consequence only strong firms would be likely to fully benefit from the patent regime and other weaker or disadvantaged firms may otherwise only regard patents as a means of exclusion and appropriation. Further research is required to find out whether the potential for the use of patent rights is more significant for different types of firms; for example large vs. small or domestic vs. foreign firms.

Furthermore, the current paper finds that both patenting and cooperating on innovation are important factors influencing the innovation performance of firms. Enterprises that report the use of patents and cooperation with research organisations exhibit an increased innovation performance, over and above patenting or cooperation per se; however, the combination of patenting and cooperation with other businesses, suppliers, customers or competitors, does not translate into increased innovation performance as far as our sample is concerned. This may be because of limitations of the indicators used to measure both cooperation and patenting. Both indicators are self reported measures taking a value of one if a firm declared to have used patents or engaged in cooperation. The data does not allow us to capture patent or cooperation intensity; however, it is likely that the extent to which an enterprise uses patents as well as the extent and strength of the cooperative matter in terms of the innovation performance of firms.

The relationship between patenting, external networks and innovation performance is found to be industry specific and future research examining across and within industry effects may be useful. Finally, it is likely that the extent of a firm's R&D efforts directly impact on its use of external knowledge, such as argued by Cohen and Levinthal (1989). While we control for the main effects of in-house R&D, we do not examine the interaction between R&D, patenting and cooperation.

With respect to further policy implications, the design of the patent regime is developed to maximise the incentives to invest in R&D. A policy implication is that the resulting regime, e.g. the strength of patent rights, may differ depending on whether patents are believed to provide incentives to solely or mainly the creation of knowledge, as opposed to incentives to both the creation and diffusion of knowledge. The consideration of the knowledge diffusion effect of the patent regime may lead to different considerations for the design of the system. While strong patent rights may not be contrary to knowledge diffusion, equally weak patent protection may not

necessarily be adverse to economic growth, as discussed by Ordover (1991) in the context of a comparison between the US and Japanese patent regimes. The argument for strong and reinforcing patent rights has, nevertheless, mainly been based on the knowledge creation effect of patents, insisting on the maximisation of the protection to inventors as an incentive to research investments, and neglecting its potential impact on the transfer and exchange of knowledge.

7 References

- Acs, Z. J. and Audretsch, D. B. (1988) Innovation in large and small firms: an empirical analysis, *American Economic Review*, 78 (4): 678-690.
- Almeida, P. and Kogut, B. (1997), 'The Exploration of Technological Diversity and the Geographic Localization of Innovation', *Small Business Economics*, 9, pp.21-31.
- Andersen, B. (2004), 'If 'intellectual property rights' is the answer, what is the question? Revisiting the patent controversies', *Economics of Innovation and New Technology*, vol.13, n.5, July, pp.417-442.
- Baptista, R. (2000), 'Do innovations diffuse faster within geographical clusters?', *Research Policy*, 18, pp.515-535.
- Blind, K., Edler, J., Frietsch, R. and Schmoch (2006), 'Motives to patent: Empirical evidence from Germany', *Research Policy*, 35, pp.655-672.
- Cantwell, J.A. (1994), 'Introduction', in J.A. Cantwell (ed.) *Transnational Corporations and Innovatory Activities*, London: Routledge.
- Cantwell, J.A. (1998), 'Innovation as the principal source of growth in the global economy' in D. Archibugi, J. Howells and J. Michie (eds.) *Innovation in the Global Economy*, Cambridge University Press.
- Cohen, W.M. (1995) Empirical Studies of Innovative Activity, in: Stoneman, P. (ed.) *Handbook of the Economics of Innovation and Technological Change*. Oxford, Blackwell, 182-264.
- Cohen, W.M. and Levinthal, D. (1989), 'Innovation and learning: the two faces of R&D', *Economic Journal*, 99, pp.569-596.
- Cohen, W.M., Goto, A., Nagata, A., Nelson, R. and Walsh, J. (2002), 'R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States', *Research Policy*, 31, pp.1349-1367.
- Cohen, W.M., Nelson, R.R. and Walsh, J.A. (2000), 'Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not)', National Bureau of Economic Research (NBER) Working Paper Series, n.7552.
- Freeman, C. (1991) Networks of innovators: a synthesis of research issues, *Research Policy*, 20(5): 499-514.
- Frenz, M. and Ietto-Gillies, G. (2006) The impact of internal and external networks on innovation performance. Evidence from the UK Community Innovation Survey, *CIBS working paper*: 1-06.

- Frenz, M., Michie, J., and Oughton, C. (2005) Knowledge transfer, business-university co-operation and innovation performance; paper presented at the *RINET and Cambridge-MIT Conference on Knowledge Exchange and Regional Competitiveness*, 27th February 2004, Cambridge.
- Hagedoorn, J. (2002) Inter-firm R&D partnerships: an overview of major trends and patterns since 1960, *Research Policy*, 31(4): 477-492.
- Hagedoorn, J. (2003), 'Sharing intellectual property rights – an exploratory study of joint patenting amongst companies', *Industrial and Corporate Change*, vol.12, n.5, pp.1035-1050.
- Hall, B.H. and Ziedonis, R.M. (2001), 'The patent paradox revisited: an empirical study of patenting in the US semiconductor industry 1979-1995', *The Rand Journal of Economics*, 32, 1, pp.101-128.
- Jaffe, A. (1986), 'Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value', *American Economic Review*, vol.76, n.5, pp.984-1001.
- Jaffe, A. (1989), 'Real Effects from Academic Research', *The American Economic Review*, vol.79, n.5, pp.957-970.
- Jaffe, A. and Trajtenberg, M. (1996), 'Flows of knowledge from universities and federal laboratories: Modeling the flow of patent citations over time and across institutional and geographical boundaries', *Proceedings of the National Academy of Sciences of the United States of America*, vol.93, n.23, pp.12671-12677.
- Jaffe, A. Trajtenberg, M. and Henderson, R. (1993), 'Geographical localisation of knowledge spillovers as evidence by patent citations', *Quarterly Journal of Economics*, vol.108, pp.577-599.
- Kortum, S. and Lerner, J. (1999), 'What is behind the recent surge in patenting?', *Research Policy*, 28, pp.1-22.
- Levin, R.C., Klevorick, A.K., Nelson, R.R. and Winter, S. (1987), 'Appropriating the returns from industrial research and development', *Brookings Papers on Economic Activity, Microeconomics*, 3, pp.783-831.
- Mansfield, E. (1986), 'Patents and innovation: An Empirical Study', *Management Science*, vol.32, n.2, pp.173-181.
- Mowery, D. C. (1999) America's Industrial Resurgence: An Overview, *US Industry in 2000: Studies in Competitive Performance*, Washington DC: National Academy Press, 1-16.
- Nelson, R.R. and Winter, S. (1982), *An Evolutionary Theory of Economic Change*, Cambridge, Massachusetts: Harvard University Press.
- Ordober, J.A. (1991), 'A Patent System for Both Diffusion and Exclusion', *Journal of Economic Perspectives*, vol.5, n.1, pp.43-60.

Pakes and Schankerman (1984), 'The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources', in Z. Griliches (ed.) *R&D, Patents, and Productivity*, The University of Chicago Press.

Parr, R.L. and Sullivan, P.H. (1996), 'Vital Resources of the Future-Knowledge', in R.L. Parr and P.H. Sullivan (eds.) *Technology Licensing. Corporate Strategies for Maximizing Value*, USA: John Wiley and Sons, Inc.

Patel, P. and Pavitt, K. (1994) National innovation systems: why they are important, and how they might be measured and compared, *Economics of Innovation and New Technology*, 3 (1): 77-95.

Polanyi, M. (1967), *The Tacit Dimension*, London: Routledge and Kegan Paul.

Scherer, F.M. (1980), 'The economics of the patent system', in F.M. Scherer *Industrial Market Structure and Economic Performance*, Chicago: Rand Mc Colledge Publishing Company.

Sullivan, P.H. and Daniele, J.J. (1996), 'Intellectual Property Portfolios in Business Strategy', in R.L. Parr and P.H. Sullivan (eds.) *Technology Licensing. Corporate Strategies for Maximizing Value*, USA: John Wiley and Sons, Inc.

Teece, D.J. (1987), 'Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy' in D.J. Teece (ed.) *The Competitive Challenge: Strategies for Innovation and Renewal*, Cambridge, MA: Ballinger.

Tether, B. S. (2000) Who co-operates for innovation, and why. An empirical analysis, *Research Policy*, 31(6): 947-967.

Tilton. J.E. (1971), 'Europe', in J.E. Tilton *International Diffusion of Technology: The case of Semiconductors*, Studies in the Regulation of Economic Activity, Washington: The Brookings Institution.