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The impact of patenting on collaboration: Evidence from a Norwegian panel of two waves of the Community Innovation Survey

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Abstract
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1. Introduction

In addition to creating incentives to innovate, patenting influences coordination costs and therefore can affect the way industries organize. (Somaya & Teece 2000) An important way in which patent regimes may shape organizational patterns is through the scope to encourage or discourage coordination of (technological) knowledge production among different actors. An expanding set of literature has pointed to the growing importance of cooperation in knowledge production. During the same period patenting has surged well beyond its traditional peg to R&D expenditures. (Hall & Ziedonis, 2001) The coinciding surge in patenting and growing collaboration activities raises the question of the relationship between the two.

This paper focuses on the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors. In particular, it links this growing focus to the question of coordination in 'networks of innovators' or 'industrial network settings'. This paper is concerned with how firms manage exchanges with other organizations in order to improve their access to new knowledge and to develop new products. (see discussion in Iversen, 2009) In general, patenting may precede collaborative effort, may accompany it, and/or may follow it. The latter scenario is the more prominent focus of the (mainly industrial organization) literature. (Spence, 1984, ff)

The focus of this paper is instead on patenting as a precursor of research collaboration. It looks at the extent to which the recent patenting activity of an enterprise influences its likelihood to engage in collaborative innovation activities. We examine how patenting affects the incidence and duration of innovation collaboration and whether there are differences emerge based on different types of partnerships: following Janne & Frenz (2006), we differentiate between collaborations that are horizontal (ie. competitors), vertical (e.g. suppliers) or that involve outside research organizations. The aim is to study the coordinative role of the patent system in a way that will contribute to policy relevant analysis.

This paper studies this relationship between patenting and research collaboration using a balanced panel of Norwegian responses (N=2448) to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006. We discuss contexts in which research collaborations may involve patenting. We base the analysis on patenting (and the controls) taking place in the first period while looking for a collaboration effect to continue into the second. In general, we assume that patents play a larger role in the strategies of these collaborating firms than non-collaborative firms. We account for a range of other factors that might affect the propensity to collaborate. In addition to R&D activity, industry dummies, and firm-size, we account for Strategic activity, including reported changes in the basis for partner relationships; Fiscal constraints including sensitivity to high development costs; Technological dimensions, such as technological complexity and the reliability of lead-time that might affect the propensity to collaborate; and length of product-cycles, where we use an ordinal variable of product-cycles from the Norwegian survey.

The paper proceeds as follows: An introduction of the theoretical background in Section 2 gives way to an overview of different empirical approaches in Section 3. Section 4 goes on to develop hypotheses and to introduce the data and methodology to study it. Results are presented in Section 5, and the final section concludes.

2. Innovation collaborations and patenting

Inter-firm innovation activity has increased in number (e.g. Hagedoorn & Narula, 1996) and variety (e.g. Hagedoorn & Schankenraad (1990) in the modern economy.1 This development can be thought of in stylized terms as involving the spread of corporate R&D activities (Chandler, 1992), to increased combination between internal and external R&D activities (Mowery, 1983), to more widespread and more complex 'networks of innovators'. (Freeman, 1991)

The more fruitful of these collaborative networks are expected to integrate rather than merely reassemble the complementary knowledge of the individual collaborators. Powell et al (1996) argue that the trend towards greater collaboration points to a reorientation of the locus of innovation, and, potentially, to the development of networks of learning. If so the shift can affect where innovation takes place, with whom, and how the process is coordinated. This raises a set of questions which has exercised the literature, including the determinants of collaboration, their dimensions, and impacts (e.g. the danger of cartel). We start by considering some of these questions before focusing on the role that patenting plays in coordination process. We distinguish different types of innovator networks, since collaboration may take on a variety of forms.

The expansion of collaborative forms has coincided with the changing factors both within the firm and without. The literature indicates that co-operations between two or more agents can take a variety of forms, depending on: (i) the type of partner (e.g. collaboration with competitors, suppliers/customers or universities and research organizations); (ii) the governance of the collaboration (e.g. sub-contracting, strategic alliances, joint ventures, research consortia); (iii) the geographical distance between collaborating partners (local collaborations or cross-border co-operation); (iv) the type of activity carried out in the cooperation (e.g. innovation-specific, pre-competitive or near market research); (v) the duration of the cooperation and (vi) whether or not the exchange is a repeated exchange or a one off.

Networks of innovators have grown to encompass a widening range of external agreements both to other firms and to other institutions (primarily universities and other public and private research institutions). The 'peculiar attributes' of new knowledge (highlighted in Arrow, 1962), the need for a minimal level of 'absorptive

[1] Relevant literature is diverse. See Grandori & Soda (1995) illustrates the trends in the organizational studies literature; Caloghirou et al.(2003) survey relevant literature in areas of industrial organization and strategic management. In the current period of renewed interest, Negassi (2004) or Grimpe & Kaiser (2010) provide reviews that confirm that formal R&D collaboration remains a focus.

capacity' in the contracting firm, and the pervasive uncertainty surrounding market and technological factors during the innovation process have supported this premise.[2]

3. Patents and innovation collaboration: empirical approaches

The proliferation of research collaborations has spawned interest in the more specific role played by patent in research oriented collaboration. A variety of recent articles provide literature reviews of the relationship between collaboration, inter-mural R&D, and innovation output (including patents or new products). The mainly theoretical industrial organizational work has tended to consider collaboration among competitors.[3] This dominant tradition (Spence, 1984 ff) tends to consider research collaboration mainly between rival firms who are likely to retain varying degrees of competitive intent towards one another. (Prahalad and Hamel, 1990 and Hamel, 1991, Shapiro and Willig, 1990)

Given this focus, this dominant mode of inquiry finds that collaborative agreements are more beneficial in cases where it is difficult to appropriate emerging knowledge. [4] In this view, collaboration provides a mode to internalize the externalities (appropriate) that emerge under these circumstances and to share research results among consortium partners. For these firms, the underlying goal of maintaining competitive advantage is offset by the need to coordinate information flows during collaborative technological innovation. Knowledge spillovers increase the incentives to cooperate especially if cooperation allows knowledge transfers to take place among the collaborating partners more securely. If they work well, R&D alliances and other forms of collaboration are expected to lead to patenting as these spillovers are made appropriable. In addition to increasing the patenting activity of the individual participant firms, collaboration may also lead to co-patenting. During collaboration, knowledge is expected to spill over between partners, who also share other risks as well as costs associated with joint research work. This may lead to one or another form of co-patenting. In this case patenting (and patent-based licensing arrangements) is more likely to evolve at an intermediate stage as a byproduct of the collaboration. Studying the patenting activity of 145 R&D alliances in Japan, Branstetter & Sakakibara (2002) show that research consortia tend to increase their patenting after entering a consortium.

However, data which can be used to study collaboration and patenting has not been readily available. Several empirical approaches can be differentiated in the literature that has blossomed here. We should first note that much of this literature studies the

[2] A contrary current has emerged in the Open Innovation literature. (Chesbrough, 2003) Here the focus on complementarities between internal and external innovation efforts has given way to one substitution. In this stream, 'markets for knowledge' are thought to have become sufficiently efficient while the tradability of new knowledge has increased. There is however less empirical work to corroborate this position.

3 However, Kleinknecht and Van Reijnen, 1992 also consider the type of partner (supplier, customer, public labs, etc.) or of the type of agreement (joint venture, research partnerships, license contracts, equity holding).

[4] See Spence, 1984 for a seminal paper in this tradition. For a review of the overlapping issues, consult Caloghirou et al. (2003). or the review sections of Negassi (2004); Czarnitzki, D. et al. (2006); as well as Grimpe & Kaiser (2010)

determinants and/or outputs of collaborative innovation. In this literature, the relationship between collaboration and patenting is itself something of a bi-product. In most cases, patenting enters into the equation as a proxy for innovation output.
We differentiate approaches that primarily focus on survey data from that which focuses primarily on patent-data: these two main approaches have increasingly been merged to include elements of patent data in the analysis of survey data (see Grimpe & Kaiser, 2010 for a recent example of this) or elements of survey data in the analysis of patent-data. (see Fontana & Geuna, 2010 for a recent example of this) We consider some aspects and findings of these two approaches.

Co-patenting analysis

Hagedoorn (2003) provides an exploratory look at the joint-patenting of firms. This form of co-patenting activity (co-assignees who co-own title to the invention) is shown to be highly industry-specific. This is especially the case for chemicals and information technology, where the propensity to patent is high, such as those relevant to technology –based networks. Information in the patents themselves provides other more indirect evidence of collaboration. Gay et al (2008) study ‘collective knowledge’ by focusing on the incidence of co-invention in US patents with European applicants. They document an increase tendency for patents to include multiple inventors (and with increasing average numbers of inventors).

Co-patenting indicates a form of collaboration, but provides limited insight into the nature of collaboration. A new approach combines the information in the patent-document with information from a survey of the patent’s inventors. This approach was developed in the European Patval database, which addressed a cross-country survey to inventors involved in a sample of EPO (European Patent Office) patents applied for in 1993-1997. Fontana & Geuna (2010) used this data to study research cooperation based on specific patents. They find that almost 30 percent of the patents in the Patval population involved some form of co-patenting, while over 20 percent involved other formal collaborative agreements. A small minority involved a licensing agreement without a form of co-invention. Among other things this study indicates that there are national differences in collaborations especially among the less formal relationships (e.g. co-inventorships).

The Patval inventor survey has led to similar surveys in other countries, including the Australia, the US and Japan. Nagaoka & Walsh (2009a; 2009b) carried out a Patval-based study to compare patent uses in the US and Japan. The results of these inventor-based surveys corroborate the picture that, while there are national differences, invention in both countries draws heavily on outside knowledge sources and often involves cooperative activity. National and international surveys continue to be the most prevalent mode to study collaboration and, more or less directly, the role of patenting. Cohen et al (2002) follow the tradition of national surveys that target the R&D labs of manufacturing firms (Yale and Carnagie Mellon), showing that patents are used more often in Japan than the US to facilitate intra-industry spillovers.

Surveys and the Community Innovation Survey

A growing number of studies have used the European Community Innovation Survey(CIS). The CIS is perhaps the most comprehensive – in terms of the breadth of sectors and firms and in terms of the breadth of information – survey readily available The CIS is a periodic survey of enterprises in EU (current) member states as well as a number of associated countries including Norway. It is based on a core-set of common questions (deriving from the Oslo Manual, 1992; 2005) as well as a small number of country-specific questions.[5] A basic set of question is currently run every two years.

One advantage of the CIS itself is that it is comprehensive: it includes information about the enterprise, product and process innovation, innovation activity and expenditure, effects of innovation, innovation co-operation, public finding of innovation, information source for innovation, and patents. This provides a broad vantage point to study the interplay between propensities to patent and to cooperate in the context of other factors that might influence each. Another advantage of CIS is that it is periodic, leading to the ability to use panels of responses.

Different configurations of CIS data have been used to study different aspects of the collaboration. The configurations of data used vary in terms of geographic scope (single country, two countries or multiple countries) and temporal scope (cross-section; two or more wave panels). In addition, studies have supplemented the survey data with other data such as R&D budgets (Negassi, 2004) or the patent-stock of the respondent enterprises. (Czarnitzki et al, 2007; Grimpe & Kaiser, 2010) CIS based studies have looked at different dimensions of collaboration, which bear on the relationship between patenting and collaboration in different ways. Areas of analysis include:

1. The determinants of R&D co-operation and its impact on innovative performance. (Cassiman & Veugelers, 2002; 2006; Negassi, 2004; Faria & Schmidt (2004); López (2008))
2. Complementarities of innovation activities in terms of innovative output, (Schmiedeberg, 2008; Grimpe and Kaiser, 2010)
3. As well as more heterogeneous studies that for example focus on differences in collaboration strategies (Belderbos et al 2004) or the relationship between R&D collaboration, subsidies and patenting activity (Czarnitzki et al. (2007).

These different studies provide a number of observations that speak to the question of how patenting and collaboration interrelate. Studies of the determinants of collaborative innovation tend to show that firms that rate 'strategic IP protection' (patent, design, and trademark) highly are more likely to engage in internal R&D activities while those that rely on other modes of protection—such as lead-time and technological complexity— also engage in all R&D activities. (Cassiman & Veugelers, 2002; 2006; Schmeideberg, 2008) This is consistent with the industrial organization premise, that spillovers increase incentives to cooperate. Thus patents are expected to follow from collaboration.

The two country study (Germany and Portugal) of Faria & Schmidt (2004) uses cross-sectional data (CIS3) to identify factors that influence the probability of a firm cooperating with a foreign partner on innovation activities. It posits that IPR protection should correlate with a lower incidence to collaborate on the premise that firms that find IPR important are unlikely to collaborate for fear that intramural

[5] For an English review of the Norwegian data see the English section of http://www.ssb.no/emner/10/03/rapp_innov/rapp_200946/rapp_200946.pdf.

knowledge will spill over to partners. This traditional expectation is not supported. They show that patents and other protection methods positively influence the decision to cooperate with foreign partners. They reason that firms may be more likely to use protection methods if they cooperate in order to protect their knowledge from spilling over to the cooperation partner, but are unable to study this more closely due to an acknowledged problem of the cross-sectional data.6 Using CIS4 for Germany, Schmidt (2006) goes on to tests the hypothesis that patent protection is used to prevent knowledge spillovers, but does not arrive at robust conclusions.

Janne & Frenz (2006) turn this expectation around. They again use cross-sectional data (CIS4) for the UK to show that patenting is strongly related to firms that engage in different types of collaboration (see below), especially those that have research cooperation (ie. cooperation with universities and other research institutions). These studies indicate that patenting accompanies collaboration on the basis shown in Japan where research consortia tend to increase their patenting after entering a consortium. (Branstetter & Sakakibara, 2002). The premise that concurrent patenting may enhance knowledge transfers among the collaborating partners is furthermore supported by the co-patenting studies cited above.

A third way to conceive of the relationship is that patents precede collaboration. Czarnitzki et al. (2007) conceive of patenting both as precursor and as output of R&D collaboration while whether firms' innovation activities are stimulated by public funding and/or co-operation. Based on two waves of CIS data, this two country study uses patent stocks (linked via patent-data) as a measure of successful R&D. Following the general IO premise, it expects collaborative firms to invest more in R&D as well as to patent more if spill-over effects in R&D co-operations are high. Pre-collaboration patents are furthermore used as a means to signal potential partners that the firm has important capabilities and that it is worth collaborating with. This is similar to the position taken in Grimpe & Kaiser (2010) who use the patent stock of the firm (also using linked patent data) and a patent-dummy to proxy the accumulated prior knowledge base of the firm. The focus of these two studies is not directly on the relationship between patenting and collaboration however.

Determinants of the interplay between patents and collaboration

Thus, this growing set of empirical studies serves to focus on the relationship between patenting and research collaboration. The survey based literature points to some basic determinants of collaboration. Fritsch and Lukas (2001) indicate a positive impact of firm size and of R&D intensity of firms on R&D cooperation. López, 2008 shows that collaborations might be motivated by the need to defray high-costs and a high risks. And Janne & Frenz (2006) show that the relationship between patenting and collaboration is highly industry-specific, as are patterns of collaboration that emerge in the patent-based studies reviewed above (e.g. Hagedoorn, 2003).

In addition, the empirical literature indicates that patenting affects different stages of research collaborations. Three types of relationships are highlighted above: patenting may precede collaboration, it may accompany it and/or may follow it. In addition, the literature points to the importance of distinguishing between the type of cooperation.

[6] This is the acknowledged endogeneity problem which is encountered when trying to observe patents and collaboration in the same reference period.

For theoretical reasons, (i.e. to highlight the partitioning of knowledge externalities between rival firms) the traditional focus has involved collaborations between competitors (e.g. Branstetter & Sakakibara, 2002) or between firms and universities (e.g Mowery, 1983). However, Tether (2002) shows that there are differences between the way service and manufacturing firms interact with specialist knowledge providers. Belderbos et al (2004) emphasize the importance of differentiating three types of partner (horizontal, vertical, and university–firm cooperation) to study cooperation strategies (using two waves of Dutch CIS). Relying on one wave of the CIS in the UK, Janne & Frenz (2006) take this distinction further to study whether patenting accompanies collaboration.

4. Data and methodology

In this paper, we expect innovative firms that participate in collaborative relationships to be more patent-active than other innovative firms (i.e. that launch significantly improved products): other things being equal. In a research-based collaboration, the collaborators are assumed to have complementary research capabilities. In order to enter into formal research collaborations we assume that each collaborator will already have a knowledge strategy that covers the commercially valuable knowledge it brings to the collaboration (a) and the new knowledge that emerges from the collaboration (b).

We pick up on the observation above that patenting may play a role at different stages of research collaborations: that it may precede collaborative effort, may accompany it and/or may follow it. The latter scenario is as demonstrated above the more prominent focus of the (mainly industrial organization) literature. Following the literature above, we focus on patenting as a precursor for or byproduct of collaboration. Patenting may be expected to predate innovative collaborations for a variety of reasons.

1. Predisposition at the firm-level: A preliminary reason for existing patenting to correlate with subsequent collaboration involves firm-level strategy. Firms that engage in collaborations will on average have a more outwardly-oriented innovation strategy than others. (see the governance literature, e.g. Granstrand, 2006) Such a strategy also makes the choice of patenting more likely as it provides a means to coordinate and control certain types of commercially significant knowledge during partnerships with other entities. Firm management may be more likely to initiate or okay potential collaborations if patents are felt to be an important way to reduce the risk of losing control of proprietary knowledge. However, a more-outwardly oriented firm-strategy may make both patenting and collaboration more likely. This entails to a degree endogenous factor of strategy which we address with by trying to control for firm-level strategy.
2. Helping firms find collaborators: In bringing collaborators together, patenting may act as a signal to potential collaborators which marks its knowledge endowment (e.g. Grimpe & Kaiser, 2010) in a given technological space. (viz prospects-theory, Kitch 1972) Previous-patenting may further increase the likelihood that firms find each other in the first place (the signaling effect). If collaboration tends to be rooted in existing commercial relationships, the signal effect might be strongest in cases where firms are searching for complementary knowledge which is more basic. If so, it might be instrumental

in collaborations involving university research where a pre-relationship is less likely.

3. Initiating collaborations and keeping them together: The more prevalent and instrumental rationale involves the effect of patenting on contractual relationships. Patents may strengthen non-disclosure and other agreements that accompany collaborations and may lay the basis for cross-licensing arrangements. (viz contract theory of patents e.g. Denicolo and Franzoni, 2003) Patenting strengthens contractual relationships and affords the firm with room for maneuver which may be a precondition to enter into relationships with other entities. In facilitating collaboration among partners which maintain some degree of commercial rivalry, this is thought to be precondition. This is especially the case if the collaboration is to be successful in the sense that it lays the basis for new commercially viable innovations. Patenting of own knowledge also involves a temporal aspect when entering a research collaboration. Absorption, in turn, is higher when a firm carries out own R&D (Cohen and Levinthal, 1989). Agreeing on access to knowledge, transparency and trust are all important elements in collaborations, and, in turn, will condition whether and how patents may be used to distribution and generate knowledge via collaborations. But this will differ according to the nature of the participants, the nature of the relationships, and according to other factors

Data

In focusing on the relationship between patenting and collaboration, this study follows in the tradition of CIS based studies. It uses balanced panel of Norwegian enterprises that responded both to the fourth and fifth Community Innovation Surveys (CIS4 and CIS5) [7].

- CIS4, reference year 2004 and observation period from 2002-2004
- CIS2006, reference year 2006 and observation period from 2004-2006.

In this study, we use the responses from 2448 Norwegian enterprises who responded in both waves of the survey. Our dependent variables relate to collaboration on innovation. We concentrate on two aspects of this relationship. First we explore how patenting affects different stages of research collaborations: here the dependent variable distinguishes between sporadic and continuous collaborations. Second, we investigate how patenting might affect different types of partnerships: here the dependent variable distinguishes between horizontal, vertical, and university–firm cooperation.

Our primary independent variable is patenting. Here we rely on a binary variable for whether the firm patented in the first period. We follow the literature (e.g. Schmiedeberg, 2008) to assume that differences between patenting and not patenting firms are more important than marginal effects of additional patents In addition we take into account a range of determinants suggested by the literature.

[7] CIS http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis : it is based on random sampling of manufacturing and service enterprises, stratified by firm-size, region, and industry. See above for an introduction.

Duration of innovation collaboration:
To understand whether patenting acts as a precursor—and/or is concurrent— to research collaboration, the study focuses on the effect that patenting (in the first period) has on the propensity to engage in cooperative activity in the total period. In short the study posits that a firm that patents early innovative activities will be more likely to collaborate throughout the period. Accordingly, our dependent variable (DVcoop) takes the following categories/scores: no cooperation (value of 0), sporadic or intermittent cooperation (value of 1) and continuous cooperation (value of 2). . Different types of cooperation, sporadic or continuous, are associated with the relevance of patents to protect innovations in CIS4 (reference period 2002 to 2004). Thus we differentiate between research collaboration that is sporadic (i.e. it takes place in only one of the periods) from that which is persistent (the firm engages in it) in the model. The prior assumption is that the latter reflects a stronger climate for collaboration which is what we posit that patenting contributes to. The third possible outcome is no collaboration.

Type of partnership in innovation collaboration We then distinguish the propensity to collaborate based on type of collaboration partner. The dependent variables ("DVcoop_vert", "DVcoop_hor" and "DVcoop_kb") are used to estimate the effect patenting has on horizontal (competitors), vertical (suppliers), and institutional cooperation (university and other research institutes), respectively.

Approach

Generalized linear models (GLMs) have become widely used to evaluate ordinal response data, especially in conjunction with CIS. GLMs model a function of the probability that a unit in the analysis falls in a given category (e.g. that a firm that patents in period one is a firm that collaborates continuously) as a linear combination of the independent variables. In the case of a probit model, this function, referred to as the link function, is the inverse cumulative standard normal distribution, while in the case of the logistic model, it is the log odds. (see also Gujarati, 2003: Chapter 15) We employ a combination of these models (namely ordered probit and multinomial logit), first, to evaluate how precursor patents affect the probability of the three ordered outcomes: no collaboration, sporadic collaboration, or continuous collaboration; and then to evaluate how patents affect the probability of the three types collaboration; horizontal, vertical, and institutional cooperation.

In addition to patenting, a range of factors can help to determine collaborative propensity/behavior. It is important to take into account variables that might affect the propensity to collaborate, especially given that logistic estimations are known to be sensitive to unobserved heterogeneity (Mood, 2009). A primary predictor is that a firm has own research activity. Own research activity is of course a precondition for collaborative research (cf Fritsch and Lukas, 2001); in addition it raises the firm's absorptive capacity. We apply a measure for sporadic and continuous internal R&D (dummy variables) as well measures of R&D expenditure (log of R&D expenditure in the first period) to control for this. Firm-size and industry are two other acknowledged predictors of the propensity to collaborate (see discussion above). The natural log of number of employees and industry dummies at the two-digit level are included to capture these two noted determinants.

These aggregations may hide other structural factors that otherwise might raise or lower the probability of collaborative activity. We use controls based on the:

A. Strategy: A firm's overall strategy is expected to influence its interest and openness to partnerships, as observed above. To account for this, we use responses by the firm on whether, in the first period (2004), they introduced new strategies, management structures, knowledge management techniques to deal with partners and internal to the enterprise.
B. Fiscal constraints: Firms may seek partnerships due to impracticalities of going it alone. We control for whether the firm finds (in 2004) high development costs, the existence of dominant market players, lack of in-house technological know-how or skilled labor to hinder their innovation, since partnerships may be a way for the firm to overcome these barriers.
C. Technological dimensions: The technology itself will also affect the propensity to collaborate. Firms responded on whether the firm relied on complexity of technology or on lead-time help the firm to maintain their innovative advantage. We control for these two proxies of technological complexity since they also serve to make collaboration more attractive (modular technologies and division of labor) and more secure, especially alongside patenting. These are multinomial measures on the same basis as the dependent variable: whether they were relied on sporadically, continuously or not at all.
D. Product Cycles: In addition, information about the product-life cycle of the firm's technology is used based on a special question in the Norwegian CIS (2004). A firm might team up to be competitive if product cycles in its markets are shorter than average but over a certain minimum threshold. This effect is controlled for.

Table 1 Descriptive Statistics

Variable	Description	Observations	Mean	Stand Dev	Min	Max
DVcoop	Cooperation duration: 0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2447	0,51	0,73	0	2
DVcoop_horizontal	Cooperation with competitors:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,17	0,49	0	2
DVcoop_vert	Cooperation with suppliers or customers:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,45	0,74	0	2
DVcoop_kb	Cooperation with university and other research institutes:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,41	0,71	0	2
patents	Firm applied for patents in 2002-2004	2390	0,14	0,35	0	1
lnemp	Natural log of employment 2004	2448	4,18	1,21	2,3	9,3
RD	R&D active in both periods=2 in one period =2 not at all =0	2448	0,81	0,90	0	2
lnRD4	Average R&D expediture for both periods	1047	7,74	1,71	0	13,2
complexity	Complexity of design: sporadic or continuous importance	2274	0,30	0,59	0	2
headstart	Lead-time advantage on competitors: sporadic or continuous importance	2280	0,52	0,74	0	2
prod_life	Product life-cycle: five intervals	2310	4,84	1,38	1	6
strategy	Change in business strategy (yes or no) 2002-2004	2328	0,24	0,43	0	1
mantech	Change in management techniques (yes or no) 2002-2004	1930	0,17	0,38	0	1
structure	Change in firm organization (yes or no) 2002-2004	1929	0,31	0,46	0	1
hcos_4	High innovation costs a constraint: (Likert-scale) 2004	2303	1,04	1,07	0	3
hper_4	Problem with retaining or recruiting qualified personnel a constraint: (Likert-scale) 2004	2294	0,73	0,84	0	3

* values are converted into dummy variables in the estimations.
**We also use 2-digit level industry dummies (SIC).
The presentation of the correlation matrix is found in the Annex.

We also conduct a series of standard tests. The mean variance inflation factors (VIF) is 2.97 for the wide definition of R&D (N=1701) and 2.6 for the narrower definition (N=756). There are higher values among the industry dummies, but all variables are well under ten.

5. Results

In the first step, an ordered probit model is used to test whether patenting affects the odds that the firm also collaborates (DVcoop), taking into account the above control variables. R&D is a major determinant of collaboration. We run the model twice. The first uses two dummy variables to account for whether the firm reports intermittent R&D or persistent R&D activity, respectively, through the two periods. The second uses R&D expenditures (log of R&D in 2004).

The first is a looser definition of the underlying activity the firms might collaborate on. It allows us to consider the importance of patents among a group firms with broader R&D activities. It fits the responses of 1701 firms to the probability of collaboration, both intermittent and continuous. The stricter definition of the second estimation allows us to focus on the effect of patenting on more traditional R&D active companies. It fits the responses of 756 firms to the probability of collaboration, both intermittent and continuous. Reporting the two separately provides a composite view of R&D activities which we will return to when looking at the importance of different types of partners.

Both estimations present a clear indication that precursor patents contribute, rather than detract from, the propensity to collaborate. Our other major independent variables have largely the expected signs. Patenting in period 1 is positive and significant. Firm size (natural log of employment "lnemp") is as expected positive. In addition to patenting in period 1, the continuous importance of lead-time in product markets appears to be an even strong positive predictor. The fact that the firm introduced new strategies also increases odds of collaboration, although only overall corporate strategy is statistically significant in both equations. The odds of cooperation are also heightened if complexity of technological design is continuously important, a result that is statistically significant in the second equation. The high cost of innovation, lack of internal technological know-how, and to a lesser degree the lack of skills are also positive, but these results are not statistically significant. The product life information does not provide a clear story here.

Table 2 The impact of patenting and other covariates on the odds for sporadic and continuous innovation collaboration: Results Ordered Probit: R&D accounted for by dummies (i) and expenditure (ii)

Dependent variable:	**Cooperation: none, sporadic, continuous**		**Cooperation: none, sporadic, continuous**	
Est. model	**Ordered probit**		**Ordered probit**	
Independent variables	**coef**	**se**	**coef**	**se**
Patents Applied for 2004	0,382***	0,10	0,425***	0,10
Lead-time advantage used continuously	0,434***	0,12	0,458***	0,13
Product life-cycle: <1 year	0,219	0,24	-0,161	0,36
Product life-cycle: 1-3 years	0,005	0,16	0,081	0,18
Product life-cycle: 4-6 years	-0,155	0,12	-0,153	0,14
Product life-cycle: 7-9 years	-0,198	0,15	-0,188	0,17
Product life-cycle: 10+ years	0,032	0,08	0,039	0,11
Complexity of design continuously important	0,210	0,14	0,204***	0,15
Log employment	0,167***	0,03	0,147***	0,05
R&D Sporadic	0,882***	0,10		
R&D Continuous	1,563***	0,10		
Change to corporate strategy	0,175**	0,08	0,253***	0,10
Management techniques	0,271***	0,10	0,171	0,12
Organisational structure	0,194**	0,08	0,170	0,11
Marketing strategy	0,059	0,08	0,091	0,09
Cost: high impact	0,012	0,14	-0,073	0,17
Skills: high impact	0,073	0,20	0,082	0,24
Technological knowledge: high	0,331	0,27	0,465	0,33
Market knowledge: high impact	-0,166	0,23	-0,195	0,25
Log R&D expenditure			0,082**	0,04
Industry dummies	included		included	
/cut1	*0,963*	*0,59*	*-0,158*	*0,75*
/cut2	*2,156****	*0,59*	*0,904*	*0,74*
Number of observations	*1701*		*756*	
R2	*0.3166*		*0.1203*	
Loglikelihood	*-1076.091*		*-730.3528*	
Wald chi2	*957.50*		*205.37*	
*notes: *** p<0.01, ** p<0.05, * p<0.1*				

CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.
Notes: The base group for the multinomial logit is no cooperation; for patents the base group is ‘not used’. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is ‘no impact’. For product cycle, the category ‘uknown’ is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

We note first that the equation based on R&D dummies is highly skewed. The values of Cut1 and Cut2 indicate that this equation is based on a population, of which about 15 percent of the reference group fall into the sporadically collaborating category and only 1.6 in the continuously collaborating category. The second equation based on R&D expenditure is more balanced: with 43 percent not collaborating, 39 percent collaborating intermittently, and 18 percent collaborating continuously.

In both cases, the results demonstrate a consistent relationship between patenting and the probability of collaboration. The model which uses R&D dummies indicates that patenting in 2004 increases the odds of collaboration by .38 standard deviations relative to the outcome of no collaboration. In the narrower model, the impact is higher (.43 standard deviations), while narrowing the difference with the coefficient for lead-time.

However, the coefficients need to be interpreted carefully since they represent standard normal scores (z statistics) in terms of a latent variable that represents the propensity to collaborate. We first report the marginal effects (AME) of patenting in each equation. A table with marginal effects for all variables is provided in Annex 2. This step indicates that the outcome of sporadic collaboration is different than that of continuous collaboration. And that the type of R&D reported should be accounted for.

Table 3 Marginal effects of Patenting on Sporadic and Continuous Collaboration: for R&D dummy and R&D expenditure equations respectively

	Outcomes	Variable	dy/dx	z	P>z
RD Dummies	Sporadic Collaboration	patents	0,03	3,64	0
	Continuous Collaboration	patents	0,06	4	0
RD expenditure	Sporadic Collaboration	patents	0	0,44	0,66
	Continuous Collaboration	patents	0,13	4,22	0

Stata 11SE: Average marginal effects, Robust VCE model.

Accounting for the effects of the other variables, patenting in 2004 has a marginal effect of about 3 percent on the probability of sporadic collaboration and 6 percent in terms of continuous collaboration. (both highly significant) The effect doubles when moving from intermittent to persistent collaboration. The effect of patenting on collaboration among firms reporting R&D expenditure in 2004 indicates that patenting is a stronger predictor of continuous collaboration. In this equation, the effect of patenting is negligible and statistically insignificant, while the effect of patenting on the odds that the firm engages in continuous collaboration is 13 percent and highly significant.

The importance of patenting increases in step with more persistent collaboration. In the next step, we look more closely at the responses from the 756 firms that report R&D expenditures in 2004. We use a multinomial logit model to indicate the effects patenting and the other covariates on sporadic and continuous collaboration, relative to a base outcome of no collaboration.

Table 4 The impact of patenting and other factors on the odds for sporadic and continuous innovation collaboration: Multinomial Logit: R&D accounted for by expenditure (2004)

Est. Model: multinomial Logit	**Cooperation:** ***Base outcome= no collaboration***			
	sporadic		**continuous**	
Independent variables	**coef**	**se**	**coef**	**se**
Patents Applied for 2004	0,706***	0,256	1,005***	0,263
Lead-time advantage used continuously	0,347	0,292	1,164***	0,325
Product life-cycle: <1 year	0,775	0,865	-13,94***	0,785
Product life-cycle: 1-3 years	0,408	0,425	0,266	0,490
Product life-cycle: 4-6 years	-0,612*	0,317	-0,409	0,334
Product life-cycle: 7-9 years	-0,540	0,373	-0,517	0,413
Product life-cycle: 10+ years	-0,146	0,255	0,058	0,283
Complexity of design continuously important	1,176***	0,416	0,725*	0,416
Log employment	0,231**	0,110	0,360***	0,117
R&D Expenditure (log)	0,059	0,081	0,219**	0,093
Change to corporate strategy	0,520**	0,228	0,634***	0,236
Management techniques	0,744***	0,289	0,470	0,327
Organisational structure	-0,147	0,240	0,409	0,258
Marketing strategy	-0,062	0,212	0,214	0,224
Cost: high impact	0,070	0,393	-0,147	0,448
Skills: high impact	-0,227	0,676	0,300	0,701
Technological knowledge: high	0,231	0,694	0,914	0,760
Market knowledge: high impact	0,273	0,576	-0,269	0,701
constant	-15,49***	1,390	-2,395	1,531
Industry dummies	Included		Included	
Number of observations	756			
Pseudo R2	0.1612			
Loglikelihood	-696.40982			
Wald chi2	NA			
note: *** p<0.01, ** p<0.05, * p<0.1				

CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.
Notes: The base group for the multinomial logit is no cooperation; for patents the base group is 'not used'. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is 'no impact'. For product cycle, the category 'uknown' is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

Noting the relationship between probit and logit models[8], the multinomial logit focuses on the responses of 756 of those firms (based on logged R&D expenditure in 2004). The base outcome is no collaboration. The results reinforce the picture created in the results above, providing output that is consistent with expectations. It illustrates again that patenting is an important predictor of collaboration but that its effect increases the likelihood more for continuous than for intermittent collaboration. Important structural factors (Firm-size and R&D expenditures) follow this same

[8] Comparisons of logit and probit coefficients can be made by dividing the logit coefficients by 1.8. (Gujarati, 2003; 615)

pattern. Firms that continuously rely on lead-time advantage are also much more likely to engage in continuous collaborations rather than not collaborating or collaborating only sporadically. The same goes for the effect that changes in corporate strategy have on collaboration, while the other forms of strategic change lose predictive power and/or are statistically insignificant.

On the other hand, reliance on complexity of design is more important as a predictor of sporadic rather than continuous collaboration. The introduction of new management techniques corresponds here with a robust effect on the odds of sporadic collaboration. One interesting new thing is that product lifecycle 1 (products with lifecycles under 1 year) is strongly negative for continuous collaboration: again an intuitive outcome. A positive (but insignificant) effect is suggested for firms with product-cycles that are shorter than average (between 1 and 3 years), but more than 1 year.

In the final step we consider whether patenting affects the probability of different types of collaborators. Following earlier work (see above: e.g. Belderbos et al, 2004; Janne & Frenz, 2006), we distinguish between vertical and knowledge-based relationships, i.e. those mainly between suppliers and those mainly with universities, respectively. The estimations involving Horizontal collaborations with competitors failed. The following presentation is therefore based on collaborations with two types of partners: suppliers and customers (vertical) and university and other research institutes (institutional cooperation). We maintain the ordered categories between firms that collaborate intermittently and those that do so continuously.

Table 5 The impact of patenting and other factors on vertical and research institution collaboration: Multinomial Logit: R&D accounted for by expenditure (2004)

Dependent variable:	Vertical Collaboration				Collaboration with research organizations			
Est. Model: multinomial Logit	sporadic		continuous		sporadic		continuous	
Independent variables	coef	se	coef	se	coef	se	coef	se
Patents Applied for 2004	0,495*	0,270	1,064***	0,238	0,414*	0,248	1,035***	0,242
Lead-time advantage used continuously	0,362	0,319	0,828***	0,286	0,079	0,285	0,999***	0,305
Product life-cycle: <1 year	-13,852***	0,700	0,512	1,019	1,183	0,779	-14,136***	0,736
Product life-cycle: 1-3 years	0,123	0,459	0,595	0,415	-0,741*	0,445	-0,376	0,433
Product life-cycle: 4-6 years	-0,177	0,336	-0,373	0,317	-0,182	0,316	-0,504	0,327
Product life-cycle: 7-9 years	-0,527	0,435	-0,248	0,378	-0,394	0,365	-0,592	0,394
Product life-cycle: 10+ years	0,172	0,264	-0,135	0,265	0,094	0,254	-0,227	0,275
Complexity of design continuously important	0,892**	0,396	0,977***	0,360	0,397	0,345	0,279	0,354
Log employment	0,109	0,119	0,190*	0,105	0,355***	0,110	0,451***	0,114
R&D Expenditure (log)	0,010	0,081	0,171*	0,096	0,016	0,074	0,191*	0,101
Change to corporate strategy	0,647***	0,229	0,604***	0,221	0,287	0,218	0,514**	0,224
Management techniques	0,101	0,296	0,661**	0,281	0,066	0,265	0,269	0,289
Organisational structure	0,303	0,247	0,230	0,234	0,096	0,223	0,087	0,240
Marketing strategy	0,184	0,229	0,126	0,209	0,151	0,208	0,334	0,215
Cost: high impact	0,060	0,403	0,089	0,388	0,025	0,386	-0,183	0,415
Skills: low impact	-0,847**	0,404	-0,798**	0,367	-0,623*	0,351	-0,244	0,440
Technological knowledge: high	0,389	0,790	1,429**	0,654	-0,204	0,847	0,707	0,794
Market knowledge: high impact	-0,224	0,590	-0,054	0,599	-0,219	0,609	0,026	0,688
constant	-0,432	1,474	-1,854	1,429	-0,747	1,394	-2,959**	1,424
Number of observations	756				756			
Pseudo R2	0.1545				0.1472			
Loglikelihood	-677.85597				-692.93803			
Wald chi2	1144.08				1423.40			
note: *** p<0.01, ** p<0.05, * p<0.1: Industry dummies not reported								

Source: CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.
Notes: The base group for the multinomial logit is no cooperation; for patents the base group is 'not used'. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is 'no impact'. For product cycle, the category 'uknown' is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

The results indicate some added distinctions in the relationship of these covariates of collaboration already presented. Disaggregated in this way, the size-effect is now seen to be strongest (and most strongly significant) in relation to the collaborations with research organizations, both in terms of the odds that firms collaborate intermittently or continuously. R&D expenditures are much more strongly associated with continuous than sporadic collaboration with both types of partners, but the results are less robust. (significant at the 10 percent level) The strongly negative result for the shortest product-cycles is found in both groups, but isolated to the propensity for continuous collaboration.

The importance of lead-time advantage is again seen in terms of increasing the probability of continuous collaboration also with both suppliers (vertical) and with research organizations. The importance of complexity of design also has a positive effect, but this is found in relation to vertical collaborations and not to collaborations with research organizations. The effect of the introduction of new management techniques influences the odds of collaborations with suppliers and customers more than those with research organizations, although corporate structure effects are strong for continuous collaboration with either set of collaborator.

Firms that name the lack of technological knowledge as having a high impact on their innovation activities, are much more likely to collaborate vertically with suppliers and customers on a continuous basis (significant at the 5 % level). Meanwhile, the lack of skilled employees has a negative effect on vertical collaborations of both durations.
Patenting is again consistently positive in relation to both types of collaboration: however it is a stronger predictor of continuous than of sporadic collaboration. It remains positive (and weakly significant, now at the 10 percent level) for sporadic collaboration. The most important effect of patenting is on the propensity to collaborate continuously. This impression is confirmed when looking more closely at the marginal effect of patenting in the first period on both sporadic and continuous collaborations involving each of the two types of collaborators. Marginal effects are reported for all variables in Annex 3 and 4.

Table 6 Marginal effects of Patenting on Sporadic and Continuous Collaboration: for collaborations with suppliers and with research organizations respectively

Equations	Outcomes	Variable	dy/dx	z	P>z
Vertical collaboration	Sporadic Collaboration	patents	0,00	0,06	0,95
	Continuous Collaboration	patents	0,16	4,34	0,00
Collaboration with Research Organizations	Sporadic Collaboration	patents	-0,02	-0,91	0,36
	Continuous Collaboration	patents	0,07	4,68	0,00

Stata 11SE: Average marginal effects, Robust VCE model.

The effect of patenting in 2004 has negligible (and in the case of collaboration with research organizations a negative impact) on the likelihood of intermittent collaboration: this effect is very weak and statistically insignificant. Patenting however has a strong positive (and highly significant) effect on the probability of continuous collaboration. This rings true for both types of collaborators but is strongest (16 percent) for collaborations involving suppliers or other vertical relationships.

6. Conclusions

If patenting were solely about keeping knowledge resources in house, there might be very little collaboration among patenting firms. A textbook firm that uses patents to minimize knowledge outflows and to maximize the capture of rents from knowledge generated outside (e.g. from universities) would be an unwilling research collaborator and an unattractive partner. Yet, patenting and of research-based collaborations have risen hand in hand the past two or three decades, suggesting a positive relationship between the two.

This paper studied this relationship between patenting and research collaboration using a balanced panel of Norwegian responses (N=2448) to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006. We discussed contexts in which research collaborations may involve patenting, given that patenting may precede collaborative effort, may accompany it, and/or may follow it. The latter scenario is established as the more prominent focus of the (mainly industrial organization) literature.

The focus of this paper has instead been on patenting leading simultaneous with or subsequent to research collaboration. In general, we assume that patents play a larger role in the strategies of these collaborating firms than n non-collaborative firms. We account for a range of other factors that might affect the propensity to collaborate. In addition to R&D activity (dummy and expenditure), industry dummies, and firm-size, we account for **Strategic activity**, including reported changes in the basis for partner relationships; **Fiscal constraints** including sensitivity to high development costs; **Technological dimensions**, such as technological complexity and the reliability of lead-time that might affect the propensity to collaborate; and length of product-cycles, where we use an ordinal variable of product-cycles from the Norwegian survey. We do so to minimize unobserved heterogeneity.

We use standard generalized-linear models (ordered probit and multinomial logit) to evaluate how precursor patents affect the probability of the three ordered outcomes: no collaboration, sporadic collaboration, or continuous collaboration. Collaboration is then differentiated to analyze the effect patenting has on collaborations that involve competitors (horizontal), that involve suppliers and customers (vertical), and that involve involving outside research organizations.

The results find a strong and consistently positive effect of patenting on the probability that the firm collaborates. This effect comes into relief most strongly when using R&D expenditures (logs 2004) to account for the role of R&D in the collaborations. Patenting affects the propensity for continuous collaboration most strongly but it also increases the odds of sporadic collaborations significantly.

The higher impact on continual collaboration comes through still more strongly when the distinction between horizontal, vertical and research organization collaboration are studied. Unfortunately we have insufficient observations to study horizontal partnerships. Looking at vertical and research organization collaboration, we find patenting to again be consistently positive in relation to both types of collaboration. Patenting is here again a stronger predictor of continuous than of sporadic collaboration.

These estimations support the position that patenting of own knowledge contributes to the probability that the firm also collaborates with other firms. Patenting is positive and significant in each model, but clearest in relation to the probability that the firm will continue to collaborate. Furthermore it is clearest in relationship to continuous collaborations with suppliers and customers (i.e. vertical collaboration) .

The paper contributes to a better appreciation of the relationship of patenting and research collaboration, in terms of the persistence of (continuous & intermittent) as well as in terms of the type of collaboration (horizontal, vertical, and research organizations). Furthermore it provides an understanding of the role that other factors—Structural (e.g. size), Strategic activity, Fiscal constraints, Technological dimensions, and product cycles— have on research collaboration.

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Annexes

Annex 1 Correspondence Matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cooperation: Values 0,1,2	1,00													
Patents applied for (2004)	0,25	1,00												
log enterprise size (2004)	0,18	0,10	1,00											
R&D active: Values 0,1,2	0,33	0,20	0,04	1,00										
log R&D expenditures (2004)	0,23	0,30	0,25	0,35	1,00									
Complexity of design: Values 0,1,2	0,19	0,22	-0,02	0,22	0,30	1,00								
Lead-time advantage: Values 0,1,2	0,25	0,21	0,03	0,33	0,31	0,51	1,00							
Product life-cycle: five intervals	0,02	-0,05	0,26	-0,14	-0,16	-0,19	-0,18	1,00						
Business strategy: 2002-04	0,15	0,05	0,15	0,09	0,15	0,05	0,13	0,00	1,00					
Management techniques: 2002-04	0,15	0,02	0,18	0,12	0,15	0,06	0,14	0,03	0,10	1,00				
Firm organization: 2002-04	0,16	0,09	0,07	0,16	0,21	0,16	0,20	-0,07	0,13	0,43	1,00			
High costs constraint: 2004	0,05	0,01	-0,09	0,03	0,05	0,09	0,10	-0,08	0,10	-0,01	0,03	1,00		
Skilled personnel constraint: 2004	0,08	0,13	0,00	0,06	0,11	0,05	0,08	-0,10	0,03	0,02	0,05	0,29	1,00	
Tech knowledge constraint: 2004	0,10	0,02	-0,07	0,05	0,03	0,11	0,09	-0,06	0,06	-0,03	0,03	0,31	0,50	1,00

Annex 2 Collaboration Duration: Marginal Errors for Broad R&D Category (using R&D dummies): Ordered Probit Model

Ordered Probit Model	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,03	3,64	***	0,06	4,00	***
leadtime3	0,03	3,42	***	0,07	3,51	***
life_cycle1	0,02	0,90		0,03	0,90	
life_cycle2	0,00	0,03		0,00	0,03	
life_cycle3	-0,01	-1,28		-0,02	-1,30	
life_cycle4	-0,02	-1,34		-0,03	-1,35	
life_cycle5	0,00	0,38		0,00	0,38	
complex3	0,02	1,43		0,03	1,46	
lnemp	0,01	4,42	***	0,03	4,87	***
RD2	0,07	9,24	***	0,13	8,61	***
RD3	0,12	13,36	***	0,24	14,28	***
strategy	0,01	2,21	**	0,03	2,25	**
mantech	0,02	2,70	***	0,04	2,83	***
structure	0,01	2,38	**	0,03	2,40	**
marketing	0,00	0,77		0,01	0,77	
cost4	0,00	0,09		0,00	0,09	
skill4	0,01	0,36		0,01	0,36	
tech4	0,03	1,22		0,05	1,22	
market4	-0,01	-0,71		-0,03	-0,71	
N	1701					
chi2	957.5					
df_m	47					

*Some variables including industry dummies and intermediate variables are not reported

Annex 3 Collaboration Duration: Marginal Errors for narrow R&D Category (using log R&D expenditure): Ordered Probit Model

	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,002	0,44	***	0,13	4,22	***
leadtime3	0,002	0,45	***	0,14	3,42	***
life_cycle1	-0,001	-0,33		-0,05	-0,45	
life_cycle2	0,000	0,31		0,02	0,44	
life_cycle3	-0,001	-0,41		-0,05	-1,08	
life_cycle4	-0,001	-0,41		-0,06	-1,10	
life_cycle5	0,000	0,28		0,01	0,34	
complex3	0,001	0,41		0,06	1,37	
lnemp	0,001	0,44	***	0,04	3,09	***
lnRD4	0,000	0,44		0,02	2,27	**
strategy	0,001	0,44	***	0,08	2,69	***
mantech	0,001	0,42		0,05	1,39	
structure	0,001	0,44		0,05	1,61	
marketing	0,000	0,41		0,03	0,98	
cost4	0,000	-0,31		-0,02	-0,42	
skill4	0,000	0,27		0,02	0,34	
tech4	0,002	0,43		0,14	1,40	
market4	-0,001	-0,39		-0,06	-0,77	
N	756					
chi2	205.4					
df_m	46					

*Some variables including industry dummies and intermediate variables are not reported

Annex 4 Vertical Collaboration: Marginal Errors for narrow R&D Category (using R&D dummies): mlogit

Vertical Collaboration	Sporadic Collaboration			Continuous Collaboration		
Est model: mlogit	ME	Z		ME	Z	
patents	0,002	0,06		0,16	4,34	***
leadtime3	-0,002	-0,04	*	0,12	2,64	***
life_cycle1	-2,204	-13,84	***	1,07	5,83	***
life_cycle2	-0,023	-0,36		0,10	1,47	
life_cycle3	-0,001	-0,03		-0,05	-1,08	
life_cycle4	-0,065	-1,05		-0,01	-0,12	
life_cycle5	0,037	0,97		-0,04	-0,85	
complex3	0,070	1,38		0,11	2,11	**
lnemp	0,004	0,21	*	0,03	1,51	*
lnRD4	-0,011	-0,9		0,03	1,9	*
strategy	0,059	1,87	*	0,06	1,81	*
mantech	-0,031	-0,8		0,11	2,64	***
structure	0,031	0,91		0,02	0,53	
marketing	0,020	0,6		0,01	0,28	
cost4	0,003	0,05		0,01	0,18	
skill4	-0,115	-1,19		0,01	0,14	
tech4	-0,040	-0,34		0,23	2,04	**
market4	-0,031	-0,36		0,01	0,06	
N	756					
chi2	1423.4					
df_m	92					

*Some variables including industry dummies and intermediate variables are not reported

Annex 5 Vertical Collaboration: Marginal Errors for narrow R&D Category (using R&D dummies): mlogit

Institution	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,00	0,01		0,14	4,22	***
leadtime3	-0,06	-1,27		0,16	3,59	***
life_cycle1	1,22	8,80	***	-2,42	-15,64	***
life_cycle2	-0,11	-1,42		-0,01	-0,14	
life_cycle3	0,00	0,07		-0,07	-1,45	
life_cycle4	-0,03	-0,46		-0,07	-1,15	
life_cycle5	0,03	0,81		-0,04	-1,09	
complex3	0,05	0,94		0,02	0,35	
lnemp	0,03	1,75	*	0,05	2,88	***
lnRD4	-0,01	-0,86		0,03	1,99	**
strategy	0,01	0,42		0,06	1,95	**
mantech	-0,01	-0,17		0,04	0,93	
structure	0,01	0,30		0,01	0,21	
marketing	0,00	0,09		0,04	1,35	
cost4	0,02	0,28		-0,03	-0,51	
skill4	-0,03	-0,29		0,06	0,63	
tech4	-0,09	-0,67		0,13	1,19	
market4	-0,04	-0,42		0,02	0,19	
N	756					
chi2	1423.4					
df_m	92					

*Some variables including industry dummies and intermediate variables are not reported