Strategic Management of Innovation and Patenting Performances

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Abstract

This paper intends to contribute to the literature on the determinants of firms' patenting performances. In this respect it puts forward several new hypotheses related to the relationship between the strategic management of innovation and patenting performances. It relies on an original survey questionnaire on innovation competencies, innovation strategy and the perceived innovation barriers of 148 large firms in Belgium. The econometric results confirm several hypotheses already tested in the literature, including the positive impact of firm size, market concentration and technological opportunity. In addition, innovation strategy (e.g., product vs. process innovation; university partnership; the share of basic and applied research in total R&D), innovation competencies (e.g., ideas storage and codification ; use of academic information), and barriers perception (e.g., internal barriers ; risk/cost barriers) are all significant determinants of patenting performances.

JEL: O31, O32, O34, L25

Keywords: Innovation competencies, Innovation performances, Barriers to innovation, Patents.

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Strategic Management of Innovation and Patenting Performances

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1. Introduction

This paper is about intellectual property (IP), "*once considered the most boring subject in the world*" [Rivette and Kline, 2000, chapter 1, p. 1]. The authors of "*Rembrandts in the Attic*" all too amply demonstrate that the ownership of ideas is now becoming part of the day-to-day business live, policy debates, and legal arguments. Indeed, publications on the strategic management of IP have recently flourished [e.g., Parr and Sullivan (1996) and Glazier (2000)]. This focus on IP is also witnessed by a vast economic literature, with both theoretical and empirical contributions.

Pioneer work in the field of patents and IP probably started with the contributions of Schmookler (1957), Nelson (1959), Arrow (1962) and Scherer (1965). Since then, academic research has continuously and increasingly tackled various aspects of IP, from the theoretical analysis of patenting systems [e.g., Baumol (2002)], to the use of patent data to measure innovation performances and knowledge spillovers indicators [e.g., Griliches (1990)]. With the development of extensive and accessible patent databases, several authors have analyzed the micro-determinants of innovation using patent indicators [e.g., Duguet and Kabla (1998) and Cohen *et al*. (2000)]. This literature has two main justifications. First, innovation is considered as an important driver of sustainable growth. Policy-makers and company boards are therefore interested in the firms' patenting performances, as indicator of innovative performance. [1] Second, patenting is a legal protection mechanism that avoids innovative profits to freely spur out to other firms or countries. Together with copyrights, trademarks and other legal mechanisms, patents are a central concern for all institutions involved in the generation of knowledge.

This paper intends to contribute to the specific literature attempting to identify the firms and market characteristics underlying the large variance observed across firms in terms of patenting performance. In what follows we put forward and test several new hypotheses on the role of innovation strategy, innovation competencies, and the perceived barriers to innovation and patenting. In this respect, an original survey data on 148 large firms in Belgium is used. Two econometric models are developed to evaluate the impact of several potential determinants of patenting performances. The first one attempts to explain the probability for a firm to have a patent portfolio. The second one attempts to explain the breadth of this patent portfolio.
The estimates show that the two models yield different results. All the significant determinants of the probability to have at least one patent also influence the breadth of the patent portfolio. However, there are much more factors that also play a significant role in explaining the breadth of the portfolio. Several, but not all, of the new hypotheses are confirmed by the estimates, underlying therefore the importance of innovation strategy, innovation competencies and the perception of barriers to innovation.

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[1] Patent-based indicators are one measure of innovative activity, among others. The validity of patents as indicator of innovation is debatable (Griliches, 1990), for three main reasons. First, not all innovations are patentable since the three conditions of non obviousness, inventive step and industrial application must be satisfied in order to get a patent application granted. Second, the propensity to patent 'patentable' inventions varies considerably across firms, time and industry [see for instance Scherer (1983), Hall *et al.* (1986) and Arora (1997)]. In some sectors patent protection is relatively inefficient and secrecy is favored as a mechanism to secure the rents due to an invention. The importance of the various protection mechanisms varies across industries and is very important for only a few of them, mainly chemicals and pharmaceuticals [Mansfield (1986), Levin *et al.*(1987)].

The next section presents first the main hypotheses already tested in the literature on the determinants of firms' patenting performances. Then, several new hypotheses are suggested. They concern the firms' innovation strategy, innovation competencies and barriers perception. Section 3 develops the empirical implementation. It shows how the questionnaire has been built and presents the two main econometric models. Many sub-competencies have been used to create 'aggregate' competencies through a principal component analysis. The empirical results are interpreted and discussed in section 4. The last section concludes and draws some policy and managerial implications.

2. Literature Review and Tested Hypotheses

Pioneer work in the field of patents and intellectual property started with the contributions of Nelson (1959) and Arrow (1962). A few years later, one of the first empirical studies linking inventive activity, approximated by the firms' number of patent applications, and some firm and industry characteristics was performed by Scherer (1965). With the development of extensive and accessible patent databases, several authors began to study the determinants of innovation using patent indicators.[2]

The recent studies on the determinants of firms' patenting performances are summarized in Appendix 1. They include include Crépon *et al*. (1996, 1998), Duguet and Kabla (1998), Brouwer and Kleinknecht (1999), Baldwin *et al*. (2001), Cassiman *et al* (2001) and van Ophem *et al*. (2001). Most of these studies focus on the determinants of either the number of yearly patent applications, or the probability for a firm to have applied for at least one patent.

In what follows we present first the basic hypotheses that have already largely been tested and discussed in the literature. They relate to the firm size, competitive environment, technological and market opportunities, the propensity to enter into collaborative research, and R&D intensity. We then put forward several new hypotheses, which have little or no empirical validation so far. They concern the domestic or foreign nature of firms, their degree of internationalization, their information sources, their projects selection processes, their product or process oriented innovation strategy, the perceived ineffectiveness of the patent system, the perceived barriers to innovation, and the age of the firm.

Basic Hypotheses

> *Hypothesis 1 – Large firms have a higher probability to have at least one patent and have larger patent portfolios.*

Most econometric studies on innovation evaluate the impact of the firms' size in an attempt to further test the famous Schumpeterian hypothesis that large firms are more innovative than small ones. This hypothesis has later been stigmatized as the fourth stylized fact of Cohen and Klepper (1996). The advantage of being large comes from three main factors, summarized in Cohen and Levin (1989). First, large firms can benefit from economies of scale and scope that make them more competitive in comparison to their smaller competitors. Second, large firms can benefit from complementarities and spillovers between different departments. Finally, large firms are favored by capital markets for the financing of risky innovation projects. Baldwin *et al*. (2001) find that the effect of the firm size depends on the innovation indicator used, with a weaker relationship when relying on patent data than when relying on the percentage of innovative sales, i.e. an indicator of innovation output. According to van Ophem *et al*. (2001) the effect of the firm size on its patent applications is debatable. Large firms can more easily rely on market lead to secure their innovation rents, and hence are less likely to need patent protection. However, they are better able to set up a patent department and to face potential litigations. Their econometric analysis shows a positive effect of firm size on the number of patent applications. Some authors find no significant impact of the size variable when it is controlled for other effects like industry effects, differences in access to external know-how and appropriability conditions [Duguet and Kabla (1998), Crépon *et al*. (1998) and Cassiman *et al*. (2001)]. Brouwer and Kleinknecht (1999) shed some light on this debate by using two different patent indicators. They find

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[2] Patent-based indicators are one measure of innovative activity, among others. The validity of patents as indicator of innovation is debatable (Griliches, 1990), for three main reasons. First, not all innovations are patentable since the three conditions of non obviousness, inventive step and industrial application must be satisfied in order to get a patent application granted. Second, the propensity to patent 'patentable' inventions varies considerably across firms, time and industry [see for instance Scherer (1983), Hall *et al.* (1986) and Arora (1997)]. In some sectors patent protection is relatively inefficient and secrecy is favored as a mechanism to secure the rents due to an invention. The importance of the various protection mechanisms varies across industries and is very important for only a few of them, mainly chemicals and pharmaceuticals [Mansfield (1986), Levin *et al.*(1987)].

that the probability of having at least one patent application increases more than proportionately with the number of employees while the number of patent applications increases less than proportionately. This means that small firms that do apply for patents do it proportionately more, probably to compensate for disadvantages in terms of market share, marketing and brand name.

Hypothesis 2 – Firms that face little competition have a higher probability to have at least one patent and have larger patent portfolios than firms facing intense competition.

Another determinant of innovation that is quite controversial is the intensity of the competition firms face. It is measured either by the firm market share or by an index of industry concentration. The debate originates from Schumpeter's hypothesis that firms with a higher market power are more innovative than firms with weak market power. This hypothesis has later been challenged by several authors. Two effects work indeed in opposite directions. On the one hand there is the replacement effect implying that firms with more power on the market invest less in innovation because the gains they would get would only replace current gains (Arrow, 1962). On the other hand there is the efficiency effect following which firms with a high market power invest more in innovation because they do not face competition for the exploitation of their inventions (Gilbert and Newberry, 1982). The impact of this variable varies quite importantly according to the innovation indicator used. Results of studies using the same innovation indicator can also be very different, as argued by Cohen and Levin (1989) in their review of the literature on the relationship between R&D and market power. Concerning the number of patent applications, Duguet and Kabla (1998) and Nielsen (2001) find a positive influence of the firm market power, i.e. the efficiency effect seems to dominate the replacement effect.

Hypothesis 3 – Firms in high technological opportunity sectors have a higher probability to have at least one patent and have larger patent portfolios than firms in low technological opportunity sectors.

The technological opportunity is generally measured at the industry level and has been defined by Levin *et al*. (1987) as the extent to which an industry relies on science-based research. The technological opportunity is expected to positively influence R&D investments. The innovation output will probably be more influenced by market-related variables because it is more directly linked to the market. In this respect, the status of patent indicators is controversial. Patents are a kind of intermediate indicator reflecting the output of research activities but not necessarily implying the commercialization of an invention. Firms in high technological opportunity sectors are found to patent more than other firms [Crépon *et al*. (1996, 1998) and Brouwer and Kleinknecht (1999)] but the difference is not always significant [Duguet and Kabla (1998) and Baldwin *et al*. (2001)]. Concerning the market-related variables, Crépon *et al*. (1996) find that they have a positive and significant impact on patent applications, but the effect is generally found insignificant [Duguet and Kabla (1998), Crépon *et al*. (1998) and Cassiman *et al*. (2000)].

Hypothesis 4 – A higher R&D intensity is associated with a higher probability to have at least one patent, and with a larger patent portfolio.

Another issue that has largely been studied in the literature is the relationship between R&D and patents. Scherer (1965) considers patents as an indicator of R&D success. In this perspective R&D precedes patent applications and the causality goes from R&D to patents, with R&D being eventually lagged in the equations. More recently, Hall *et al*. (1986) argue that there is a strong contemporaneous effect between R&D and patenting and that it is difficult to find the adequate lag structure between R&D and patents. One could say that the lag structure is less important that it might seem because once a research unit is established in a company it is likely to invest a relatively stable amount of resources and to generate a quite constant flow of patents. Most studies including an R&D indicator in the patent equations find a positive and significant relationship [Duguet and Kabla (1998), Crépon *et al*. (1998) and Brouwer and Kleinknecht (1999)]. However, recent evidence shows that one additional patent application induces an increase in R&D four years later (van Ophem *et al*., 2001) and that four years lagged R&D expenditures do not influence patent applications [van Ophem *et al*. (2001) and Cincera (1997)]. These results have thrown back the discussion about the causality link between R&D and patents. Actually, the relationship between R&D and patents could be seen as a virtuous cycle. The former induces the later, which in turn requires further development costs in order to reach profitability.

> *Hypothesis 5 – Taking part in research partnerships leads to a higher probability of having at least one patent, and to larger patent portfolios.*

Using a dummy variable, Brouwer and Kleinknecht (1999) and van Ophem *et al*. (2001) find that the firms participating in research partnership and collaboration apply for more patents than the firms that are more 'inward' looking. Firms can collaborate with various types of partners: competitors, vertical partners, universities, consultants, complementary firms and other firms of the same group. These institutions form an external stock of knowledge that might prove useful for the firms' own innovation activities. A research collaborative agreement implies a mutual access to the partners' knowledge base. Therefore, collaborative firms would be more likely to seek patent protection for their own knowledge base. Moreover, when patented, the firm knowledge base becomes a tradable asset that can reveal very useful when negotiating a collaboration agreement.

New Hypotheses

Other hypotheses about the determinants of patenting performances have not been subject to a wide empirical validation yet or have not been suggested so far. They are related to the firm strategy (i.e., process vs. product innovation, diversification, degree of internationalization), its innovation competencies (i.e., information sources, project selection processes), its perception of barriers to innovation, its perception of the effectiveness of the patent system, its geographical origin (i.e. domestic vs foreign firm), and its age.

> *Hypothesis 6 – Foreign firms have a higher probability to have at least one patent and have larger patent portfolios.*

Another variable eventually included in patent regressions is the firm's geographical origin. The issue is to test whether foreign firms have better patenting performances than local firms. A common thought is that foreign firms are more innovative than local ones. As a consequence they are likely to patent more. Since foreign firms are subsidiaries of sister companies it could be argued that they are less involved in patenting. Patents could indeed be managed at the group level, in the country of origin. This hypothesis is tested and confirmed by Baldwin *et al*. (2001) on Canadian firms' survey data.

> *Hypothesis 7 – Firms that look for information beyond their boundaries have a higher probability to have at least one patent, and have larger patent portfolios.*

There are various potential external information sources firms can use in their innovation projects. There are the customers, suppliers and competitors, scientific institutions like universities and research institutes, consultants, and also patent databases, the scientific literature and market surveys. Looking globally to these information sources, Cassiman *et al*. (2001) find a positive relationship between the recourse to various information sources and the firm propensity to patent.

> *Hypothesis 8a – The importance of the development of new products in a firm's strategy is associated with a higher probability to have at least one patent, and to a larger patent portfolio.*
> *Hypothesis 8b – The importance of the development of new processes in a firm's strategy is associated with a weaker probability to have at least one patent, and to a smaller patent portfolio.*

It is traditionally found that process innovations are less likely to be patented [Arundel and Kabla (1998) and Brouwer and Kleinknecht (1999)] and that secrecy is a more appropriate protection mechanism for this type of innovation [Cohen *et al*(2000)]. It is indeed more difficult to track down imitations of processes than imitations of products. Therefore, the publication of technical information a patent requires might be more worthwhile in the case of a product innovation, for which infringement is easier to detect. Moreover, imitating a process innovation might be more difficult than a product innovation because a lot of specific know-how is generally needed in order to make use of a new process, specific expertise that potential imitators are lacking. Firms might therefore opt for a non legal protection mechanism such as secrecy. At the opposite, product innovations might be easier to imitate through reverse-engineering and a legally enforceable protection with patents might be necessary.

Hypothesis 9 – Firms that perceive a higher "ineffectiveness" of the patent system and a higher cost of patenting have a lower probability to have at least one patent, and have smaller patent portfolios.

The advantage for a firm to patent an invention is not always clear since a patent offers protection to its holder at the high indirect cost of revealing important technical information. Actually, applying for a patent does not seem to be the most popular protection mechanism for manufacturing firms, which often favor secrecy and lead time over competition [Levin *et al*. (1987), Brouwer and Kleinknecht (1999) and Cohen *et al*. (2000), Arundel (2001)]. The risk to face competitors "inventing around" and the disclosure of critical information are found to be the most important reasons why patents are not always efficient at protecting innovation rents [Levin *et al*. (1987), Scotchmer and Green (1990) and Cohen *et al*. (2000)]. For instance, Mansfield *et al*. (1981) found that patent protection does not increase imitation time and costs dramatically. Patent costs influence the behavior of small and large firms differently. The high costs of application and litigation prevent small firms to use the patent system more intensely while large firms seem more able to afford the fixed costs associated with a patent (Cohen, 1995).

Hypothesis 10 – Firms that highlight more barriers to innovation have a lower probability to have at least one patent, and have smaller patent portfolios.

Some authors use innovation survey data to test the effect of potential barriers to innovation on the firms innovation activities [Lööf and Heshmati (2002) and Veugelers and Cassiman (1999)]. They generally find that a lack of interest from customers, a lack of technological information and a lack of qualified personnel have a negative impact on firms' innovation. At the opposite, the lack of external financial means and costs (and risks) barriers positively affect innovation. It must be noticed that the positive impact concerns the firms' innovation performances, measured as the level of innovation investment by Lööf and Heshmati (2002) and as the decision to innovate or not by Veugelers and Cassiman (1999). Innovation barriers could also have an impact on the firms' patenting performances, as indicator of innovation involvement and R&D success. Cassiman *et al* (2001) find that high innovation costs and lack of financing have a positive effect on the firms' propensity to patent. This counter-intuitive positive effect highlights a recurrent problem of measurement of the barriers to innovation. Indeed it is often difficult to discern the firms' perception of the barriers from the barriers that effectively hinder the firms' innovation efforts and their patenting performances.

Hypothesis 11 – The youngest and oldest firms have a higher probability to have at least one patent and have larger patent portfolios than firms of intermediate age.

The firm age could influence its patent portfolio in two opposite directions. Young firms might be more dynamic and have a less rigid structure favorable to innovation, and hence patenting. However, over time, older firms might have built a larger technological expertise protected by a larger number of patents. They also probably have more resources to sustain strong patenting strategies. The relationship between the firm age and its patenting performances might therefore be U-shaped with better performances for young and old firms as opposed to firms of intermediate age.

Hypothesis 12 – Firms with a higher degree of internationalization have a higher probability of having at least one patent, and have larger patent portfolios.

Firms operating in a large number of countries can be expected to have better patenting performances for two main reasons. First, they face a larger potential market than firms operating more in their local or regional market and they face more international competition. Both aspects increase the need for higher innovation efforts. The number of countries in which a firm operates would reflects some kind of market opportunity effect. Second, an international competition increases the need for innovation rents protection because the number of potential imitators increases and infringement is more difficult to detect. This would translate into a higher propensity to patent innovations on a global scale

Hypothesis 13 – A better projects selection process leads to a higher probability of patenting and to larger patent portfolios.

Only a small share of innovative ideas receives the necessary resources to enter into the development phase. And much fewer reach large scale production and commercialization. Therefore, firms need to have an efficient ideas selection process enabling them to track down the projects to push forward [Montoya-Weiss (2000), Cooper *et al*. (2001)], i.e. the ones that will most probably lead to important profits. As indicator of R&D success we might expect the patent portfolios to be positively influenced by the capacity of firms to implement an efficient projects selection process. A good selection process might rely on a systematic storage of innovative ideas, on an IT-based knowledge codification system, on a formal estimation procedure of the probability of success of the projects, and on a good assessment of the potential barriers to innovation beforehand.

Hypothesis 14 – A higher proportion of basic and applied research in total R&D budget leads to a higher probability of patenting and to larger patent portfolios.

If the positive relationship between the relative effort in research and patenting has been widely illustrated, there is no evidence so far about the content of R&D. R&D is traditionally composed of basic research, applied research and development. Since patents are by definition a codification of an invention, they might rather be the outcome of basic and applied research as opposed to development activities. The latter would surely be associated with patenting (development of inventions), but provided a sufficient share of total R&D is devoted to basic and applied research.

3. Empirical Implementation

Two main models are used in order to identify the determinants of firms' patenting performances. The first one focuses on whether firms have a patent portfolio or not, i.e. the probability for a firm to have at least one patent. The second one intends to explain the breadth of this portfolio, i.e. the number of patents a firm has in its patent portfolio. This dual approach has already been adopted by some authors like Crépon *et al*. (1996, 1998) and Brouwer and Kleinknecht (1999). However, they used information about the number of yearly patent applications while our data concern all patents in force in the firms' patent portfolio.

- Insert figure 1 around here -

The empirical methodology is illustrated in figure 1. In the left-hand side box are the 19 explanatory variables included in the two models and the number of the related theoretical hypotheses. On the right-hand side boxes are the econometric models used and the corresponding dependent variables. A binary logit model is used to estimate the probability for a firm to have at least one patent. A count model with a negative binomial specification is used to estimate the breadth of the patent portfolio.[3]

The data used in this study come from an original survey on firms' innovation competencies and performances in Belgium. The questionnaire was sent to the CEO's of 1301 large firms active in all sectors in Belgium. A total of 148 questionnaires were filed and sent back. However, due to missing data, only 97 questionnaires could be used in this study. An extensive statistical analysis of the survey results can be found in Peeters and van Pottelsberghe (2003). The sample composition and summary statistics are provided in table 1.

- Insert table 1 around here -

Less than half the firms of the sample claim to have at least one patent. The average patent portfolio is composed of 33 patents. However, the standard deviation of this variable is very large. The average firm of the sample counts 595 employees, is 34 years old and is operating in 25 different countries. Nearly half the firms of the sample are foreign firms active in Belgium and 37% belong to a high-tech or medium high-tech industry. Concerning the R&D activities, 93% of firms claim to have some kind of R&D activity. On average the sample allocates 35% of its R&D budget to basic and applied research, as opposed to development activities. Finally, 42% of firms give a high importance to process innovation. This is higher than the percentage of firms that give a high importance to product innovation (32%).

There are two types of variables used in this study: binary and numerical variables. Part of the numerical variables are the firms' coordinates on various factorial axes representing the type of partnerships, information sources, the firms' projects selection process and potential barriers to innovation and to patenting. The construction of the factorial axes is explained in appendix 2.

The explanatory variables are grouped into four categories: control variables, strategic variables, competencies variables and barriers-related variables.[4] These variables enable to test the hypotheses presented in the previous section.

The Control Variables

The control variables include the firm size, age, country of origin, its industry concentration and an indicator of its technological opportunity.

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[3] The breadth of the patent portfolio has also been estimated with a censored logistic model in order to check the robustess of the estimates. The results are presented in Appendix 5; they confirm the estimates of the negative binomial model.

[4] Appendix 3 presents a synthetic table with the definition of variables.

- The *firm size* is measured by the total number of employees in the firm or branch.
- The *firm age* is the number of years, in 2000 at the time of the survey, since the creation of the company. The square of the firm age is also introduced to check for potential non linear relationship with the firms' patenting performances.
- The firm *country of origin* is proxied by a binary variable taking the value of 1 if the firm belongs to a foreign group and 0 if not.
- The *sector concentration* is proxied by a C-4 index, i.e. the total sales of the four largest firms in the firm's main sector of operation (in terms of sales) divided by the total sales of the sector of activity. This is an imperfect variable since it is measured at the Belgian level while a lot of firms have international competitors. Moreover it is based on firms operating in the same kind of activity and do not necessarily reflects the firms' direct competitors.
- The *sector technological opportunity* variable is a dummy variable taking the value of 1 if the firm belongs to a high-tech (HT) or medium-high-tech (MH) sector and 0 if not[5].

The Strategic Variables

The strategic variables include the degree of internationalization, the relative importance of the development of new products and new processes in the firm global strategy, the share of basic and applied research in total R&D budget, and the firm's research partnerships.

- The *degree of internationalization* is proxied by the number of countries a firm is operating in. A firm is considered to operate in a country if it has customer contacts in this country.
- The effect of the *innovation strategy* (product-oriented and / or process-oriented) on the firms' patenting performances is studied thanks to two dummy variables. They take the value of 1 if the firm answered 4 or 5 (on a Likert scale ranging from 0 to 5) to the question of the importance of product innovation, and to the question of the importance of process innovation. A firm can therefore be oriented towards both types of innovations, they are not mutually exclusive.
- When studying the link between *R&D* activities and firms' patenting performances we focus on the relative importance of basic and applied research in the total R&D budget, as opposed to development activities.[6]
- Another strategic decision the firm has to take is the involvement in *research partnerships*. Two variables based on a factorial analysis take this factor into account. The first one reflects the collaborations with universities and research institutes. The second one reflects the collaborations with competitors and negatively relates to the use of consultants and vertical partners as innovation partners. Both variables are expected to have a positive impact on the firms' patent portfolio. The main reason for a positive impact of the universities and research institutes partnerships would come from the basic nature of academic research. Collaborating with competitors implies reciprocal openness and access to the firms' knowledge base. The need for patent protection would therefore be more required.

The Competencies Variables

The competencies variables come from several factorial analyses of the basic survey data. They include the information sources used by firms and the extent to which they implement an efficient

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[5] The sector technological opportunity is similar to the OECD classification: HT= aeronautic construction, desks and computing machines, pharmaceuticals products, radio, TV and telecommunication machines, and MH= professional equipment, motorcar vehicles, electric machines, chemical industries, other transport equipment, non-electric machines.

[6] The effect of the firms' total R&D intensity (percentage of sales allocated to R&D) has been tested too. This variable proved significant only in the count model at the 15% level and not in the binary model. The firms' R&D intensity has thus some determining influence for the breadth of the firms' patent portfolio but not for the probability of patenting. Moreover, the introduction of this variable induced a sharp decrease in the number of observations due to a low response rate (the firms were more willing to provide information on the composition of their R&D activities than their total budget for R&D). Therefore the R&D intensity was not included in the final regressions.

projects selection process. These competencies were composed of questions for several sub-competencies (see appendix 2 and Peeters and van Pottelsberghe, 2003). A principal component analysis allowed to identify the relationship between the sub-competencies and to use the coordinates of the firms on one or two factorial axes. The number of axes (1 to 3) was chosen so that more than 50 per cent of the variance across firms was explained.

- Two variables reflect the *information sources* firms use for their innovative projects. The first one represents the importance firms give to consultants, competitors and vertical partners as information source for their innovation projects. The second one represents the importance of universities and research institutes. We expect universities and research institutes information to have a positive effect on the firms' patenting performances. These institutions traditionally develop basic knowledge useful to firms seeking to launch quite radical innovations, which are more likely to be patented. The impact of the other sources of information is more ambiguous. Consultants, customers and suppliers are commercial partners that provide mainly non technical information. The link with the firms' patenting performances is thus less straightforward.
- Another factorial analysis is used to build two variables related to the firms' *projects selection process*. The first variable (i.e. the firms' coordinates on the first factorial axis related to the projects selection process) reflects the capacity of firms to select the most promising innovation projects thanks to a formal evaluation of the probability of success, a systematic storage of innovative ideas and the use of a knowledge codification system. The second one reflects the extent to which firms assess the potential barriers to innovative projects beforehand.

The Barriers Variables

There are two kinds of barriers-related variables coming from two factorial analyses of several sub-competencies of the basic survey data (see appendix 2 and Peeters and van Pottelsberghe, 2003).

- The first one reflects the *perceived limitations of the patent system* that might reduce the firms' use of the patent system. A single factorial axis enables to efficiently summarize all barriers to the use of the patent system assessed in the survey. The coordinates of firms on this factorial axis constitutes a variable that accounts for the cost of fees and protection, the lack of effectiveness of the patent protection, the disclosure of important information and the lack of information on the intellectual property system.
- The second one reflects the *barriers to innovation*. Three variables are built using the firms' coordinates on three factorial axes representing three categories of barriers to innovation. These variables are barriers specific to internal organization issues, barriers due to cost and risk issues, and barriers specific to external use of innovation. The internal barrier variable represents the firm's internal rigidities, its employees' resistance to change, its lack of relevant competencies, time constraints, a lack of communication and a lack of leadership. The risks- and costs-related barriers are the high costs and high economic risks associated with innovation and the lack of financial resources. The external barriers come from the customers' rigidities and a lack of reaction to new products, and from inappropriate public regulations. Similarly to their potential effect on the firms' innovation activities, these barriers might have a negative impact on the firms' patent portfolio.

The Econometric Framework

A logit model is used to estimate the equation related to the probability for a firm to have at least one patent. It is written as follows:

$$y_i = \begin{cases} 1 & if\ y_i^* \geq 0 \\ 0 & if\ y_i^* < 0 \end{cases} \quad \text{with } y_i^* = \alpha + \beta_t X_i + \varepsilon_i \qquad \text{(model 1)}$$

where ε_i follows a logistic distribution $F(t)=\frac{1}{1+e^{-t}}$, and $\beta_t=(\beta_1\ \beta_2\ .....\ \beta_p)$ is the vector of the p parameters associated to the vector of the p explicative variables $X_i^t=(x_{i1}\ x_{i2}\ .....x_{ip})$. y_i^* is the latent dependent variable that represents some decision criteria. If y_i^* is positive the firm has a patent portfolio with a least one patent. If y_i^* is negative the firm has no patent portfolio.

A negative binomial model is used to estimate the equation related to the breadth of the firms' patent portfolio. This method is relevant for four main reasons. First, as a count model it accounts for the non-negativity and discreteness of the data. Second, as opposed to the poisson model it allows the conditional mean and variance of the dependent variable to be different. Third, the coefficients can be estimated using the pseudo-maximum likelihood approach that yields robust estimates even if the distribution is not correctly specified. Finally, it enables to correct for possible heteroscedasticity without loosing too much efficiency. The negative binomial model can be written as follow:

$$z_i / x_i \sim NB\left(\frac{\theta(\lambda_i+1)}{\theta+1}, \frac{\theta}{\theta+1}\right) \qquad \text{(model 2)}$$

Where $X_i^t=(x_{i1}\ x_{i2}\ .....x_{ip})$ is the vector of explicative variables, $\lambda_i=e^{\beta' x_i}$ is the conditional mean of the dependent variable, and θ a parameter that enables the introduction of some heterogeneity in the model (if θ = 0, the poisson and the negative binomial model are equivalent).

Estimates based on a censored logistic model are provided for comparison in appendix 5. They confirm and validate the results obtained with the negative binomial model.

4. Empirical Results

As a preliminary step it is useful to analyze the correlation matrix of all the variables included in the econometric model. The matrix is presented in appendix 4. The correlation coefficients between the partnerships, information sources and projects selection variables are relatively high. Therefore, in order to avoid potential multicollinearity biases, all the variables have not been introduced simultaneously in the model. Five different models (see columns 1 to 5 in table 2) have been estimated. Model 1 is the basic model including the control and strategic variables, except the collaboration partners. All the subsequent models add to this basic model different types of variables. Model 2 includes the two partnerships variables, model 3 includes the two information sources variables, model 4 includes the two projects selection variables and model 5 includes the four barriers variables. For each model, the first column relates to the logit specification, i.e. the probability for a firm to have at least one patent, and the second column relates to the negative binomial specification, i.e. the breadth of the patent portfolio.[7]

Some correlations are important to highlight since they prove helpful for the interpretation of the econometric results. The highest correlations concern scientific partnerships. Firms that collaborate with scientific institutions are mainly large HT firms, active in concentrated industries, and operating in a relatively high number of countries. They invest a large share of their R&D budget in basic and applied research and give a high importance to both product and process innovation. In terms of competencies they rely on outside information relatively more than other firms and are better at

[7] Due to the risk of multicollinearity the extended model including all categories of variables simultaneously is not presented but the results are provided in appendix 5. The first column relates to the logit specification and the second column shows the coefficients obtained with the negative binomial specification. The results of the censored logistic specification are presented in the third column to check the robustness of the estimates. These estimates with all variables confirm the results of models 1 to 5 in table 2, except for a few variables for which the estimated parameters are less significant due to multicollinearity.

codifying and selecting ideas. They also perceive more limitations of the patenting system than other firms.

There is a positive relationship between the number of countries a firm is operating in and the strategic importance it gives to product innovation. In other words, it seems that being active on the international market requires more innovative products in order to stay competitive. The correlation between the use of external sources of information and the capacity to codify and store ideas is also high and significant. The firms that actively seek for outside information seem to be competent in knowledge and information management.

- Insert table 2 around here -

The Control Variables (model 1 in table 2)

The firm size has no impact on the probability for a firm to have a patent portfolio but it has a positive effect on the breadth of its patent portfolio. This positive relationship between a firm number of employees and its patenting performances matches the results of many studies in the field [Crépon *et al*. (1996), Brouwer and Kleinknecht (1999), Baldwin *et al*. (2001), and van Ophem *et al*. (2001)]. It means that large firms are either more innovative than small firms or that they have a larger propensity to patent. Large firms are indeed more likely to have a patent department responsible for all patent applications and the coordination of the whole patent portfolio. Through this department they develop an in-house specific expertise that fosters patent applications. Smaller firms have to outsource this competence, at a higher cost, which might further reduce their propensity to patent. Finally, large firms are better able to afford patent litigations than small firms.

- Insert table 3 around here -

Table 3 is a synthetic table of our results compared to the average results of previous studies in the field. It should be noticed that many studies include an indicator of R&D intensity in their equations and find a positive impact on firms' patenting performances. However, due to a lack of data, we do not introduce this variable. Instead of that we test the impact of the firms' involvement in basic and applied research (as opposed to development activities) on the probability to have a patent portfolio and on the breadth of this portfolio.

A U-shaped relationship is found between a firm's age and both the probability of having a patent portfolio and the breadth of this portfolio. This tends to suggest that two effects are working in opposite directions. On the one hand the need to protect the inventions might be more important for younger firms because they have no market power. On the other hand, older firms might have a large technological background, and hence, more patents. Actually, the bottom of the U-curve corresponds approximately to 50 years. During the first 50 years of the company live its propensity to patent seems to decrease. After about 50 years the firm's use of the patent system goes up. This could be a response to young and dynamic entrants in the industry that threaten the old firms' position.

The C-4 concentration index has a positive and significant coefficient in both the binary and the count models[8]. This result stands for the efficiency effect to dominates the replacement effect. The replacement effect suggests that firms with a high market power invest less in innovation projects because they would only replace current gains. At the opposite the efficiency effect calls for higher innovation investments from firms that face less competition for the exploitation of their innovations. These firms are thus likely to have a higher research output, and hence a larger patent portfolio. In this respect these results corroborate the findings of Nielsen (2001).

[8] When partnerships and barriers variables are introduced in the logit model the concentration index loses some significance, with a p-value of 13%.

The industry technological opportunity is also found to have a positive impact on the breadth of the firms' patent portfolio, but not on the probability of patenting. This confirms that sectors with an important scientific background patent more than others. Two main explanations might be raised for this result. First, scientific and technological inventions best fit the patentability conditions of inventive step and non obviousness. Second, such inventions could lead to subsequent inventions by competitors or firms in other sectors. The original inventor would probably prefer to patent his technology in order to be able to charge eventual followers, either by licensing the technology or by filing a patent litigation in case of illegal use of it. The positive link found between the sector technological opportunity and the firms' number of patents matches the findings of Crépon *et al.* (1996) and Brouwer and Kleinknecht (1999). However, it does not mean that firms in lower technological opportunity sectors are less innovative. They could be as innovative but launch innovations that are less likely to be patented.

The Strategic Variables (Models 1 and 2 in table 2)

The firms' degree of internationalization, approximated by the number of operating countries, is found to positively influence their patenting performances and the probability to have a patent portfolio. This can be the result of both the larger potential market and the increased competition international firms face that calls for more patent protection. At the opposite, being part of a foreign group does not seem to impact on the firms' patenting performances

The importance firms give to the development of new products has a positive impact on the breadth of their patent portfolios. Conversely, a large focus towards process innovation is associated to smaller patent portfolios. This matches the eighth hypothesis and corroborates Arundel (2001)'s finding that process oriented R&D is associated to a higher importance of secrecy as protection means. The disclosure of a process innovation might indeed lead other firms to use the technology, eventually for different applications. This might be very harmful since this kind of infringements is difficult to track down, and proving the paternity of a new process is uneasy. There is no significant impact of the importance of product and process innovation on the probability to have a patent portfolio.

Allocating a large portion of total R&D budget to basic and applied research has a positive effect on both the probability for a firm to have at least one patent and on the breadth of its patent portfolio. Basic and applied research projects are indeed more likely to lead to scientific breakthrough inventions, which are in turn more likely to be patented.

The last type of strategic variables relate to the partnerships firms develop for their research and innovation projects. The positive impact already found for the firms' proximity to scientific knowledge, i.e. operating in high technological opportunity sectors and the importance of basic and applied research, is confirmed by the positive and highly significant coefficient obtained for the partnerships with universities and research institutes. This holds for both the probability of having at least one patent and the breadth of the patent portfolio. The partnerships with competitors are also associated with better patenting performances, as opposed to the commercial partnerships with consultants and vertical partners. One reason for this could be that the need for protection is higher for the firms that collaborate with competitors than for the firms that collaborate with consultants or vertical partners.

The Competencies Variables (Models 3 and 4 in table 2)

The extent to which firms get information from their customers, suppliers, competitors and consultants does not seem to be relevant to differentiate firms' patenting performances. At the opposite, the scientific information firms get from universities and research institutions are an important determining factor of the breadth of their patent portfolios. When the impact of the information variables is tested alone, the scientific information proves highly significant in the binary model too. This variable loses some significance when tested simultaneously with other variables probably because it is correlated with the importance firms give to the development of new processes and to basic and applied research. It is significant at a 12% probability threshold in the binary model.

The competence of ideas storage and codification is significant in both the binary and the count model when the projects selection variables are tested separately from the rest of the model. When introduced simultaneously with the strategic and control variables, the ideas storage and codification variable loses its significance in the binary model.[9] Nevertheless, it is a major determinant of the breadth of their patent portfolios. In other words, the more firms focus on the management and codification of their knowledge base, the larger is their patent portfolio. The assessment of the potential barriers to innovation projects has no impact on the firms' patenting performances.

The Barriers Variables (Model 5 in table 2)

The perceived ineffectiveness of the patent system does not seem to affect the firms' patenting performances. All firms, with both a high and low propensity to patent, seem to identify the shortcomings of the intellectual property systems. Therefore, the perceived barriers to patenting do not allow to differentiate firms' patenting performances.

At the opposite, what is observed for the barriers to innovation matches our expectations: the higher the perceived barriers to innovation, the weaker the probability for a firm to have at least one patent, and the smaller the firms' patent portfolio. The most important barriers that discourage firms from developing a strong patent portfolio are related to the risks and costs of innovative barriers. The internal barriers such as the employee resistance to change, the internal rigidities and the lack of relevant competencies have also a negative and highly significant impact on the breadth of the firms' patent portfolios. The effect is less relevant for the external barriers coming from customers and regulation. In this respect, the present results do not corroborate the previous findings of Cassiman *et al.* (2001) who show that financial barriers actually have a positive impact on the firms' propensity to patent.

Two general remarks can be made when looking at the 5 models of table 2 simultaneously (and summarized in table 3). First, it appears that all the factors affecting the probability to have at least one patent also influence significantly the breadth of the patent portfolio. On the other hand, several factors affect 'only' the breadth of the patent portfolio. In other words, it might be easier to increase the propensity to patent innovation when firms already patent than to induce firm to start patenting. A learning process seems to be at work. Second, for both the binary logit (the probability to have at least one patent) and negative binomial (the breadth of the patent portfolio) estimates, the best fit model is Model 2, were only two variables are added to the basic model. Model 2 concerns the strategic variables of R&D partnership with universities, research institutes and competitors. The extent to which firms decide to effectively collaborate with such institution seems therefore to be one of the key characteristics that would induce an improved patenting performance.

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[9] This is probably because of the high correlations with the product and process innovation variables and with the importance of basic and applied research.

5. Concluding Remarks

The objective of this paper was to better understand the factors that influence large firms' patenting performances, both in term of the probability to have a patent portfolio and in term of the breadth of this patent portfolio. In this respect several new hypotheses have been put forward regarding the role of innovation competencies, innovation strategy and the perceived barriers to innovation and patenting.

An original survey data on large firms' innovation competencies and performances in Belgium has been used for the empirical implementation. The probability to have at least one patent has been analyzed through a binary logit model. The determinants of the breadth of the patent portfolio have been estimated with a negative binomial count model. The estimates validate several of the suggested hypotheses regarding the determinants of patenting performances.

A first interesting observation is that all the factors affecting the probability to have at least one patent also influence significantly the breadth of the patent portfolio. The reverse is not true. Several factors affect 'only' the breadth of the patent portfolio. In other words, it might be easier to increase the propensity to patent innovation when firms already patent than to induce firm to start patenting. A learning process seems to be at work.

The firms that show the best patenting performances are large firms operating in highly concentrated markets and belong more to high-tech and medium high-tech industries. In addition to these 'traditional' factors, firms with a relatively high patenting performance differentiate themselves in several respects related to innovation strategy, innovation competencies and barriers perception:

- they are closely linked to scientific knowledge through collaboration agreements with universities and research institutes, and through their intensive use of scientific information;
- they devote an important share of their total R&D budget to basic and applied research;
- they favor new product development, as opposed to new process development;
- they have a tendency to enter into research collaboration more with competitors than with vertical partners and consultants;
- they have developed an effective ideas storage and codification process;
- they operate in an important number of different countries, which increases the need for protection;
- They recognize that the most important barriers to innovation are related to cost and risk issues and to an internal organizational issues (internal rigidities, resistance to change, and a lack of competencies, communication and leadership).

These results all too amply demonstrate that there are several avenues for managerial improvement in terms of both innovation strategy and innovation competencies. There is a very strong impact of the strategic decision to enter into research collaboration with universities and competitors. This last observation provides further validation of the current policies aiming at fostering industry-university partnerships.

The factors that were supposed to influence patenting performances but turn out to have no significant impact in the two models are the following:

- belonging to a foreign group;
- looking for commercial information from consultants, competitors and vertical partners;
- assessing the potential barriers to individual innovative projects beforehand;
- the perceived ineffectiveness of the patent system.

The two factors that negatively influence firms' patenting performances are of particular interest. First, the firms that strongly emphasize the development of new processes appear to have smaller patent portfolios. This is probably due to a lower effectiveness of the patent system in the case of process innovations. Indeed, detecting the imitation of a new process is not easy and the disclosure of technical information, as required with patents, could be very risky. Second, the internal and cost/risk related barriers also reduce the propensity to patent inventions.

There are clearly rooms for policy and managerial implications in this respect. On the policy side, risk and cost related barriers could be reduced through appropriate loans and grant or fiscal incentives to research, like R&D tax credits. Overcoming internal rigidities is probably a bigger challenge. It would involve the educational system and regional culture, as well as a management culture towards innovation. The current surge of policies towards a "continuous education system" is potentially promising in this respect.

Several new factors have been highlighted as being strong determinants of patenting performances, including innovation strategy, innovation competencies and the perceived barriers to innovation and patenting. The above findings clearly demonstrate that innovation performances are not exclusively related to research activities. R&D is certainly a necessary condition for substantial innovation but is far from being sufficient. Several organizational competencies and complementary strategies also play a substantial role regarding patenting performances.

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Appendix 1 – Literature Review

	Dependent variable	Size	Market share	Foreign nationality	Diversification	Firm age	Sector concentration	Market opportunities	Technological opportunities	Appropriability conditions	Innovation output	R&D	External information	Cooperation
Scherer (1965)	**0 / 1**													
US, 448 firms	**# A**	/\	ns		ns				+					
Crépon, Duguet	**0 / 1**	+	+		+		-	+	+	+				
and Kabla (1996)	**# A**	+	ns		ns		ns	+	+	+				
France, 9871 firms														
Cincera (1997)	**0 / 1**													
181 international firms	**# A**								+			+		
Duguet and Kabla (1998)	**0 / 1**													
France, 299 firms	**# A**	ns	+		ns		ns	ns	ns	ns		+		
Crépon, Duguet	**0 / 1**													
and Mairesse (1998)	**# A**	ns						ns	-			+		
France, 4164 firms														
Brouwer and Kleinknecht (1999)	**0 / 1**	+							+		+	+		+
Netherlands, 1300 firms	**# A**	+							+		+	+		+
Baldwin, Hanel	**0 / 1**													
and Sabourin (2001)	**# A**	+		+							+			
Canada, 1200 firms														
Cassiman, Perez-Castrillo and	**0 / 1**													
Veugelers (2001)	**# A**	/\						+		+			+	
Belgium, 370 firms														
Nielsen (2001)	**0 / 1**	/\	+			-	+							
Denmark, 557 firms	**# A**													
van Ophem, Brouwer,	**0 / 1**													
Kleinknecht and Mohnen (2001)	**# A**	+										ns		+
Netherlands, 460 firms														
TOTAL	**0 / 1**	+	+		+	-	"+ / -"	+	+	+	+	+		+
	# A	+	ns	+	ns		ns	"+ / -"	+	"+ / ns"	+	+	+	+

Synthetic table of studies on the determinants of firms' patenting performances.
Column 1 presents the authors and year of publication of the studies.
Column 2 shows the dependent variables of the studies: 0 / 1 = Has the firm applied for a patent or not, in a given period? ; # A = Number of patents the firm has applied for, in a given period.
Columns 3 to 13 present the relationship between the explicative variables and dependent variables included in each study.
The last two rows indicate which relationship is found most often for each explicative and dependent variable: + : positive relationship; - : negative relationship; /\ : inverted U-shaped relationship; ns : non significant relationship; "…/…": no clear relationship.

Appendix 2 – Construction of the Factorial Axes

The asterisks highlight the variables that contribute the most to the interpretation of the factorial axes, and the percentage of the total variance explained by the axes used in this paper. The number of factorial axes was selected so that the cumulated percentage of explained variance is above 50%.

Information sources

INFORMATION SOURCES	Coordinates on the axes Factor 1	Factor 2	Factor 3
Customers	-0.53*	-0.38	-0.04
Suppliers	-0.53*	-0.54	-0.36
Competitors	-0.63*	-0.29	0.43
Consultants	-0.72*	0.29	0.16
Universities & research instit.	-0.35	0.75*	0.27
Inside the group	-0.40	0.49	-0.69

Principal components analysis, own survey, 2000, 148 firms

Factors	Eigenvalues	Percentages	Cumulated Percentages
1	1.75	29.22	29.22*
2	1.42	23.62	52.84*
3	0.89	14.76	67.60
4	0.78	12.97	80.57
5	0.65	10.83	91.41
6	0.52	8.59	100.00

Ideas selection process

IDEAS SELECTION	Coordinates on the axes Factor 1	Factor 2	Factor 3
Ideas storage	0.83*	-0.18	0.31
Knowledge codification	0.74*	-0.42	-0.53
Success proba estimation	0.84*	-0.01	0.31
Projects barriers assessment	0.60	0.77*	-0.21

Principal components analysis, own survey, 2000, 148 firms

Factors	Eigenvalues	Percentages	Cumulated Percentages
1	2.28	57.05	57.05*
2	0.80	19.99	77.04*
3	0.52	12.90	89.94
4	0.40	10.06	100.00

Research partnerships

PARTNERSHIPS	Coordinates		Contributions		Cosinus squared	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
Competitors: YES	-1.18	0.84*	8.90	12.00*	0.28	0.14*
NO	0.24	-0.17	1.80	2.40	0.28	0.14
Vertical: YES	-0.39	-0.28	4.10	5.30	0.34	0.17
NO	0.87	0.61*	9.00	11.80*	0.34	0.17*
Research instit: YES	-0.78*	0.25	11.50*	3.20	0.59*	0.06
NO	0.76*	-0.25	11.20*	3.10	0.59*	0.06
Universities: YES	-0.71*	0.22	10.90*	2.70	0.65*	0.06
NO	0.92*	-0.28	14.20*	3.50	0.65*	0.06
Inside group: YES	-0.42	0.07	4.10	0.30	0.26	0.01
NO	0.62	-0.10	6.00	0.40	0.26	0.01
Consultants: YES	-0.55	-1.00*	3.90	34.00*	0.15	0.50*
NO	0.28	0.50*	2.00	17.00*	0.15	0.50*
Other firms: YES	-0.67	-0.24	7.30	2.40	0.33	0.04
NO	0.49	0.17	5.30	1.80	0.33	0.04

Multiple correspondences analysis, own survey, 2000, 148 firms

Factors	Eigenvalues	Percentages	Cumulated Percentages
1	0.37	37.14	37.14*
2	0.14	14.01	51.15*
3	0.14	13.82	64.97
4	0.12	11.82	76.79
5	0.10	10.11	86.89
6	0.09	9.30	96.19
7	0.04	3.81	100.00

Barriers to the use of patents

PATENTS BARRIERS	Coordinates on the axes Factor 1	Factor 2	Factor 3
Cost of fees	-0.86*	0.02	0.23
Protection cost	-0.86*	0.06	0.23
Efficiency lack	-0.86*	0.09	-0.08
Secrecy better	-0.84*	0.27	0.13
Market lead better	-0.84*	0.00	-0.25
Short PLC	-0.72*	-0.34	-0.51
Disclosure risk	-0.84*	0.18	0.07
Risk of copy	-0.91*	0.10	-0.06
Lack of information	-0.46	-0.80	0.28

Principal components analysis, own survey, 2000, 148 firms

Factors	Eigenvalues	Percentages	Cumulated Percentages
1	5.87	65.26	65.26*
2	0.89	9.88	75.15
3	0.71	7.87	83.02
4	0.54	6.01	89.03
5	0.35	3.94	92.97
6	0.26	2.91	95.88
7	0.20	2.23	98.12
8	0.13	1.50	99.61
9	0.03	0.39	100.00

Barriers to innovation

INNOVATION BARRIERS	Coordinates on the axes Factor 1	Factor 2	Factor 3
Economic risk	-0.28	-0.80*	0.00
High costs	-0.24	-0.83*	0.14
Lack of financing	-0.32	-0.58*	0.27
Internal rigidities	-0.68*	0.19	0.02
Customers rigidities	-0.48	0.03	-0.60*
Resistance to change	-0.64*	0.17	-0.20
Lack of competencies	-0.70*	0.03	0.24
Customers reaction lack	-0.52	-0.02	-0.55*
Public regulations	-0.26	-0.33	-0.44*
Time constraints	-0.70*	-0.02	0.18
Lack of communication	-0.70*	0.30	0.18
Lack of leadership	-0.70*	0.30	0.36

Principal components analysis, own survey, 2000, 148 firms

Factors	Eigenvalues	Percentages	Cumulated Percentages
1	3.76	31.33	31.33*
2	2.02	16.86	48.19*
3	1.24	10.33	58.52*
4	1.00	8.32	66.84
5	0.89	7.39	74.23
6	0.61	5.11	79.34
7	0.54	4.53	83.87
8	0.54	4.47	88.35
9	0.42	3.49	91.83
10	0.41	3.44	95.27
11	0.31	2.58	97.85
12	0.26	2.15	100.00

Appendix 3 – The Variables

NAME	CONSTRUCTION / INTERPRETATION	TYPE
<u>DEPENDENT VARIABLES:</u>		
- Existence of a patent portfolio	The firm has at least one patent (yes/no)	0 / 1
- Breadth of the patent portfolio	Number of patents in the firm's patent portfolio	#
<u>CONTROL VARIABLES:</u>		
- # of employees in 2000	Number of employees in the firm in 2000	#
- Firm age	Number of years since the creation of the company	#
- Foreign group	The firm belongs to a foreing group (yes/no)	0 / 1
- Sector concentration	(Sales of the 4 largest firms of the sector / total sales of the sector) * 100	%
- Technological opportunity	The firm is active in a high-tech or medium high-tech sector (yes/no)	0 / 1
<u>STRATEGIC VARIABLES:</u>		
- # of operating countries	Number of countries where the firm has customer contacts	#
- New products development	4 or 5 on a 5-points scale for the importance of new products development	0 / 1
- New processes development	4 or 5 on a 5-points scale for the importance of new processes development	0 / 1
- % basic & applied in R&D	% of the total R&D budget allocated to basic and applied research	%
Collaboration partners:		
- Universities & research institutes	Scientific institutions	Coordinates of the firms on the factorial axes
- Competitors >< consultants & vertical partners	Competitors, as opposed to other commercially related firms	
<u>COMPETENCIES VARIABLES:</u>		
Information sources:		
- Consultants, competitors & vertical partners	Commercially related firms as information source for innovation projects	
- Universities & research institutes	Scientific institutions as information source for innovation projects	
Projects selection:		
- Ideas storage and codification	The use of systems to store and codify the firm's ideas and knowledge	
- Projects barriers assessment	The assessment of potential barriers to innovation beforehand	
<u>BARRIERS VARIABLES:</u>		
- Barriers to patents use	The barriers to the use of patents by firms	
Barriers to innovation:		
- Internal to the firm	The internal barriers to innovation (organizational, resistance to change…)	
- Risks and costs related	The risk and costs related barriers to innovation	
- External to the firm	The external barriers to innovation (customers, regulations…)	

Appendix 4 – The Correlation Matrix

	# employees	firm age	foreign group	sector concentration	technological opportunity	# operating countries	new products	new processes	basic&applied research	scientific partners	competitors partners	commercial information	scientific information	ideas storage & codification	projects barriers assessment	barriers to patents	internal barriers	costs & risks barriers	external barriers
# employees	1																		
firm age	0.1400	1																	
foreign group	-0.0684	-0.0244	1																
sector concentration	0.0072	0.2559*	-0.1137	1															
technological opportunity	0.0331	0.0417	0.0018	0.1387	1														
# operating countries	0.0824	0.1359	0.0725	0.1470	0.2305*	1													
new products	0.1301	-0.0128	-0.0560	0.1904	0.0689	0.3456*	1												
new processes	0.0101	0.0626	-0.0346	0.1528	0.0957	0.0366	0.1744	1											
basic & applied research	-0.0046	0.0406	-0.0901	0.1205	0.0764	0.1345	0.1445	0.2043*	1										
scientific partners	0.2550*	0.1615	0.1121	0.2690*	0.2479*	0.2882*	0.2314*	0.2568*	0.3209*	1									
competitors partners	-0.0673	0.0603	-0.0583	-0.0237	0.0147	0.0199	-0.1758	0.1445	0.1742	0.0453	1								
commercial information	0.1475	0.1521	0.0612	0.1545	-0.0310	0.1185	0.0380	0.1558	0.1694	0.3063*	-0.1303	1							
scientific information	0.1624	-0.1088	0.1856	-0.0381	0.1150	-0.0338	0.0012	0.2554*	0.3049*	0.4423*	0.1769	0.0609	1						
ideas storage & codification	0.1703	0.0803	0.0455	0.2451*	0.1526	0.1693	0.2382*	0.2132*	0.2743*	0.5624*	-0.1371	0.3956*	0.3523*	1					
projects barriers assessment	-0.1950	0.0410	0.0384	-0.0296	-0.0134	-0.0372	-0.0917	-0.0362	0.1335	-0.0010	-0.1951	0.0006	-0.2119*	-0.0786	1				
barriers to patents	0.0248	0.1452	-0.2240*	0.3115*	0.0228	0.2576*	0.2705*	0.0501	0.3765*	0.2352*	-0.0735	0.0543	-0.0620	0.0680	0.0086	1			
internal barriers	0.0922	0.2635*	-0.0747	0.1750	-0.0565	0.0441	0.1081	-0.0373	-0.3133*	-0.0716	-0.1606	0.1294	-0.0854	-0.0767	-0.1100	0.0275	1		
costs & risks barriers	-0.1087	0.0369	-0.0706	-0.1240	0.0851	-0.2474*	-0.1120	0.0223	0.0210	0.0117	0.1010	-0.0946	0.0533	0.0311	-0.0169	0.0234	-0.1313	1	
external barriers	0.0446	0.0750	-0.0748	0.0382	-0.0869	-0.0926	-0.0024	0.0562	0.1477	0.1511	0.0979	0.0095	0.1468	0.1798	0.1721	-0.0130	-0.0217	-0.0418	1

*Correlation coefficients between the explanatory variables, own survey, 2000, 97 firms, * significant at the 5% probability threshold.*

Appendix 5 – Extended Model [10]

	Binary Logit		Negative Binomial		Censored Logistic	
	coefficient	p-value	coefficient	p-value	coefficient	p-value
control variables						
nb of employees in 2000	0.0010	0.4096	0.0006***	0.0029	0.0384***	0.0000
firm age	-0.0917**	0.0380	-0.0740***	0.0002	-2.0637*	0.0750
age square	0.0011***	0.0043	0.0007***	0.0000	0.0226**	0.0135
foreign group	-0.1474	0.9228	0.1443	0.7592	-0.5827	0.9819
sector concentration	0.0138	0.7692	0.0250	0.1012	0.5681	0.4315
technological opportunity	-0.1492	0.8786	1.5354**	0.0241	48.6059*	0.0706
strategic variables						
nb of operating countries	0.0620**	0.0322	0.0077	0.5015	-0.0160	0.9685
new products development	1.9146	0.3131	3.1297***	0.0000	110.5048***	0.0049
new processes development	-3.3716***	0.0030	-1.4982***	0.0005	-90.4389***	0.0049
% basic & applied research in R&D	0.0504***	0.0072	0.0168	0.1117	0.3561	0.5576
collaboration partners:						
- universities & research institutes	5.0812***	0.0000	2.3262***	0.0000	109.6607***	0.0034
- competitors >< consultants & vertical partners	6.1112**	0.0194	1.9945***	0.0026	105.6626**	0.0101
competencies variables						
information sources:						
- consultants, competitors & vertical partners	-0.4996	0.3418	-0.2132	0.2585	-16.7159	0.1010
- universities & research institutes	0.9354*	0.0819	0.2396	0.4942	5.4565	0.7132
projects selection:						
- ideas storage and codification	0.2054	0.6657	0.2459	0.4103	16.6697	0.1630
- projects barriers assessment	0.6862	0.2017	0.4779**	0.0266	14.8356	0.3499
barriers variables						
- barriers to patents use	0.4033	0.1619	0.1577	0.1120	2.4786	0.7278
barriers to innovation:						
- internal to the firm	0.0771	0.8085	-0.4651***	0.0018	-14.6507*	0.0526
- risks and costs related	-1.4562**	0.0431	-0.6560***	0.0023	-21.7010*	0.0542
- external to the firm	-1.4727**	0.0173	-0.2937	0.1574	-23.9605**	0.0373
C	-3.3776	0.2320	-3.9664***	0.0010	-155.3884**	0.0175
# observations	97		97		97	
Log-likelihood	-19.3297		-191.0556		-273.6372	
Mc Fadden R-squared	0.7107					
Pseudo R-squared			0.5642			

Extended model including all explicative variables simultaneously, own survey, 2000.
** significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.*

[10] Censored logistic model: $z_i = \begin{cases} z_i^* & if\ z_i^* \succ 0 \\ 0 & if\ z_i^* \leq 0 \end{cases}$ with $z_i^* = \gamma + \delta X_i + v_i$ where ε_i follows a logistic distribution $F(t) = \frac{1}{1+e^{-t}}$, and $\delta_t = (\delta_1\ \delta_2 .....\delta_p)$ is the vector of the p parameters associated to the vector of the p explicative variables $X_i^t = (x_{i1}\ x_{i2} .....x_{ip})$. z_i^* is the underlying true number of patents in the firm patent portfolio.

Tables and figures to be inserted in main text

Figure 1: Econometric framework

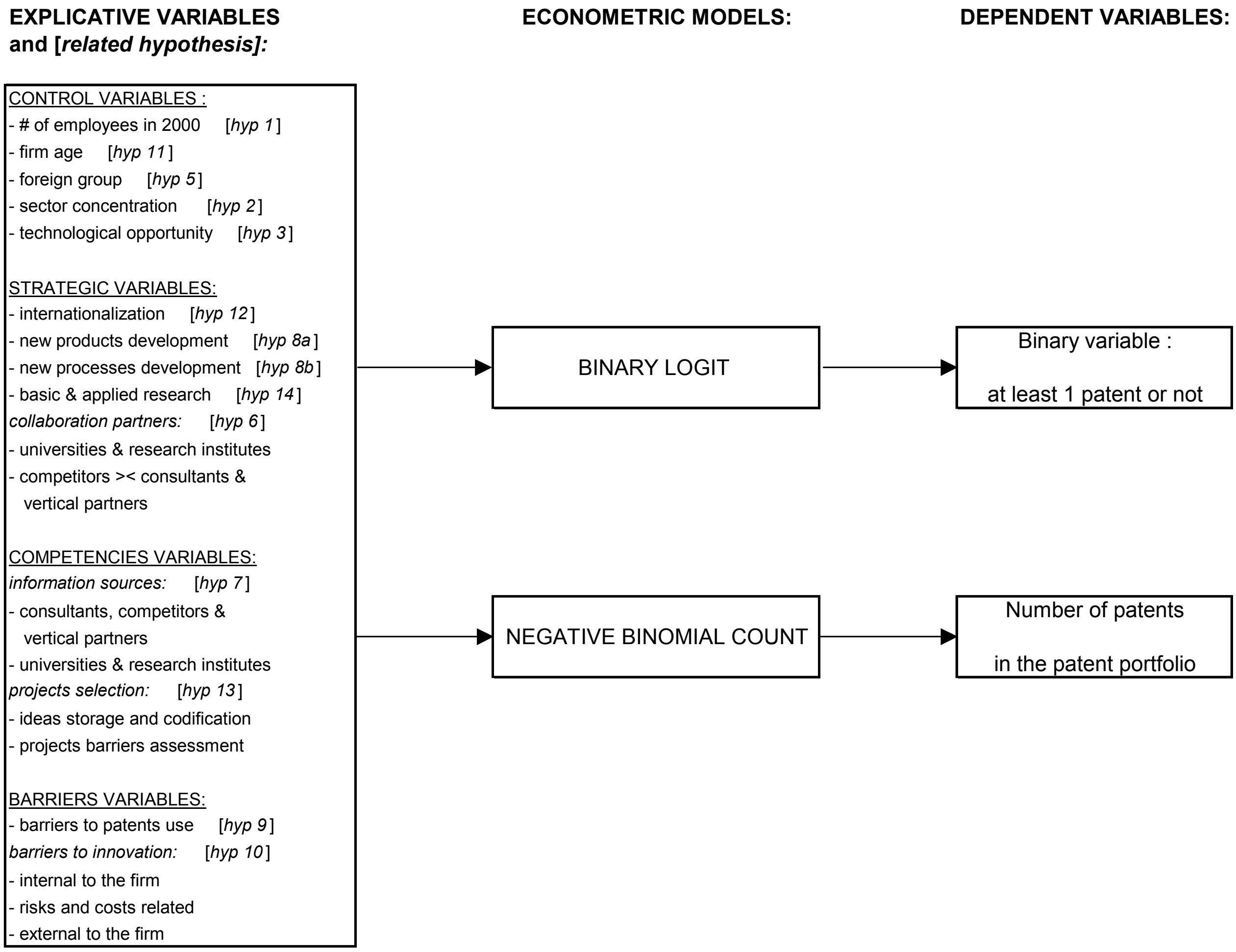

Table 1: Summary statistics

VARIABLES	Type	% of yes	mean	std. dev.
At least 1 patent?	0 / 1	45%		0.50
Number of patents	#		33	129.83
Firms' characteristics:				
Number of employees in 2000	#		595	1102.38
Firm age	#		34	29.52
Foreign firm?	0 / 1	44%		0.50
Sector characteristics:				
Sector concentration	%		63.51	26.04
HT / MH ?	0 / 1	37%		0.49
Strategic variables:				
Number of operating countries	#		25	30.32
R&D activity?	0 / 1	93%		0.26
% of basic & applied in R&D	%		35.18	27.43
Importance of:				
new products development	0 / 1	32%		0.47
new processes development	0 / 1	42%		0.50

Basic statistics, own survey, 2000, 97 firms.
The first two rows present summary statistics for the dependent variables of the two econometric models. The following rows present summary statistics for of the 10 explanatory variables.
Column 2 shows the type of variable. Column 3 shows the percentage of firms that have answered "yes" in case of a binary variable. Column 4 shows the average answer in case of a numerical variable. The last column gives the standard deviation.

Table 2: Econometric results

	- Model 1 -				- Model 2 -				- Model 3 -				- Model 4 -				- Model 5 -			
	Binary Logit		Negative Binomial		Binary Logit		Negative Binomial		Binary Logit		Negative Binomial		Binary Logit		Negative Binomial		Binary Logit		Negative Binomial	
	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value	coefficient	p-value
control variables																				
nb of employees in 2000	0.0004	0.2325	0.0008***	0.0021	0.0002	0.5203	0.0005***	0.0009	0.0005	0.2990	0.0005**	0.0116	0.0004	0.2697	0.0006***	0.0000	0.0006	0.1668	0.0007***	0.0000
firm age	-0.0490	0.1110	-0.0847***	0.0001	-0.0593**	0.0198	-0.0669***	0.0004	-0.0390	0.1269	-0.0678***	0.0019	-0.0480	0.1080	-0.0702***	0.0003	-0.0560*	0.0845	-0.0820***	0.0002
age square	0.0005*	0.0554	0.0007***	0.0000	0.0006***	0.0005	0.0006***	0.0001	0.0005**	0.0212	0.0006***	0.0002	0.0005**	0.0495	0.0005***	0.0001	0.0007**	0.0408	0.0007***	0.0000
foreign group	-0.3488	0.5486	1.2700**	0.0111	-0.2090	0.7721	0.4586	0.2618	-0.6240	0.3461	0.7698	0.1683	-0.3115	0.5992	1.2164**	0.0139	-0.3142	0.6646	0.4042	0.4277
sector concentration	0.0252*	0.0549	0.0453***	0.0001	0.0227	0.1234	0.0333***	0.0013	0.0265*	0.0748	0.0385***	0.0001	0.0253*	0.0517	0.0312***	0.0021	0.0277	0.1063	0.0509***	0.0000
technological opportunity	0.4051	0.4963	2.2809***	0.0003	0.1311	0.8671	1.3128**	0.0379	0.1714	0.7799	1.5187**	0.0284	0.4299	0.4772	1.8432***	0.0032	0.6664	0.3197	2.1256***	0.0015
strategic variables																				
nb of operating countries	0.0232**	0.0215	0.0162**	0.0505	0.0272	0.1065	0.0124*	0.0926	0.0297**	0.0209	0.0280**	0.0136	0.0227**	0.0261	0.0144*	0.0550	0.0156	0.1384	0.0205***	0.0060
new products development	0.9065	0.1367	3.6720***	0.0000	1.9596**	0.0156	3.2521***	0.0000	0.9460	0.1401	3.0078***	0.0000	0.8988	0.1314	2.9336***	0.0000	1.0534	0.1313	3.2644***	0.0000
new processes development	-0.6364	0.2809	-1.2166**	0.0225	-2.0347**	0.0225	-1.8446***	0.0000	-0.7681	0.2398	-1.4398***	0.0047	-0.6799	0.2546	-1.2905**	0.0105	-0.6503	0.2856	-0.5118	0.2772
% basic & applied research in R&D	0.0379***	0.0007	0.0380***	0.0001	0.0374***	0.0068	0.0249***	0.0008	0.0341***	0.0027	0.0229***	0.0072	0.0387***	0.0008	0.0326***	0.0001	0.0344***	0.0074	0.0300***	0.0076
collaboration partners:																				
- universities & research institutes					2.4354***	0.0001	2.2686***	0.0000												
- competitors >< consultants & vertical partners					3.2009**	0.0120	1.3781***	0.0087												
competencies variables																				
information sources:																				
- consultants, competitors & vertical partners									-0.1277	0.6138	-0.0161	0.9333								
- universities & research institutes									0.5279	0.1178	1.0205***	0.0039								
projects selection:																				
- ideas storage and codification													0.0258	0.8965	0.5889***	0.0063				
- projects barriers assessment													-0.1996	0.5716	-0.0116	0.9635				
barriers variables																				
- barriers to patents use																	0.1946	0.1617	-0.1275	0.3605
barriers to innovation:																				
- internal to the firm																	-0.3006	0.1878	-0.5667***	0.0022
- risks and costs related																	-0.4281*	0.0934	-0.3887*	0.0923
- external to the firm																	-0.4395	0.1115	0.2079	0.4031
C	-3.7626***	0.0000	-6.1644***	0.0000	-3.2564	0.0080	-4.1684***	0.0000	-3.8181***	0.0001	-4.6449***	0.0000	-3.7680***	0.0001	-4.4091***	0.0000	-4.0270***	0.0010	-6.4711***	0.0000
# observations	97		97		97		97		97		97		97		97		97		97	
Log-likelihood	-43.6268		-252.1520		-31.6894		-210.4609		-41.8393		-237.0277		-43.4394		-242.0128		-38.7914		-232.5785	
Mc Fadden R-squared	0.3471				0.5257				0.3738				0.3499				0.4194			
Pseudo R-squared			0.4249				0.5200				0.4594				0.4480				0.4695	

*Own survey, 2000, * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. White corrected estimations for potential heteroscedasticity.*

Table 3 – Synthetic table of our results compared to the literature

	LITERATURE		OUR RESULTS	
	0 / 1 A	# A	Logit 0 / 1 P	Negative binomial # P
CONTROL VARIABLES :				
- # of employees in 2000 [*hyp 1*]	+	+	ns	+
- firm age [*hyp 11*]	-		U	U
- foreign group [*hyp 6*]		+	ns	ns
- sector concentration [*hyp 2*]	" + / - "	ns	+	+
- technological opportunity [*hyp 3*]	+	+	ns	+
STRATEGIC VARIABLES:				
- internationalization [*hyp 12*]			+	+
- new products development [*hyp 8a*]			ns	+
- new processes development [*hyp 8b*]			ns	-
- research activities [*hyp 4*]	+	+		
- basic and applied research [*hyp 14*]			+	+
collaboration partners: [*hyp 5*]	+	+		
- universities & research institutes			+	+
- competitors >< consultants & vertical partners			+	+
COMPETENCIES VARIABLES:				
information sources: [*hyp 7*]		+		
- consultants, competitors & vertical partners			ns	ns
- universities & research institutes			+	+
projects selection: [*hyp 13*]				
- ideas storage and codification			ns	+
- projects barriers assessment			ns	ns
BARRIERS VARIABLES:				
- barriers to patents use [*hyp 9*]	-	" - / ns "	ns	ns
barriers to innovation: [*hyp 10*]				
- internal to the firm			ns	-
- risks and costs related			-	-
- external to the firm			ns	ns

The column "literature" presents the average results of the existing literature summarized in appendix 1.
0 / 1 A = The firm applied for a least one patent or not; 0 / 1 P = The firm has at least one patent in its patent portfolio; # A = Number of patents the firm has applied for; # P = Number of patents in the firm patent portfolio.
+ : positive relationship; - : negative relationship; /\ : inverted U-shaped relationship; ns : non significant relationship; "…/…": no clear relationship.