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Innovation strategy and the patenting behavior of firms

Abstract This paper investigates whether firms' innovation strategies affect their patenting behavior, as measured by both the probability of having a patent portfolio and the number of active patents held. Three main dimensions of an innovation strategy are taken into account: the relative importance of basic research, applied research and development work in total R&D activities, the product or process orientation of innovation efforts, and the extent to which firms enter into collaborative R&D with other institutions. The major findings can be summarized as follows: *(1)* taking into account the various dimensions of an innovation strategy turns out to approximate the patenting behavior of firms better than the traditional Schumpeterian hypotheses related to firm size and market power; *(2)* there is a positive relationship between the patent portfolio of firms and an outward-oriented innovation strategy characterized by R&D partnerships with external organizations — scientific institutions and competitors in particular; *(3)* process-oriented innovators patent less than product-oriented innovators; *(4)* a stronger focus on basic and applied research is associated with a more active patenting behavior; *(5)* firms that perceive high barriers to innovation (internal, risk-related or external

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barriers) have smaller patent portfolios; *(6)* the perceived limitations of the patent system do not significantly influence the patenting behavior, suggesting that firms patent for other strategic reasons than merely protecting innovation rents.

Keywords Product innovation · Innovation strategy · Collaborative R&D · Patent portfolio · Patent system

JEL Classification O31 · O32 · O34 · L25

1 Introduction

The literature attempting to understand the patenting behavior of firms has mainly focused on 'traditional' determinants related to firm and sector characteristics. These determinants are generally borrowed from the literature on innovation performance. They relate to the well known Schumpeterian hypotheses (i.e., large firms and firms with a strong market power innovate more) and to indicators of technological opportunity and research efforts. The present paper adds to the existing body of knowledge on patenting determinants by investigating the influence an innovation strategy may exert on the likelihood that a firm develops a patent portfolio and on the number of patents it holds.

A formal firm-level measurement of innovation strategy enables us to account for three main dimensions of an innovation strategy: the relative importance of basic and applied research in the total R&D activities of a firm, the product or process orientation of innovation efforts, and the extent to which R&D is performed jointly with other institutions (competing firms, vertical partners, universities, public labs...). The theoretical framework further suggests that a firm's patenting behavior might be influenced by its perception of the limitations and inefficiencies of the patent system. Furthermore, it is argued that the patenting behavior might correlate with the perceived barriers to the innovation process (internal barriers, risk and cost-related barriers and external barriers to innovation).

This paper departs from existing empirical studies on patent determinants by going beyond the traditional factors related to firm size, market power, technological opportunity, and research efforts. The main contribution consists in explicitly taking into account differences in innovation strategies and in the perception of barriers to innovation and to patenting. It also differs from previous studies in the indicator of patenting behavior used. While the existing literature on patent determinants has mainly focused on the number of yearly patent applications made by firms, this research uses data on the number of patents firms have accumulated over time in their patent portfolio, and for which they still pay renewal fees. This approach enables us to control for contextual effects that may affect the patenting behavior of a firm in a given period without necessarily reflecting its general attitude towards patenting.

The main finding of the present paper concerns the use of R&D partnerships in a firm's innovation strategy. An outward-oriented innovation strategy that relies on collaborations with external organizations is associated with a more active patenting behavior than an inward-oriented innovation strategy that relies on in-house R&D exclusively. The type of partners firms work with is also important in determining their attitude vis-à-vis patenting. Firms that do R&D with scientific institutions and competitors patent more than firms that collaborate with their customers, their suppliers or with consultants. The positive effect of partnerships with scientific institutions probably results from the basic nature of the research activities involved, which are more likely to result in patentable knowledge. This effect is called the ‘novelty’ effect. Undertaking R&D activities with external organizations implies, at least to some extent, a mutual access to the partners’ knowledge bases. Such partnership induces a higher need for intellectual property (IP) protection, especially in the case of collaborations with competing firms. This effect is referred to as the ‘need’ effect. More generally, a patent also helps clarifying issues of ownership over co-developed inventions and prior knowledge of each partner, which further explains the positive relationship observed between R&D partnerships and patenting behavior.

The econometric results also show that an innovation strategy that targets the development of new processes is associated with lower patenting behavior, while product-oriented innovators patent more than other firms. The importance given to research activities, as opposed to development work, also positively affects the probability of having a patent portfolio. The perceived barriers to innovation turn out to be a good predictor of firms’ patenting behavior, as opposed to the perceived barriers to the patenting system, which do not have any significant impact.

The paper is structured as follows. The next section summarizes the main findings of the existing empirical literature on determinants of patenting activities. Section 3 presents the theoretical model underlying this study with a particular emphasis on three hypotheses related to the role played by innovation strategy variables. The empirical implementation is developed in Section 4. Two econometric models are used to evaluate the impact of several potential determinants of patenting behavior. The first model estimates the probability for a firm to have a patent portfolio. The second model estimates the number of patents possessed. Section 5 discusses the empirical results. Section 6 concludes.

2 Traditional determinants of patenting

Pioneer work in the field of patent economics probably started with the contributions of Schmookler (1957), Nelson (1959), Arrow (1962), and Scherer (1965). Since then, academic research has increasingly tackled various aspects of the patenting behavior of firms, from the theoretical analysis of patent systems (e.g., Baumol 2002), to the use of patent data to measure innovation performance and knowledge spillover 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 as a measure of innovative output (e.g., Crépon et al. 1996, 1998; Duguet and Kabla 1998; Cohen et al. 2000).[1] Most of these studies have focused on traditional determinants of patenting

[1] Patent-based indicators are only one measure of innovation output. They are imperfect for three main reasons (Griliches, 1990). 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; Arora 1997). Third, 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 patents are important for only a few of them, mainly chemicals and pharmaceuticals (Mansfield 1986; Levin et al. 1987).

behavior, such as firm size, market power, market and technological opportunities, and R&D efforts.

The effect of firm size on patenting is systematically taken into account in the extant literature. This derives from the well-known Schumpeterian hypothesis that large firms are more innovative than smaller ones (Schumpeter 1942). The advantage of being large comes from three main factors summarized by Cohen and Levin (1989). First, large firms benefit from economies of scale and scope that make them more competitive in comparison to their smaller competitors. Second, they can benefit from complementarities and spillovers between different departments. Third, large firms are favored by capital markets for the financing of risky innovation projects. Although the empirical evidence seems to tilt towards a validation of the Schumpeterian hypothesis, some authors argue that the relationship is not straightforward. For instance, Baldwin et al. (2002) find that the effect of 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 firm size on patent applications is debatable. Large firms can more easily rely on market lead to secure 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. The econometric analysis of van Ophem et al. (2001) shows a positive effect of firm size on the number of patent applications. However, some authors find no significant impact of the size variable when it is controlled for other factors such as industry effects, differences in access to external know-how, and appropriability conditions (Duguet and Kabla 1998; Crépon et al. 1998; Cassiman et al. 2001). Brouwer and Kleinknecht (1999) shed some light on this debate by using two different patent indicators. They find 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 and brand name.

Another determinant of innovation that is quite controversial relates to the level of competition. This is usually measured by an indicator of 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 (Schumpeter 1942). This hypothesis has been challenged by several authors. Two effects work indeed in opposite directions. On the one hand, there is the replacement effect, or cannibalization effect, implying that firms with more market power invest less in innovation because the potential 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 indicator of innovation used. Results of studies using the same innovation indicator are often contradictory as well, as illustrated 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 impact of firm's market power, i.e. the efficiency effect would dominate the replacement effect.

Two variables that are also traditionally included in patent equations are market and technological opportunities. Market opportunities reflect the existence of some market in demand of novelty. Technological opportunities are generally measured at the industry level and were defined by Levin et al. (1987) as the extent to which an industry relies on science-based research. Demand-pull variables are expected to have a stronger impact on innovation output indicators than on R&D investments because output measures are more directly linked to the market. In this respect, the status of patent indicators is ambiguous. 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; Brouwer and Kleinknecht 1999) but the difference is not always significant (Duguet and Kabla 1998; Baldwin et al. 2002). As regards market opportunity variables, Crépon et al. (1996) find that they have a positive and significant impact on patent applications, but other authors find no significant effect (Duguet and Kabla 1998; Crépon et al. 1998; Cassiman et al. 2001).

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. More recently, Hall et al. (1986) argued that there is a strong contemporaneous effect between R&D and patenting and that it is difficult to find the adequate lag structure between them. Most studies that include an R&D indicator in patent equations find a positive and significant relationship (e.g., Duguet and Kabla 1998; Crépon et al. 1998; Brouwer and Kleinknecht 1999). Actually, the relationship between R&D and patents can be seen as a virtuous cycle - the former induces the latter, which in turn requires further development costs in order to reach the market.

3 Theoretical framework and hypotheses

Beside the traditional determinants related to firm and sector characteristics widely discussed in the literature, this paper explicitly takes into account the effect that different innovation strategies may have on the patenting behavior of firms. Variables that reflect the perception firms have of certain barriers to innovation and to the use of the patent system are introduced as well. Different firms pursuing similar innovation strategies may indeed have different attitudes as regards patenting because they differ in their perception of the limitations of the patent system. Differences in observed patent portfolios may also reflect a lower innovativeness resulting from higher perceived barriers to innovations. Both effects will be controlled for in the empirical models.

As far as the innovation strategy is concerned, three dimensions are tackled in this paper: the kind of innovation a firm seeks to develop (product or process), the type of R&D activities it undertakes (basic and applied research or mainly development work), and the extent and type of R&D collaborations with external organizations (outward- versus inward-oriented innovation strategy).

Hypothesis 1a The importance of the development of new products in a firm's innovation strategy is associated with a higher probability to have at least one patent, and with a larger patent portfolio.

Hypothesis 1b The importance of the development of new processes in a firm's innovation strategy is associated with a weaker probability to have at least one patent, and with a smaller patent portfolio.

A firm's innovation strategy can focus on product innovation, process innovation, or both. It is traditionally found that new processes are less likely to be patented (Arundel and Kabla 1998; Brouwer and Kleinknecht 1999) as secrecy is a more appropriate protection mechanism for this type of innovation (Cohen et al. 2000). It is indeed more difficult to track down imitation of processes than imitation of products. Therefore, the publication of technical information a patent requires may be acceptable in the case of a product innovation, for which infringement is easier to detect, but not for a process innovation. 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 imitators lack. Firms might therefore opt for a non-legal protection mechanism such as secrecy. At the opposite end of the spectrum, product innovations might be easier to imitate through reverse-engineering and legally enforceable protection might be needed.

Hypothesis 2 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 R&D efforts 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), provided a sufficient share of total R&D is devoted to basic and applied research.

Hypothesis 3 Taking part in research partnerships leads to a higher probability of having at least one patent, and to larger patent portfolios.

In order to develop new products and processes, certain firms rely on in-house R&D exclusively. Other firms are more outward-oriented and enter into R&D collaboration agreements in order to access external knowledge, share the risks and costs of innovation with other organizations, and accelerate the innovation process. Organizations with which firms can collaborate to implement R&D projects are numerous. They include competitors, customers, suppliers, universities, research institutes, consultants, etc. Launching R&D partnerships is likely to increase the need for patent protection because it implies, at least to some extent, a sharing of one's knowledge with external organizations. A legally enforceable protection mechanism such as a patent is also helpful to clarify issues of ownership over co-developed knowledge. Both arguments stand in favor of a positive effect of R&D partnerships on patenting activity. Moreover, when patented, a firm's knowledge-base and innovation output become tradable assets that can be very useful when negotiating future collaboration agreements. Using a dummy variable, Brouwer and Kleinknecht (1999) and van Ophem et al. (2001) find that firms participating in research partnerships apply for more patents than firms that focus more on internal research.

The theoretical model underlying this study suggests that, in addition to the traditional determinants discussed in extant literature and the role played by the type of innovation strategy pursued, the patenting behavior of firms may be influenced by the limitations of the patent system they recognize and by the barriers that perceive as hindering their innovation efforts.

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. 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; Cohen et al. 2000; Arundel 2001). The risk to having competitors "inventing around" and the disclosure of critical information are the most important reasons patents are not always considered as an efficient protection mechanism of innovation rents (Levin et al. 1987; Scotchmer and Green 1990; Cohen et al. 2000). This is illustrated by Mansfield et al. (1981), who find that patent protection does not increase imitation time and costs dramatically. Firms that perceive a higher "ineffectiveness" of the patent system and a higher cost of patenting are therefore likely to patent less than other firms.

Some authors use innovation survey data to test the effect of potential barriers to innovation on firms' innovation activities (e.g., Lööf and Heshmati 2002; 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 innovation performance. Cassiman et al. (2001) find that high innovation costs and lack of financing have a positive effect on 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 firms' perception of barriers from the barriers that actually hinder their innovation efforts and patenting activities. Moreover, at similar levels of innovation output, firms that encountered difficulties affording the high development costs of their innovations may be more likely to patent than other firms. Nevertheless, it seems reasonable to expect firms that perceive higher barriers to innovation to patent less than other firms, as a result of lower innovativeness.

4 Empirical implementation

4.1 The model

Two econometric models are used in order to identify the determinants of firms' patenting behavior. The first one focuses on whether firms have a patent portfolio or not, i.e. the probability of a firm having at least one active patent. The second one is intended to explain the size of the patent portfolio, i.e. the number of active patents a firm possesses. Crépon et al. (1996) and Brouwer and Kleinknecht (1999) have already adopted this dual approach. However, they used information about the number of yearly patent applications, while the present data concern active patents in the patent portfolio of firms.

Three reasons justify the choice of patent portfolios as indicators of patenting behavior. First, patents in a firm's portfolio are 'active' in the sense that renewal fees have been paid. In the case of older patents, this guarantees that the innovation rents they are supposed to protect are actually still protected. Second, these patents bear in themselves an element of 'quality' that patent applications lack. These patents have indeed been granted, which means that the inventive step and industrial applicability of the underlying technology have been recognized by a competent institution. As a result, studying patent portfolios instead of patent applications guarantees that patents that are looked at can actually be used both as a protection mechanism and as strategic tools to build a firm's technological and competitive position. Third, a patent portfolio is built over time. It is therefore a more adequate indicator of patenting behavior since it is less subject to particular events that may affect the number of patents a firm applies for in a given period of time. A firm may be a recurrent innovator with a strong preference for patent protection but no patent application in the particular time frame in which a study is interested. Another firm may happen to apply for one or more patents because of a significant technological invention that would be made during the studied period. This may, however, be highly contextual and not reflect a general active patenting behavior. Looking at the patent portfolio a firm builds over time enables us to lower these potential contextual biases and provides a more stable indicator of patenting behavior.

The empirical methodology is illustrated in Fig. 1. The explanatory variables are listed in the left-hand side box. The econometric models and corresponding dependent variables are listed in the middle and right-hand side boxes, respectively. A binary logit model is used to estimate the probability of a firm having at least one patent. A count model with a negative binomial specification is used to estimate the number of active patents firms possess.[2] Since the dependent variable is not especially determined by independent stochastic processes, in order to check the robustness of the results a tobit model is also used to estimate the size of the patent portfolio.

4.2 The data

The data set used in this study comes from an original survey on firms' innovation competencies and performance undertaken in Belgium in 2001. The questionnaire was sent to the CEO's of 1,301 large firms. The selection criteria depended on the main sector of activity of firms. The OECD terminology was used to classify the sectors.[3] For lower-technology firms (ML and LT) and service companies, the criteria were a number of employees greater than or equal to 201 and a total turnover

[2] Since the distribution of the patent variable is skewed towards low values, a negative binomial model is more appropriate than a Poisson model. It allows the conditional mean and variance of the dependent variable to differ.

[3] The OECD classifies manufacturing sectors into four categories: high-tech (HT), medium-high-tech (MH), medium-low-tech (ML), and low-tech (LT). HT=aeronautic construction, desks and computing machines, pharmaceuticals products, radio, TV and telecommunication machines; MH=professional equipment, motorcar vehicles, electric machines, chemical industries, other transport equipment, non-electric machines; ML=rubber and plastic materials, naval construction, other industrial sectors, non-iron metals, non-metallic mineral products, metallic works, petroleum and coal, steel industry; LT=paper, printing and editing, textile industry, clothing and leather, food, drinks and tobacco, wood and furniture. A category was added for all service companies: commerce, hotels and restaurants, transports, posts and telecommunications, insurances, financial services, real estate activities, computer activities.

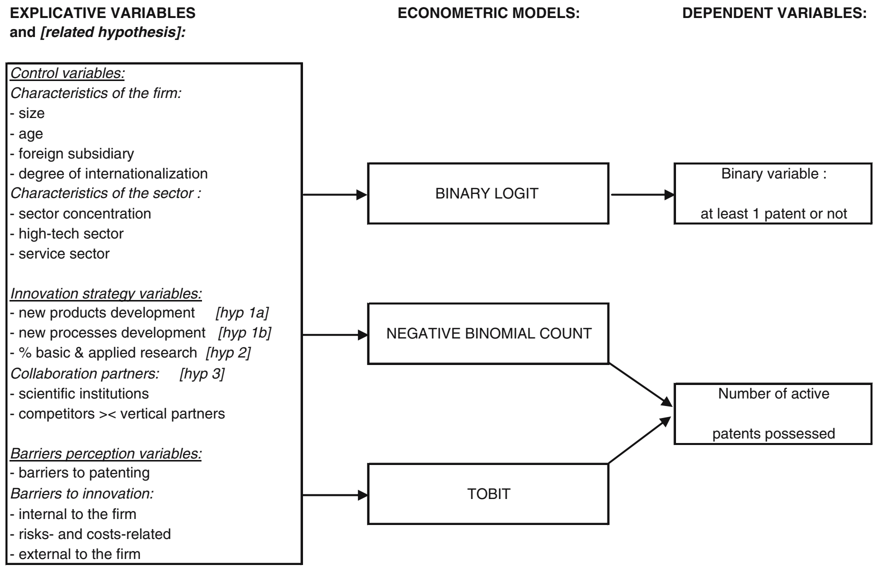

Fig. 1 Econometric framework

greater than USD 2.5 million. The criteria for higher-technology firms (HT and MH) were less restrictive, since all firms with at least 51 employees and a turnover above USD 1.25 million were selected. Data on the total number of employees and turnover of firms came from the Dun & Bradstreet database. Given Belgium's language disparity, CEO's were proposed to answer the questionnaire in Dutch or English and in French or English, depending on the region in which they were based.

Respondents were asked to rate their use of several routines and practices related to four main aspects of the innovation process: the development of a corporate culture of innovation, the generation of innovative ideas, the implementation of innovation projects, and the protection of intellectual property. For most of these questions, respondents had to answer on a Likert scale, ranging from 5 to 0 (systematically, often, sometimes, seldom, not at all, irrelevant). A few questions required yes/no answers or broad percentages. Firms were also asked to answer general descriptive questions and to provide information on the barriers to innovation they perceived and on their innovation output as regards the last three years preceding the survey.

The survey builds on existing surveys on innovation such as the Yale Survey and Carnegie-Mellon Survey on Industrial Research and Development in the U.S., the Community Innovation Survey launched in several European countries jointly by EUROSTAT and OECD, the Growing Small- and Medium-Sized Enterprise Survey in Canada, and the survey on innovation competencies launched in France by the SESSI (Industrial Statistics Service at the French Ministry of Industry). However, it distinguishes from previous surveys by combining six main peculiarities. Firstly, it adopts a systematic approach of the competencies along the entire innovation process, from ideas and knowledge generation to commercialization of new products and processes. Secondly, firms are asked to give a relatively precise evaluation of their use of several routines and practices, since most questions have to be answered on a 5-point Likert scale and not on a 'yes or no' basis. Thirdly, all firms have to answer all questions, not only those that have introduced an innovation over the last few years preceding the survey. This aims at reducing the risk of bias towards innovative firms. Fourthly, the survey is not restricted to manufacturing firms, since service companies are included in the sample as well. Fifthly, the different competencies are assessed using a large range of questions on specific routines and practices. This enables the gathering of detailed information while causing a relatively low response rate, mainly because of the length of the questionnaire. Finally, this is the first survey dedicated to innovation competencies of firms in Belgium.

4.3 Basic statistics

A total of 148 questionnaires were filed and sent back. The comparison of response rates according to firm size, sector of activity, age, region of activity in Belgium, and language of the CEO does not highlight significant differences. This limits the risk of selection bias that may result from a low response rate. Only large firms with more than 500 employees have a slightly higher response rate that should be taken into consideration when interpreting the empirical results.[4]

Large firms account for 33% of respondents (see Appendix 1). Medium and small firms represent 36% and 31%, respectively. Service companies are the most represented category with 28% of the sample, followed by medium high-tech firms that account for 26%. High-tech firms represent about 10% of responding firms. Medium-low-tech and low-tech firms represent 20% and 16%, respectively. In terms of geographical repartition, 54% of firms are based in the Flemish-speaking part of Belgium, 26% in Brussels, and 18% in the French-speaking part of Belgium. Belgian subsidiaries of foreign groups account for 52% of the sample. This repartition reflects quite well the composition of the Belgian economy, with an important percentage of major firms operating in the North of the country (Flemish-speaking) and being foreign-owned subsidiaries.

An extensive statistical analysis of the survey results can be found in Peeters and van Pottelsberghe de la Potterie (2003a). Among the participants to the survey, about 80% of firms declared some kind of R&D activity and a similar percentage claimed to have a positive share of their turnover coming from new or significantly improved products or processes in 2000. However, only about one out of two firms have applied for at least one patent between 1990 and 2000. This percentage is significantly higher for large firms and firms operating in sectors of relatively high technological opportunity (see Fig. 2).

Possible reasons as to why firms do not systematically patent their inventions are summarized in Fig. 3. The highest rated barriers that prevent firms from using the patent system to protect their innovation rents relate to the lack of effectiveness of the system. Many firms consider that market lead is more efficient than relying on the protection of a patent. More than half of firms feel unable to prevent competitors from copying their technology even if a patent protects it, and 44% of

[4] In the remainder of this section, large firms refer to firms with 500 employees or more, medium firms have between 200 and 499 employees, and small firms do not exceed 199 employees.

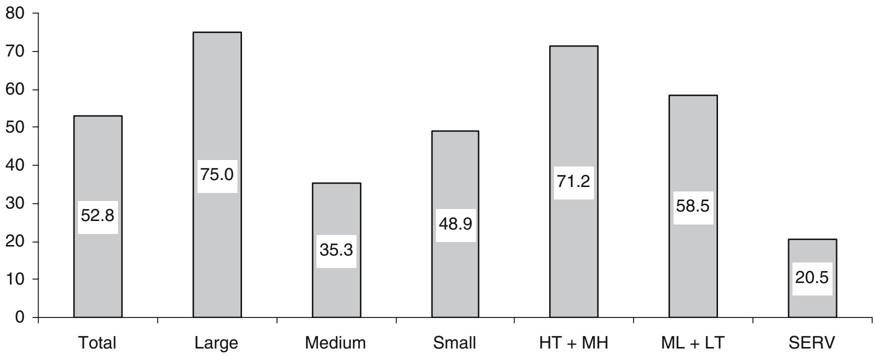

Fig. 2 Percentage of firms with at least one patent application between 1990 and 2000

firms consider secrecy as more efficient than patenting. The next category of factors that prevent firms from using the patent system relates to the cost of patents. The cost of protection in case of litigation and the cost of fees are considered to significantly limit the use of the patent system by about 40% of firms. Finally, only one firm out of five does not patent because it lacks information on the process.

Due to missing data, only 97 questionnaires could be used for the multivariate analysis. The composition of this final sample does not significantly differ from the larger sample of 148 responding firms. Although small samples limit the possibility of generalizing empirical findings, the actual size of the database should provide interesting insights into the innovation-patenting nexus, especially for R&D-active firms.

Summary statistics relative to the final sample are provided in Table 1. A little less than half the firms claim to have at least one active patent. 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. The average firm size is about 600 employees. Concerning the R&D activities, 93% of firms claim to undertake R&D activities. 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 (answer of 4 or 5 on a 5-point Likert scale for the importance of process innovation). This is higher than the percentage of firms that give a high importance to product innovation (32%).

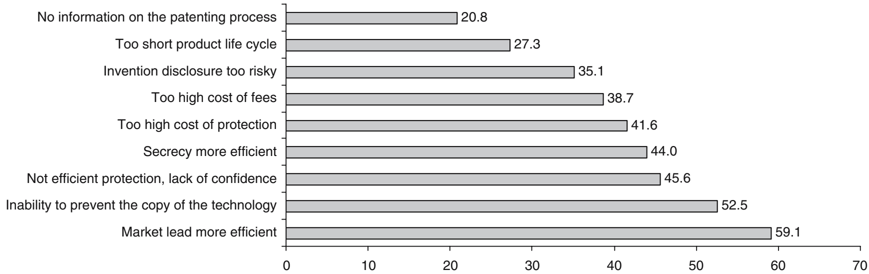

Fig. 3 Percentage of 4 or 5 answers on 5-point Likert scale to nine potential barriers to patenting

Table 1 Final sample summary statistics

Variables	Type	Percentage (%) of yes	Mean	Standard deviation
At least 1 patent?	0/1	45%		0.50
Number of patents in the portfolio	#		33	129.83
Characteristics of firms:				
Number of employees in 2000	#		595	1,102.38
Age of the firm	#		34	29.52
Foreign subsidiary?	0/1	44%		0.50
Number of operating countries	#		25	30.32
Characteristics of sectors:				
Sector concentration (C-4 ratio)	%		64	26.04
HT/MH ?	0/1	37%		0.49
Innovation strategy:				
R&D activity?	0/1	93%		0.26
Percent (%) of basic & applied research in R&D	%		35	27.43
Product orientation	0/1	32%		0.47
Process orientation	0/1	42%		0.50

The first two rows present summary statistics for the dependent variables of the two econometric models. The following rows present summary statistics for ten 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 displays the mean of the numerical variables. The last column gives the standard deviation. Basic statistics, own survey, 2000, 97 firms.

4.4 The variables

The dependent variable of the first equation is the probability that a firm has at least one active patent. The dependent variable of the second equation is the number of active patents possessed by firms. These indicators of patenting behavior are built using answers to the survey question relative to the ‘*total number of patents in force*’ in the patent portfolio.

Two types of explanatory variables are used in the empirical analysis: binary and numerical variables. Some numerical variables consist of the firm coordinates on factorial axes coming from factor analyses realized on sub-sections of the survey. They represent the type of institutions with which firms enter into R&D partnerships and the barriers to innovation and to patenting they perceive. The contribution of each survey item to the determination of the factorial axes and the percentage of variance explained by these axes are provided in Appendix 2.[5] The number of factorial axes used in the empirical study is determined so that the cumulated percentage of explained variance was above 50%. The explanatory

[5] A detailed description of the factor analyses may be found in Peeters and van Pottelsberghe de la Potterie (2003b).

variables are grouped into three categories: control variables, innovation strategy variables, and indicators of perceived barriers.[6]

4.4.1 Control variables

Control variables include the firm size, age, domestic or foreign nature of ownership, degree of internationalization, and indicators of sector concentration and technological opportunity. *Firm size* is measured as the total number of employees in a firm. *Firm age* is the number of years, 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 patenting behavior. The firm age could influence its patent portfolio in two opposite directions. Young firms may be more dynamic and have a less rigid structure favorable to innovation, and hence patenting. They may also patent more to compensate for lower market power. However, over time, older firms may have built a larger technological base protected by a larger number of patents. Age may, therefore, act as an indicator of experience and accumulated intangible assets. Older firms have probably also more resources to sustain an active patenting behavior. The relationship between a firm's age and its patenting behavior might therefore be U-shaped, with higher records for young and old firms as opposed to firms of intermediate age.

The *domestic or foreign nature of a firm*'s *ownership* is controlled for using a binary variable taking the value of 1 if the firm belongs to a foreign group and 0 otherwise. A common thought is that foreign firms are more innovative than local ones and might therefore patent more (Baldwin et al., 2002). Nevertheless, since foreign firms are often subsidiaries of larger companies, they could be less involved in patenting. Patents could indeed be managed at the group level, in the country of origin.

The *degree of internationalization* is measured by the number of countries in which a firm operates. A firm is considered to operate in a country if it has customer contacts in this country. Firms operating in a large number of countries can be expected to patent more for two main reasons. First, they face a larger potential market than firms operating only in their national or regional market. The number of countries in which a firm operates would therefore reflect some kind of market opportunity effect that would foster innovation efforts. Second, these firms face higher international competition, what increases the need for innovation rents protection because the number of potential imitators increases and infringement is more difficult to detect. Both aspects are likely to translate into a higher patenting activity.

The *sector concentration* is proxied by the C4 concentration ratio—i.e. the total sales of the four largest firms (in terms of sales) in a firm's main sector of operation divided by the total sales of the sector. The sector of activity is determined using the four digits Nace-bel code. This is an imperfect variable since it is measured at the Belgian level, while many firms face international competition. Moreover, it is based on firms operating in the same kind of activity and does not necessarily reflect the impact of direct competitors. This is, however, the best approximation that could be made using available data.

[6] Appendix 3 provides a synthetic table with the definition of all variables introduced in the regressions.

The *sector technological opportunity* is proxied by three dummy variables based on the OECD classification of sectors of activity (see footnote 4). The first one takes the value of 1 if the firm belongs to a high-tech or medium-high-tech sector and 0 otherwise. The second one takes the value of 1 if the firm belongs to a medium-low-tech or low-tech sector and 0 otherwise. The third one takes the value of 1 if the firm is a service company and 0 otherwise. Since the three dummies sum up to 1, the second modality is removed and considered the reference group. As shown by authors such as Crépon et al. (1996, 1998) and Brouwer and Kleinknecht (1999), technological opportunities are expected to positively influence patenting behavior.

4.4.2 Innovation strategy variables

Innovation strategy variables include the relative importance of the development of new products and new processes in innovation strategy, the share of basic and applied research in total R&D budget, and the extent and type research partnerships.

The product or process orientation of a firm's innovation strategy is measured by two dummy variables. The first one takes the value of 1 if the firm answered 4 or 5 (on a Likert scale ranging from 0 to 5) to the question on the importance of product innovation. The second dummy equals 1 if the firm answered 4 or 5 to the question on the importance of process innovation. A firm's strategy can therefore be oriented towards both types of innovations or none. These two dummy variables are not mutually exclusive. They enable to test the first hypothesis discussed in Section 3, i.e. a product-oriented innovation strategy positively relates to a firm's patenting behavior and a process-oriented innovation strategy negatively relates to a firm's patenting behavior.

The relative importance of research versus development activities is taken into account in the regressions using the percentage of the total R&D budget firms allocate to basic and applied research, as opposed to development work. This variable is used to test hypothesis 2, that the higher the ratio of research activities on development work, the higher the patenting activity.

The involvement in *research partnerships* is accounted for by two variables. They are based on a factor analysis of the questions relative to the existence of R&D collaboration agreements with different types of partners (see Appendix 2). The first variable (factorial axis) distinguishes firms that do collaborate from those that do not. It is particularly correlated with the collaboration of firms with universities, research institutes and public labs. The second axis positively correlates with the collaborations with competitors and negatively correlates with the use of consultants and vertical partners as research partners. These variables enable to test hypothesis 3, that firms that do not exclusively rely on in-house R&D and collaborate with external organizations to develop new knowledge patent more than other firms.

4.4.3 Barriers perception variables

The last type of variables is derived from the assessment made by firms of certain barriers that might prevent them from innovating and from patenting. Firms had to rate, on a 5-point Likert scale, 15 potential barriers to innovation and nine potential barriers to patenting. For each type of barriers a factor analysis of the scores attributed to the various potential barriers was performed (see Appendix 2). The resulting factorial axes were used as explanatory variables to control for the fact that high perceived barriers to patenting and to innovation may negatively affect the patenting behavior of firms, beyond the effect of firm and sector characteristics and beyond the effect of the adopted innovation strategy.

The first factor analysis relates to the *perceived limitations of the patent system*. A high correlation among the different perceived limitations enables a single factorial axis to summarize effectively all barriers to the use of the patent system assessed in the survey. The coordinates of firms on this factorial axis can therefore be used as a variable that accounts for the perception of high cost of fees and protection associated with patents, the lack of effectiveness of the patent protection and preference for secrecy and market lead to secure innovation rents, the disclosure of important information, and the lack of information on the patenting process.

The second factorial analysis concerns the *perceived barriers to innovation*. Three variables are built using firms' coordinates on the factorial axes that represent three categories of potential barriers to innovation. The first category (factorial axis) accounts for the internal barriers that may hinder innovation: organizational rigidities, employee resistance to change, lack of relevant competencies, time constraints, lack of communication, and lack of leadership. The second category stands for the risk- and cost-related barriers: high costs and high economic risks associated with innovation projects, and lack of financial resources. The third category comprises the external barriers to innovation resulting from customers' organizational rigidities, customers' lack of reaction to new products, and inappropriate public regulations. As a result of their negative effect on firms' innovativeness, these barriers are likely to negatively influence the development of patent portfolios.

5 Empirical results

Estimation results are presented in Table 2. The first column relates to the probability of having a patent portfolio (binary logit model). The second column relates to the number of patents firms possess (negative binomial model). In order to check the robustness of the estimates, the size of the patent portfolio is also estimated through a tobit model. Both models yield similar results in terms of the sign and significance of the estimated parameters.[7]

[7] The estimated parameters of the logit model are not readily interpretable in terms of variation in the probability of observing a patent portfolio. However, a simple transformation enables to interpret them as variations in the odds ratios: $(e^{\hat{\beta}} - 1) = \Delta\left(\frac{P(Y=1)}{P(Y=0)}\right)$. The value of coefficients estimated through the negative binomial and tobit models cannot be interpreted directly either, as they depend on the value of the explanatory variables. The advantage of the tobit model is that it formally differentiates firms that have a patent portfolio from those that do not. However, following Hausman et al. (1984) the negative binomial estimates will be used to interpret the results. As a count model, it explicitly takes into account the non-negativity and discreteness of the data. Moreover it enables to deal with distributions that are skewed towards low values, which is the case in this study where a relatively high proportion of firms have no or only a small number of patents. The discussion in the remainder of this section will rely on average elasticities computed for a hypothetic firm characterized by all explanatory variables equal to their average value: $\lambda * \widehat{\beta}$ with $\lambda = e^{\hat{\beta}'\overline{X}}$. This hypothetic firm is referred to as the 'average firm'.

Table 2 Econometric results

	Binary logit	Negative binomial	Tobit
Control variables:			
Characteristics of the firm:			
- *Size*	0.0002 *(0.0006)*	0.0005*** *(0.0002)*	0.0282** *(0.0141)*
- *Age*	−0.0972*** *(0.0352)*	−0.0699*** *(0.0197)*	−3.5718** *(1.7028)*
- *Age square*	0.0010*** *(0.0003)*	0.0007*** *(0.0001)*	0.0385*** *(0.0134)*
- *Foreign subsidiary*	0.1390 *(1.0289)*	0.3281 *(0.4539)*	3.9264 *(41.3408)*
- *Degree of internationalization*	0.0228 *(0.0209)*	0.0068 *(0.0065)*	−0.1375 *(0.6404)*
Characteristics of the sector:			
- *Sector concentration*	0.0304 *(0.0289)*	0.0247** *(0.0122)*	1.1548 *(1.0630)*
- *High-tech*	−0.3221 *(0.9583)*	1.1814 *(0.7441)*	65.2059 *(47.0637)*
- *Service*	−1.8424 *(1.3879)*	−1.4548 *(0.9506)*	−60.4581 *(74.5017)*
Innovation strategy variables:			
New products development	1.7252 *(1.5993)*	3.1157*** *(0.7002)*	201.2267*** *(58.2937)*
New processes development	−3.1781*** *(1.0360)*	−1.5871*** *(0.4137)*	−199.6456*** *(47.9000)*
Percent (%) basic & applied research	0.0480*** *(0.0142)*	0.0186* *(0.0096)*	0.7837 *(0.8317)*
Collaboration partners:			
- *Scientific institutions*	4.6208*** *(0.8388)*	2.7775*** *(0.4954)*	217.8098*** *(48.9936)*
- *Competitors >< vertical partners & consultants*	4.1403** *(1.8146)*	1.3686** *(0.6979)*	176.5967*** *(59.9951)*
Barriers perception variables:			
Barriers to patenting	0.3359 *(0.2482)*	0.1362 *(0.1121)*	−4.3532 *(10.3145)*
Barriers to innovation:			
- *Internal*	−0.0392 *(0.3135)*	−0.3853*** *(0.1476)*	−26.3472** *(12.3453)*
- *Risks and costs*	−1.0553** *(0.5042)*	−0.5563*** *(0.2028)*	−34.5365** *(16.8960)*
- *External*	−1.1497*** *(0.3857)*	−0.2177 *(0.1774)*	−26.9095 *(17.0926)*
Constant	−2.5619 *(1.8957)*	−3.5088*** *(1.1171)*	−221.5423** *(104.5934)*
Log-likelihood	−20.5410	−192.5528	−285.3077
Mc Fadden R-squared	0.6926		
Pseudo R-squared	0.5608	0.5608	

Own survey, Belgium, 2001. 97 firms. S-E into parentheses. Significativity levels: * 10%, ** 5%, *** 1%

Not surprisingly, large firms appear to have more patents than smaller firms. However, firm size is not a significant determinant of the probability of having a patent portfolio. As regards the age of firms a U-shaped relationship is found with both the probability of having a patent portfolio and the number of patents possessed. Two effects work indeed in opposite directions. On the one hand, the need to protect the inventions may be more important for younger firms because they have no market power. On the other hand, older firms may have a larger technological base protected by more patents. The foreign ownership and degree of internationalization of firms do not seem to influence their patenting behavior, as the coefficients are not significantly different from zero. Firms operating in concentrated sectors have on average more patents than firms operating in competitive sectors, but they do not have a significantly higher probability of having a patent portfolio. The sector technological opportunity variables do not turn out to be significant determinants of patenting behavior. This may be due to the heterogeneity of firms included in the three broad sector categories, or to the difficulty of assigning one specific sector of activity to multi-business firms operating in more than one market.[8]

The innovation strategy variables are the central concern of this paper. Their effect on firms' patenting behavior appears to be much more important than the effect of firm and sector characteristics traditionally discussed in the literature. The first two variables are a measure of the orientation of the innovation strategy towards product innovations (new growth potentials) or process innovations (cost cutting). A strong focus towards process innovations negatively impacts the probability of having at least one patent. It reduces the odds ratio, i.e. the probability of having a patent portfolio divided by the probability of not having any patent, by 96% $\left(\Delta\left(\frac{P(Y=1)}{P(Y=0)}\right) = \left(e^{\widehat{\beta}} - 1\right) = e^{-3.18} - 1 = -0.96\right)$. On the contrary, giving a high importance to the development of new products in a firm's innovation strategy does not significantly impact the probability of having a patent portfolio. The negative effect of being a process innovator is significant in terms of number of patents as well, and the development of new products positively affects the size of the patent portfolio. Actually, if the 'average firm' is a process innovator its expected number of patents is reduced by six. Conversely, if it is a product innovator, its expected number of patents increases by 11 (λ=3.67 and the elasticities are 3.67*(−1.59)=−5.84 and 3.67*3.12=11.45 respectively).[9] These results validate the first hypothesis and corroborate Arundel's (2001) finding that process oriented R&D is associated with a greater importance given to secrecy as a protective means. The disclosure of a process innovation might indeed lead other firms to use the underlying technology, as infringements is difficult to track down and proving the paternity of a new process is uneasy.

The second innovation strategy variable concerns the relative involvement of firms in basic and applied research, on the one hand, and development work, on the other hand. The results clearly indicate that firms that allocate a large portion of

[8] Sector dummies would have been another way to control for sector effects. However, this would have multiplied the number of dummies in the model and eventually lead to a lack of degrees of freedom given the small size of the sample. Moreover, the problem of assigning a particular sector of activity to multi-business firms would have been accentuated.

[9] It can actually be shown that the largest patent portfolios are those of firms pursuing an innovation strategy exclusively targeted at new product development, followed by firms pursuing a mixed strategy aiming at both product and process innovations. The patent portfolio of exclusive process innovators is not significantly different from firms that do not seek high innovation goals of any kind.

their R&D budget to basic and applied research have a higher probability of having a patent portfolio. Increasing the share of basic and applied research in total R&D budget by 1% increases the odds ratio by 5%. The share of basic and applied research also positively influences the number of patents, but the significance is low (10%) and the parameter is small. The elasticity computed for the 'average firm' is 0.07, suggesting an average effect much lower than one additional patent when the share of basic and applied research in total R&D budget increases by one percent. The use of the share of basic and applied research in total R&D and not the level of these expenditures may partly explain this result.[10] In a nutshell, hypothesis 2, according to which a higher share of basic and applied research (as opposed to development), would be associated with a more active patenting behavior is confirmed for the probability to have a patent portfolio and, to a much lower extent, for the number of active patents in the portfolio. However, for the size of the portfolio the positive effect is very small. Moreover, the 'research' variable is not significant in the tobit model.

The third set of results and major findings of this study concern the strategic decisions related to the extent to which firms enter into collaborative R&D and the type of partner they choose. The two explanatory variables introduced in the model are the firms' coordinates on two factorial axes (see Appendix 2). Firms that do not exclusively rely on their in-house R&D to develop new knowledge and enter into R&D collaborations with one or more external organizations have positive coordinates on the first axis. Appendix 2 also reveals that the first axis is strongly determined by the opposition between firms that collaborate with scientific institutions (positive values on the axis) and firms that do not (negative values on the axis). The second axis shows an opposition between firms that favor their competitors as opposed to consultants and vertical partners for collaborative R&D projects. Hypothesis 3, which suggests that firms that collaborate with external organizations patent more than other firms, is empirically validated, as shown by the positive and highly significant coefficient of the first collaboration variable, i.e. the first factorial axis. A one point increase in the variable is actually associated with a 100% increase in the odds ratio and about ten additional patents for the 'average firm'.[11] Since this first factorial axis is strongly associated with scientific partnerships, it can be concluded that the positive effect of R&D partnerships on patenting is particularly significant for collaborations with universities, research institutes and public labs. Another interesting finding is that firms that enter into research partnerships with competitors, patent more than firms that prefer to partner with consultants, suppliers or customers. A one point increase of this variable increases the odds ratio by 62% and the expected number of patents of the 'average' firm by 5.

[10] The effect of firms' total R&D intensity (percentage of sales allocated to R&D) has been tested as well. This variable proved significant only in the count model at the 15% level and not in the binary model. In other words, the firms' R&D intensity has some determining influence for the number of patents firms hold 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 (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.

[11] The drawback of working with factorial axes as explanatory variables is that it is difficult to interpret what a one point increase in a firm's coordinates on an axis represents in reality.

Two main factors may explain the positive and significant coefficients of the R&D collaboration variables: a 'need' effect and a 'novelty' effect. The 'need' effect refers to a higher need for patent protection resulting from the mutual access to the partners' knowledge bases. Everything else being equal otherwise, the propensity to patent an invention is indeed higher for an invention made under a collaborative framework than for an invention exclusively made in-house. The 'novelty' effect refers to potentially more fundamental and breakthrough knowledge generated by R&D collaborations compared to in-house R&D, which would result in more patents. Both effects explain the positive influence that collaborating with external organizations has on the patenting behavior of firms. It can however be argued that, in case of partnerships with scientific institutions, the 'novelty' effect would dominate, and in case of partnerships with competitors, the 'need' effect would dominate. Firms usually turn to universities, research institutes and public labs when they seek to launch science-related innovation projects that they may not be able or willing to implement alone, because of a lack of skills and capabilities, a high uncertainty associated with high R&D costs, or an inadequacy with their current portfolio of R&D projects. These 'scientific' partnerships, if successful, are likely to result in fundamental knowledge that is more likely to be patented than applied knowledge. This 'novelty' effect associated with scientific partnerships probably also captures the effect on the patenting behavior of firms of the dichotomy between research activities, on the one hand, and development work, on the other hand, which was only poorly captured by the percentage of basic and applied research in the total R&D budget.

Since R&D collaboration implies sharing knowledge with partners, the need for patent protection is likely to be higher than when innovation projects rely exclusively on a firm's own R&D activities. In that respect, partnering with competitors is particularly tricky, as any knowledge leakage could be exploited to directly compete in the firm's end-market. Even though the research teams of competing firms that perform joint R&D projects may not intend to use the knowledge they access through the partnership in a harmful way, the knowledge eventually diffuses into the respective organizations and might end up being exploited by other teams. For similar reasons, issues of ownership over the knowledge developed in partnership are of particular relevance when firms directly compete in the same end-market.

The last type of factors whose influence on the patenting behavior of firms is tested relates to perceived barriers that may prevent them from innovating and from using the patent system. Firms that perceive more barriers to innovation are likely to innovate less than other firms, which would in turn negatively affect their patenting activity. This effect is controlled for in the regressions and it appears indeed that higher perceived barriers to innovation negatively affect both the probability of patenting and the size of the patent portfolio. Whereas the perceived internal barriers negatively affect the size of the patent portfolio, the perceived external barriers influence negatively the probability to have a patent portfolio. Risk and cost related barriers to innovation affect both the probability to have a patent portfolio and its size.

A similar negative effect was expected for the perception of important limitations and high costs of the patent system. However, the empirical results do not validate this assumption, as the parameter associated with the variable that summarizes the perceived barriers to patenting is not significantly different from zero. This result may be due to the fact that firms that have a substantial experience in patenting understand the potential shortcomings (in terms of effectiveness and cost) of the patent system better than firms that do not patent. More fundamentally, this suggests that, even though the patent system has obvious limitations, firms still use it. Actually, the estimates show that firms that claim that secrecy or market lead may be more efficient than patent protection, and that patents are costly to apply for and to enforce, do develop patent portfolios anyway. This finding confirms what was already observed with the Carnegie–Mellon survey (Cohen et al. 2000), i.e. firms patent for many more reasons than merely protecting their intellectual capital from imitation. Applying for a patent is indeed a strategic decision that is not only driven by the desire to protect innovation rents (e.g., Teece 1998; Rivette and Kline 2000; Sherry and Teece 2004). A patent is also a highly valuable tool for technological negotiations with competitors or with potential collaborators, for the exclusion of rivals from a particular technological area, for licensing agreements and attraction of capital, for avoiding to be blocked by competitors' patents, and for building competitive advantage (e.g., Parr and Sullivan 1996; Teece 1998; Glazier 2000; Reitzig 2004).

6 Concluding remarks

This paper investigates the relationship between the innovation strategy adopted by firms and their patenting behavior. The patenting behavior is measured both in terms of the probability of having a patent portfolio and in terms of number of active patents held by the firm. Three main hypotheses are formulated regarding the dimensions of an innovation strategy. The first one concerns the orientation of the firm's research activities towards new products or new processes. The second one relates to the composition of R&D activities and the relative importance of basic and applied research, on the one hand, and development work, on the other hand. The third hypothesis addresses the extent to which firms enter into R&D collaborations to develop new knowledge, and the type of partners they choose. Two additional hypotheses are put forward on the potential influence of the perceived barriers to innovation and to patenting. Finally, traditional determinants related to firm and sector characteristics are introduced in the regressions as control variables.

Patent portfolios are considered a better indicator of patenting behavior than patent applications because they involve granted patents for which renewal fees are still paid. Moreover, since they are built over time, they are less subject to contextual factors that may affect the patent applications of firms in a particular period of time without reflecting their general attitude vis-à-vis patenting. A binary logit model is used to estimate the probability of having a patent portfolio, and a negative binomial model estimates the number of active patents firms hold. Empirical results reveal that innovation strategy variables play a greater role in determining firms' patenting behavior than the traditional firm and sector characteristics widely discussed in extant literature.

The key finding of the paper is the highly positive and significant influence exerted on firms' patenting behavior by an outward-oriented innovation strategy that relies on partnerships with external organizations for research projects. Two effects may explain this finding. First, a '*need*' effect results from the mutual access to the partners' knowledge base in the frame of a collaborative R&D project, which increases the need for legally enforceable protection mechanisms such as patents. The '*need*' effect would be of particular importance for R&D collaborations with competitors. Second, a '*novelty*' effect is induced by collaborative R&D oriented towards basic knowledge and risky projects. These research partnerships are likely to result into fundamental knowledge that partners may want to patent to secure innovation rents. The '*novelty*' effect is probably of higher importance for scientific partnerships with universities, research institutes and public labs. Finally, patents are useful to clarify issues of ownership over co-developed knowledge.

It is also found that process innovators patent less than product innovators and that a higher importance of basic and applied research in total R&D budget is associated with a more active patenting behavior. However, the latter effect is relatively small and probably partially captured by the '*novelty*' effect underlying the positive effect of scientific partnerships on patenting.

The survey data reveal that the most important perceived limitations of the patent system relate to its lack of effectiveness and the preference for market leadership and secrecy as means to secure innovation rents. The second category of limitations concerns the high costs of patent fees and patent protection in case of litigation. The quantitative results show that high perceived barriers to patenting do not affect the actual patenting behavior of firms. This suggests that, even though the patent system has obvious limitations, firms patent anyway because patents serve more goals than just the protection of innovation rents (e.g., patent races, blocking competition, building strong positions for technological negotiations...).

This study contributes to the debate on the relevance of patents as indicators of innovation. Existing literature argues that patent-related indicators are imperfect because their link with innovation depends on the type of firms and sectors considered. But the present findings reveal that their relevance would depend even more on the innovation strategy pursued by firms. In other words, even when considering firms of similar size, age, ownership type, market power, and market and technological opportunities, the observed patenting behavior still depends on their strategic choices regarding innovation: product versus process, the relative importance of research and development activities, and the extent and type of R&D partnerships with external organizations. Therefore, when using patent-related indicators of innovation, researchers should be aware and explicitly take into account the fact that the empirical results not only refer to a particular type of firms and sectors but also to a specific set of innovation strategies.

In terms of policy implications, it is not obvious that improving the effectiveness of the patent system and reducing the cost of patents will result in a greater level of patenting. Actually, firms seem to use the patent system for many more reasons than merely securing innovation rents, and these other more strategic reasons appear to outweigh the potentially prohibitive costs of patenting and the inefficiencies of the system.

Though the present study provides interesting insights on the patenting behavior of firms, certain limitations should be acknowledged. First, the small size of the sample of firms limits somewhat the possibility for generalizing the findings and calls for further validation of the conclusions on larger databases of companies and in other countries than Belgium. Second, the lack of panel dataset prevents from investigating more deeply the causal relationships between R&D and patents, and between collaborations and patents. It is rational to believe that R&D activities may result into inventions that firms may want to patent, but it can also be argued that patented knowledge calls for further R&D to reach the stage of a marketable innovation. Similarly, R&D collaborations may be associated with more patenting because of a 'need' effect and a 'novelty' effect. However, it could further be argued that patents facilitate R&D collaborations, since they constitute useful tools for firms to negotiate with potential partners. A dataset including a time dimension would be required to formally test these possible reverse causations.

Appendix 1: Composition of the sample of 148 surveyed firms

Percent (%) in column Percent (%) in row	HT	MH	ML	LT	SERV	Total
LARGE	21.4	42.1	50.0	29.2	19.1	*33.1*
	6.1	32.7	30.6	14.3	16.3	*100*
MEDIUM	21.4	15.8	36.7	45.8	52.4	*35.8*
	5.7	11.3	20.8	20.8	41.5	*100*
SMALL	57.1	42.1	13.3	25.0	28.6	*31.1*
	17.4	34.8	8.7	13.0	26.1	*100*
Total	*100*	*100*	*100*	*100*	*100*	*100*
	9.5	*25.7*	*20.3*	*16.2*	*28.4*	*100*

Source: Own survey, Belgium, 2001

Appendix 2: Construction of the factorial axes

The following three factor analyses relate to the type of institutions with which firms collaborate, the perceived barriers to innovation, and the perceived barriers to patenting. The asterisks mark the survey items that contribute the most to the interpretation of the factorial axes, and the percentage of total variance explained by the factorial axes used in empirical study.

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

Partnerships	Coordinates		Contributions		Cosinus squared	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
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

Multiple correspondences analysis, own survey, 2001, 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, 2001, 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

Factors	Eigenvalues	Percentages	Cumulated percentages
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, 2001, 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: Definition of variables

Name	Construction/interpretation	Type
Dependent variables:		
-Existence of a patent portfolio	The firm has at least one patent (yes/no)	0 / 1
-Size of the patent portfolio	Number of patents in the firm's patent portfolio	#
Control variables:		
Firms' characteristics:		
-Size	Number of employees in the firm in 2000	#
-Age	Number of years since the creation of the company	#
-Foreign subsidiary	The firm belongs to a foreign group (yes/no)	0 / 1
-Degree of internationalization	Number of countries in which the firm has customer contacts	#
Sector characteristics:		
-Concentration	(Sales of the four largest firms of the sector/total sales of the sector)*100	%
-High-tech	The firm is active in a high-tech or medium-high-tech sector (yes/no)	0 / 1
-Service	The firm is active in a service sector (yes/no)	0 / 1
Innovation strategy variables:		
-New products development	4 or 5 on a 5-point scale for the importance of new products development	0 / 1
-New processes development	4 or 5 on a 5-point scale for the importance of new processes development	0 / 1
-Percent (%) basic and applied in R&D	Percent (%) of the total R&D budget allocated to basic and applied research	%
Collaboration partners:		
-Universities & research institutes	Scientific institutions as partners for R&D collaborations	Coordinates on factorial axes
-Competitors><consultants & vertical partners	R&D partnerships with competitors, as opposed to consultants, suppliers and customers	
Barriers perception variables:		
-Barriers to patenting	Barriers perceived by firms to the use of the patent system	
Barriers to innovation:		
-Internal to the firm	Internal organizational barriers perceived by firms	
-Risks-and costs-related	Risks- and costs-related barriers perceived by firms	
-External to the firm	External barriers from customers and regulations perceived by firms	

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