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SLEEPING PATENTS: ANY REASON TO WAKE UP?

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Abstract

  Patents are typically characterized as very valuable assets for firms. Nevertheless, there are many patents in a firm's portfolio that are actually never used. In this paper, we claim that there is a relationship between a firm's decision to use or not to use a patent and the characteristics of the underlying invention. We characterize patent use according to the "sleeping" or "non-sleeping" character of the patents in the firm's portfolio. We characterize the underlying invention along different dimensions captured by the patent, i.e. importance, strategic fit, scope and innovativeness. We perform an empirical analysis on a set of patent-active firms in the chemicals industry that trade some of their patents through what is currently the only website specialized in firm technology transfer through the Internet, yet2.com. We use The NBER Patent Citations Data File to obtain information about the patents granted to these firms. Our results suggest that sleeping patents are more innovative, broader and no less important than their counterparts. We conclude that such patents are worth "waking up", especially when the underlying invention is applicable to business areas far away from the patentholder's strategic core. These results suggest that there is potential for markets for technology to develop.

Keywords: patents, innovativeness

SLEEPING PATENTS: ANY REASON TO WAKE UP? (1)

Introduction

"The Bell Laboratory's most significant invention of the past 50 years was the transistor, which created the modern electronics industry. But the telephone company saw so little use for this revolutionary new device that it practically gave it away to anybody who asked for it – which is what put Sony, and with it the Japanese, into the consumer-electronics business."

The Economist, Nov. 1st 2001

The above quote illustrates two well-known facts about invention processes. First, a given technology may be (more) useful outside the sector and/or the firm where it was originally developed. Second, if this is true, then re-invention is very likely to occur unless there is inter and intra-sectorial technology transfer.

However, technology transfer is not usual. In many cases, technologies lie under- or unexploited on company shelves. This may result in duplication of inventive efforts or technologies that never reach the market. According to the European Patent Office (2001), duplication of inventive efforts costs the European Union $20 billion each year. Moreover, some industry estimates suggest that a patent-intensive company may shelve up to 70% of its patents, a proxy for inventive activity. Under- and non-exploitation has become especially striking nowadays, when knowledge needed in one sector may come from a completely unrelated sector. In fact, recent estimates indicate that some companies have begun to transfer technology –embodied in (neglected) intellectual property assets– to outside industries. According to *The McKinsey Quarterly* (2002, Number 4), 10% of the patent portfolio of a company with at least 450 patents and $50 million spent in R&D expenses may be transferred to outside industries. There are a lot of examples of technologies coming from external industries: the fibreglass cables in the telephone industry that were developed by a glass company, Corning; the Olestra molecule from Procter & Gamble that started out as a low-fat ingredient for snack foods and ended up as a pollutant remover on contaminated soil; a technology developed by Boeing as part of a military application that was used for Touchbridge Systems as part of an integrated networking system in the home environment; a new technology for expanding the capacity of fiber-optic networks discovered by Polaroid that became quite valuable to telecommunications companies. Moreover, as Cassiman and

Ueda (2002) point out, some projects conceived at big firms' labs but never developed may give birth to startups run by their inventors. These facts suggest that projects abandoned by firms are not necessarily unprofitable projects. In fact, profitability might strongly depend on the firm that exploits the project. In the patent case, for instance, the skewness on patents' profitability is well known (Scherer, 1965). Nevertheless, a patent lying on the lower part of the value distribution in the hands of its current patentholder could be at the opposite extreme of the distribution if exploited by another firm.

In this paper, we analyse the characteristics of the patented inventions that remain unexploited on firms' shelves. We assume that a firm's decision whether or not to use an invention is related to the intrinsic characteristics of that invention. In particular, we are interested to know whether neglected projects are actually low value inventions or whether they in fact hide a potential value that could be exploited in other hands or in another industry. We focus on patent-protected projects because patents contain information on the characteristics of the underlying invention. Different elements of the patent have been tested as proxies for different invention dimensions, including value –social value (Trajtenberg, 1990), private value (among others, Harhoff et al., 1999) and market value (Hall et al., 2000)–, basicness (Trajtenberg et al., 1992) and scope (Lerner, 1994). Some of these validated patent-based proxies have been used to analyse firm decisions such as startup formation (Shane, 2001).

The literature has underlined as main determinants of project rejection the lack of complementary assets to bring an innovation to market (Shane, 2001) and the poor fit of the project with the firm's strategy (Teece, 1986). Nevertheless, firms differ in their criteria for selecting projects. In particular, a firm will tend to reject more projects the more patent-intensive the firm is (Klepper & Sleeper, 2002), the older it is, or the higher its profits are (Cassiman & Ueda, 2002).

Also, there may be other reasons why a firm decides not to undertake a project, apart from the characteristics of the underlying invention or the characteristics of the firm. This is specially true in the case of projects protected by patents, where legal protection allows for strategic considerations. For instance, a patent may prevent competitors from entering a particular technological area. Thus, a firm may use a patent merely for blocking purposes –either because it wants to reserve to itself the right to enter this area in the near future or because it wants to prevent competitors from strengthening their position by entering that area. Patents may also allow a firm to wait until market uncertainty is overcome (Takalo and Kanniainen, 2000). In these and similar cases, even if projects are not developed and marketed, we cannot consider them as rejected projects. They serve a definite purpose in the firm's project portfolio: their strategic use.

Moreover, patent-protected projects facilitate arm's-length technology transactions. A project protected by an intellectual property right makes the transfer less subject to problems of opportunism (Arora and Fosfuri, 2000). This is specially true in industries where patents are an effective means of protection –chemicals, software, machinery and engineering services– and as a result, markets for technology arise (Arora et al., 2000). In these industries, therefore, patented projects may have a quite straightforward outside opportunity, i.e. licensing or sale. This means that even if a patented project has no value inside the firm, the firm may choose to license it to some other company that will be able to extract rents from it. However, this alternative turns out to be very costly outside these industries, when the deal links firms in different sectors or, even in the mentioned sectors, for newcomers or small firms. In many cases, in fact, licensing is impracticable even for patented projects.

In this paper we focus on patent-protected projects for a number of reasons. First, patents are a good proxy for inventive activity by firms (2) and contain a lot of information about the underlying invention. More importantly, rejected projects mean rejected patents, also known as "sleeping patents". A rejected patented project is, in principle, more inefficient than a rejected project. In both cases, there is an inefficiency if the invention never reaches consumers. And in both cases there is an inefficiency if the invention is reinvented by a competitor, owing to the duplication of research efforts (3). However, if the invention is not patented in the first place, consumers will eventually benefit from the invention, whereas if it is patented, they will not benefit (or only after a delay), as the patent will prevent competitors from introducing the innovation (until the patent expires).

The literature has not devoted a lot of attention to sleeping patents, despite the importance of the phenomenon. As mentioned earlier, a huge percentage of the patents owned by patent-intensive firms are sleeping. For instance, IBM, Philips and Siemens are reported to use only around 40% of their intellectual property portfolio (4).

For our research we use a unique dataset of sleeping patents collected from yet2.com, the only website active in technology transfer between firms. We match this dataset with the NBER Patent Citations Data File in order to analyse whether sleeping patents differ significantly from the firm's "average patent" along different dimensions. This way, we are able to estimate the magnitude of the inefficiency due to the existence of sleeping patents. The greater the value potential of the underlying inventions, the more inefficient it would be to keep them sleeping. Thus, we are able to conclude whether they are worth waking up. Our results suggest that sleeping patents are more radical innovations and fit better with the firm's strategy than the rest. We do not find significant evidence that they are less important patents than the rest. These results suggest that sleeping patents are not just marginal patents but may have some hidden potential for value that could be realised in other hands than the patentholders'.

2. Theoretical development

The following section is split in two parts. Firstly, we propose a definition of sleeping patents. Secondly, we develop our hypotheses.

2.1. A definition of sleeping patents

Previous literature offers no explicit definition of sleeping patents, even though it does provide some rationale for their existence (Kutsoati and Zabojnik, 2001) (5). They are

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(2) It is worth mentioning that the relationship between patents and projects is not one-to-one. A new technology may be protected by one patent (in Chemicals, the mean is two or three patents per product) and up to one hundred patents (in Electronics, for example). In this paper, we will focus on the first type of patented inventions; therefore, we do not believe that this fact poses a serious problem to our analysis.

(3) Note that if the invention is patented, competitors may either come by chance to the same result or they may invent around the patent (it is public information). In the latter case, the inefficiency due to duplication of efforts is smaller than in the not-patented case. In this situation, the total inefficiency brought by the project rejection will be higher in the patented case as long as the inefficiency due to consumers not profiting from the innovation plus the inefficiency caused by inventing around it is greater than the inefficiency due to the duplication of efforts in the non-patented case.

(4) According to *Financial Times*, July 2001.

(5) They show that a durable-good monopolist may strategically shelve a patent (when its use is socially desirable) because its potential adoption intensifies the monopolist's time inconsistency problem.

mentioned as patents that have never turned into an industrial application (6). However, this definition of sleeping patents as patents covering inventions that have been rejected by the firm, that is, inventions that the firm has not brought to market, is not very precise. First, we should note that an invention can reach the market through development by the patentholder, or through development by a licensee or an alliance, joint venture or some other type of agreement with a third party. A licensed patent, for instance, is not a sleeping patent.

Second, not all the inventions that do not reach the market are actually rejected, especially when they are patented. The firm may choose to keep some of them for strategic reasons, given that they are protected by a patent. Some authors have recently emphasised the increasing strategic role of patents. A patent may be used to prevent entry in an area in which competitive pressures would be much higher if competitors were allowed in (Gilbert and Newbery, 1983). A patent may also be used as a "legal bargaining chip" (Hall and Ham, 1999) when negotiating a cross-licensing agreement, an infringement suit or access to external finance. A patent can be used to "build a wall" to effectively protect a really core invention by the firm (Hopenhayn and Mitchell, 1999). A patent gives the patentholder the right to wait and see how market uncertainties are resolved before launching the innovation to market (Takalo and Kanniainen, 2000). A patent may allow a firm to block entry to competitors until it has all the complementary assets needed to bring the invention to market (Shane, 2001). Therefore, patented inventions may play a key role in a firm's intellectual property strategy, even if they are not brought to market. Consequently, we cannot consider patents that are used for strategic purposes as sleeping patents.

Third, patents and inventions are not related one-to-one. One invention may be covered by many patents, and one patent may cover different inventions. The latter case is illustrated by basic inventions such as the laser or Lycra, which may generate a lot of applications but not all of them are likely to actually be developed. Therefore, we could consider applications that are covered by the patent but that are developed as sleeping applications. From this point of view, given the increasing anecdotal evidence of inventions originated in one sector but applicable to others, many patents would have sleeping applications, that is, they would be partially sleeping. If the firm were aware of this fact, it would be possible to detect sleeping applications with the help of broad-based technologists (Elton et al., 2002). In many cases, however, the patentholder is not even aware that its invention could be useful outside its sector. In these cases, the firm will not make any decision about its patent that would allow us to identify it as partially sleeping. This means that we will not be able to identify underexploited patents in a firm's portfolio unless the firm itself is aware of their status as sleeping patents. Therefore, we should restrict our definition of partially sleeping patents to patents that the firm actually knows are underexploited.

To sum up, our definition of (partially) sleeping patents is this: *patents (or applications in a patent) that are consciously not being used by the patentholder, directly or through a third party, either to launch an application to market or for strategic reasons.*

2.2. Determinants of the decision to leave a patent unexploited

In this subsection, I argue that certain dimensions of an invention, such as importance, broadness, radicalness and strategic fit, may influence the decision not to exploit a patent. I also consider firm characteristics that may influence this decision.

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(6) One of the three requisites an invention has to satisfy to be eligible for a patent is "to have industrial applicability". However, there is no requirement to actually use the patent in an industrial application once it has been granted.

– Private Value or Scientific Importance

Patent value has been captured through a variety of indicators: the social surplus brought by the protected invention; the private value as perceived by the patent owner (renewal or litigation decisions (7)); or the private value as perceived by third parties (stock market valuation, opposition (8)). The value of the invention, either social or private, has been linked in the literature to the importance the scientific community gives to the invention (Trajtenberg, 1990; Harhoff et al., 1999; Hall et al., 2000; among others). Private value translates into economic value for the patentholder (Harhoff et al., 1999). Therefore, relevant technological discoveries anticipate greater economic value for the firm. This fact supports Shane's (2001) finding about the positive effect that the importance of the invention has on the likelihood of new firm formation. Similarly, the importance of an invention is likely to affect the firm's decision of whether to undertake its development. The higher the invention's private value, the more likely it will overcome the firm's opportunity cost and the more willing the firm will be to face uncertainties. Conversely, the less important the patent, the less likely the firm will be to develop the underlying invention. Consequently, we suggest that the more valuable an invention, the less likely it will be left sleeping, and viceversa.

– Strategic fit

Established firms have developed organisational and technical capabilities associated with their core activities. As a result, they are much more efficient at exploiting opportunities inside these boundaries than outside them. That is a reason why activities such as research and development are focused on projects that will allow the firm to exploit its existing capabilities. However, outcomes from the research phase are, up to a point, random (9). In the development phase, by contrast, projects may be easily selected to better fit the complementary assets available in the firm, in order to better appropriate their value. Therefore, inventions resulting from the research process are likely to be screened according to how they fit with the firm's existing complementary assets. In research-intensive industries, a firm's existing capabilities are likely to be highly specialised in the development of a very particular type of innovation, namely, the type of innovation that is closest to the firm's existing business. Consequently, the firm will filter projects according to how close they are to its core businesses.

The same argument holds for the decision to maintain patented inventions for strategic reasons. Patents closest to the firm's core are the strategically most valuable ones to keep in order to protect key innovations, keep competitors at bay, or increase the value of the firm's patent portfolio. Of course, patents are also strategic in new areas of research, but the relative importance is lower than in key areas.

Therefore, we suggest that inventions that have a better fit with the firm's existing activities are more likely to be developed (by whatever means) by the firm. Conversely, the further removed research results are from the firm's core activities, the greater the likelihood that these results will remain unexploited.

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(7) We refer to litigation decisions where the patent owner is the plaintiff.

(8) Opposition refers to a procedure in the European Patent System where a competitor may challenge a patent in the EPO by presenting evidence that the prerequisites for patentability are not fulfilled (see Harhoff and Rietzig, 2001).

(9) An inventor's research output could be limited to the core of the firm if she credibly commits not to implement inefficient projects ex post (Rotemberg and Saloner, 1994).

– Scope

Scope refers to the technological space the patent covers or protects from infringement. Characteristics of the invention determine scope, but scope is also influenced by how inventors "design" the patent. Scope has been linked to the economic value associated with the patent (Lerner, 1994), since it determines the degree of protection, that is, the number of potential products that will infringe the patent. However, Shane (2001) considers scope a different dimension from importance. He shows that broadness is specially relevant for entrepreneurs, because it gives them more time to obtain complementary assets, and that is much more critical for new than for established firms. Therefore, scope seems to be especially valuable for firms when they need extra protection (10). This will be the case, for instance, if the invention does not fit in any of the firm's existing business and the firm must first acquire and develop new complementary assets. It will also be the case when there is high uncertainty regarding the potential value of the invention, as often happens with the outcomes of basic research. In these cases, if the invention is covered by a broader rather than a narrower patent, it is more likely that the patent will be used. To sum up, in any given situation, a broader patent is more likely to be used than a narrower patent, because patent protection will be stronger. However, the more the firm needs this stronger protection, the greater the chances that a broader patent will go to market or be used strategically compared with a narrower patent.

Nevertheless, note that the broader the patent, the larger the technological space it covers and, therefore, the larger the array of potential applications that can be developed under its protection. This means a higher probability that some of these applications will actually remain sleeping.

Therefore, two opposite effects may arise with respect to this dimension of the invention. The larger the scope, the more likely that the patent will be used and, therefore, the less likely that it will remain sleeping. However, the larger the scope, the more likely that some of its applications will actually remain sleeping.

– Radicalness or Innovativeness

Many authors have argued that entrants are more likely to introduce radical innovations than incumbents, whereas incumbents are more likely to introduce marginal improvements of current technologies (Henderson, 1993, among others). Radical innovations, as the name suggests, often represent a clean break with the firm's traditional line of research. Not only are existing assets and capabilities useless for undertaking these projects; introducing these innovations may actually destroy the firm's existing business (through cannibalization, for instance). These are the two main reasons why established firms are unwilling to engage in highly innovative projects. Conversely, entrants have no well developed skills to be undermined, so they are not reluctant to accept such projects. In fact, they are willing to undertake the projects that do not fit into established firms because they will not have to face competition from them. Shane (2001) finds some evidence of this: in their decision to form a new firm, entrepreneurs are more likely to pick up more innovative patents rather than less innovative ones. Most of the literature suggests that the allocation of projects between incumbents and start-ups is due to inefficiencies in the decision process

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(10) Even though any firm will prefer broad to narrow patents, broadness is costly (it means devoting more resources to enforcement and more possibilities of infringement, and, therefore, of litigation). Moreover, broadness is not only determined by the firm's decision.

of the incumbents. In contrast, Cassiman & Ueda (2002) suggest that it is due to the comparative advantage of the start-up to adopt more radical projects.

Previous literature clearly suggests that the more radical the invention, the less likely an established firm is to undertake its development. Therefore, in an established firm, the more innovative the invention, the more likely that it will remain sleeping.

3. Methodology

3.1. Data

The data we use come from two sources. We use "The NBER Patent Citation Data File" (Hall, Jaffe & Trajtenberg, 2001) to select a sample from the population of patents assigned from 1981 to 1999 by the USPTO to a set of 101 patent-active firms. These firms are not selected randomly but are identified as customers at yet2.com, the nowadays unique website devoted to the transfer of patented technologies between firms (11). Outside the Internet, there is no proper marketplace for technology transfer (Arora et al., 2000). Instead, there are very fragmented sectorial markets or consultant firms that search for licensees and licensors on a case-by-case basis. This fact makes selling or licensing intellectual property particularly costly. The mentioned web site, yet2.com, was founded with the aim of lowering the most elementary transaction costs, coordination costs, by creating a virtual marketplace where supply and demand of intellectual property assets could meet. Transfer of intellectual property assets also involves high levels of motivation costs (12). That is why this website created a market for underused technology focused on big and well-known firms. In this way, potential motivation costs are mitigated thanks to the reputation effects of these firms as suppliers of technology.

The reason we used this criterion (being a customer at yet2.com) to select the firms is the following: we can identify, from among all the patents that each of these firms has in its portfolio, the patents it chooses to offer on an Internet marketplace. We assume that this decision captures the fact that these are the firm's sleeping patents. Sleeping patents are idle resources for the firm. They are patented projects the firm rejects because they are not profitable enough (given the firm's opportunity cost) to warrant development or licensee search. Yet2.com has created an Internet marketplace for technology transfer that offers an alternative for all these projects by reducing the cost of the external option (licensing or selling). In most cases, however, licensing through the Web is not an alternative to traditional ways of licensing. Traditionally, licenses are signed, amidst great secrecy, among parties that transact repeatedly or that have some established reputation in the market for technology. The reason: the risks of disclosure to a third party (ex-post opportunism problems), which are minimized through market enforcement mechanisms such as reputation or repeated games. In an Internet marketplace, deals are offered in an open marketplace which almost everybody

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(11) yet2.com was founded in the year 2000 and had as initial competitors pl-x.com and ipex.com, which did not survive. Nowadays, only yet2.com (acquired by Scipher, December 2002), in the firm niche, and techex.com (acquired by UTEK Corporation, 2002), in the university niche, are devoted to the patented technology transfer business through the Internet.

(12) Motivation costs are derived from information asymmetries between the two contracting parties that may result in opportunistic behaviour. In the licensing case, for instance, the licensor does not know about the performance of the technology in the licensee's hands or how he will use the knowledge acquired in the licensing deal. Similarly, the licensee does not know about the actual quality of the technology and the degree

in the industry can access. This may raise strategic concerns for the supplier regarding disclosure (the firm reveals information to the rest of the industry players about a given technology) and unknown potential licensees (who may use the knowledge acquired during the license period to develop a competing technology). Knowing the suppliers' concerns, buyers may have their own concerns regarding the quality of the technology on offer in such a marketplace. Consequently, an Internet marketplace is unlikely to take the place of traditional licensing mechanisms. Instead, it will offer an alternative to own development (or strategic use) and traditional licensing. Thus, patents offered for sale via yet2.com are likely to be idle patents, that is, patents covering projects that the firm has decided not to develop, use strategically or license through traditional means.

We restrict our attention to firms offering patents for sale or license in the "Chemicals" or "Biotechnology" categories as defined by the United States Patent Office (13). In these sectors, patents are an effective means of protecting inventions, and technology transfer between firms is commonplace (14). Therefore, chemical and biotech patents offered for sale on the Internet have interesting characteristics. First, they are patents that can actually enforce the protection of the invention transferred and so make the transfer of technology less costly (more likely). Second, since technology transfer already takes place in these sectors, firms have had the chance to license through traditional means before deciding to offer their patents in an Internet marketplace. Third, because of the effective protection conferred in this case, strategic use is also a relevant alternative. Therefore, we have patents that firms have actually chosen not to develop, use strategically or license through traditional channels.

Having selected the sample of sleeping patents (955 observations), we identified the patentholders (101 firms). Then, from the NBER database, we identified the portfolios of patents granted to these firms in the chemicals and biotech categories from 1981 to 1999 (15). Having identified the population of non-sleeping patents, we drew from it a random sample of 18876 patents (16). From the NBER database, we retrieved individual patent information about the sleeping and non-sleeping patents, including application year, year granted, primary sector, number of citations made and received, and other primary and constructed variables.

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(13) yet2.com classification of technologies into categories is based on the patentholder's criteria and does not necessarily correspond with the classification proposed by the NBER authors, based on the primary class the United States Patent Office (USPTO) assigns the patent. Consequently, we select the patents that fit the "Chemical" or "Drugs and Medical" categories under both classifications. This selection may introduce some bias, since we restrict the analysis to patents that fall within these categories according to their primary class. However, a given patent can have applications in more than one sector, and this is captured by both its primary and secondary classes. Thus, we are missing the effect of patents whose secondary classes are mapped into the chemicals and biotech sectors. Nevertheless, including all the patents identified under chemicals or biotech in yet2.com independently of their USPTO classification would have introduced more serious biases.

(14) As Arora (1994) points out: "in the chemical industry (..) the object of discovery can be described clearly in terms of formulae, reaction pathways, operating conditions and the like". This fact makes clear the object of the patent and, thus, strengthens the protection. This strong protection makes licensing specially feasible and a major strategy of rent appropriation in this sector, as opposed to others.

(15) Sleeping patents identified are granted up to 2002, but the NBER database from which we extract the information only covers up to 1999.

(16) The non-sleeping patent population (from chemicals and biotech) adds up to 64006 patents. Consequently, non-sleeping patents represent only 1.5% of the whole sleeping-patents population (see Table 1 for the distribution of sleeping and non-sleeping patents across patentholders). We therefore draw a random sample of the non-sleeping-patents population in order to achieve 5% sleeping-patents vs. 95% non-sleeping patents. The random sample was obtained by Stata7 by randomly selecting 28% of the whole portfolio of chemicals and biotech patents of these firms. The only restriction was to maintain the overall proportion of chemicals and biotech patents found in the sleeping-patent sample (86% vs. 13%).

3.2. Analysis

We have used these data to estimate the probability of patent rejection by the firm. Each observation represents a patent. The outcome variable is a binary dependent variable: it captures the decision by the firm whether or not to offer a patent in the mentioned Internet marketplace (we assume that this decision reflects the sleeping or non-sleeping nature of the patent). We should therefore use a discrete choice model with the following specification for patent *j* in firm *I*:

$$Y^*_{ij} = \beta^{@}X_{ij} + \varepsilon_{ij} \qquad \text{where} \qquad \begin{cases} Y_{ij} = 1 \\ Y_{ij} = 0 \end{cases} \text{if} \qquad \begin{aligned} Y^*_{ij} > 0 \\ Y^*_{ij} \leq 0 \end{aligned}$$

where Y^*_{ij} denotes the unobservable propensity to sleep, X is a vector of patent-varying exogenous variables and ε_{ij} is the unobservable error term. Therefore, it is assumed that patent sleeping incidence is observed only when the patent's propensity to sleep is greater than a threshold equal to zero. Nevertheless, we cannot assume independence on the error terms since, by construction, there are many patents in the sample owned by a given firm *i*. Thus, each firm represents a cluster of correlated observations. In order to capture unobserved firm-specific effects, we should introduce an extra variable to the model, α_i.

$$Y^*_{ij} = \alpha_i + \beta'X_{ij} + \varepsilon_{ij} \qquad\qquad j = 1,2,...N_i \quad ; \quad i = 1,2,...I$$

where α_i captures the firm-specific unobserved characteristics. The dilemma is whether α_i should be treated just as a constant term over firms (fixed effects model) or as a random variable just like the error term (random effects model). The latter approach obtains more efficient estimates but it requires the assumption that the α_i's are independent of the X's, that is, the firm effects term should be uncorrelated with the explanatory variables (if our estimates are to be consistent). The Hausman test allows to test this assumption (Maddala, 1993). The results of the Hausman test differ with the specification of the model. Thus, we do not find conclusive evidence either for rejection or for acceptance of the null hypothesis of consistency of the random effects model. Nevertheless, we are interested in including some firm-invariant variables such as the size of a firm's patent portfolio. In this case, if we use the fixed effects model we cannot estimate the parameters λ, because α_i captures the effect of all the time-invariant variables. Therefore, since we do not find conclusive evidence for the rejection of the random effects model and we want to estimate the parameters λ, we treat α_i as random. The specification is as follows:

$$Y^*_{ij} = \alpha_i + \beta'X_{ij} + \gamma'z_i + \varepsilon_{ij}$$

The probit regression is the most appropriate discrete choice technique to estimate it (Maddala, 1993). Therefore, we use a probit random effects model.

3.3. Variables

3.3.1. Dependent Variable

The dependent variable reflects the sleeping or non-sleeping character of the patent. Patents are coded 1 if identified as being offered in yet2.com and thus considered sleeping patents, and 0 otherwise. There are 18876 observations coded as 0 and almost one thousand patents (955 observations) coded as 1, which represents five percent of the total. These patents correspond to a set of 101 different firms. Nevertheless, we shall drop observations from firms that have less than 1% of observations coded as 1. This results in a set of 86 firms with 10956 observations coded as 0 and 907 observations coded as 1, which represents 7.65% of the total.

3.3.2. Predictor Variables

– Importance

Previous literature has suggested as a proxy for "patent value" the *number of citations* a patent receives from subsequent patents. When inventors patent an invention, they must cite the previous inventions their innovation builds upon. Patents that receive more citations are thus considered to be making a bigger contribution to the scientific community than patents with fewer citations. Therefore, citations received from subsequent patents reflect a given patent's contribution to further research (see Jaffe et al., 2000 for evidence from a survey). The validity of this proxy has been tested by analyzing its correlation with other measures of value. Trajtenberg (1990) found that the more socially valuable patents were more frequently cited. Hall et al. (2000) concluded that companies with more frequently cited patents have higher stockmarket values. Harhoff et al. (1999) found that German patents renewed to full term (17) are more highly cited and that, among the full-term patents, the most valuable ones –according to the patentholder's assessment– were also the most frequently cited.

Citations present the following practical problem: because the data are truncated at a certain point in time, patents granted closer to this truncation date have a shorter time span to receive citations. As the NBER data reveal, a patent will have received only 50% of its citations in ten years from its granted year (Hall et al., 2001), although citation lags seem to have been shortening in recent years. These authors propose two methods to empirically deal with this situation: i) standardization, which removes variance due to truncation and also some variance due to real effects; and ii) econometric models, which allow us to identify these two sources of variance but require some assumptions about the process that may drive differences in citations across groups. We use the first method, standardization, because we are working with only two groups of patents (chemicals and biotech) which we do not expect to have very divergent citation patterns (we will subtract the same real variance, if any, in both cases). Alternatively, we simply introduce year dummies (18).

– Strategic fit

We measure strategic fit through *self-citations received*. Self-citations refer to citations received from patents owned by the same firm. Therefore, as citations received proxy the importance of a patent for the scientific community, self-citations received may proxy the importance of a patent for the firm. The more important a patent is for the firm, the more likely it is to be linked to the firm's core technologies. As we will mention, the further away a technology is from the firm's current assets and capabilities, the less incentive the firm will have to invest in that technology. Therefore, the more self-citations a patent receives, the more likely it will be to fit with the firm's strategic core.

We also consider the *number of inventors* as a proxy for strategic fit. Reitzig (2001) considers that a large number of inventors points to patent complexity. We believe that the number of inventors is an indicator of the resources the firm devotes to a particular research

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(17) Patents have a 20-year validity span. However, the patentholder must pay renewal fees (annual and progressive in the German case) in order to maintain the patent right valid. Otherwise, the patent right lapses.

(18) As Shane(2001) does. See Henderson et al. (1998) and Lerner (2001) as empirical analyses using the standardization method.

line. Since an established firm has incentives to devote more resources to the projects that are closest to the firm's already existing assets, the more resources the firm devotes to a project, the better it will fit with the firm's strategy.

Following the same reasoning, we suggest another potential indicator related to the strategic fit of the patent in the firm's portfolio: the *frequency* in the firm's patent portfolio of the *patent class* to which a given patent is assigned. We assume that the more frequent the patent class is in a firm's patent portfolio, the more likely it is to represent a core research line in the firm.

– Scope

There have been different attempts to measure scope, i.e. the technological space a patent covers. The most widely used indicator (Lerner, 1994; Shane, 2001; Reitzig, 2001) is the number of patent classes a patent is assigned to, which reflects the number of potential sectors of activity in which the patent may be applicable. Instead, we use the number of patent classes the citations received by a patent are assigned to, as suggested by Trajtenberg et al. (1992). We consider that the spread across patent classes of citations received gives an idea of the technological space the patent covers (in which fields a given patent is considered as prior art). In the NBER paper, a Herfindhal-type concentration index for citations received (*generality*) is proposed:

$$Generality_j = 1 - \sum_{k}^{n_j} s_{jk}^2$$

s_{jk}^2 = percentage of citations received by patent *j* that belong to patent class *k* out of *nj* patent classes

A higher generality means a lower concentration of citations across patent classes and therefore, a higher spread of the patent impact. Therefore, the higher the generality, the higher the scope. As NBER authors point out, a general technology can be understood as a "general purpose technology".

We adjust this measure by the number of citations, since they introduce a bias (as suggested by Hall et al., 2001). Moreover, this adjustment allows to correct for correlation. We call the adjusted variable *adjusted generality*.

$$AdjustedGenerality_j = Generality_j \frac{C}{C-1}$$

C = number of citations received

We also use the number of *claims*, as proposed by Lanjouw & Schankerman (1999). Claims are the number of sentences that describe an invention; they can be interpreted as "units of invention" (Jaffe, Hall & Trajtenberg, 1999). The higher the number of such "units", the broader the technological space the patent covers. We can think that this measure as highly endogenous (Reitzig 2001), because the firm may decide to break down the "actual" blocks of invention into the smallest possible pieces. However, the firm's discretion in the way it describes the innovation is highly constrained by the type of technology and the patent officer examination.

– Radicalness/Innovativeness

We measure the degree of innovativeness with a set of variables. First, we consider the number of *citations* the patent *made* to previous patents. The lower the number of citations made, the less derivative in nature the patent is, i.e. the less it builds upon previous research (Lanjouw & Schankerman, 1999) and the more innovative it can be considered.

Second, we consider *originality (adjusted originality)*, a Herfindhal-like index that measures the concentration of the citations a patents makes across patent classes. The wider the spread of citations made, the more original the invention. A high spread of citations made means that the invention is "breaking molds" (Hall et al., 2001) rather than being a mere sequential invention. Therefore, the more radical the innovation will be.

We also consider as a proxy for innovativeness the mean time lag between the grant year of the patent and the grant year of the subsequent patents that refer to it (*forward lag*). The later the citations come, the later others realised about the potential of this area of research, meaning that the firm was initially working on it alone (19). We also introduce the analogous measure to *forward lag* but referring to citations made (*backward lag*). The older the patents the invention relies on, the less innovative it is considered.

Finally, another potential proxy for radicalness more related to the degree of innovativeness inside the firm is *self-citations made*, i.e. the percentage of citations made to previous patents assigned to the same firm over all the citations made. The lower the ratio of self-citations made, the more recent this research line is to the firm.

We propose more than one proxy for some of the patent dimensions that we want to analyze. Nevertheless, none of them aims to be "the" proxy for a given patent characteristic. Rather, they try to capture different dimensions of it. Looking at their correlation (Table 2), we can see that they are actually quite independent measures and that we will not suffer from multicollinearity problems if we use them in the same regression.

3.3.3. Control variables

– Firm characteristics

We control for the following firm characteristics: patent portfolio, size and diversification (20). These characteristics may affect the firm's decision whether to shelve or to use a patent, as well as the characteristics of the patented invention. All these measures are from 1996, the last year for which we have patent data.

The size measure is *firm sales*, obtained from Compustat. It may have a direct as well an indirect effect on the likelihood of keeping sleeping patents. On the one hand, size is a proxy for bargaining power. The larger the firm, the better positioned it is considered to be in potential licensing deals. This may affect its willingness to engage in such deals. This may mean either that the firm actually engages in more deals and, therefore, has fewer sleeping patents; or that it is more willing to wake up its patents once there is a less costly means of

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(19) Lanjouw & Schankerman (1999) suggest the interpretation for early citations

(20) The latter two measures are available only for a certain set of firms (public US-based firms with more than $10 million in assets and 500 shareholders).

marketing them (such as a Web-based marketplace). On the other hand, we may expect size to affect the way the firm perceives different invention characteristics when considering whether to adopt or reject a project. We have mentioned, for instance, that bigger firms are more reluctant to adopt more innovative projects.

The *portfolio* measure is a count measure on the number of patents granted to a given firm from 1980 to 1996. The patent portfolio is a more accurate proxy for the firm's bargaining power than firm size. If the firm has a larger amount of patents, it will actually have a stronger position in a negotiation. Moreover, a firm with a larger patent portfolio will be more used to managing and exploiting its intellectual property through licensing or sale (it will probably have a technology transfer department, for instance). Therefore, the more patent-intensive the firm, the fewer sleeping patents it is likely to have. However, for the same reason, it will not be reluctant to wake up its patents in a Web-based marketplace.

To compute the *diversification* measure, we use data on the firm's sales at the business segment level, available in Form 10-K filed with the Securities and Exchange Commission (SEC), to compute a diversification measure (as proposed in Davis et al., 1994). The diversification measure takes the form:

$$\text{Diversification} = \sum p_i \ln(1/p_i),$$

p_i = proportion of the firm's sales made in segment i (21)

We hypothesize that the more diversified the firm, the less likely it will have sleeping patents. In a diversified firm, there are more chances that a given invention will be exploited in some of the firm's activities or that it will be licensed or sold to external partners, thanks to a larger and more diversified network.

– Time

This control is required because all citations or citations-related variables are time-dependent. We control for the year in which the patent is applied for (from 1981 to 1999).

– Technology classes

The majority of the independent variables vary with the technology field of the patent, from claims to all citations-related measures. Thus, to compare patents from different fields, we should control for technology categories, which are built upon patent classes (Hall et al., 2001). These authors distinguish up to 6 technology categories, but here we shall focus only on two, Chemicals and Drugs & medical.

Table 1 presents a summary of the variables.

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(21) Segments identified according to the 4-digit level Standard Industrial Codes –SICs-

Table 1. Summary of variables

Variable name	Description	Proxy	Expected sign on the sleeping likelihood
Citations received	Number of citations the patent receives from subsequent patents	Importance	–
Self-citations received	Share of citations received from patents by the same firm	Strategic fit	–
Inventors	Number of inventors	Strategic fit	–
Frequency class	Frequency of the primary class the patent is assigned in the firm's patent portfolio	Strategic fit	–
Claims	Number of sentences describing the invention	Scope	+/–
Generality	Herfindahl index on the spread of citations received from different patent classes	Scope	+/–
Citations made	Number of citations the patent makes to previous patents	Innovativeness	–
Originality	Herfindahl index on the spread of citations made to different patent classes	Innovativeness	–
Forward lag	Mean lag between the application year of the patent and that of the citing patents	Innovativeness	+
Backward lag	Mean lag between the application year of the patent and that of the cited patents	Innovativeness	–
Self-citations made	Share of citations made to patents by the same firm	Innovativeness	+
Application year dummy	Year in which the firm submits the patent to the Patent Office	Time control	n.a.
Category dummy	Technological category that corresponds to the patent primary class	Technological control	n.a.
Portfolio	Number of patents granted to the firm (in any technological category, 1980-1996)	Firm invariant variable	+/–
Diversification	Diversification measure	Firm invariant variable	–
Sales	Firm sales (in billions)	Firm invariant variable	+/–

4. Results

4.1. Descriptive statistics

We report in Table 2 the descriptive statistics for the set of patent data that we will mainly use in the regression analysis. It corresponds to a set of 86 firms and 11863 observations (22). We can appreciate significant differences in means for the two subsamples: sleeping (Y = 1) vs. non-sleeping (Y = 0) patents. Variables with a significant and negative difference are *claims, adjusted generality, citations made, inventors, frequency, sales* and *diversification*. Variables with a positively significant difference include *citations received, forward lag, self-citations made* and *patent portfolio*.

Table 2. Descriptive statistics (non-truncated sample)

Variables	Mean	Min	Max	Mean Y=0	Mean Y=1	Difference[1] (t-test)
Citations received	4.70	0	273	4.738	4.216	.5216* (1.807)
Standardized citations received	1.095	0	63.64	.9443	.9535	−.0092 (−.1598)
Self-citations received	.255	0	1	.2554	.2504	.005 (.3329)
Inventors	2.676	1	16	2.647	3.028	−.3806*** (−6.678)
Patent class frequency	.0579	0	1	.0561	.0807	−.0246*** (−7.716)
Claims	13.81	1	136	13.68	15.44	−1.759*** (−4.357)
Generality	.3553	0	.9231	.3545	.3672	−.0128 (−.9822)
Adjusted generality	.5846	0	1	.5823	.6167	−.0343** (−2.006)
Citations made	8.91	0	213	8.86	9.48	−.6196* (−.1679)
Originality	.4175	0	.9267	.4166	.4286	−.01206 (−1.202)
Adjusted originality	.5485	0	1	.5478	.5569	−.0091 (−.7581)
Forward lag	4.846	0	17	4.895	4.165	.7301*** (6.236)
Backward lag	11.57	0	76.33	11.55	11.74	−.1902 (−.749)
Self-citations made	.2317	0	1	.2357	.1841	.0516*** (2.86)
Portfolio	3688	1	8049	3753	2910	843*** (10.03)
Sales (in millions)	19519	141	4381	19289	23866	−4577*** (−5.617)
Diversification	.838	0	1.504	.8266	1.052	−.226*** (−10.08)

[1] Mean comparison test on equality of means. Significance level: .01(***), .05(**), .10(*).

(22) Although we will report some results for the set of 101 firms, we mainly drop from the analysis the 15 firms with less than 1% of sleeping patents, since they may distort results.

In Table 3 we present the correlation between the variables used as regressors. Many of them present a correlation significant at a one percent level. However, the highest correlation coefficients are $\rho = .389$ (between general and citations received) and $\rho = .366$ (between original and citations made) (23). The next highest correlation is $\rho = .259$ (between *general* and *backward lag* and *portfolio* and *inventors*). These levels of correlation do not suggest the presence of multicollinearity problems, as confirmed by the high tolerances. When we include *diversification* and *sales*, the highest correlation level is $\rho = .727$ (24). However, no multicollinearity problems are detected when computing their level of tolerance (.44 and .37 respectively).

Table 3. Correlations (non-truncated sample)

	claims	cmade	crec	general	original	fwd	bck	selfcm	selfctr	inv	freq	portf	diversif	sales
cmade	. 210	--												
creceive	.166	.062	--											
general	.077	.021	.389	--										
original	.099	.366	.055	.194	--									
fwd lag	−.031	−.120	.239	.259	−.030	--								
bck lag	−.023	.119	−.097	−.061	.067	.043	--							
selfctm	.018*	−.021	−.004*	−.051	−.088	−.045	−.193	--						
selfctr	.062	.104	.020*	−.057	−.022	−.212	−.002*	.137	--					
inventors	.004*	−.004*	−.056	−.060	−.025	−.148	−.028	−.052	.025	--				
frequency	.003*	.021	.033	−.102	−.131	−.084	−.082	.062	.096	.067	--			
portfolio	.013*	.074	.027	.025	.101	.012	.000	.153	.094	−.259	−.300	--		
diversif	−.020*	.070	.006*	−.085	−.097	−.092	−.021	.021	.060	.016	.051	−.018*	--	
sales	−.052	.023	.014*	−.055	−.064	−.068	−.024	.053	.055	−.068	.014*	.298	.72	--

* NOT statistically significant at the 0.05 level.

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(23) When we use the adjusted measures for generality and originality, these correlation coefficients drop to $\rho = .035$ and $\rho = .136$, respectively.

(24) Despite their high correlation, we include both of them as regressors. Otherwise, all the effect is captured by one of them and the interpretation of results may be misleading.

4.2. Empirical Results

We log transform the independent variables in order to reduce their skewness (25). We present random effects probit models on a patent's sleeping likelihood (26). In Table 4, we present results in the form of marginal effects at the median (27) for the set of 86 firms.

Table 4. Probit Random Effects, Marginal effects at the Median

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Importance					
Citations received	.0016	−.0013	−.0003	9.07e-06	
	(.0045)	(.0082)	(.0133)	(.0134)	
Strategic fit					
Self citations received		−.0038	.0441	.0398	
		(.0213)	(.0425)	(.0429)	
Inventors	.0235***	.0355***	−.0411	.0564***	−.0229
	(.007)	(.0113)	(.0194)	(.0511)	(.0239)
Frequency	.0068	.0202**(***)	.0212**		
	(.0045)	(.0085)	(.0086)		
Scope					
Claims	.0086*	.014**	.0225*(**)	.0223*(**)	.0090
	(.005)	(.014)	(.0122)	(.0123)	(.0057)
Generality		.0184	.0641(*)	.0674(*)	
		(.0294)	(.0418)	(.0423)	
Innovativeness					
Cmade	−.0006	−.0188**	−.0277*(**)	−.0693**(***)	−.0298**(***)
	(.0049)	(.0096)	(.0089)	(.0291)	(.0123)
Originality		.0713**	.0721*	.0708(*)	.0357*
		(.032)	(.0438)	(.0439)	(.0201)
Forward		.0149	.07582*(**)	.0748*(**)	
		(.396)	(.0438)	(.0438)	
Backward		.0172*	.0202	.0210	.014
		(.0102)	(.0183)	(.0185)	(.0088)
Self citations made		−.0406	−.0838*	−.0834(*)	−.0682***
		(.2756)	(.05225)	(.05254)	(.0251)
Interactions					
Inventors x Cmade				.0451*(**)	.0245**
				(.0237)	(.0107)
Firm invariant					
Portfolio	−.0262***	−.0285***	−.0408***	−.0429***	−.0253***
	(.0049)	(.0077)	(.0125)	(.0129)	(.0052)
Controls					
Technological category	Included***	Included**	Included*	Included*	Included**
Application year	Included	Included	Included	Included	Included
Constant	Included	Included	Included	Included	Included
Rho	.2801***	.3051***	.3210***	.3253***	.3052***
	(.0218)	(.0268)	(.0326)	(.0321)	(.022)
N	11066	7879	5871	5871	9727
Groups	84	83	82	82	84
Wald χ^2 – test	40.33***	189.18***	160.19***	163.45***	199.65***

Standard errors in parentheses. Confidence level of the marginal effect at 1%***, 5%**, 10%*. In parentheses, the confidence level of the coefficients if it differs from the confidence level of the marginal effect.

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(25) In order not to lose observations with a zero value when taking logarithms, we add one to the original variable before doing the transformation.

(26) We also performed fixed effects models. Results are basically the same, except for the non-inclusion of the firm invariant variables and the non-significance of the *claims* variable. This fact *may* suggest that the decision on the number of *claims* used to describe an invention in a patent is strongly firm-dependent. Results do change when we use robust probit models (without controlling for firm effects).

(27) Note that the marginal effect is computed at the median of the log transformed variable. However, given that we compute it at the median, we can easily find the original value it corresponds to (i.e. the median of the original variable).

Model 1 includes one proxy for each of the four magnitudes of the patented invention we are interested in: scope, importance, innovativeness and strategic fit. In particular, we introduce the raw variables that are known from a granted patent: the number of *claims* describing the invention, the citations received, the *citations made* and the number of *inventors*. Overall, the model is significant. The proportion of the total error variance accounted for by the random effects is significant (rho=.28, p<.000). *Claims* and *inventors* display significant positive coefficients on the patent sleeping likelihood. The magnitude of the effect of *claims* is reflected by the .85% increase in the sleeping likelihood when it increases by 1% from its median (Md = 11), with the rest of the variables constant at their median. The sign of this variable suggests that the effect of scope on the sleeping likelihood is actually positive. Similarly, the sleeping likelihood increases by 2.35% when the number of *inventors* increases by 1% from its median (Md = 2). Contrary to the prediction, this result suggests that the more inventors have been involved in a project and, therefore, the more strategic the patent, the more likely that the patent will end up sleeping. This striking result may be due to high research intensity in the firm's core areas, which is likely to result in a high likelihood of project rejection, even if the project actually fits with the firm's strategy. The proxy for importance, *citations received*, has a different sign from predicted, but is non-significant. *Citations made* displays the predicted negative sign as a proxy for innovativeness, but its coefficient is not statistically significant. *Citations received* displays an unpredicted negative sign, but its magnitude is almost nil (28). The firm-invariant *portfolio* variable has a negative coefficient significant at a 1% significance level, suggesting that the larger the firm's portfolio and, therefore, the greater its bargaining power in licensing deals, the less likely it is to have sleeping patents. In particular, there is a 2.6% decrease in the sleeping likelihood when the patent portfolio increases 1% from its median (Md=3490).

Model 2 adds all the constructed variables, i.e. those built on some of the raw variables. In particular, we include the (unadjusted) *originality* and *generality* measures, the percentage of *self-citations* and the citation lags, all of them derived from citations. The overall model is significant, as also is the proportion of the variance of the error accounted for by the random effect (rho=.305, p<.000), which increases with respect to the previous model (29). Three dimensions of the innovation appear to have a significant effect on the sleeping likelihood. First, the strategic fit of the invention shows up as a significant dimension, as reflected by the positive and significant coefficient on inventors. In fact, the increase in the sleeping likelihood is higher than in the previous model (an increase of 3.55% if it increases 1% from the median). *Patent class frequency* also displays a positive sign, but is only significant at a 13% level. *Self-citations received* is not significant but displays the predicted positive sign. The evidence, therefore, is inconclusive. However, it suggests that, contrary to predictions, the strategic fit dimension has a negative effect on the sleeping likelihood. Second, patent scope appears also as having a positively significant effect on the patent sleeping likelihood. Both *claims* and *generality* display a positive sign, even though only the former is significant (a 1.4% increase in the sleeping likelihood if claims increases by 1% from the median, Md=12). Therefore, the larger the space a patent covers, the greater the likelihood that the patent (or some of its applications) is (are) actually sleeping, instead of

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(28) An alternative specification with standardized citations received displays basically the same results.

(29) We have to be careful when comparing results from this model with results from previous or subsequent models, since the analysis in this case is performed with a reduced set of patents, namely, the patents that have at least one citation made and one citation received. The reason lies in the fact that when we introduce citations derived variables in the analysis, some of them take missing values when citations made or received are equal to zero. These observations are then not included in the regression, having as a result a sample truncated at citations made and citations received equal to zero –note that citations are independent variables-.

a higher likelihood of being used. Third, the more innovative the invention, the higher the sleeping likelihood, as predicted. All the variables that proxy for this dimension have the predicted sign except *backward lag*, which is significantly negative at a 10% level. The negative effect of *citations made* becomes significant (30) (a 1% increase from Md=6 decreases the sleeping likelihood by 1.89%). *Originality* is the other significant variable; when it increases by 1% from its median value (Md=.5), it increases the sleeping likelihood by 7.13%. Therefore, the more radical the patented innovation is considered, the more likely it is to remain on the firm's shelves. *Citations received*, as a proxy for importance, has a non-significant negative coefficient, but the effect is very close to zero. This result suggests that sleeping patents are not significantly less important than non-sleeping patents. On the other hand, the effect on the sleeping likelihood of the *portfolio* variable remains negative and significant.

In *Model 3* we replicate Model 2 with the *originality* and *generality* measures adjusted by the number of citations made and received, respectively. As mentioned in section 3.3.2., these adjustments correct for a downward bias in the measures as originally computed. However, they introduce another kind of bias in the regression: the sample is truncated at citations made or received equal to one (31). Results do change somewhat from the previous model. In this model, we find more conclusive evidence of the positive effect of the strategic fit dimension on the sleeping likelihood. The effect of *inventors* remains positive and significant, but it is stronger (a 1% increase in the number of inventors from its median increases the sleeping likelihood by 5.6%). The effect of *frequency* becomes significant and is non-negligible (a 2% increase in the sleeping likelihood for a 1% increase from its median, Md=.28). *Self-citations received* becomes positive, as predicted, but remains non-significant. Second, with respect to the scope dimension, claims is still positive and significant, but its effect is stronger, too (a 2.25% increase in the sleeping likelihood). The positive effect of *generality* on the sleeping likelihood becomes significant at a 10% significance level (even though the marginal effect is not significant in itself) and its effect is quite strong (a 6.4% increase in the sleeping likelihood when *adjusted originality* increases by 1% from its median, Md=.67). Third, along the innovativeness dimension, some changes are worth mentioning. *Citations made* (32) and originality remain significant and the effect of their coefficient is similar in dimension. Backward lag is no longer significant but maintains its contrary-to-predicted sign. Instead, the positive effect of *forward lag* becomes significant and quite strong (a 7.6% increase in the sleeping likelihood for a 1% increase from its Md=4.8). *Self-citations made* also becomes significant, with the strongest marginal effect of all the variables (8.4% decrease, Md=.11). The evidence of the positive effect on the sleeping likelihood of the innovative dimension is quite conclusive. However, many of these changes in the significance of the variables seems to be due to the sample truncation and not to the inclusion of the adjusted variables on originality and generality (33).

Model 4 introduces the effect of interactions. In particular, we test the effect of the interaction between inventors and *citations made* (34), that is, between strategic fit and

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(30) Citations made becomes significant when we include the originality variable.
(31) This is due to the adjustment made to these variables, which consists on multiplying the original variables by (citations/(citations-1)). Therefore, these adjusted measures take missing values when citations are equal to one. Consequently, the sample considered for the analysis with adjusted measures is truncated at one.
(32) In this case, citations made becomes significant only when we control for *originality*, *self-citations made* and *backward lag*.
(33) When we run Model 2 with the sample used in Model 3, i.e. a truncated sample at citations equal to one, we find the coefficients on frequency, forward lag (but not backward) and self-citations made significant, as we find with Model 3. The magnitude of the coefficients is more similar to the one in Model 3.
(34) The rest of interactions display no significant effect when using the sample truncated at citations equal to one.

innovativeness. The inclusion of this interaction makes the *inventors* variable no longer significant. *Citations made* remains negative and significant. The interaction between the two displays a positive and significant coefficient. This means that a more innovative patent is more likely to remain shelved the lower its fit with the firm's strategy. In contrast, a patent with a higher fit is more likely to be left sleeping the less innovative it is (35). These results suggest some very interesting conclusions about the rejection of projects by established firms. Specifically, firms are more likely to reject more innovative projects in strategically remote areas and to reject less innovative projects in strategically closer areas. The rest of the results remain basically the same.

Model 5 predicts the likelihood of a sleeping patent taking into account only the information known at application date, that is, all the variables to do with the number of citations made as well as the number of inventors (36). Results differ slightly from previous specifications. The main difference is that claims, the proxy for scope, is positive but only significant at a 10.7% confidence level. *Citations made, originality* and *self-citations made*, which account for radicalness, remain significant and suggest the positive effect that this dimension has on the sleeping likelihood. The interaction of citations made and inventors remains positive and significant. The firm's *portfolio* also remains positive and significant and with a similar magnitude than in previous models. These results suggest that with only the information available at grant date we are able to detect which invention dimensions affect the sleeping likelihood, except for scope.

4.2.1. Some more results

In this section, we include two other firm-invariant characteristics that we believe may capture some of the firm effects considered unobserved in previous models and captured by the rho. In particular, we are interested in testing whether measures such as diversification or size change the results. However, these data are available for only a very reduced set of patentholders, namely 22 firms (37). Results are reported in Table 5. Results are very similar and divergences are due mainly to the restriction in the sample.

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(35) Note that the effect of inventors is given by the sum of the coefficients on inventors and on the interaction. Even though the first coefficient is negative, the overall effect is positive, because the effect of the interaction is always positive –the sample is restricted to patents with more than one citation- and greater than the negative coefficient on inventors.

(36) The specification reported as Model 5 includes the originality measure adjusted. Results do not change significantly in the alternative specification including the non-adjusted measure.

(37) Four of these 22 firms have a proportion of observations coded with Y=1 lower than 1% and are eliminated from the analysis. However, results basically do not change when included.

Table 5. Probit Random Effects, Marginal effects at the Median. Sample big US firms

Variables	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Importance						
Citations received		−.0032	−.009	−.0100	−.0096	
		(.0058)	(.0066)	(.0128)	(.0126)	
Strategic fit						
Self citations received			−.0428	−.0017	−.0058	
			(.0327)	(.0402)	(.0395)	
Inventors		.0357***	.0465***	.0423**(***)	−.0331	.0322***
		(.0107)	(.0166)	(.0204)	(.0494)	(.0095)
Frequency		.0185**	.0264**(***)	267**(***)		
		(.0081)	(.0115)	(.0116)		
Scope						
Claims		.0077	.0145	.016	.0157	.0077
		(.0069)	(.0103)	(.0126)	(.0125)	(.0065)
Generality		.0082	.0208	.0217		
		(.043)	(.0396)	(.0389)		
Innovativeness						
Cmade		−.0065	−.0334**	−.0369**(***)	−.0628**(***)	−.0162**
		(.0067)	(.0146)	(.0187)	(.0299)	(.0079)
Originality			.0795*(**)	.0809 (*)	.0799(*)	.0176
			(.0463)	(.0433)	(.0502)	(.0232)
Forward			.0369	.0622 (*)	.0604(*)	
			(.0293)	(.0466)	(.0458)	
Backward			.0219	.0272	.0270	.019*
			(.0157)	(.0202)	(.0198)	(.0102)
Self citations made			−.068*	−.0545	−.0058	−.0557***
			(.0402)	(.0402)	(.0395)	(.0256)
Interactions						
Inventors x Citations made					.0324(*)	
					(.0222)	
Firm invariant						
Portfolio	−.052**	−.0398***	−.0594***	−.0832***	−.0815***	−.0427***
	(.00899)	(.0106)	(.0176)	(.0293)	(.0290)	(.0097)
Diversification	.1494***	.1162***	.1978	.2730***	.2708***	.1333***
	(.0201)	(.026)	(.0507)	(.0891)	(.0899)	(.0241)
Sales	−.001*	−.0016**	−0021***	−.0010	−.0011	−.0008
	(.0006)	(.0000)	(.001)	(.0000)	(.0011)	(.0006)
Controls						
Technological category	Included *	Included *	Included **	Included *	Included *	Included *
Application year	Included	Included	Included	Included	Included	Included
Constant	Included **	Included	Included	Included **	Included *	Included
Rho	.1947***	.1176** *	.1729***	.2652***	.2677***	.1685***
	(.0279)	(.0184)	(.0304)	(.0495)	(.0497)	(.0244)
N	6493	6053	4569	4620	3568	5534
Groups	18	18	18	18	18	18
Wald _2 – test	241.9 ***	146.6***	174.8***	133.07 ***	189.34***	188.07***

Standard errors in parentheses. Confidence level of the marginal effect at 1%***, 5%**, 10%*. In parentheses, the confidence level of the coefficients if it differs from the confidence level of the marginal effect.

Model 0 includes only this new set of firm-invariant characteristics. Overall, the model is significant. We can observe that *rho* drops to quite low levels (rho=.114), but it is still significant. The variables capturing firm characteristics all display significant coefficients. The effect of *portfolio* remains negative, suggesting that, all the other firm characteristics equal, a firm with more patents in its portfolio is less likely to shelve patents. The reported marginal effect shows that the probability of a sleeping patent decreases by .043% when the firm's portfolio increases by 1% above the median (Md=5192 patents). The effect of *sales* on the sleeping likelihood is positive. This finding may support the idea that bigger firms are not proactive in intellectual property management, whether because of organizational inertia, because of expected negative profitability, or for other reasons. The

significant positive effect of the *diversification* coefficient on the sleeping likelihood is even more striking. A priori, more diversified firms appear to be more likely to market their underused intellectual property than less diversified ones. However, this positive effect may derive from a bias in the data source. This potential bias may arise because more diversified firms are better able to perceive that their patents could be useful in other sectors. Therefore, they are able to "identify" more sleeping patents than less diversified firms. Also, they may perceive less risk than less diversified firms in posting their sleeping intellectual property in an open marketplace. Therefore, we could not assess whether more diversified firms are actually more likely to shelve patents, or have a higher propensity to detect sleeping patents or to use (Web-based) intellectual property markets than less diversified ones.

Diversification remains positive and significant across all the models. Sales turns negative and non-significant when we introduce the variables containing patent information. With respect to the patent characteristics, there are no major changes except for *claims*, which remains positive but is no longer significant in any of the models. We must bear in mind that these results are quite dependent on this very restricted sample (38). We conclude, therefore, that the inclusion of *diversification* and *sales* captures a great deal of the otherwise unexplained firm effects but it does not affect significantly the results for the rest of variables, except (potentially) for the scope dimension. Note that the interaction between *inventors* and *citations made* is significant at only a 10.5% confidence level and is not significant at all in *Model 5* (39).

To sum up, we cannot say whether differences in results with respect to the whole set of firms are due to the restricted set of firms or to the inclusion of two firm-invariant variables. However, unreported regression results suggest that the inclusion of these two control variables lowers the unobserved firm-specific effects captured by rho but does not affect results on the patent-derived variables. If this were the case, we could interpret the results from Table 4 without restrictions.

4. Conclusions

This paper analyses a firm's decision to exploit (itself or through a third party) or not to exploit a patent-protected invention. This decision is captured through another decision made by the firm that we can observe, namely, the decision whether or not to offer its intellectual property for license or sale in a Web-based marketplace. We believe that this is a marginal alternative for exploiting intellectual property, especially for big firms, which have access to more resources either to exploit by themselves or to license their intellectual property. Therefore, all the patents for which the firm chooses this alternative can be considered sleeping patents (40).

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(38) It is not clear whether this change in significance is due to the introduction of *sales* and *diversification* or to the sample restriction. Note that if we run the models for this restricted sample without including *diversification* and *sales*, results are quite similar than when we include then. Only Model2 and Model3 present a significant coefficient on *claims* at a 10% confidence level when we do not include these two firm invariant characteristics. Therefore, *claims* is not robust in the set of the "big US firms" if we do not control for *diversification* and *sales*. This fact also suggests a potential difference in the determinants of the patent sleeping likelihood between "big US firms" and the rest of patentholders.

(39) Again, this effect seems to be due to the sample attrition. When we run Model 4 without including *sales* and *diversification*, the interaction is significant only at a 12% confidence level. In Model 5 it is not significant either with its inclusion or without it.

(40) The reverse is not necessarily true. The firm may just select among its sleeping patents the ones that are most likely to be licensed in order to offer them in the web-based marketplace. However, we do not believe this to be the case, because, if they actually are sleeping patents, firms have nothing to lose by posting them in the web marketplace.

Our findings suggest that, controlling for firm and other patent characteristics, an invention's strategic fit with the firm's strategy and an invention's degree of innovativeness positively affect the invention's sleeping likelihood. More interestingly, a patent's sleeping likelihood also depends positively on the interaction between these two dimensions. Thus, a more innovative patent is more likely to remain sleeping the less well it fits with the firm's core business. And a better fitting patent is more likely to remain sleeping the less radical it is. Some of these results, in particular the result on the innovativeness dimension, are in line with the results from previous literature, which has found that more innovative projects are more likely to be rejected by established firms. However, our findings suggest that this is particularly the case the further away from the firm's core the invention is. Rejections at the firm's core are of less innovative patented projects. Therefore, it is not that established firms do not undertake innovate ideas but rather that they let pass by innovative ideas that do not fit exactly with their core (at least, that is the case with patent-protected projects). Another interesting result, though not so robust, is the positive effect of the scope dimension on the sleeping likelihood. Scope is a very controversial patent characteristic. Previous findings suggest that it is a very valuable characteristic for patentholders, but some literature suggests that it may introduce some market inefficiencies. Our results suggest that, in fact, broader patents are more likely to remain (partially) sleeping. Surprisingly, we do not find conclusive evidence that sleeping patents are significantly less important than non-sleeping ones, contrary to our initial beliefs but consistent with the rest of our results.

We believe these findings to be relevant. They suggest two important facts. First, sleeping patents do not appear to be marginal patents. They are innovative and broad and are not considered significantly less important by the scientific community. Second, firms seem to have a propensity to patent not just what they want to bring to market but any of their research results, both in their core and non-core areas (especially patent-intensive firms, which have a low marginal cost when applying for an additional patent). Given that there is no requirement to put a patent to work in a certain number of years, many firms apply for patents without taking into account the probability of using them. This behavior results in a large amount of patent-protected inventions that lie forgotten on firm's shelves and never reach the market or, even worse, are reinvented by others, who cannot develop them because the patent blocks the area. Moreover, firms do not realise that their un(der)used patents might be valuable in other hands or for other uses, as our findings suggest. This is something that large, patent-intensive firms, with the help of consultant firms, are beginning to realize and implement by hiring broad-based technologists who can help to identify potential uses for a technology across industries. However, even if firms are aware of potential applications for their underused inventions, they are reluctant to incur the costs of searching for potential partners. At the heart of these problems is the lack of markets for intellectual property. If such markets existed, firms' underused technologies, technical problems with no solution, and capital would find each other and efficient deals would be struck.

Further research should focus more deeply on the characteristics and determinants of sleeping patents. In particular, it would be worth further analyzing firm characteristics that may affect the propensity to shelve patents.□

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