Sleeping patents: any reason to wake up?[†]

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(Comments welcome)

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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 the firm's decision on patent use 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 chemical sector that trade some of their patents at the nowadays unique 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 not less important than their counterparts. We conclude that such patents are worth to "wake up", especially when the underlying invention is applicable to business areas that do not fit in the patentholder's strategic core.

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 is 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 imply duplication of inventive efforts or technologies that never reach the market. According to the European Patent Office (2001), the costs of duplication of inventive efforts costs the European Union $20 billion each year. Moreover, some industry estimates point out that a patent intensive company may shelve up to a 70% of their patents, a proxy for inventive activity. Un(der)exploitation has become especially striking nowadays, when knowledge needed in one sector may come from a completely unrelated sector. In fact, recent estimates point out 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 become 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 know (Scherer, 1965). Nevertheless, a patent lying on the lower part of the value distribution in hands of the 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 in firm shelves. We assume that the firm's decision about the use of an invention is related to its intrinsic characteristics. Particularly, we are interested to know whether neglected projects are actually low valued inventions or they do hide a potential value that could be exploited in alternative hands or in alternative sectors. We focus on patent protected projects, since patents contain information on the characteristics of the underlying invention. Different elements of the patent have been tested as proxies for different invention dimensions. Among these, value -social value (Trajtenberg, 1990), private value (among others, Harhoff et al, 1999) or market value (Hall et al, 2000)-, basicness (Trajtenberg et al, 1992) or scope (Lerner, 1994). Some of these validated patent-based proxies, among others, have been used to analyse firm decisions such as startup formation (Shane, 2001).

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 in the firm's strategy (Teece, 1986). Nevertheless, firms differ in their criteria to select projects. In particular, a firm tend to reject more projects the more patent intensive she is (Klepper & Sleeper, 2002), the older she is or the higher her profits are (Cassiman & Ueda, 2002).

As well, there might be other reasons why a firm does not 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 prevents competitors to enter in a certain technological area. Thus, a firm may use a patent only for this blocking purpose -because she wants either to reserve to herself the right to enter in a near future in this area or to avoid that competitors strengthen their positions by entering in it-. Patents allow also to wait until market uncertainty is overcome (Takalo and Kanniainen, 2000). In these and similar cases, even though projects are not developed and marketed, we could not consider them as rejected projects. They have some reason-to-be in the firm's projects 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 opportunism problems (Arora and Fosfuri, 2000). This is specially true in a few industries where patents are actually effective as means of protection –chemicals, software, machinery and engineering services- and where, 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 selling. This means that, even though a patented project has no value inside the firm, she might license it to some other firm that could extract rents from it. However, this alternative turns 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 a non-relevant alternative even for patented projects.

In this paper, we focus on patent protected projects. Reasons are multiple. First, patents are a good proxy for inventive activity of firms[1] and they 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 reach consumers. In both cases too, if it is reinvented by some competitor, there is an inefficiency due to the duplication of research efforts[2]. However,

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[1] It is worth to mention 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.

[2] 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 is greater than the inefficiency due to the duplication of efforts in the non-patented case.

consumers would finally benefit from the invention if it was not patented in the first place but they would not benefit (or they would with delay) if it was, since the patent prevents the competitor from introducing the innovation (until it expires).

Literature has not spent a lot of attention to sleeping patents despite the importance of the phenomenon. As previously mentioned, in patent-intensive firms a huge percentage of their patents are sleeping. For instance, IBM, Philips or Siemens are reported to only use approximately 40% of their intellectual property portfolio[3].

We use a unique dataset of sleeping patents collected from yet2.com, the only active website in technology transfer between firms, and we match it 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 posed by sleeping patents. The greater the value potential of the underlying inventions, the more inefficient 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 they fit better into 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 they may have some hidden potential for value that could be realised in other hands rather than the patentholders'.

[3] According to *Financial Times*, July 2001

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

In previous literature, there is not an explicit definition for sleeping patents, even though there is some rationale for their existence (Kutsoati and Zabojnik, 2001)[4]. They are mentioned as patents that have never turned into an industrial application[5]. This definition of sleeping patents as patents that cover rejected inventions by the firm, that is, inventions that the firm does not launch to the market, however, is not very precise. First, we should note that one invention can reach the market through own development by the patentholder, through development by a licensee or through an alliance, joint venture or some other type of agreement with a third party. Thus, 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 can be used to prevent entry in an area that, were competitors in, competitive pressures would be much higher (Gilbert and Newbery, 1983). A patent could also be used as a "legal bargaining chip" (Hall and Ham, 1999) when the firm negotiates some 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 how market uncertainties are solved before launching the innovation to market (Takalo and Kanniainen, 2000). A patent may allow the firm to block entry to competitors until she has all the complementary assets needed to bring the invention to market (Shane, 2001). Therefore, patented inventions may perform a key role in the firm's intellectual property strategy, even if they are not brought

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[4] 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.

[5] One of the three requisites an invention has to satisfy to ask for a patent is "to have industrial applicability". However, there is no requirement to actually use the patent in an industrial application after it is granted.

to market. Consequently, we can not consider as sleeping patents those patents that are strategically used.

Third, patents and inventions are not related one-to-one. One invention may be covered by many patents or one patent may cover different inventions. The latter case is illustrated by basic inventions such as the laser or Lycra, that may generate a lot of applications but usually, not all of them are actually developed. Therefore, we could consider the applications covered by the patent but non-developed as sleeping applications. Under this point of view, and 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 is aware of this fact, it would be possible to detect sleeping applications with the help of broad-based technologists (Elton et al, 2002). However, in many cases, the patentholder is not even aware that her invention could be useful outside her sector. In this case, the firm will not make any decision over her patent that allow us to identify it as partially sleeping. Therefore, we will not be able to identify underexploited patents in a firm's portfolio unless the firm is conscious of their sleeping character. As a consequence, we should restrict our definition of partially sleeping patents to patents that the firm is consciously aware that they are underexploited.

To sum up, our definition of (partially) sleeping patents refers to *patents (or applications in a patent) that are consciously not being used by the patentholder, directly or through a third party, neither to launch an application to market nor for strategic reasons.*

2.2. Determinants of the sleeping likelihood

In this subsection, I argue why some invention dimensions such as importance, broadness, radicalness and strategic fit may influence the decision of leaving a patent sleeping. I also consider some firm characteristics that may also influence this decision.

- 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[6]) or the private value as perceived by third parties (stock market valuation, opposition[7]). The value of the invention, either social or private, has been linked by the literature to the importance the scientific community gives to it (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 (2001)'s 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 overcomes the firm's opportunity cost and the more willing the firm would be to face uncertainties. Viceversa, the less important the patent, the less likely the firm will develop the underlying invention. Consequently, we suggest that the more valuable the invention, the less likely it would be sleeping, and viceversa.

- Strategic fit

Established firms develop organisational and technical capabilities associated with their core activities. As a result, they are much more efficient to exploit opportunities inside these boundaries than outside them. That is a reason why activities such as research and development are focused on projects that allow to exploit already existing capabilities. However, outcomes from the research phase are, up to a point, random[8]. Conversely, in the development phase, projects could be easily selected to better fit to the complementary assets available in the firm, in order to better appropriate their value. Therefore, inventions that result from the research process are likely to be screened out according to how they fit in the firm's existing complementary assets. In research intensive industries, it is likely that existing capabilities in the firm are highly specialised in the development of a very particular type of innovations, namely, the closest to the

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[6] We refer to litigation decisions where the patent owner is the plaintiff

[7] Opposition refers to a procedure at 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)

[8] 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)

firm's existing business. Consequently, the firm will screen out the projects according to the distance with respect their 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 more valuable to strategically keep in order to protect key innovations, to keep competitors away or to increase the value of her 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 with a better fit into the firm's existing activities are more likely to be developed (through any form) by the firm. Conversely, the further away research results are from the firm's core activities, the higher the likelihood that these results remain sleeping.

-Scope

Scope refers to the technological space the patent covers or protects from infringement. Characteristics of the invention determine scope, but it is also influenced by how inventors "design" the patent. Scope has been related to the economic value associated to 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 to get an extra protection[9]. This will happen, for instance, when the invention does not fit in any of the firm's existing business and she must acquire and develop new complementary assets. This will also be the case when there is high uncertainty on the potential value of the invention, as it happens with the outcomes of basic research. In these cases, if a broader rather than a narrower patent covers the invention, it is more likely that it is used. To sum up, in any given situation, a broader patent is more likely to be used than a narrower patent, because patent protection is stronger. However, the more the firm needs this stronger protection, the more the

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

likelihood of a broader patent to go to market or to be strategically used increases with respect to a less broad 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 actually remain sleeping.

Therefore, two opposite effects may arise with respect this dimension of the invention. The larger the scope, the more likely that the patent is used and, therefore, the less likely that it remains sleeping. However, the larger the scope, the more likely that some of their applications 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 its name suggests, often represent a clear break with respect to the traditional research line of the firm. Not only existing assets and capabilities are useless to undertake these projects but their introduction may destroy existing business of the firm -through cannibalization, for instance-. These are the two main reasons why established firms are not willing to engage in very innovative projects. Conversely, entrants have no developed skills to be undermined; thus, they are not reluctant to accept these projects. In fact, they are willing to undertake the projects that do not fit into established firms, since they will not face their competition. Shane (2001) finds some evidence in this direction: entrepreneurs are more likely to pick up more innovative patents rather than less innovative ones in their decision to form a new firm. Most of the literature suggests that the allocation of projects between incumbents and start-ups is due to inefficiencies in the decision process of the incumbent. Conversely, 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 remains sleeping.

3. Methodology

3.1. Data

The data we use comes 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 identified as customers at *yet2.com*, the nowadays unique website devoted to the transfer of patented technologies between firms[10]. Outside the Internet, there is not any 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 to lower 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[11]. That is why this website created a market for underused technology focused to 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 criteria (being a costumer at *yet2.com*) to select the firms is the following: we can identify the patents that each of these firms choose to offer on an

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

[11] Motivation costs are derived from information asymmetries between the two contracting parties, that may result in potential opportunistic behaviour. In the licensing case, for instance, the licensor does not know about the performance of the technology on 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 of assistance that will receive from the licensor. These asymmetries may translate into costs after and before the negotiation of the deal.

Internet marketplace from all the patents she has on her portfolio. We assume that this decision captures the sleeping character of her patents. Sleeping patents are idle resources for the firm. They are patented projects the firm rejects because they are not profitable enough (under her opportunity cost) to engage in development or in 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). However, in the majority of cases, licensing through the web is not an alternative to traditional ways of licensing. Traditionally, licenses use to be signed, surrounded by high degrees of secrecy, among parties that transact repeatedly or that have some established reputation in the market for technology. The reason: the risks of licensing associated with disclosure to a third party (ex-post opportunism problems), that are minimized through mechanisms of market enforcement such as reputation or repeated games. In an Internet marketplace, deals are offered in an open marketplace where almost everybody in the industry can have access to. This fact may raise strategic concerns on disclosure (the firm reveals information to the rest of the industry players about a given technology) and on unknown potential licensees (that may use the knowledge acquired during the license period to develop afterwards a competing technology) by suppliers. Knowing suppliers' concerns, buyers might have their own concerns on the quality of the technology offered in such a marketplace. Consequently, an Internet marketplace is not likely to substitute traditional licensing mechanisms. Instead, it offers an alternative to own development (or strategic use) and traditional licensing. Thus, it is likely that patents in *yet2.com* are idle patents, that is, patents covering projects that the firm has rejected to develop, to use strategically and to license through traditional means.

We restrict our attention to firms offering patents to sell or license under the "Chemicals" or "Biotechnology" categories as defined by the United States Patent Office[12]. In these sectors, patents are effective as means of protecting inventions and

[12] *yet2.com* classification of technologies into categories is based on the patentholder's criteria and it 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 to 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 that which secondary classes are mapped into the chemicals and biotech sectors. Nevertheless, including all the patents

technology transfer between firms is usual[13]. Therefore, chemical and biotech patents offered in the Internet have interesting characteristics. First, they are patents that can actually enforce the protection of the invention transferred and thus, make less costly (more likely) the transfer of technology. Second, since there is already technology transfer in these sectors, firms have had the possibility to license through traditional means before considering to offer their patents in an Internet marketplace. Third, due to the effective protection conferred in this case, strategic use is also a relevant alternative. Therefore, we have patents that firms have actually rejected to develop, use strategically or license through traditional channels.

Once selected the appropriate sleeping-patent sample (955 observations), we identify their patentholders (101 firms). Then, from the NBER database, we select the portfolios of granted patents in the chemicals and biotech categories from 1981 to 1999[14] from these firms. Once identified the population of non-sleeping-patents, we draw a random sample from it of 18876 patents[15]. From the NBER database, we retrieve individual patent information about the sleeping and non-sleeping patents, including application year, granted year, primary sector, number of citations made and received, and other primary and constructed variables.

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identified under chemicals or biotech in ye2.com independently of their USPTO classification would have introduced more serious biases.

[13]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, strong the protection. This strong protection makes licensing specially feasible and a major strategy of rent appropriation in this sector, as opposite to others.

[14] Sleeping patents identified are granted up to 2002, but the NBER database where we extract the information only covers up to 1999.

[15] The non-sleeping patent population (from chemicals and biotech) sums up to 64006 patents. Consequently, non-sleeping patents represent only a 1.5% with respect to 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 a 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 on the sleeping-patent sample (86% vs. 13%).

3.2. Analysis

We use 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 to offer a patent in the mentioned Internet marketplace -we assume that this decision reflects the sleeping or non-sleeping character of the patent-. We should therefore use a discrete choice model with the following specification for patent *j* in firm *I*:

$$Y^{*}_{ij} = b^{"} X_{ij} + e_{ij} \qquad \text{where} \begin{cases} Y_{ij} = 1 & \text{if} \quad Y^{*}_{ij} > 0 \\ Y_{ij} = 0 & \quad\;\; Y^{*}_{ij} \leq 0 \end{cases}$$

where Y^{*}_{ij} denotes the unobservable propensity to sleep, X is a vector of patent- varying exogenous variables and $å_{ij}$ 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 can not 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, $á_i$.

$$Y^{*}_{ij} = a_i + b'X_{ij} + e_{ij} \qquad j = 1,2,\ldots N_i \;\; ; \quad i = 1,2,\ldots I$$

where $á_i$ captures the firm specific unobserved characteristics. The dilemma is whether it 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 $á_i$'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 neither for the rejection nor for the 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 the firms' patent portfolio. In this case, if we use the fixed effects model we cannot estimate the parameters ë, because $á_i$ 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 ë, we treat $á_i$ as random. The specification is as follows:

$$Y^{*}_{ij} = a_i + b'X_{ij} + g'z_i + e_{ij}$$

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 a 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 will result in a set of 86 firms with 10956 observations coded as 0 and 907 observations coded as 1, which represents a 7.65% of the total.

3.3.2. Predictor Variables

-Importance

Previous literature has suggested as proxy for “the patent value” the ***number of citations a patent receives*** from subsequent patents. When inventors patent some invention, they must cite the previous inventions their innovation build upon. Patents that receive more citations are making a higher contribution to the scientific community that patents with less citations. Therefore, citations received from subsequent patents reflect the contribution to further research of a given patent (see Jaffe et. al 2000 for evidence from a survey). The validity of this proxy has been tested by analyzing its correlation with different measures of value. Trajtenberg (1990) found that more socially valuable patents were more cited. Hall et al.(2000) concluded that companies with more cited patents have higher stockmarket values. Harhoff et al. (1999) found that German patents renewed to full-term[16] are more highly cited and that, among the full-term patents, the more valuable -according to the patent owner appreciation- were also more cited.

Citations present a practical problem: since data is truncated at a certain point in time, patents granted closer to this truncation data have a shorter time span to receive citations. As the NBER data reveals, a patent will have received only 50% of its citations in ten years from its granted year (Hall et al, 2001) despite citation lags seem to be shortening nowadays. These authors propose two methods to empirically face this situation: *i)* standardization, that removes variance due to truncation and also some variance due to real effects and *ii)* econometric models, that allow us to identify these two sources of variance but requires some assumptions about the process that may drive differences in citations across groups. We use the first method, since we only work with two groups of patents (chemicals and biotech) which we do not think to have very divergent citations patterns (we will subtract the same real variance, if any, in both cases). Alternatively, we simply introduce year dummies[17].

-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 for the scientific community, self-citations received may proxy the importance inside the firm. The more important a patent for the firm, the more likely that it is linked to technologies that constitute the firm's core. As we will mention, the further away a technology is from the firm's current assets and capabilities, the less incentive she has to invest on it. Therefore, the more self-citations a patent from the firm receives, the more likely it will fit in the firm's strategic core.

We also consider the ***number of inventors*** as a proxy for strategic fit. Reitzig (2001) considers that it points to patent complexity. We believe that the number of inventors is an indicator of the resources the firm devotes to a particular research line. Since an established firm has incentives to devote more resources to projects that are

[16] 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 ellapses.

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

closer to the firm's already existing assets, the more resources the firm devotes to a project, the better it will fit in 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*** a given patent is assigned to. We assume that the more frequent the patent class is in a firm's patent portfolio, the more likely it represents 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 (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 can 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 n_j patent classes

A higher generality means a lower concentration of citations across patent classes and therefore, a higher spread of the patent impact. Therefore, higher the generality, 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 and 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 is highly endogenous (Reitzig 2001), because the firm may decide to break down the "actual" blocks of invention into smallest pieces. However, the discretion about how to describe the innovation is highly constrained by the type of technology and by 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 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 higher the originality, the more spread the citations made. A high spread of citations made means that the invention is "breaking molds" (Hall et al, 2001) instead of a mere sequential invention. Therefore, the more innovative 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 alone working on it[18]. We also introduce the analogous measure to *forward lag* but when referring to citations made (***backward lag***). As the invention relies on older patents, 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 is this research line to the firm.

[18]Lanjouw & Schankerman, 1999 suggest the interpretation for early citations

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, but 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 used in the same regression.

3.3.3. Control variables

-Firm characteristics

We control for the following firm characteristics: patent portfolio, size and diversification[19]. 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 patent sleeping likelihood. On the one hand, size is a proxy for bargaining power. The larger the firm, the better positioned she is considered to be in potential licensing deals. This fact may affect their willingness to engage in them. This may mean either that she actually engages in more deals and, therefore, has fewer sleeping patents or that she is more willing to wake up their patents once there is a costlier alternative to market them (such as a web based marketplace). On the other hand, we may expect that size affects how the firm perceives different invention characteristics when considering 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 she actually enjoys a stronger position in a negotiation. Moreover, a firm with a larger patent portfolio is more used to manage and take advantage of her intellectual property through licensing or selling (she probably has a technology transfer department, for instance).

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

Therefore, the more patent intensive the firm, the less sleeping patents she is likely to have. However, for the same reason, she will not be reluctant to wake up her 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 the 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:

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

p_i = proportion of the firm's sales made in segment i[20]

We hypothesize that the more diversified the firm, the less likely she will have sleeping patents. In a diversified firm, there are more chances that a given invention is exploited in some of the firm activities or that it is 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. I 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, that are built upon patent classes (Hall et al. 2001). They distinguish up to 6 technology categories but we focus only on two, chemicals and drugs & medical.

Table 1 presents a summary of the variables.

[20] Segments identified according to the 4-digit level Standard Industrial Codes –SICs-

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[21]. 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 c*laims, 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*.

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 ñ=.389 (between *general* and *citations received*) and ñ=.366 (between *original* and *citations made*)[22]. The next highest correlation is ñ=.259 (between *general* and *backward lag* and *portfolio* and *inventors*). These levels of correlation does not suggest the presence of multicollinearity problems, as confirmed by the high tolerances. When we include *diversification* and *sales*, the highest correlation level is ñ=.727 [23]. However, no multicollinearity problems are detected when computing their level of tolerance (.44 and .37 respectively).

4.2. Empirical Results

We log transform the independent variables in order to reduce their skewness[24]. We present random effects probit models on the sleeping likelihood of a patent[25]. In

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[21] 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.

[22] When we use the adjusted measures for generality and originality, these correlation coefficients drop to ñ=.035 and ñ=.136, respectively.

[23] 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.

[24] In order not to lose observations with a zero value when taking logarithms, I add up one to the original variable before doing the transformation.

[25] 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).

Table 4, we present results in the form of marginal effects at the median[26] for the set of 86 firms.

Model 1 includes one proxy per each one of the four magnitudes of the patented invention we are interested in: scope, importance, innovativeness and strategic fit invention dimension. 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 in 1% from its median (Md=11), with the rest of variables constant at their median. The sign of this variable suggest that the effect of scope over the sleeping likelihood is actually positive. Similarly, the sleeping likelihood increases a 2.35% when the number of *inventors* increase in 1% from its median (Md=2). Contrary to the predicted, this result suggest that the more inventors devoted to a project and, therefore, the more strategic is the patent, the more likely that it ends sleeping. This striking result may arise because of the high research intensity in the firm's core areas, which is likely to result in a high propensity of project rejection, even that they actually fit in the firm's strategy. The proxy for importance, *citations received* has a different sign from predicted, but it is not significant. *Citations made* displays the predicted negative sign as a proxy for innovativeness but its coefficient is not statistically significant. *Citations received* displays a contrary to the predicted negative sign, but its magnitude is almost nil[27]. The firm-invariant *portfolio* variable has a negative coefficient significant at 1% significance level, suggesting that the larger the firm's portfolio and, therefore, her bargaining power in licensing deals, the less likely a patent is sleeping. In particular, there is a 2.6% decrease in the sleeping likelihood when the patent portfolio increases 1% from its median (Md=3490).

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[26] 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).

[27] An alternative specification with standardized citations received displays basically the same results.

Model 2 adds all the constructed variables, i.e. built upon some of the raw variables. In particular, we include the (not adjusted) *originality* and *generality* measures, the percentage of *selfcitations* and the citation *lags,* all of them derived from citations. The overall model is significant as well as the proportion of the variance of the error accounted by the random effect (rho=.305, p<.000), that increases with respect to the previous model[28]. 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 on the sleeping likelihood is higher than in previous model (an increase of 3.55% if it increases 1% from the median). *Patent class frequency* also displays a positive sign, but it is only significant at a 13% level. *Self- citations received* is neither significant but it displays the positive-predicted sign. The evidence, therefore, is not conclusive. However, it suggests a contrary to the predicted negative effect over the sleeping likelihood for the strategic fit dimension. Second, patent scope appears also as positively significant over the patent sleeping likelihood. Both *claims* and *generality* display a positive sign even though only the former is significant (1.4% increase on the sleeping likelihood if *claims* increases a 1% from the Md=12). Therefore, the larger the space a patent covers, the higher the likelihood that the patent (or some of its applications) is (are) actually sleeping, instead of a higher likelihood of being used. Third, the more innovative the invention, the more likely the sleeping likelihood appears, as predicted. All the variables that proxy for this dimension have the predicted sign except *backward lag*, that is significantly negative at a 10% level. The negative effect of *citations made* becomes significant[29] (1% increase from the Md=6 decreases the sleeping likelihood by a 1.89%). O*riginality* is the other significant variable, that increases the sleeping likelihood on 7.13% when it increases 1% from its median value (Md=.5). Therefore, the more radical the patented innovation is considered, the more likely it will

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[28] 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 on 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-.

[29] C*itations made* becomes significant when we include the *originality* variable.

remain in the firm's shelves. *Citations received*, as proxy for importance, turns to a non-significant negative coefficient, but the effect is very close to zero. This result suggest 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 remain 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[30]. Results do change somewhat from previous model. In this model, we find more conclusive evidence on the positive effect of the strategic fit dimension on the sleeping likelihood. The effect of *inventors* remain positive and significant but it is stronger (1% increase in the number of inventors from its median increases the sleeping likelihood in 5.6%). The effect of f*requency* becomes significant and it is not negligible (2% increase in the sleeping likelihood for a 1% increase from its median, Md=.28). *Self-citations received* becomes positive, as predicted, but it remains not significant. Second, with respect to the scope dimension, claims is still positive and significant, but its effect is stronger too (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 on itself) and its effect is quite strong (6.4% increase in the sleeping likelihood when the *adjusted originality* increases 1% from its median, Md=.67). Third, along the innovativeness dimension, some changes are worth to mention. C*itations made*[31] and *originality* remain significant and the effect of its coefficient is similar in dimension. *Backward lag* is no more significant but maintains its contrary-to-the-predicted sign. Instead, the positive effect of *forward lag* becomes significant and quite strong (7.6% increase in the sleeping likelihood for a 1% increase from its Md=4.8). S*elf-citations made* becomes also significant with the strongest

[30]This is due to the adjustment made to these variables, that consists on multiplying the original variables by (citations/(citations-1)). Therefore, these adjusted measured take missing values when citations are equal to one. Consequently, the sample considered for the analysis with adjusted measures is truncated at one.

[31] In this case, *citations made* becomes significant only when we control for *originality*, *selfcitations made* and *backward lag*.

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 on the significance of variables seems to be due to the sample truncation issue and not to the inclusion of the adjusted variables on *originality* and *generality*[32].

Model 4 introduces the effect of interactions. Particularly, we test the effect of the interaction between *inventors* and *citations made*[33], that is, between strategic fit and innovativeness. The inclusion of this interaction makes the *inventors* variable no longer significant. *Citations made* remain negative and significant. The interaction between both displays a positive and significant coefficient. This means that a more innovative patent is more likely to remain shelved the lower its fit in the firm's strategy. On the other hand, it is more likely that a patent with a higher fit will be sleeping the less innovative it is[34]. These results suggest very interesting facts about the rejection of projects by established firms. In particular, they are more likely to reject higher innovative projects in further away areas and to reject lesser innovative projects in closer areas. The rest of 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 related with the number of citations made as well as the number of inventors[35]. 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*, that 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* remains also

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[32] 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.
[33] The rest of interactions display no significant effect when using the sample truncated at citations equal to one.
[34] 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*.
[35] 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.

positive and significant and with a similar magnitude than in previous models. These results suggest that only with 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 to test whether measures such as diversification or size change the results. However, this data is only available for a very reduced set of patentholders, namely 22 firms[36]. Results are reported in Table5. Results are very similar and divergences are mainly due to the restriction in the sample.

Model 0 includes only these 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 display all significant coefficients. The effect of *portfolio* remains negative, suggesting that, all the other firm characteristics equal, a firm with more patents in her portfolio is less likely to shelve patents. The reported marginal effect shows that the probability of a sleeping patent decreases in .043% when the firm's portfolio increases in one percent from the median (Md=5192 patents). The effect of *sales* over the sleeping likelihood is positive. This fact may support the idea that bigger firms are not proactive in intellectual property management, were it because of organizational inertia, were it because of expected negative profitability, were it 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 more able to perceive that their patents could be useful in other sectors. Therefore, they can "identify" more sleeping patents than less diversified firms do. On the other hand, 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

[36] 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.

are actually more likely to shelve patents or they 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 to negative and not significant when we introduce the variables containing patent information. With respect to the patent characteristics, there are no major changes but *claims*, that remains positive but it is no longer significant in any of the models. We must bear on mind that these results are quite dependent on this very restricted sample[37]. We conclude, therefore, that the inclusion of *diversification* and *sales* capture a great deal of the otherwise unexplained firm effects but it does not affect significantly the results for the rest of variables, except for (potentially) the scope dimension. Note that the interaction between *inventors* and *citations made* is only significant at a 10.5% confidence level and it is not significant in Model 5[38].

To sum up, we can not assert whether differences in results with respect 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 without restrictions results from Table 4.

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[37] It is not clear whether this change on 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 do. 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.

[38] 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 is not significant neither with its inclusion or without it.

4. Conclusions

This paper analyses the decision of a firm on whether to exploit -by herself of by a third party- a patent protected invention. This decision is captured through another decision made by the firm that we can observe, that is, whether she offers her intellectual property for license or sale in a web-based marketplace. We believe that this is a marginal alternative to exploit 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[39].

Our findings suggest that, controlling for firm and other patent characteristics, the strategic fit in the firm's strategy and the degree of innovativeness of the invention affect positively its sleeping likelihood. More interestingly, the sleeping likelihood of a patent depends also positively on the interaction between these two dimensions. Thus, the more innovative the patent, the more likely it will remain sleeping if it fits poorly in the firm's core. And, the more core the patent, the more likely it will remain sleeping if it is a less radical innovation. Some of these results, in particular the result on the innovativeness dimension, is aligned with results from previous literature, that found that more innovative projects are more likely to be rejected by established firms. However, our findings point out that this is specially the case the further away from the firm's core the invention is. Rejections at the firm's core are from less innovative projects. Therefore, it is not that established firms do not undertake innovate ideas but they let pass by innovative ideas that do not fit exactly in their core. Another interesting result, even 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 point out 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

[39] The reverse is not necessarily true. The firm may just select among her sleeping patents the ones that are more 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.

conclusive evidence that sleeping patents are significantly less important than the 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, broad and 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 not-core areas (specially patent intensive firms, that 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 big amount of patent protected inventions that lie forgotten on firm's shelves and they never reach the market or, even worse, they are reinvented by others who can not develop them because the patent blocks the area. Moreover, firms are not aware that their un(der)used patents might be valuable in other hands or for other uses, as our findings suggest. This is something that big patent intensive firms, with the help of consultant firms, are beginning to realize and implement by hiring broad-based technologists that help to identify potential uses for a technology across industries. However, even if firms were aware of potential applications for their underused inventions, they are reluctant to incur in the costs needed to search for potential partners. The lack of markets for intellectual property is at the heart of these problems. If these markets existed, firms underused technologies, technical problems with no solution and capital would find each other and efficient deals would be realized.

Further research should focus deeper on the characteristics and determinants of sleeping patents. Especially, it would be worth to analyze further firm characteristics that affect this likelihood. It would also be interesting to deserve some attention to sleeping patents from universities.

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Appendix

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	Herfindhal 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	Herfindhal 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	+/-

Table 2. Descriptive statistics (non-truncated sample)

VARIABLES	*Mean*	*Min*	*Max*	*Mean Y=0*	*Mean Y=1*	*Difference[æ] (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)

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

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	.727	--

* NOT statistically significant at the 0.05 level

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

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

Variables	**Model 0**	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Importance						
Citations received		-.0032 (.0058)	-.009 (.0066)	-.0100 (.0128)	-.0096 (.0126)	
Strategic fit						
Self citations received			-.0428 (.0327)	-.0017 (.0402)	-.0058 (.0395)	
Inventors		.0357*** (.0107)	.0465*** (.0166)	.0423**(***) (.0204)	-.0331 (.0494)	.0322*** (.0095)
Frequency			.0185** (.0081)	.0264**(***) (.0115)	.0267**(***) (.0116)	
Scope						
Claims		.0077 (.0069)	.0145 (.0103)	.016 (.0126)	.0157 (.0125)	.0077 (.0065)
Generality			.0082 (.043)	.0208 (.0396)	.0217 (.0389)	
Innovativeness						
Cmade		-.0065 (.0067)	-.0334** (.0146)	-.0369**(***) (.0187)	-.0628**(***) (.0299)	-.0162** (.0079)
Originality			.0795*(**) (.0463)	.0809 (*) (.0433)	.0799(*) (.0502)	.0176 (.0232)
Forward			.0369 (.0293)	.0622 (*) (.0466)	.0604(*) (.0458)	
Backward			.0219 (.0157)	.0272 (.0202)	.0270 (.0198)	.019* (.0102)
Self citations made			-.068* (.0402)	-.0545 (.0402)	-.0058 (.0395)	-.0557*** (.0256)
Interactions						
Inventors x Citations made					.0324(*) (.0222)	
Firm invariant						
Portfolio	-.052** (.00899)	-.0398*** (.0106)	-.0594*** (.0176)	-.0832*** (.0293)	-.0815*** (.0290)	-.0427*** (.0097)
Diversification	.1494*** (.0201)	.1162*** (.026)	.1978 (.0507)	.2730*** (.0891)	.2708*** (.0899)	.1333*** (.0241)
Sales	-.001* (.0006)	-.0016** (.0000)	-0021*** (.001)	-.0010 (.0000)	-.0011 (.0011)	-.0008 (.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*** (.0279)	.1176** * (.0184)	.1729*** (.0304)	.2652*** (.0495)	.2677*** (.0497)	.1685*** (.0244)
N	6493	6053	4569	4620	3568	5534
Groups	18	18	18	18	18	18
Wald $\div^2$ – 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.