PATENTS AND OPEN INNOVATION: BAD FENCES DO NOT MAKE GOOD NEIGHBORS

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ABSTRACT
This paper analyses the links between patents and open innovation. Departing from the “second best” approach to patents, it has recently been argued that patents can accelerate open innovation by fostering collaborations, exchanges and interactions between actors in the innovation process. The argument put forward is that “good fences make good neighbors”, suggesting that by protecting innovative actors from free-riding, patents reduce the costs and dangers of open innovation. We show that patents do not necessarily provide good fences. The proliferation of patents in some sectors and the bad quality of patent information usually makes it very difficult in reality to agree upon what is and what is not protected by a patent. This prompts problems such as anticommons, trolling (hold-up), and the multiplication of wasteful litigations. We conclude by discussing some evolutions of patent laws which could limit those problems and make patents a real support for open innovation.

Keywords: Patent, Open Innovation, Trolls, Anticommons, Notice Failure, Notice Externality

Codes JEL: O34

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INTRODUCTION: BEYOND THE “SECOND BEST” THEORY OF PATENTS

Why do we need patents? The usual argument, which we shall call the “second best” theory of patents, argues that patents are needed to solve a double problem: a problem of incentives, on the one hand, and a problem of knowledge diffusion, on the other hand (the so-called Arrow dilemma, 1962, which highlights the difficulty to achieve both optimal incentives to produce knowledge, and optimal level of dissemination of the knowledge produced3). First, patents induce firms to invest in R&D and in the economic valorization of inventions (Nordhaus, 1969; Kitch, 1977); second, they encourage firms to disclose their inventions, i.e. disseminate technical knowledge within the economy and fight secrecy (Encaoua et al., 2006). Yet, in the short run, patents give market power to inventors, thus creating monopoly deadweight loss and static inefficiency. Consequently, patents are not a “first best”, but only a “second best” option. As reminded by Schumpeter (1942), static inefficiency is the price to pay in order to induce innovation and dynamic efficiency.

If this vision of patents has the merit of consistency and simplicity, a growing number of researchers tend to oppose it more or less head-on (Kingston, 2001; Bessen, Meurer, 2008; Boldrin, Levine, 2008; Hilaire-Pérez et al., 2013). First, this standard interpretation relies on an unrealistic view of the innovation process. It is based on the traditional Arrovian framework, which considers innovation as an individual and isolated act to produce a public good (knowledge is reduced to information, i.e. is easy to reproduce). This view emphasizes incentives and the importance of patents to exclude imitators. It largely neglects the properties of knowledge (its tacit dimension), and of the innovation process (which is largely a collective process requiring collaborations and interactions). As suggested by Cohendet and Pénin (2011), when these properties are taken into account, the main source of market failure might not be a problem of incentives but of coordination, and the main role of the patent system might not be to exclude others but to include all the different stakeholders in the innovation process.

Second, the standard view is not confirmed by most empirical studies, which put forward three important insights (Levin et al., 1987; Cohen

3. In his seminal paper, Arrow (1962, p. 619) concludes: “To sum up, we expect a free enterprise economy to underinvest in invention and research (as compared with an ideal) because it is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use… Further, to the extent that a firm succeeds in engrossing the economic value of its inventive activity, there will be an under-utilization of that information as compared with an ideal allocation”.
et al., 2000; Sakakibara, Branstetter, 2001; Arundel, 2001). First, patents are not the most efficient instrument to protect an invention (secrecy, lead time, complementarity with other assets, are usually preferred). Second, except for the pharmaceutical industry, patents are not necessary to increase incentives to innovate (most firms would invest a similar amount in R&D without the existence of the patent system). Third, the use of patents is strategic (defensive use, signaling, knowledge management, etc.). In conclusion, most empirical studies question the global positive effect of patents on incentives to innovate (see Bessen, Meurer, 2008, for a survey)\textsuperscript{4}. This conclusion is robust according to the different methodologies used, such as a questionnaire-based inquiry (Mansfield, 1986; Levin et al., 1987; Cohen et al., 2000), natural experiments (Sakakibara, Branstetter, 2001; Lerner, 2002), or, more recently, lab experiments (Meloso et al., 2009).

It is rare to observe such unanimity among empirical studies conducted over such a large period of time, on such a wide range of countries, and based on such different methodologies. Combined with the weak theoretical basis of the Arrow model, our conclusion is therefore that the second-best theory might not be the most appropriate way to justify the existence of the patent system. We therefore turn towards another possible argument, namely the link between patents and open innovation (Chesbrough, 2003; Pénin, 2017).

Many recent studies have highlighted that the patent system might, paradoxically, promote open innovation by stimulating inter-firm collaborations and markets for technology (Arora et al., 2001; Chesbrough, 2003; West, 2006; Alexy et al., 2009; Hagedoorn and Ridder, 2012; Hagedoorn, Zobel, 2015; Zobel et al., 2016). Indeed, it seems that to open up a firm’s boundaries can be risky, and patents can often help mitigate some of the risks and difficulties associated with open innovation. In other words, patents might provide fences which, in turn, might favor interactions among actors of the innovation process (based on the well-known adage “good fences make good neighbors”).

The aim of this paper is to further explore the links between patents and open innovation. We investigate how patents can foster open innovation, and also what are the dangers they entail and what could be done, from a policy perspective, to make sure that patents support open innovation. In particular, we explore the role of the quality of patent information. Patents might not necessarily provide good fences. When patent information quality

\textsuperscript{4} As summarized by Lerner (2009, p. 347): “the lack of a positive impact of strengthening of patent protection on innovation is a puzzling result. It runs against our intuition as economists that incentives affect behavior”.
is poor, firms might not be able to understand with certainty what is and what is not protected by a patent. Bad patent information quality might be due to the proliferation of patents, or to the way patents are drafted and indexed in databases. Whatever the reason, we show that the poor quality of patent information generates important social costs such as anticommons, trolling (hold-up), and the multiplication of wasteful litigations.

The paper is divided as follows. In Section 2 we explain why patents can be structuring elements of open innovation. Section 3 discusses the issue of the quality of patent information. Section 4 analyzes the consequences of poor information quality. Section 5 concludes by discussing how to improve the quality of patent information and thus make patents a real support of open innovation.

GOOD FENCES MAKE GOOD NEIGHBORS: PATENTS AS STRUCTURING ELEMENTS OF OPEN INNOVATION

Open innovation is a relatively new term depicting an older reality. Innovation is an interactive process, as innovators are no longer isolated and self-reliant, but collaborate with upstream and downstream actors to benefit from increasingly complex knowledge flows (Chesbrough, 2003). The functioning of open innovation can take various forms, from in- and out-licensing, spin-ins and spin-outs, co-conception and co-development, research joint ventures, to crowdsourcing, community innovation and online market places. The main link between these forms is that open innovation entails flows of knowledge between different actors, and on both sides of the market (Chesbrough, Euchner, 2011). The literature distinguishes three faces of open innovation according to the different possible direction of the knowledge flows: i) “outside-in”, when a firm absorbs knowledge coming from outside (for example when a firm relies on crowdsourcing); ii) “inside-out” when a firm releases to others knowledge that it has developed internally (for example when it grants a patent license to another firm), and “coupled” when knowledge flows both from inside to outside, and from outside to inside (such as in an inter-firm partnership, for example). Consequently, opening up the innovation process brings risks, the importance of which depends first and foremost on the direction of knowledge flows, but also on the actors involved and the type of knowledge exchanged.

This is why, in most cases, intellectual property rights (IPR), and patents specifically, are considered to play an important role in open innovation (Pénin et al., 2011; Laursen, Salter, 2014; Zobel et al., 2016). Firms
that actively include patents in their open innovation strategy can enhance the returns on their R&D efforts (Alexy et al., 2009). Although this seems strange, the marriage between open innovation and patents can be explained by the multiple roles that the latter can play in an innovative environment (see Veer, Jell, 2012 for an overview). Table 1 summarizes the multiple roles that patents can play in open innovation.

Table 1 – The role of the patent system and the three faces of open innovation

<table>
<thead>
<tr>
<th>Outside-in</th>
<th>Coupled</th>
<th>Inside-out</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exclusion</strong></td>
<td>Help to limit secrecy; increase the external stock of knowledge available to be absorbed</td>
<td>Avoid free-riding; increase trust; act as bargaining chips</td>
</tr>
<tr>
<td><strong>Disclosure</strong></td>
<td>Facilitate identification of relevant external knowledge to be absorbed</td>
<td>Facilitate identification of partners</td>
</tr>
<tr>
<td><strong>Codification</strong></td>
<td>Facilitate absorption of external knowledge</td>
<td>Structure collaboration; common language; reduce misunderstandings among partners; ease output sharing</td>
</tr>
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</table>

First, patents are a tool to codify and protect knowledge, and as such have an impact on how knowledge is disseminated (Grindley, Teece, 1997; Pisano, Teece, 2007; Pries, Guild, 2011). As open innovation revolves around knowledge-sharing, patents can be used to transfer knowledge between actors in the open innovation environment, while preventing the involuntary spillover of information (Cassiman, Veugelers, 2002; Lawson et al., 2012; Laursen, Salter, 2014). Second, even though patents mainly provide exclusion rights, this does not automatically imply that firms will use them to this end. This is the principle behind the out-licensing and co-licensing of technologies, where the possibility to exclude carries more value than exclusion itself (Arora et al., 2001). Moreover, some innovators are interested in the rapid adoption of their invention rather than minimizing spillovers, and patents can help in this case too (West, 2006). Third, openness is not synonymous with innovation without protection. Rather, firms engaging in this process are usually looking to maintain a large degree of control over their inventions. This implies that, while the innovation process is open—i.e. firms interact with each other—it is still possible that the outcome of the process is protected by patents, and for its owner to capture profits. For example, firms can open up their innovative activity by including suppliers, customers, research centers, etc., while keeping competitors away. In this case, protecting their inventions with patents is paramount, not only to diffuse information to collaborators, but also to reduce the risk of imitation.
Teece (1986) had posited that firms’ ability to profit from their inventions without needing to internalize the entire innovation process—from R&D to commercialization—depends primarily on appropriability. More recently, the link between open innovation and appropriability has been tested in numerous empirical studies (Anand, Khanna, 2000; Laursen, Salter, 2006; West, 2006; Gambardella et al., 2007; Laursen, Salter, 2014). Some types of open innovation are shown to only be possible when IP protection is strong, as formal appropriability depends on IP regulation (West, 2006). Strong patents spur the creation of markets for technology, which support R&D and commercial collaborations, and also technological transfer (Arora et al., 2001). Well-functioning technology markets have created specialized innovators, thus increasing innovation quality and welfare (Spulber, 2008; De Rassenfosse et al., 2016).

The ability of patents to play multiple roles in innovation stems from two important properties: they can both disclose and protect information simultaneously (Olander et al., 2010; Cohendet, Pénin, 2011). By disclosing information about the inventor and her/his invention, patents first act as signals to possible investors, licensees, or collaborators (Long, 2002; Veer and Jell, 2012; Hoenig and Henkel, 2015; Henttonen et al., 2015; Hottenrott et al., 2015). They make up public catalogs of know-who and know-how, which are then used to find up- and downstream partners to bring inventions to market. They are especially important in industries characterized by high numbers of small and heterogeneous firms, as they facilitate interaction between them by enabling technological transfer through licensing, and by framing non-market alliances (Hagedoorn, Ridder, 2012).

In markets for technology, patents enable knowledge trading (Arora, Ceccagnoli, 2006; Branstetter et al., 2006; Gans et al., 2008) by solving Arrow’s paradox (Arrow, 1962). They do so by disclosing information, which allows technology sellers to signal their products’ value, while at the same time protecting them from free-riding by competitors and technology buyers (Arora et al., 2001; Arora, Gambardella, 2010). In these markets, patent quality or strength boosts the volume of licensing transactions, as it allows the correction of information asymmetries between buyers and sellers through signaling, and it increases the appetite for innovation by preventing free-riding (De Rassenfosse et al., 2016). Moreover, patents may also enhance the transfer of tacit knowledge. Licensing contracts often contain clauses for transferring tacit knowledge, such as technical assistance, which are not included in the patent itself and thus remain private (Pénin, 2005). Patents can thus transfer both patented and unpatented rights between licensor and licensee (Foray, 2004).
However, technology markets are not foolproof and patents are not the right answer to every problem (Arora et al., 2001; Gans, Stern, 2010; Agrawal et al., 2015). Razgaitis (2006) analyzes a survey of 524 U.S. and Canadian firms and shows that 66% of them think that IP deals are more likely to fail than deals involving tangible assets, the leading cause being the financial terms. Regarding the role of patents, De Rassenfosse et al. (2016) show empirically that, while patents do protect buyers against expropriation, they do not help technology trading through their “disclosure effect”—i.e. increased information-sharing during negotiations. Lastly, a large number of firms are serial patentors, creating volumes of unused, or sleeping, patents which increase search costs, while spending huge sums in application and renewal fees every year (Alexy et al., 2009; Cassiman, Valentini, 2016; Torrisi et al., 2016). These results suggest that patent quality mediates their effect on open innovation.

Patents can also impact cooperation beyond the signaling phase. Once partnerships are formed, patents can help structure collaborations—either formal or informal—by ensuring a common language among partners (Bureth et al., 2007). They first do so in the early stages of a partnership by helping to determine the terms of each partner’s involvement. Alleviating information asymmetries, patents are used as bargaining chips when inputs and tasks are allocated, and also when establishing the ownership of outputs (Hagedoorn, 2003; Zobel et al., 2016). Moreover, patents can incentivize firms to enter collaborations by reducing the risks of potential free-riding by the partners (Ordover, 1991; De Rassenfosse et al., 2016). Being legal documents of codified knowledge, patents represent a credible threat to block malfunctioning partnerships, and their quality-quantity ratio determines the bargaining power of each actor.

In their use as bargaining chips—within and outside of formal collaborations—patents may also be traded against other patents, with no money exchange involved. Cross-licensing is widespread in complex technological sectors where innovations combine several overlapping patents (Cohen et al., 2000; Torrisi et al., 2016). Firms involved in such industries tend to build up large patent portfolios which they will use as bargaining chips to acquire technologies held by other firms, and which are needed for their own products (Hall, Ziedonis, 2001).

Finally, the main post-collaboration use of patents is focused on output-sharing. When the outcome is easily divided and more than one patent is filed, firms may choose to split the portfolio and incur profits from out-licensing the technologies or from normal product selling. In cases where inventions are not easy to divide among partners, co-patenting may help in sharing the partnership’s outcome (Hagedoorn, 2003).
Summing up, patents are present throughout all the steps of the open innovation process as a structuring element. Initially, they facilitate knowledge inflows through signaling and in-licensing contracts. Then they help to coordinate the production of knowledge by different collaborators—starting with their use as bargaining chips and ending with their potential as contract enforcers. Finally, they help manage the outflows of knowledge and distribute profits through out-licensing or ensuring monopoly profits. As such, in open innovation, firms are not only producers but also active users of patents and other IP (Chesbrough, 2012) which, more broadly, serve at every stage of the open innovation process. As such, their quality can affect the way knowledge is created, used and disseminated, and the way open innovation pans out.

ARE FENCES SO GOOD? THE IMPORTANCE OF PATENT INFORMATION QUALITY

On the Quality of Patent Information

The theory that patents might be structuring elements of open innovation processes relies on one fundamental hypothesis: patents provide good fences, i.e. they act like property. Good neighborhood relations require that fences are clearly delimited, and that the property of each neighbor is clearly defined. If the information about a property right is fuzzy, if ownership is uncertain, then neighborhood relations are likely to be damaged. In the case of technological interactions, good fences are largely related to the quality of patent information. By patent information we mean all the information which is related to patents and which enable patent users (firms, but also public organizations, individuals, etc.) to identify relevant patents in order to take strategic decisions. Patent information is of good quality and patents provide good fences when it is easy and not too expensive for users to find the information that they need.

Good patent information allows navigating at reasonable cost through the patent ticket. It enables firms to identify technological neighbors. Good patent information is critical for strategic planning in order to identify new partners, new technological avenues or new threats, but also, and above all, for performing freedom to operate analyses, i.e. to identify potential patents that a firm might infringe. A patent offers a legal exclusivity to its owner. It is therefore critical that the perimeter of protection delivered by the patent, and the owner of this patent, are easy to identify so that patent users can assess their freedom to operate and eventually negotiate access with the
patent owner. Good patent information minimizes the probability of costly patent litigations.

Before we go further, it is important to mention that this question about the quality of patent information is distinct, even if not entirely independent, from the question of the quality of patents as it is usually discussed in the literature (van Pottelsbergh de la Potterie, 2011; Schuett, 2013; Atal, Bar, 2014). In this literature, a patent is considered low quality when it should not have been delivered, i.e. it does not fulfill the minimum deliverance criteria, in particular novelty and inventive steps. Low-quality patents are therefore related to the fact that patent offices make mistakes and deliver patents which should not be granted (because they are not new or because the inventive step is low). But this is different from the issue of the quality of patent information. It is indeed possible that low-quality patents have good informational properties in the sense that, even if they should not have been delivered, they are easy to identify and to understand. On the contrary, it is also possible that good patents have bad informational properties because they are difficult to identify, or their perimeter of protection is difficult to understand.

The quality of patent information relies mostly on two pillars: the structure of patent databases (how easy it is to browse them) and the structure of the patent document (how it is drafted). More specifically, at least three conditions are necessary in order to ensure good quality of patent information (Chien, 2012; Menell, Meurer, 2013):

1. Users can identify potential relevant patents at a minimum cost and with minimum uncertainty (in order to find partners, to avoid infringing these patents, etc.). This requires reliable and public patent databases, but also information systems and indexation systems (dispatching patents across technological classes, etc.).
2. Users can understand, at a minimum cost and with minimum uncertainty, the perimeter of protection of each patent, i.e. what is protected by the patent and what is not. This depends on the way patent documents are drafted, claims are presented, etc.
3. Firms can, at a minimum cost and with minimum uncertainty, identify who are the stakeholders concerned by the patent (the real owner, the licensees, etc.). This again depends on the way patent databases are updated during the life of the patent, and on the way patent documents are drafted.

According to Menell and Meurer (2013) the fulfillment of these three conditions strongly depends on the inherent characteristic of the resource, and the institutions. The characteristics of the resource impact its ability to
be indexed or perfectly appropriated. Boundary information might be more difficult to code in some cases than in others. With regard to patents and technology, this point is related, among others, to the more or less tacit nature of knowledge (how to code boundaries on things that can hardly be explicitly expressed, such as firms’ know-how), to the evolving nature of the technological landscape (how to code boundaries on things that do not exist yet), and to the complex nature of the technology (boundaries are obviously more difficult to establish when a single invention is subject to hundreds or thousands of patents, which is typically the case in sectors where technology is complex)\(^5\). This means that different technological properties and technological regimes in different sectors will lead to different levels of patent information quality. Due to the inherent properties of the technology, in some sectors patents enjoy better informational quality than in others. For example, in pharmaceuticals or chemistry, technology tends to be more codified and simple, thus leading to better patent information. Conversely, in ICT there are more patents (technology is complex) and technology is evolving very fast, contributing to damaging the quality of patent information.

The quality of patent information is also largely determined by patent institutions such as patent offices and patent dispute resolution mechanisms. Menell and Meurer (2013) identify in particular four points linked to the way institutions perform, and which affect the quality of patent information. Patent registry (how it is indexed, etc.), the existence of private institutions that publicize and clear patents (patent brokers), the nature of dispute resolutions institutions (patent courts, etc.), and the existence of risk-spreading mechanisms (such as insurance mechanisms). Some offices and courts might pay more attention to the question of patent information and be more careful when evaluating patent cases. This explains why the quality of patent information might be different across countries. In particular, it explains why problems raised by the patent system seem to be more important in the United States than in Europe (Menell, Meurer, 2008).

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5. In patent literature, a technology is said to be complex when a single innovation combines several technological blocks. Its implementation therefore requires the combination of several overlapping patents. In this case, since patents are usually held by different firms, each patent owner does not benefit from a monopoly over the innovation. They do not have the freedom to operate the innovation. Conversely, a technology is said to be simple when an innovation builds on one single technology. In this case, if the technology is patented, then the patent owner benefits from a monopoly right over the innovation and has the freedom to operate it.
Why Patents Might Not Provide Good Fences?

In this section we discuss the three conditions introduced above and which are necessary in order to ensure good patent information quality.

A first necessary condition is that patent databases must make it possible to easily identify relevant patents. Each user of the patent system must be able to easily find the information that it needs, and that allows him to take relevant strategic decisions. For example, a firm that is looking for a partner with technological complementarities must be able to browse patent databases in order to identify that partner. In other words, patent databases must make it possible to identify technological neighbors at a minimum cost. Similarly, if one firm aims at launching a new product on the market, it must be able to easily identify potential patents that it could infringe, in order to negotiate licenses ex-ante.

However, this is not exactly what patent databases offer. Existing patent classifications, such as the International Patent Classification (IPC) for example, are useful to take strategic decisions about the identification of potential partners or potential future technological avenues (technological forecasting). Based on patent databases, firms increasingly perform patent mapping and patent landscaping, i.e. they organize patent information in such a way as to understand what is happening in a given sector, in a given company, or with a given technology (Lee et al., 2015).

But these classifications do not allow the identification of patent neighbors from a legal point of view. They do enable patents to be found in similar technological classes, but they are of little help in performing exhaustive freedom to operate analyses, i.e. identifying patents that a firm might infringe. So far, there is no reliable patent index that allows users to find adjacent inventions. For example, in the case of land ownership, in most developed countries there is a public land registry that allows with certainty, and at a minimum cost, the identification of adjacent neighbors. Investors can easily identify stakeholders with whom they need to negotiate in order to develop real estate projects. There is nothing comparable for patents. This is highly problematic since, as we will see below, the absence of precise patent indexation favors hold-up behavior and patent trolling.

The issue of patent classification and indexation naturally escalates with the existing number of patents (Mulligan, Lee, 2012). The more patents in a sector, the more important it is to have an indexation system that enables users to easily find relevant patents. In the absence of reliable indexation, each user must analyze all the patents in force in the economy. Thus, the more patents there are, the more patents firms have to analyze, and the more costly this is.
This explains why patents are so problematic today in sectors where millions of them are sometimes in force, such as ICT. In these sectors, due to the absence of reliable patent indexes, it is highly costly to identify patents that a firm can infringe, thus inducing a proliferation of costly litigations. In the case of software, for example, Mulligan and Lee (2012) performed an original simulation exercise which shows that given the number of software patents in the USA, the number of firms developing software, and the time required to analyze each patent, if each firm wants to perform an exhaustive freedom to operate analysis before it launches new software, it would require more patent lawyers than there are in the US. This simple simulation exercise demonstrates the absurdity of the situation nowadays. In some sectors where huge numbers of patents are in force, it becomes rational for firms not to perform freedom to operate analyses. Since these are costly and hardly reduce the probability of future litigations, it is rational for firms to keep their money aside in preparation for future litigation. Although rational from the firm point of view, these behaviors and the proliferation of patent litigation they induce entail a huge cost for society.

The second necessary condition to ensure good patent information quality is that the boundaries provided by patents (the claims) and the description of the information that they contain must be understandable. When reading a patent, users must be able to understand what is protected by this patent (the borders or boundaries), and to understand the description of the invention that is patented. However, this condition does not often hold. Many patents are difficult to read and understood, even by experts. The technical information included in the patent is often of little help to readers. Worse, the perimeter of protection of the patent is often hard to decipher.

This difficulty in reading and understanding patents has many origins. First, it is sometimes difficult to describe with precision technologies that are mostly based on tacit knowledge and know-how. It is difficult to place boundaries on things that are hard to describe. Related to this problem, our language and words often lack the precision to define things. Thus, in sectors where knowledge is more codified, such as chemistry, where a technology can be defined by a mathematical formula, things are clearer and patent information is of better quality. But in sectors where technologies must be defined by words, there is still a significant element of uncertainty due to the ambiguity of these words. This is reinforced by the length of some patent documents, which are sometimes more than 100 pages long (Guellec, van Pottelsbergue de la Potterie, 2007). This length is supposed to increase the precision of the patent by describing each part exhaustively. But in practice it often increases confusion and uncertainty. Furthermore, boundaries also lack precision because, contrary to land, which is fixed, the knowledge space
is moving, constantly expanding, and seeing the introduction of new concepts. And, as Menell and Meurer (2013) put it, it is always more difficult to “map terra incognita”. Finally, on top of these problems that depend on the nature of knowledge of technologies, the behaviors of patent users also contribute to blurring patent information. Sometimes borders are voluntarily kept unclear by patent applicants themselves. It can indeed pay off for patent owners to generate uncertainties for their competitors, as illustrated by the example of pre-emptive patents (Guillec et al., 2012).

Consequently, even when relevant patents can be identified (the technological neighbors), it might be difficult (even for experts) to understand their perimeter of protection exactly, and whether or not a given organization infringes these patents, thus largely increasing the cost of freedom to operate analyses. An emblematic illustration of this point is provided by the case of Polaroid versus Kodak in the mid-1970s, concerning instant cameras. Everybody remembers the outcome of this case and how costly it has been for Kodak. But, as mentioned by Menell and Meurer (2013), few remember that Kodak, before putting its technology on the market in order to compete with Polaroid, did hire a top patent lawyer in order to work closely with Kodak’s engineers and to avoid infringing Polaroid’s patents. It was only after lawyers guaranteed that Kodak’s technology was non-infringing that Kodak decided to enter the market, with the dramatic consequences that are now well-known. And ironically, Menell and Meurer also recall that in the ruling of the case the US judge acknowledged this fact and almost congratulated Kodak for its behavior. But at the end, the judge strongly disagreed with Kodak’s lawyers. Therefore, this historical example nicely illustrates the difficulties in defining the perimeter of protection of a patent exactly, and how people can easily disagree on this. And this uncertainty with regard to patents’ perimeter of protection obviously makes it difficult to navigate the patent ticket and develop safe technological collaborations.

Finally, the third necessary condition for good patent information quality is that patent stakeholders (owners, licensees, etc.) are easily identifiable by the users of the system. If a firm wants to negotiate a license, it must be able to identify the owner of the patent. Similarly, in order to use patent information for strategic planning, for example by analyzing the patent portfolio of a competitor or the evolution of patent applications in a given sector, one needs information about who really uses the patents. Yet in most countries today, this information about who are the real users is not easily available. If the applicants and the owners are listed in the patent document and are therefore public, there is no obligation for firms to disclose changes after the deliverance of the title. Information about licenses and even exclusive licenses, for example, can be (and usually are) kept secret. It
is the same when a patent holder goes bankrupt and its patents are bought by other companies. And, on top of that, it is also possible for patent owners to rely on shell companies that make it possible to hide the real owner of the patent.

In most cases, the real stakeholder of a patent is therefore very difficult to identify. This problem is known in the literature as the “who owns what” problem or “patent recordation failure” (Chien, 2012). In the case of the US, Chien (2012) concluded that “under the current rules, it is impossible to know who owns a particular patent, or what patents a particular entity owns”. To illustrate this result she showed that, based on an analysis of 915 patent litigations in the US, in a third of the cases, “the plaintiff was not the patent owner of record the day the litigation was initiated” (Chien, 2012). Given this situation, it is therefore highly problematic for users of the patent system to identify who are the real stakeholders. This poor information seriously limits the value of patent databases to serve firms’ strategic decisions but, most of all, benefits patent trolls and contributes to provoking litigations, as we will see in the next section.

To conclude, it seems that the three conditions necessary to ensure good patent information quality do not hold in many cases. Menell and Meurer (2013) speak of “notice failure” or “notice externality” to designate the issue of bad patent information quality. In line with Bessen and Meurer (2008), they make a parallel with the quality of land ownership information, which is considered much better than the quality of patent information:

“In modern real estate markets, notice rarely poses a serious problem for property development. Land boundaries are typically recorded in government administered and publicly accessible recording offices. Landowners can usually determine who their neighbors are and the boundaries of their land relatively easily […]

Effective notice is a far greater challenge when the resources in question are intangible […]

[To check patent] is not an easy task given the millions of issued patents (plots of intangible real estate). Unlike real estate maps, [patent] records are not organized geographically. The PTO’s classification system was (and remains) outdated and does not deal well with cutting edge technologies for the simple reason that it is difficult to “map” intangible terra incognita. Furthermore, the proliferation of digital technology patents creates countless new neighbors, often with fuzzy, multidimensional boundaries” (Menell, Meurer, 2013, p. 2).
THE CONSEQUENCES OF BAD FENCES

Bad patent information induces a certain number of costs for the users of the patent system who have to spend more money to overcome the bad quality of information. As evaluated by Bessen and Meurer (2008), direct costs include the greater costs of browsing patent databases, determining the owners of potentially conflicting patents, evaluating patents and ascertaining boundaries, and greater dispute resolution costs, since the probability of patent litigation is increased.

But the bad quality of patent information also makes it more costly to perform open innovation. First, it seriously limits the value of patent information for strategic planning to find corresponding partners and to enforce collaboration. In Section 2 we argued that patents can serve as signaling devices to find innovation partners. Yet, bad patent information damages the signal’s quality. It therefore not only increases search time and costs, but also reduces the probability to find partners (Comino, Graziano, 2015) and results in increased collaboration failure rates (De Rassenfosse et al., 2016). Furthermore, one can also question the value of patent mapping under low patent information quality. Even with the best machines and algorithms, if the raw information contained in patents is wrong (if the name of the company exploiting the patent is wrong, for example), patent maps will be misleading. In addition, patents of a lower quality will also make it harder to enforce cooperation contracts, and their power as bargaining chips will also be reduced. Unclear patent borders can only increase uncertainty and the probability of conflicts. This lowers the positive effect that patents can have on innovation collaborations.

Second, the bad quality of patent information increases transaction costs, making markets for technology less efficient. High transaction costs might prevent the completion of mutually beneficial technological transactions. The theory of markets for technology assumes that patents provide good fences, i.e. that they correctly signal the actors on markets for technology, and efficiently protect them from free-riding. As written by Menell and Meurer (2013), this theory is based on a view that is much too “contract- and property-friendly”. Given the bad patent informational properties, it is likely that in many cases patents do not avoid free-riding, but on the contrary spur it on. As we discuss below, they can provoke hold-up situations favoring trolling and reducing the efficiency of markets for technology (Pénin, 2012). Consequently, bad patent information quality will provide lower out-licensing and/or monopoly profits for technology sellers (Magliocca, 2007; Reitzig et al., 2007; Reitzig et al., 2010).
Related to this point, bad patent information can also make it more difficult to access past knowledge. Research and innovation is a cumulative process. Innovators build new knowledge on the shoulders of other previous researchers, drawing from the pool of knowledge that is available: the larger this pool, the greater the opportunities to explore new avenues of research. In this perspective, patents are often considered as increasing the shoulders of giants, since the patent document is published. Patents are a way to fight against secrecy (Foray, 2004). But this argument largely loses its strength once the possibility of the low quality of patent information is considered. When patent information is bad, it might rather be the case that patents are obstacles to the reuse of existing knowledge. This point has been emphasized in particular by Dosi and Stiglitz (2013). This result can have important consequences for the valorization of public research. In the last three decades, universities and public research organizations have been encouraged to almost systematically patent their research in the belief that patents would favor the transfer of this research to firms (Mowery et al., 2001). But this will hardly be the case if patents have low-quality information. In this case, patents might contribute to increasing the cost of accessing and using public research (Archibugi, Filipetti, 2017).

Third, bad patent information quality, since it makes freedom to operate analyses prohibitively costly, favors patent trolling and the risk of patent litigation. Trolling behaviors consist of companies trying to provoke infringement and place infringing firms in hold-up situations (Pénin, 2012). Hold-up means that a firm has made sunk investments, such as research and development investments, marketing investments or specific assets investments, and is therefore committed to its technological trajectory. It can hardly stop using the technology if it is accused of infringement. Therefore, firms trapped in hold-ups are in a very uncomfortable and unbalanced position to negotiate licenses on infringed patents. Consequently, the strategy followed by patent trolls is to try to provoke hold-up situations by hiding their patents or by refusing to grant licenses before potential infringers have made sunk investments. This enables patent trolls to capture a share of the value that is much higher than the intrinsic value of the technology they own (Lemley, Shapiro, 2006; Farrell et al., 2007; Shapiro, 2010). The use of patents to provoke hold-up situations may also occur during the implementation of standards, where firms that own essential patents might be tempted to hide them during negotiations to increase their value ex-post (Tassey, 2000). This is particularly the case for ICT (Maskus, Merill, 2013; Lemley, Shapiro, 2013).

Patent trolling entails important costs for society. According to a White House patent report (2013), trolls sued approximately 100,000 companies
in the United States in 2012. Similarly, Bessen et al. (2011) found that “NPE lawsuits are associated with half a trillion dollars of lost wealth to defendants from 1990 through 2010, mostly from technology companies. Moreover, very little of this loss represents a transfer to small inventors. Instead, it implies reduced innovation incentives and a net loss of social welfare”. Furthermore, patent trolls have a deterring effect on R&D investment since, given the risk of encountering a patent troll, innovative companies might be more reluctant to invest (Pénin, 2012). In the same vein, due to the risks of trolling, firms might be more reluctant to collaborate and perform open innovation. Finally, patent trolls might also reduce the diffusion of a given technology (Tucker 2013).

The existence of patent trolls is clearly linked to the bad quality of patent information. In a world where patent information is perfect, i.e. where patent users can identify at a minimum cost patents that they might infringe, firms that are trapped in hold-up situations are those that have not done clean freedom to operate analyses. Firms that perform these analyses properly can identify relevant patents and either invent around them or negotiate a license. But in a world with bad patent information, freedom to operate analyses are too costly and it is impossible for a manufacturing firm to evaluate ex-ante its freedom to operate. In such a world patent trolling is pervasive.

Fourth, bad patent information also massively increases the problem of “the tragedy of the anticommons” (Heller, Eisenberg, 1998) and the proliferation of costly patent litigations. A tragedy of the anticommons occurs when a technology is protected by a large number of patents. Therefore, ownership over this technology is fragmented. It is shared between a large number of patent holders, each having the right to refuse that others exploit the technology. In this case, firms that want to use the technology must obtain the agreement of all the patent owners. This fragmentation of ownership over a single technology therefore entails important transaction costs and induces a risk that the technology does not diffuse as it should. Due to the proliferation of patents, a promising technology might remain underused because it is too costly to negotiate and buy licenses from all the patent owners. This problem of anticommons is also known in the literature as a problem of royalty stacking (David, 2011). Empirically, the anticommons problem has been put forward by Murray and Stern (2007) and Von Graevenitz et al. (2011; 2012)6.

6. Note that in practice, in sectors where there is a large number of patents in force, such as ICT, firms try to overcome the anticommons problem by forming patent pools (Merges, 2001, Shapiro, 2001), and sometimes even pools of patent pools (den Uijl et al., 2013).
If the anticommons problem is a possible consequence of the proliferation of patents, another possible consequence is the multiplication of patent litigations. Indeed, when a large number of patents protect a single technology, potential users of this technology must negotiate licenses with all the patent holders. If this is too costly, they can either decide not to use the technology, inducing an anticommons effect, or they can decide to use it without the permission of the patent owners. This second option might thus provoke a multiplication of costly and wasteful patent litigation.

Obviously, the main cause of the anticommons problem lies in the proliferation of patents in a given sector. The more patents, the more likely it is to experience anticommons or litigations. This is linked to the well-known problem of multiple marginalization already put forward by Cournot almost two centuries ago. But the risk of anticommons and costly litigations is also largely reinforced by the low quality of patent information, which makes it even more difficult to navigate through the patent thicket. Indeed, when patent information is of good quality, firms can identify relevant patents and negotiate a license for each of them. In this case, the proliferation of patents only makes it much more costly for manufacturing firms to use the technology, since they have to buy a license for each patent they use (thus leading to the phenomena of royalty stacking). But when patent information is of low quality, firms have difficulty identifying relevant patents, thus facing the risk of hold-up and multiple litigations in addition to the problem of royalty stacking. In other words, the low quality of patent information worsens the problem raised by the proliferation of patents.

**CONCLUSION: HOW TO IMPROVE PATENT INFORMATION?**

This paper emphasizes the importance, but also the dangers, that the patent system can entail for the process of open innovation. Paraphrasing Zobel et al. (2016), whether or not patents enable or hinder open innovation is still to be established, but this issue is crucial for both policy and management, as innovation becomes systemic—that is, innovation is increasingly dependent on knowledge exchange and collaboration. In particular, we have shown that the quality of information plays a central role in the relation between patents and open innovation. If patent information is of reasonably good quality, patents will be likely to accelerate open innovation processes. But if patent information quality is poor, then it is unlikely that patents will positively affect open innovation. In this latter case, patents increase transaction costs, favor trolling and hold-up, and lead to anticommons and to the multiplication of wasteful litigations.
It is therefore critical to make sure that patent systems ensure a good quality of information for their users. Yet, we believe that this is not the case nowadays in most countries where the multiplication of fuzzy and unclear patents makes it very costly and sometimes impossible for users to decipher patent information. However, some simple changes could largely improve the quality of patent information. In line with Meurer (2016)\(^7\) and Meurer and Menell (2013), we identify four dimensions along which patent reforms could play.

**Better Incentives for Patent Applicants to Disclose Information**

The patent system must make sure that applicants have incentives to disclose full and clear information and make it as difficult and costly as possible to hide patents. This is not the case today. For example, in most countries, patents are published 18 months after the priority application. In the USA, the situation is even worse, since applicants can keep the patent application secret all along the application process (which can take years) and make the patent public only when it is granted. This means that during this period of secrecy users of the patent system cannot know about the pending patents. Some users might therefore be trapped into costly hold-ups due to this secrecy, even though, should the application have been public, they might have been willing to change their technological trajectory.

A first and simple measure to improve the quality of patent information might be reducing this period of secrecy, or eliminating it altogether, and making sure that patents are published on the day of their application in order to enable patent users to take strategic decisions with the best possible information. Such a policy would drastically reduce the search costs for collaborators, increasing the incentives for open innovation. Nevertheless, a balance must be struck between early disclosure to improve information, and incentives for using the patent system. The latter is paramount to ensuring that innovators have at least marginal incentives to patent, rather than using secrecy to protect their inventions. For example, if patent applications are to be made public in their entirety and from the onset, checks and

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7. As Meurer concludes (2016, p. 78): “Patents are not sufficiently property-like in the sense that the U.S. patent system provides poor notice regarding the existence, ownership, and scope of patent rights. Poor notice makes it hard for innovators to avoid infringement during development of a new technology, and it makes it hard to negotiate a patent license early on before an innovator gets locked into a particular design. Notice-based patent reforms should increase the transparency of the patent system, encourage patent applicants to mark the boundaries of their property rights more clearly, and mitigate harms caused by notice failure through appropriate limitations on remedies.”
balances need to be designed so that imitators cannot use the information in patent applications to imitate yet-to-be-patented inventions. Although patentable inventions can be protected ex-post from imitation, patent applications that are eventually not granted still entail a cost for the applicant and provide valuable information about possible improvements to the technology that competitors can use to patent themselves slightly better versions of the original application. Combined with the inherent riskiness for any innovation activity, a poorly-designed transparency policy would push risk-averse innovators away from using patent systems altogether.

In the same line of transparency, many changes during the lifetime of a patent are not made public. The ownership of a patent can change without users learning about it, thus making informed decisions more difficult to make. Again, a simple change would be to require that any changes during the patents’ lifetime are made public in transparent databases. This is by far the least costly measure that would ensure better information for patent users. Costs are minimal, not only for patent offices, but also for licensors and licensees; the only significant cost increase would be for patent trolls. Such a measure would not only reduce trolling behavior, but also reduce search costs and increase the incentives for open innovation through inter-firm collaboration.

Furthermore, low patent information quality also comes from the strategic behavior of applicants, who often have incentives to generate uncertainty. Lowering the quality of patent information might increase competitors’ cost and thus be beneficial for the patent holder. Some applicants might therefore be tempted to draft very long patent documents with fuzzy borders, unclear claims, etc., in order to create ambiguity. As a way to limit these behaviors and to improve the way patents are drafted, Menell and Meurer (2013) suggest fining patents that are too long, or that contain too many claims. On the other hand, too-short applications may artificially limit the information available on the new technology, reducing information quality and distorting its borders. This would have the reverse effect, where patents become too vague and fail to serve their open innovation channeling purpose. There is a clear need to balance clarity and compactness, and policy-makers should ensure that any patent system does not sacrifice one for the other, but rather finds the right equilibrium between the two.

Mulligan and Lee (2012) go even further and propose to allow patents only in sectors where the knowledge base is codified enough, such as in chemistry or pharmaceuticals. In other sectors where the structure of the knowledge base does not allow the drafting of clear and unambiguous patents, for example software, they recommend the suppression of the patent system altogether. However, this too has drawbacks, as alternatives to patents
would be needed to ensure that those sectors incite innovation through R&D. Remember that one of the main theoretical roles of patents is to protect innovators from free-riding competitors. A system lacking such protection mechanisms—be it patents or other IPR—is more likely to discourage firms to invest in R&D and innovate. Another consequence of such a move is increased costs for open innovators, who would lose patents as a mechanism to find collaborators and engage in open innovation. Consequently, sectors where patents are abolished would need other incentives to share information and facilitate open innovation.

**Discouraging Strategic Blocking Behavior and Low-Quality Applications**

Similarly, patent applicants often have incentives to apply for pre-empting patents (Guellec et al., 2012). Pre-empting patents are patents which, after a couple of months or years, are withdrawn by the applicant and are never examined nor granted. This strategy allows patent applicants to pre-empt a technology during a period of time. It is like buying an option on the technology. If, after the pre-empting period, the technology is promising, the application is maintained, otherwise it is withdrawn. Pre-empting patents therefore increase uncertainty for patent users. They also increase the number of patent applications. Due to the structure of patent fees, pre-empting strategies are almost costless for applicants. In most countries applicants pay very low fees when they apply for a patent. The bulk of the cost comes when the application is examined and, above all, when the patent is granted. A simple measure to avoid or at least limit pre-empting patents would therefore be to change the structure of patent fees and make patent applications more expensive at the beginning of the process, and/or make it more costly to withdraw an application.

Of course, increasing either the overall application cost or the expected cost of being granted a patent may induce innovators to change their IPR strategy away from patents and towards secrecy. While overall application costs can be maintained by changing the structure of patent fees alone, the expected cost of being granted a patent will inevitably change with the fee structure. Applicants will pay more at the beginning of their application, which is the riskier period in terms of being granted a patent. Increasing the incentives to use secrecy might also increase the cost of open innovation, specifically through higher search costs for potential collaborators. Conversely, search costs would be lowered through another mechanism, namely the reduction of patent applications containing irrelevant or fuzzy information.
Finally, since the quality of patent information is linked to the number of patents in force, it might also be effective to limit the number of patents that are granted, especially for technologies that are not always novel or innovative. The most immediate way to do so would be to increase application fees to discourage innovators with possibly less valuable inventions from applying. However, earlier studies have found that the price elasticity of patent applicants is low (de Rassenfosse, van Pottelsberghe de la Potterie, 2013), implying that, in order to have a significant effect on the number of applications, the increase in patent fees should be high. And a too-substantial increase might create problems for small firms, individuals or public organizations. Alternatively, some authors have proposed fining applicants when a patent application is refused (Caillaud, Duchêne, 2011).

**Better and Faster Examination Process**

The system must make sure that offices in charge of the examination and deliverance of patents do this in a reliable and prompt way. Today, we observe congestion problems (too many applications, not enough examiners) at all main offices, which affects the quality of patents delivered and the length of the examination procedure (which usually takes years). These lengthy procedures generate uncertainty (since, during the time of the examination, users do not know whether or not a patent will be delivered), and favors pre-empting strategies. It is therefore important to encourage patent examiners to accelerate the examination process and to encourage them to reject patents that would be unclear and ambiguous.

A first answer to this congestion problem would be to hire more examiners, as many studies have shown that in the last few decades the number of patents and the average length of these patents have increased far more than the number of examiners (Guellec, van Pottelsbergue de la Potterie, 2007). However, we fear that this solution would not solve the problem, but only induce firms to increase their demand for patents. To solve the problem in the long run it is likely that the only solution will be for the offices to refuse more patents (thus inducing firms to lower patent demand, expecting more refusals and increasing the expected cost of receiving a patent). Yet, in most offices, patent examiners do not have enough incentives to refuse patents. For example, their bonus is usually a function of the number of patents that have been examined (which is supposed to approximate their productivity). But the problem is that it takes much more time to refuse a patent than to accept one. In the case of refusal, the examiner must write a report describing the reasons for refusal, which can be time-consuming. This means that in case of doubt, patent examiners have more incentives to accept a patent,
contributing to patent inflation. We believe that one important challenge for patent offices will be to set up incentives for examiners to refuse more patents with poor information quality. Not going as far as Mulligan and Lee (2012), who propose to suppress the patent system in sectors where patents cannot be unambiguous, one could envisage adding another patentability condition, that the perimeter of protection of the patent must be clearly defined and easy to understand. Examiners could therefore refuse all patents that do not fulfill this condition.

A last measure which could improve the examination process would be to open it to the other users of the system. As is now the case in most offices, the examination process takes the form of a closed bilateral discussion between the applicant and the examiner. At the beginning, the application is kept secret from the other users. After 18 months, in most offices, the application becomes public, but other users (competitors, etc.) cannot intervene. If they have some information that could improve the examination process, invalidate the patent application, for example, or limit its scope, they cannot bring it to the examiner. It is only after the patent has been accepted that, during the opposition phase, other users can bring information in. This bilateral process is therefore obviously not efficient, since it is quite unlikely to exploit all the possible information. It would be important, as early as possible, to encourage other users to bring information during the examination process in order to enrich and improve it. Especially since it is precisely these users who are likely to have the best information about the inventions and technologies developed in their sector. Moreover, involving more stakeholders in the application process would increase the incentives for, and benefits of, open innovation. Stakeholder involvement can increase the acceptance of risks inherent to open innovation, thus bringing benefits beyond information acquisition (Wayne Gould, 2012).

**Better Registration and Indexation Systems**

Any patent system must make sure that users can identify their technological neighbors with a maximum of certainty. This implies that patent databases must be public, easy to browse and, most of all, indexed to facilitate the identification of owners. It is on this last point that most remains to be done. We believe that it is fundamental to work on a reliable patent index that could help firms determine with enough precision the patents that they could infringe, but also patent owners that are close-enough technological neighbors to form R&D collaborations in an open innovation paradigm. Ideally, one should be able to do with patents what has been done with land property, *i.e.* build a public registry that indicates without ambiguity the
property of each citizen. Due to the immateriality of knowledge, it is likely that this ideal cannot be reached for patents on new technologies. It is nevertheless important to try to improve things as they are today.

To conclude, this paper can be seen as a warning: patents can be formidable accelerators of open innovation; however, for this to happen, reforms are needed urgently. Fences need to be good to make good neighbors, and this requires improving the quality of patent information. Without any improvement in this sense, transaction costs will always impede the reuse of existing technologies, trolls will always be around the corner, and anticommons will always threaten cumulative innovation. Radically improving patent information is without doubt one of the most important challenges that patent systems all over the world will have to overcome in the near future.

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