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Patents and Innovation: Friends or Foes?

François Lévêque and Yann Ménière

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Foreword

Over 2 million patents are currently in force in the EU and in the USA. Do they testify innovation is blockaded for they restrict freedom in research or do they give evidence innovation is flourishing for patent law provides incentives to invent new products and processes? In other terms do patents freeze or spur innovation?

The question arises for massive anecdotal evidence shows the patent system may have turned on its head, e.g., USPTO and EPO examiners spend less than 30 hours per application to assess whether the technical input is useful, novel and non-obvious; as a result, the list of trivial patents such as one-click online shopping is growing each day; some companies, so called patent trolls, have specialized in amassing patents just to litigate and get damage rewards; one of them has recently obtained \$ 612,5 million from the manufacturer of BlackBerry to settle an alleged patent infringement; European patents are translated in several different languages, a costly burden for applicants, although nobody reads the translations.

The belief of the layman in the patent system has evaporated. He is at best skeptical on the benefits of patents for society.

Economists are not innocent for this change in perception. 50 years ago they established (Nordhaus, 1969) that patent law tends to stimulate R&D too much in organizing races to patent first with too many firms. By contrast, during the 1990s, they pointed out that patents hinder innovation in reducing incentives for secondary inventors when research is cumulative and in raising an anticommons problem whereby patents are allotted to a multitude of small owners.

For people unfamiliar with how economic theory goes, it may seem that economists also changed their mind and burnt today what they incensed over the past. In fact, it is important to know two features of development in economics. Firstly, economists are mainly interested in pointing out what does not work rather than what does work. Market failures and public intervention failures are what drive their curiosity. The light they cast on the world in their papers is rarely pink. Secondly, economic models are local; they focus on a small number of parameters and trade-offs. They do not pretend to embrace a whole system and being able to calculate a net gain for society in taking into account all phenomena they study in isolation.

This may misleadingly give the impression that economic theory has now proved that patent law hinders innovation rather than it stimulates it, that is, that absent patent law, innovation will be stronger.

The aim of this study is to try to get a clearer picture on what economics enables us to say on the impact of patents on innovation. We are grateful to Air Liquide, Alcatel, Microsoft, Philips and SAP for the opportunity they give us to revisit this basic question. This study has been carried thanks to their financial support. Of course, its contents only engage their authors and not these companies.

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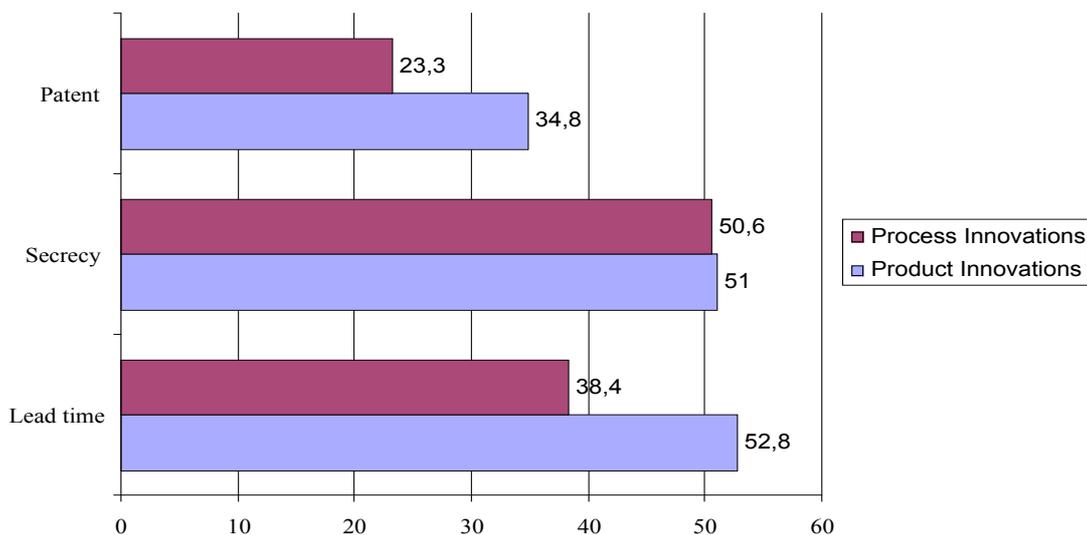
Executive Summary

What are the impacts of the patent system on innovation? The report addresses this question in surveying the economic literature that has flourished on patents over the past ten years. Four main economic impacts are successively discussed: the creation of incentives to innovate, the diffusion of knowledge through information disclosure, facilitating technology transfers through licensing, and the organization of cumulative R&D. The first three impacts correspond to the key roles of intellectual property rights. The fourth one focuses on the most debated and complex effects of patents in sectors such as software and biotechnology.

Incentives to innovate

Whether patents stimulate innovation is critical to know. Such a dynamic effect is required to counterbalance the static loss for users who will be confronted with the monopoly price the exclusive right may confer on the invention. Of course, patent protection is not the single available mechanism that enables firms to recoup their investments in R&D through pricing over marginal cost. Secrecy can be very effective to protect inventions on manufacturing process; the producer of a new product can be protected by the lead in the market he enjoys over his competitors. In fact, according to a US survey, secrecy and lead time are more popular than patents amongst R&D managers to protect product and process innovations. The issue, therefore, is to estimate the additional protection the patent system offers. In other terms, in absence of patent law, what would be the decrease in investments in innovation, if any?

Figure 1: Patents as a protective mechanism amongst others



Mean % of innovations for which each mechanism is considered as effective. Source: Cohen *et al.*, 2000.

A first approximation is given in comparing the value of patents and the amount of R&D expenditures. As an example, the value of patents owned by US chemical firms in the early 1990s represents 14% of their investments in R&D. Such a ratio gives an idea on the share of R&D that may be recouped through patents, or, to put it another way, on the subsidy that firms

would need in order to maintain their current level of R&D in absence of patents. The table below provides other figures from different studies carried out at different periods of time in different countries and with different methodologies. It shows that the importance of patents to recoup investments, and thus their effects on innovation, depends on industrial sectors. Unsurprisingly, for pharmaceuticals patent protection is a key mechanism (drugs can easily be imitated) whereas it is not for missiles manufacturers (purchaser of weapons do not want the invention being public). We must always keep in mind that patent stimulates innovation differently from one sector or one technology to another. There is not a universal effect of patents.

Table 1: The equivalent subsidy rates of patents by industries

	USA Early 1990's	France 1969-87	Germany 1953-88
Pharmaceuticals	22%	4.1%	15.2%
Industrial Chemicals	14%	7.2%	
Food, kindred and tobacco products	2%		
Semi-conductors	23%		
Electronic components	13%		
Communication equipment	39%		
Computer	8%		12.5%
Metals	23%		
Rubber Products	19%		
Aircrafts and missiles	4%		
Instruments	16%		
Medical instruments	21%		

Sources: Lanjouw, 1998; Schankerman, 1998; Arora et al., 2005.

A second methodology for assessing the additional effect of patents on R&D consists in calculating the difference between the value of the innovation *before* and *after* it has been patented. According to a study based on the US survey mentioned above, this premium amounts to 75% to 125% of the value of patented innovations. In other terms, the value of these innovations is doubled thanks to patents. The study has also calculated the effect of the patent premium on R&D investments. It shows that a 10% increase in patent premium results in a 6% increase in the R&D expenditures of the patent holder. It is important to note, however, that patents do not always increase the value of innovations. In fact, myriads of innovations are not patented because patent disclosure increases the risk to be imitated. As already mentioned, secrecy is often the preferred protection mechanism. For those innovations, patent would therefore decrease their value. On average, the study estimates this negative premium to 10 to 50%. We must keep in mind that patent is an instrument to recoup R&D investments amongst

others and its use is decentralized and optional.

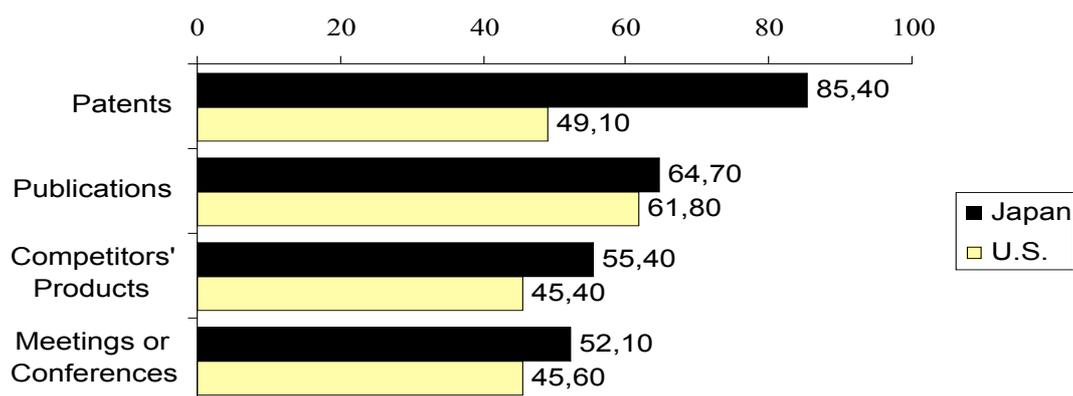
Broadly speaking, available empirical economic studies show that patents play a small but significant positive impact on R&D although this impact widely varies according to technologies and businesses.

Information disclosure

Patents increase the amount of technological information that is publicly available because patent owners must deliver a precise description of their invention. In turn, the information is used by other innovators and makes their R&D more effective and less costly.

A few empirical evidence documents this positive impact of patents. According to an OECD survey on American, European and Japanese firms, 88% of respondents report that the information disclosed in patents are useful for designing and implementing their own R&D strategy. In fact, patents are a key source of information on competitors. Another comparative study shows that patent is the first information channel on R&D of competitors in Japan and comes third in importance after scientific publications and informal exchanges in the US. Patent information disclosure enables firms to save useless duplication of R&D costs and to devote their resources to research areas that are less explored.

Figure 2: Importance of sources of information on rivals' R&D



% of Respondents Indicating Source/Channel 'Moderately' or 'Very' Important. Source: Cohen *et al.*, 2002.

Licensing technologies

Facilitating the transfers of technology is a major economic function of the patent system

although often overlooked. As any property rights, patents can be sold or rented and thus contribute to increase wealth through trade and labor division. In licensing his invention to a firm that is better placed in a product or geographic market, the patent holder can ensure a more beneficial exploitation of his invention. Licensing ensures the invention will be used by those who value it most. Moreover, this static gain reinforces the dynamic effect of patent because the better the licensees are in exploiting the invention, the higher the royalties the patent holder can expect, and thus the higher his incentives to innovate. Note that licensing is especially worthwhile for small and medium sized enterprises that may lack in-house capabilities to develop their invention and launch them into the market. A European survey shows that SMEs license 26% of their patented technologies against 9% for large firms. In other terms, patents are more critical for innovative SMEs than for innovative large companies.

Transfer of technology through licensing is especially frequent in pharmaceuticals and information and communication technologies. Interestingly, it is rapidly growing. For instance, estimated licensing revenues in the US have increased from \$ 15 billion in 1990 to more than \$ 100 billion in 1998. A survey on applicants to the European Patent Office from the EU, the US and Japan shows European companies are less incline to offer or purchase patent licenses. The EU market for technology transfers is smaller and underdeveloped. An OECD survey covering a hundred of firms confirms both the trend towards the expansion of markets for technologies and the relative lag of Europe.

Technology transfers improve the diffusion of innovations and increase the incentives to innovate. They are developing over time and benefit principally small firms and high tech sectors.

Cumulative R&D

From a political perspective, patents have been highly disputed in biotechnology and software. The defending of ethical values and the promoting of liberty to use code have been the driving forces for the opposition to the extension of patentability to these areas. From an economic point of view, the controversy is different. The issue is whether patents can improve welfare when innovation is cumulative and complementary, that is, wherever, as in biotechnology, software, computer or electronics, innovations result from other innovations and final products include numerous patents. Patents on cumulative and complementary innovations raise the risks to block downstream innovations (e.g., a patent that gives a monopoly on a critical research tool in gene sequencing) and to create royalty stacking (e.g., the MPEG-2 standard for digital video compression contains about a thousand patents belonging to 26 companies). Economic theory has characterized these risks and has demonstrated that in certain circumstances they may be

severe enough to make patents hindering innovations rather than stimulating it. A low quality of patent examination, as in the US PTO according to many observers, is one of these circumstances. However, companies have put in place multiple organizational solutions (e.g., cross-licensing, patents pools) and defenses (e.g., patent commons) to mitigate those risks.

The question whether patents in biotechnology or computers and electronics and software are welfare enhancing or welfare detrimental is therefore a factual one. Empirical studies suggest a positive answer in the case of biotechnology. They are still rare in information and communication technologies, where they suggest a weakly positive answer despite some drawbacks.

Available evidence shows that patents have an important positive impact on incentives to innovate in biotechnology. A 10% change in R&D premium induces a 10.6% increase in R&D spending. Patents also allow the division of labour between universities, biotech firms and pharmaceuticals through licensing. Some surveys focus on the risk that patents restrict access to research tools for academic and industry researchers. They tend to conclude that this is not currently the case. Concerning computers and electronics, available evidence suggests that patents as a whole have a positive impact on innovation, although they may generate legal uncertainties and obstruct the growth of small firms. A 10% change in R&D premium induces a 6% increase in R&D spending, which is in line with the average in other sectors. For software specifically those figures are not known.

As a conclusion, economic literature shows that both (i) the effects of patent on innovation are small but significant and (ii) the patent system suffers from critical imperfections. The issue is not therefore to throw the baby with the water of the bath in abolishing patents but rather to reform the patent system to increase its positive impact of patents on R&D.

Chapter 1.

Incentives to innovate

1.1. Introduction

As a first step, we present theoretical insights on the economic justification of patent as a way to create incentives to innovate and as an alternative to the funding of innovation by taxpayers. We then review the empirical literature that assesses patent effectiveness. We show that patent intervenes as a complement of other mechanisms and that its incentive power differs according to technology fields and industries. We finally discuss policy issues relating to the effectiveness of patent protection as a means to create incentives to innovate.

1.2. Theoretical insights

From an economic standpoint, patents are generally justified as a way to create incentives to innovate by conferring inventors temporary exclusive rights on the information they produce. The patent system has furthermore the advantage of being more decentralized than systems where innovation is public-funded.

a) Patents to produce information goods

Economic analysis assimilates works of the intellect such as innovation to the production of information (Arrow, 1962). In absence of policy measures such as intellectual property law or public funding, the production of such goods will be lower than what is optimal for society.

Indeed, information is a *non-excludable* good: it is impossible to exclude an individual from using information even if he does not contribute to the cost of its production. These goods pose the practical problem that entrepreneurs lack the incentives to supply them. From the outset, they know they will have difficulty being paid and covering their costs. From the point of view of the community, there is a loss in welfare because goods for which there is a market are not produced. Intellectual property is a way to solve this problem. Granting exclusive rights on information goods creates *excludability*. Conferring these rights to innovators enables them to sell the information and derive a profit from it, if it is valuable. Therefore, intellectual property creates incentives for entrepreneurs to innovate.

Moreover information is a *non-rival* good. When an individual consumes information, she does not reduce the quantity available to other people. Put differently, the cost of producing information does not depend on the number of users. This implies that if information is non-excludable, all users will be able to consume it once it has been produced. If, by contrast, information is excludable, e.g. thanks to a patent, and the producer charges for his service, non-rivalry implies the consumption is needlessly rationed. Consumers whose willingness to pay is lower than the going price are excluded from using the good, although they would have

benefited from it at no cost to anyone. Social welfare is not maximized.

Intellectual property law addresses the *non-excludability* and *non-rivalry* problems sequentially. Initially, the legal mechanism of protection makes the good excludable for a limited period. Users are required to pay for the information and some of them renounce to buy it. Subsequently, when the work passes into public domain, all users can access it free of charge. Intellectual property law thus strikes a balance between the incentives to innovate and the diffusion of the results obtained. The contradiction between incentives and use translates into economic language as a trade-off between dynamic efficiency (the production of innovations) and static inefficiency (the exclusion of some consumers).

b) The self-selection advantage of patents

Since patent protection artificially deprives some users from the consumption of information, why does the government not finance the production of innovations and distribute it for free? Public-funded innovation is actually frequent, but intellectual property law is still a more efficient mechanism in most circumstances.

The efficiency of public funding mechanisms such as prizes, grants or subsidies depends on the capability of financers to collect information on innovation opportunities (Gallini & Scotchmer, 2002). Subsidies require that the financers can (i) identify which innovation fields are valuable to society, (ii) identify which research teams are capable in this field and (iii) make sure that the selected team will make reasonable efforts once subsidized. Using grants and prizes to have private sector entities produce innovations requires that the public planner has a good idea of the expected costs and social benefits associated to a given innovation project. When such information is scarce and held by private agents, the public funded production of innovations is inefficient.

In contrast, the advantage of patent law is that it enables the decentralized self-selection and self-funding of firms and inventors who have private information on valuable innovation projects. Since they are often in the best position to compare the expected revenues of a patented innovation with the costs of developing it, firms have the right incentives to invest unilaterally in R&D, and to carry out the R&D investments in an efficient way. Conversely, it is more unlikely that wrong projects are financed. And no detection, monitoring and evaluation costs are incurred by public financers.

This self-selection mechanism is, however, not perfect. Since the private gain derived from a patent is lower than the value of the innovation to the society¹, some valuable innovation will

¹ This is due to the fact that a uniform monopoly price does not capture the entire willingness to pay of consumers. The profit of the patentee equals the social value of the innovation only in case of perfect price discrimination wherein each consumer pays a different price corresponding to his willingness to pay.

not be produced. Moreover widespread information on innovation opportunities may also reduce the efficiency of the patent system. In fact, when information on a given innovation prospect is common knowledge, the incentive to file a patent is likely to generate a *patent race* (Nordhaus, 1969; Reinganum, 1989), whereby firms tend to over-invest in R&D to innovate first.

1.3. Patent protection and patent value

The incentive power of patents is conditional on the effectiveness of patent protection with respect to other protection means. Albeit this limitation, empirical evidence suggests that patents do provide incentives. The effect of patents on innovation varies according to sectors; they are stronger in Pharmaceuticals and Chemicals.

a) Nature and effectiveness of patent protection

Generally, an innovation is not protected by a single ironclad patent, but rather by a series of patents that confer a protection which reliability may be difficult to predict. This type of protection constitutes an option for innovators, who can chose to complement it or replace it with other means of protecting their intellectual assets.

Table 2: Estimated number of patent protection applications per innovation by industry

Industry	Patents	Industry	Patents
Rubber products	8.8	Electronic components, excl. Semicond.	5.7
Transportation, excl. Aircrafts	7.8	Computers and other office equipment	5.1
Semiconductors	7.2	Other manufacturing industries	4.9
Petroleum refining and extraction	6.9	Medical instruments	4.7
Other electrical equipment	6.7	Food, kindred, and tobacco products	4.6
Machinery, excl. computers	6.7	Aircraft and missiles	4.3
Industrial chemicals	6.6	Communication equipment	2.9
Instruments, excl. chemicals	6.3	Biotech	2.2
Metals	6.1	Drugs and medicines	2.0
Other chemicals	5.8	TOTAL	5.6

Source: Arora et al., 2005.

Most innovations are protected by more than one patent. Table 2 displays for instance estimations of the number of patent applications per innovation based on a survey of 1165 U.S. firms realized in the mid-1990s (Cohen *et al.*, 2000; Arora *et al.*, 2005). According to these

estimations, an innovation is protected by 5.6 U.S. patents on average. While the number of patents per innovation is relatively smaller in Biotech or Pharmaceuticals (around two), it can rise to more than seven in fields such as Semiconductors, Transportation or Rubber products.

Such series of patents do not guarantee that an innovation is effectively protected against imitation. Indeed, the protection is effective only if the patentee is able to detect eventual infringers and go successfully through litigation. When the monitoring and litigation costs are too high in comparison with the expected benefit from the ruling, innovators may have no interest in trying to enforce patent protection (Crampes and Langinier, 2002). An innovator may thus renounce to patent in an industry where imitation is too difficult to detect because, for example, it remains hidden within competitors' production plants (Crampes and Langinier, 2002). Moreover the outcome of litigation is uncertain; patents confer only a probabilistic protection. Thus even a patent holder who has identified an imitator may prefer to accommodate it if the likelihood to win an infringement trial is not high enough (Choi, 1998). Box 1 below presents the determinants of patent litigation, and how they may favor some categories of firms.

Box 1: The determinants of patent litigation

In an ideal world, everybody knows exactly what their rights are and there would never be any litigation because the outcome of any legal action would be known in advance. Future losers would have every interest to comply from the outset with the expected verdicts and thus save on the cost of pointless litigation. In contrast, the day-to-day workings of courts stem from the ambiguity of law, which creates litigious situations. The likelihood of litigation is higher when the parties have different expectations about the outcome. This is the case when patents concern a new technological area, for which there are few legal precedents.

Litigation is also more likely when the stakes are high. Based on U.S. data, Lanjouw and Schankerman (2001) show that litigation for infringement is more common when the innovations concerned are at the base of a chain of cumulative innovations (cf. Section 4). By taking legal action, patent owners may also be attempting to establish a reputation. Indeed, patents are cited more often when they have been involved in litigation. Such a reputation also helps a firm enforce its other patents. Consequently, infringement litigation benefits large firms more, because they have large patent portfolios. Their portfolios also put them in a better position for negotiating settlements, in the form of cross-license agreements. It is harder for start-ups to enforce their rights, despite the strategic importance of patents for them. Without patent portfolios they lose out on both the effects of reputation and the bargaining chip (Lanjouw and Schankerman, 2001). A survey conducted in the biotechnology sector reveals that 55% of small firms regard litigation as an impediment to innovation, compared to only 33% of large firms (Lerner, 1995).

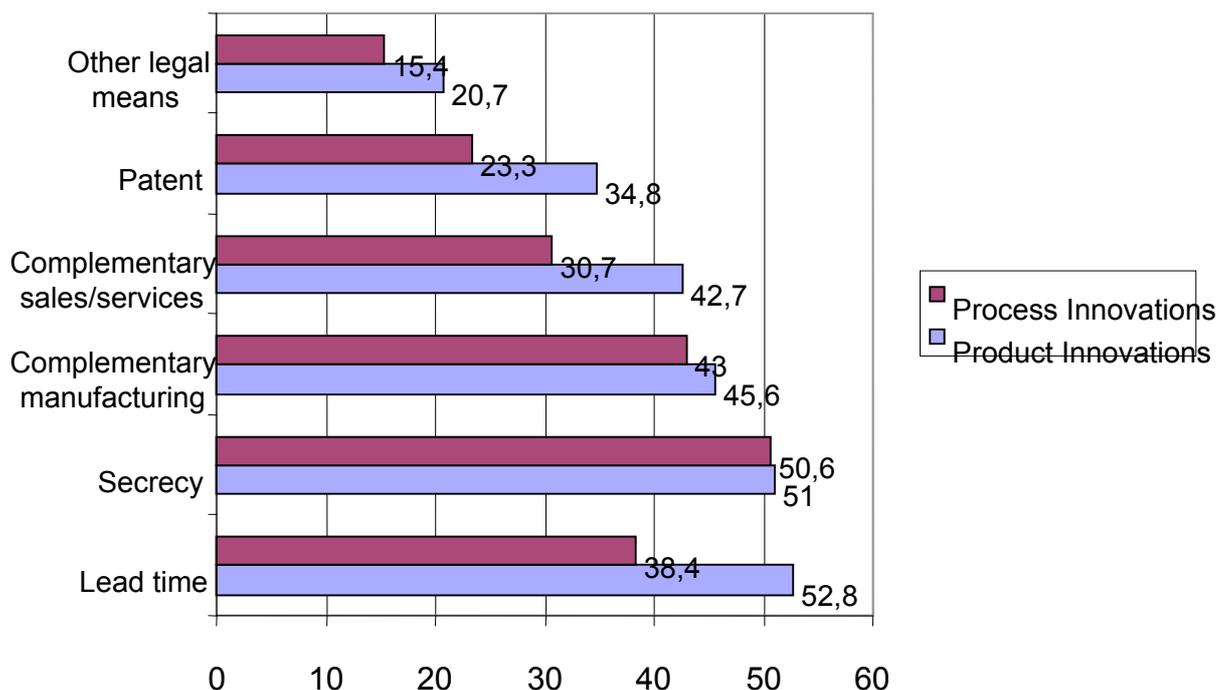
In general, legal action is rarely initiated and even less often taken to term. Firms have an interest in settling to avoid high court costs (Crampes and Langinier, 2002). In the United States the median cost to each side of a trial and appeal is estimated at \$1.5 million, compared with \$800,000 for an out-of-court settlement. Of some 1,600 patent lawsuits filed each year only 100 go as far as a court verdict (Lemley, 2001).

This imperfect protection conferred by patents is only one of several options for innovators, who may choose to replace or complement it with other protection strategies. Indeed, Cohen *et al.* (2000) identify five other appropriability mechanisms, namely:

- Secrecy.
- Other legal means (such as contractual means).
- Lead time (over competitors).
- The tying of the innovation to complementary sales/services.
- The tying of the innovation to complementary manufacturing.

In a survey of 1165 U.S. firms with at least \$5,000,000 in sale or business units of at least 20 people, Cohen *et al.* (2000) find that a patent is generally not considered the most effective appropriability mechanism (Figure 3). Respondents regard lead time and secrecy as the best mechanisms, followed by complementary sales and manufacturing. Patents come fifth for both product and process innovations, with respectively 34.8% and 23.3% of respondents considering them as an effective appropriability mechanism.

Figure 3: Patents as a protective mechanism amongst others



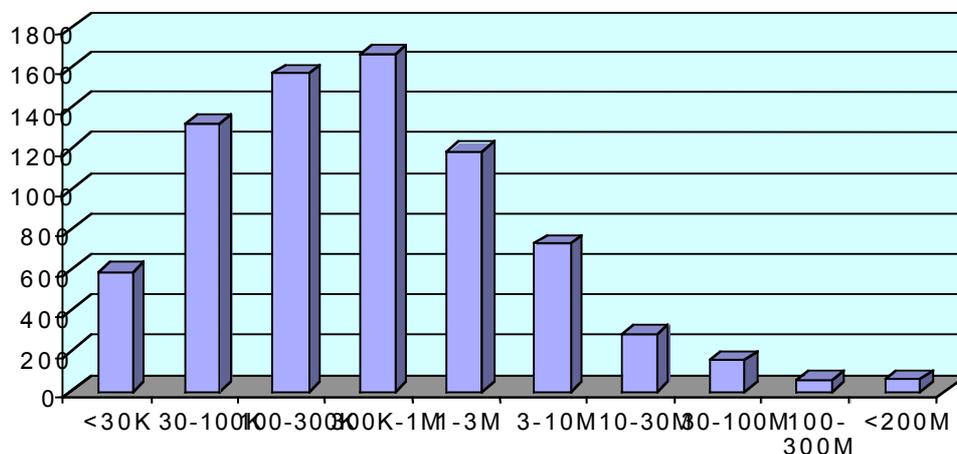
Mean % of innovations for which each mechanism is considered as effective. Source: Cohen *et al.*, 2000.

Patents are nevertheless widely used by companies, since 70% of respondents report to apply for one. In sectors like Pharmaceuticals where products can easily be reversed engineered, a patent is deemed the second most effective appropriability mechanism after trade secrets (Cohen *et al.*, 2000). In other cases, a patent intervenes as a complement of other protection means. Combined with lead time, complementary sales or complementary manufacturing, it especially allows the patentee to sue infringers in case the innovation happens to be imitated. Patent thus adds an *ex post* protection mechanism to *ex ante* mechanisms that aim rather at preventing imitation.

b) Patent value and incentives to innovate

Patent protection aims to create incentives to innovate, hence its effectiveness depends on the profit innovators can expect from patenting. There are different ways to evaluate this profit. A first approach consists in evaluating the value of *patented innovations*. It permits to highlight the highly skewed distribution of patent values, but it fails to provide a good estimate on the incentives provided by patents. Indeed measuring such incentives requires measuring the value of *patent protection*, e.g. incremental benefit of using a patent to protect an innovation that may also be protected by other means. Empirical evidence based on this approach suggests that the value of patent protection has increased over time and that patent protection has on average a small but significant positive effect on R&D spending.

Figure 4: Distribution of patent value*



*in Euros, 1993-97. Source: Gambardella et al., 2005.

A first way of measuring the profits associated to patent protection consists in measuring the value of patent innovations. A survey of 9,017 European patents granted by the European Patent Office in 1993-1998 (PatVal, 2005) provides a recent estimate of the value of underlying innovations. The methodology of this survey consisted of directly asking patent owners the minimum price at which they would have accepted to sell their patent on the very day this patent was granted. Since answers are given by patent owners taking into account the information they have at the time they respond, this methodology is likely to lead to an excessive valuation of patent values. Still, it provides a good picture of the distribution of patent value (Figure 4). Indeed, the highly skewed distribution of patent value – with the largest share of patents in the left-end of the distribution – is comparable to what has been found in other empirical studies (Pakes, 1986; Deng, 2005). The average value of all patents is around 6.36 million Euros, which is a very high and probably excessive estimate. Only 7.2% and 16.8% of patents are worth more than 10 million Euros and 3 million Euros, respectively. A share of

15.4% is worth between 1 and 3 million Euros. Finally 68% have a value lower than 1 million Euros and 8% are worth less than 30 thousand Euros.

Since innovations may be protected with other means than patents, looking at the entire value of patented innovations is not a good way to evaluate the incentives to innovate created by patents. A better indicator would be the incremental profit generated by patent protection. This is what several early studies do with a different methodology, where the value of patent protection is induced from the renewal decisions of patent holders (see Box 2). Two of these empirical studies evaluate the value of patents in Germany, France and the United Kingdom in the 1950-1972 and 1980-1985 periods (respectively Pakes, 1986; Deng, 2005). They enable us to draw time comparisons. Table 3 presents the estimated average values of patents. These values are considerably lower than the results of the PatVal survey, highlighting the fact that the value of patent protection is lower than the value of patented innovations. The estimations also reveal an important increase of the value of patent protection over time. The average patent value estimated by Deng (2005) for the 1980-1985 period ranges between 81K and 90K 1997 U.S. dollars. This is approximately ten times higher than Pakes' (1986) estimation for the 1950-1972 period. Part of this increase is due to a methodological difference. Indeed the methodology used for the 1950-1972 study does not take into account expected litigation costs, while the 1980-1985 study does (see Box 2). The increase in patent value can also be explained by an institutional change (Deng, 2005). Patents of the 1950-1972 sample were granted by national patent offices, while most patents in the 1980-1985 sample are European patents. This may affect the difference in average values of patents in the samples, for application costs at the European Patent Office are higher and innovators tend to use the European patenting route only when they expect a large enough revenues. The comparison suggests a general trend of increasing value of patent protection over time.

Table 3: The value of patent protection in Germany, France and the United-Kingdom

	Germany	France	U.K.
Deng (1980-85)	90,221*	96,768	81,351
Pakes (1950-72)	25,549	8,897	11,625

*in 1997 U.S. dollars. Source: Deng, 2005.

Several renewal-based studies compare the impact of the value of patent protection with R&D expenses. Their results are consistent and suggest that patents have a limited but significant impact on R&D spending. The method consists in calculating the Equivalent Subsidy Rates (ESR) of patents, i.e. dividing their estimated value by the firms' R&D expenses to produce those patents. The obtained ESR corresponds to the subsidy that firms would need in order to

maintain R&D at current level in the absence of patents. Using a patent-renewal methodology, Pakes (1986) calculates the ESR on company-funded R&D in three European countries in the 1970's period. He obtains estimates of 6.8% in France, 5.6% in Germany and 5.7% in the United Kingdom. Using data on all patent applications and renewals in France, respectively for the periods 1969-1982 and 1969-1987, Schankerman (1998) finds in turn an Equivalent Subsidy Ratio of 15.6%. In comparison with other policy levers such as tax breaks, these figures seem credible and substantial (Pakes & Simons, 1989; PatVal, 2005). It is however difficult to draw general conclusions on the impact of patents on R&D spending from the observation of ESR alone because ESR do not say anything about the R&D incremental response to an increase in the patent protection.

In a more recent study based on a 1994 survey of U.S. R&D managers Arora and al. (2003) use another methodology (see Box 2) to estimate the value of patent protection – denoted as the *patent premium* – and its effect on R&D spending. They define the patent premium as the difference between the value of the innovation before and after it has been patented. This premium may be positive or negative, and it actually happens to be negative on average! Indeed the expected value of an innovation would decrease by 10% to 50% if the innovation were patented. This captures the fact that many innovations are not patented because their inventors expect that patent protection would be ineffective, while patent disclosure would increase the risk that the innovation be imitated. By contrast, innovations with a positive patent premium are patented, which increases the return on the inventor's R&D investments.

When they focus on innovations that have been patented, Arora *et al.* (2003) find a positive patent premium of 75% to 125%, meaning that patenting such innovations increases their value by 75% to 125% on average. They can calculate an Equivalent Subsidy Ratio of 24% of company-funded R&D, which is higher than what studies based on patent renewals indicate. Interestingly, they can also use their model to simulate the effect of an increase of the patent premium on R&D spending. They find that a 10% increase of the patent premium would result in a 6% increase of the patent holder R&D. This suggests a substantial positive impact of patent premium on innovation.

Box 2: Methodologies to evaluate the value and impact of patent protection

While surveys provide estimates of the value of patented innovations, there are more sophisticated methods to appraise the value of patent protection. Two such techniques are presented below. The first one evaluates the incremental returns from protecting an innovation with a patent and thereby isolates the value of patent protection. The second method examines the decisions to patent an innovation and to undertake R&D each in turn. Doing so permits to get evidence on the impact of patent protection on innovation.

Patent Renewals

In several countries, patent owners must pay a renewal fee each year in order to keep their patents in force. Patent holders will decide to renew their patents only if the expected benefit from keeping their patents in force exceeds the level of the renewal fee. As a result, patents that generate more profits are more likely to be renewed and to have a

longer duration. Several studies have therefore used data on patent renewals as an indicator to estimate the value of patent protection (Pakes & Schankerman, 1984; Schankerman & Pakes, 1986; Schankerman, 1998; Lanjouw, Pakes & Putnam, 1998).

The use of patent renewals may lead to a systematic underestimation of the value of patents because it does not take into account the litigation costs which patent holders might also have to pay (Lanjouw, 1998). Indeed more valuable innovations are more likely to be involved in litigation (Lanjouw and Schankerman, 2001). If expected litigation costs are taken into account and added to the renewal cost, a patent holder's renewal decision will denote a higher profit expected from keeping the patent in force. Lanjouw (1998) develops an estimation method based on patent renewals taking into account expected litigation costs.

The value of patent protection is estimated as the incremental returns in patent protection in comparison with the best available alternative protection means. The renewal-based methodology may however affect what is the best alternative (Lanjouw, 1998). Secrecy may be this alternative before the patent is filed, but it is not available anymore after the patent has been disclosed. To the contrary, an innovator may be able to replace patent with, say, a brand name after several years of patent protection. Depending on which effect dominates, the methodology based on patent renewal tends to overestimate (in the first example) or underestimate (in the second one) the expected returns from one more year of patent protection.

Patent Premium

Arora, Ceccagnoli and Cohen (2003) develop an original methodology to calculate the value of patent protection – or “patent premium” – and its impact on R&D spending. Instead of patent renewal data, they use the result of the Carnegie Mellon survey of U.S. R&D managers in the early 1990's (Cohen *et al.*, 2000). The survey provides firm-level data on the number of patent applications, the propensity to patent, the perceived effectiveness of patent protection, and the R&D expenses of respondents.

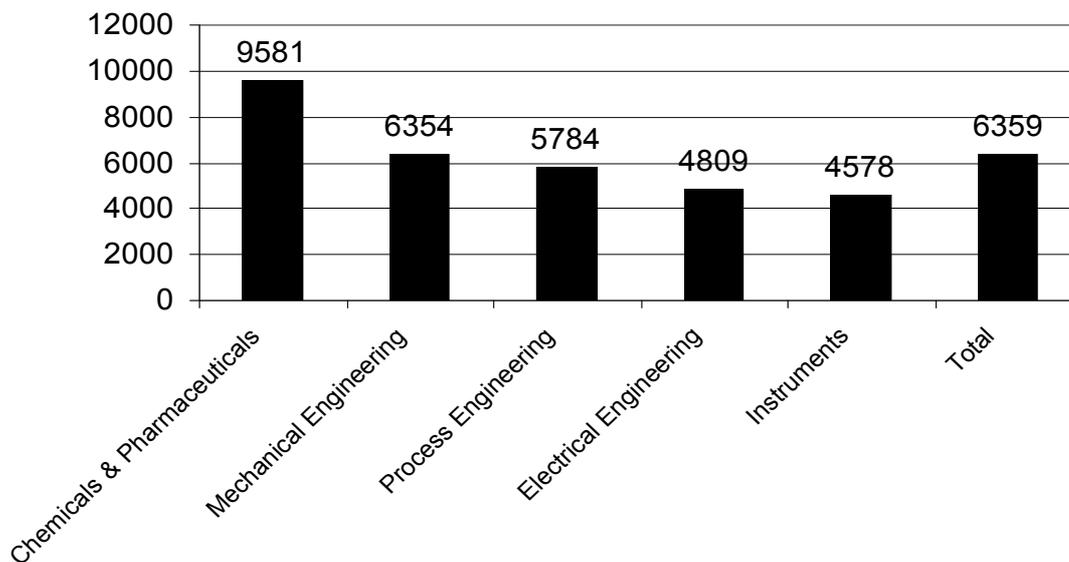
These data enable Arora *et al.* (2003) to estimate an econometric model that disentangles the effect of patent protection on innovation on the one hand, and the effect of innovation on patent filings on the other hand. They thereby solve a difficult problem raised so far by any attempt to assess the impact of patent protection on R&D and innovation. Indeed there are reciprocal effects between patent grants and R&D spending, which are impossible to assess separately without knowing to what extent firms file patents to protect new innovations or to improve the protection of the existing ones. Arora *et al.* (2003) are able to dissipate this ambiguity thanks to data on patent propensity (the number of patents filed per innovation) and on the effectiveness on patent protection that available in the Carnegie Mellon survey.

Arora *et al.* (2003) estimate a model in which firms invest in R&D to develop innovation and decide as a second step whether to patent their innovations or not. R&D decisions and decisions to patent innovations are explained separately by a set of variables, including the positive or negative premium expected from patenting an innovation. The authors firstly calculate the patent premium expected from patenting an innovation. They can then assess the impact on patenting and on R&D decisions of an exogenous variation in the patent premium.

c) Industry differences

The general results that we have presented so far hide some differences between technology fields. The empirical literature reveals that the value of patents is skewed in all fields and that patents contribute modestly but significantly to R&D in all fields. It also sheds light on sectors where patents matter more as an incentive mechanism. This is the case in sectors such as Biotechnology, Chemicals and Pharmaceuticals, where R&D investments are considerable while innovations may be difficult to protect with alternative appropriability mechanisms.

Figure 5: Average patent value by technological class

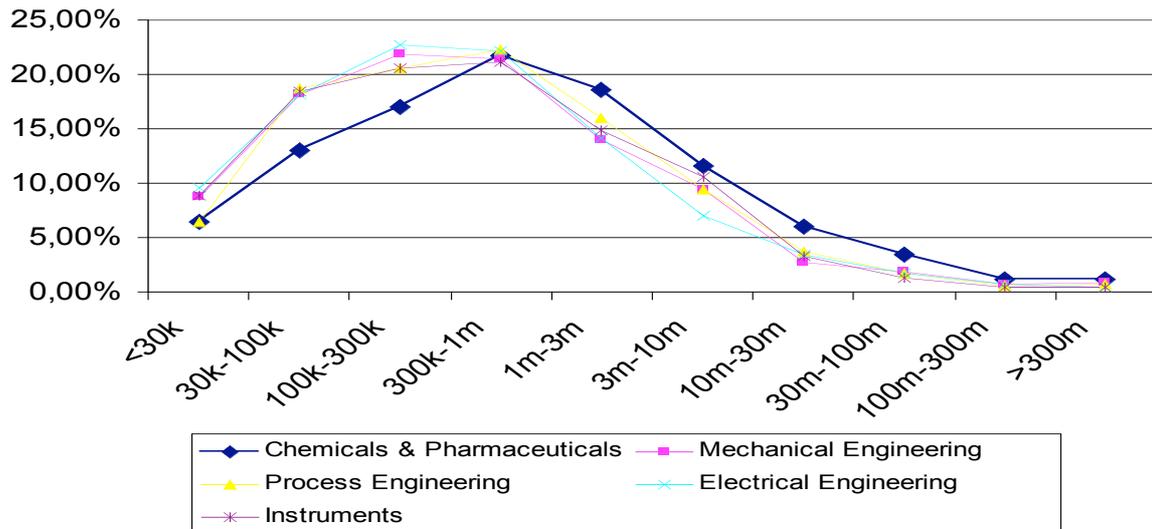


In kEuros. Source: PatVal, 2005.

Figure 5 above summarizes the PatVal survey results on the average value of patents for five “macro” technological fields. It highlights important differences between fields. The average value of a patent in Chemicals and Pharmaceuticals (9,581 kEuros) is twice as much as in the Instruments field. In the Mechanical Engineering and Process Engineering fields, the average patent value is slightly lower than the average value of all patents (6,359 kEuros as already mentioned), while Electrical Engineering is comparable to the Instruments field.

These differences in the average value of patents do not explain the highly skewed distribution of patent value observed in Figure 5. Figure 6 below displays the distribution of patent value by “macro” technological class. Except to some extent Chemicals and Pharmaceuticals where patents are more valuable, each class reproduces the skewed distribution that can be observed at the general level.

Figure 6: Distribution of patent value by technological class*



*In Euros.

Measures of the impact of patents on R&D also reveal differences between fields. Table 4 summarizes the results of three studies that evaluate the Equivalent Subsidy Rates of patents for various industries (Lanjouw, 1998; Schankerman, 1998; Arora *et al.*, 2003). Since the results correspond to different historic periods and geographical areas, they must be compared and interpreted carefully. Nevertheless, they confirm the importance of patent protection in Pharmaceutical and Chemicals, where the ESR are high. They also suggest that the patent returns on R&D funding may be higher than what the average patent value would let us expect in the Electrical Engineering field. They also highlight some fields where patent value has a very small place in total R&D spending, as in Aircrafts and Missiles.

Arora *et al.* (2003) provide evidence on the patent premium and its effect on R&D in various sectors. They find that although the average premium from patenting is negative when all industries are considered, it is positive in the sectors for Biotechnology (20% to 34% of the value of the unpatented innovation), Medical Instruments (14-22%), and Drugs and Medicines (5-11%). This implies that on average it is profitable to patent innovations in these sectors. The premium of patented innovations (or conditional premium) is very high in the sectors mentioned above, with 79% to 145% in Biotechnology, or 73% to 129% in Drugs and Medicines. Arora *et al.* (2003) find evidence of a positive impact of the patent premium on R&D in all fields. While on average a 10% change in patent premium would yield a 6% change in R&D spending, the impact would be significantly more important in Biotechnology (10.6%), Medical Instruments (9.7%), Drugs and Medicines (8.9%).

Table 4: The equivalent subsidy rates of patents by industries

	USA ¹ Early 1990's	France ²³ 1969-87	Germany ³⁴ 1953-88
Chemicals and Pharmaceuticals			
Drugs and medicines	22%		
Biotech	22%		
Industrial chemicals	14%		
Other chemicals	11%		
Petroleum refining and extraction	28%		
Food, kindred and tobacco products	2%		
Pharmaceuticals		4.0% [4.1%] ⁵	6.8% [15,2%]
Chemicals		6.7% [7.2%]	
Electrical Engineering			
Semi-conductors	23%		
Electronic components, excl. semi-cond.	13%		
Communication equipment	39%		
Other electrical equipment	34%		
Computers and other office equipment	8%		
Electronics (excluding Japan)		21.4% [35.4%]	
Computers			10.4% [12.5%]
Process Engineering			
Metals	23%		
Rubber products	19%		
Textiles			38.3% [75.4%]
Mechanical Engineering			
Machinery, excl. computers	20%		
Transportation (excl. Aircrafts)	17%		
Aircrafts and missiles	4%		
Mechanical		16.1% [29.9%]	
Engines			5.7% [11.5%]
Instruments			
Instruments (excl. Medicals)	16%		
Medical instruments	21%		

Sources: Lanjouw, 1998; Schankerman, 1998; Arora et al., 2005.

1) The study uses data from the Carnegie Mellon survey of U.S. R&D managers in the early 1990's (Cohen *et al.*, 2000).

2) The study uses data on patent applications and renewals in France, respectively for the periods 1969-1982 and 1969-1987.

3) In the cells of this Column, the first figure indicates the ESR calculated as a percentage of the R&D performed by the firms, including public funded R&D performed by the firms. The figures within brackets indicate the ESR calculated as a percentage of company-funded R&D only.

4) The study uses data on patent applications and renewals in Germany, 1953-1988.

5) These figures are surprisingly low for a sector like pharmaceuticals. As explained by Schankerman (1998), they probably reflect the specificity of the French pharmaceutical industry, which prices were tightly regulated at the time of the survey.

1.4. Policy issues

There is little evidence that the strengthening of the exclusive rights conferred by patents could foster innovation. A more reasonable policy option would therefore consist in reinforcing the effectiveness of patent protection, especially by reducing legal uncertainty and litigation costs.

a) From patent strength...

Since the incentives to innovate created by patents depend on the protection they confer, reinforcing the strength of patent protection could eventually foster innovation. However available empirical evidence suggests that beyond a certain level additional patent strength may be counterproductive and impede innovation.

Box 3: The stake of patent scope: the Myriad patent

(excerpts from S. Wallace, Public Health Genetic Unit, 26 January 2005)

"The European Patent Office, after conducting opposition hearings earlier this month, has announced that it will amend a BRCA1 gene patent (EP 705903) held by Myriad Genetics. The original patent related to 34 mutations in the BRCA1 gene sequenced from the human genome and diagnostic methods for detecting these mutations to show predisposition to breast cancer. The amended patent, according to the EPO, "...now relates to a gene probe of a defined composition for the detection of a specific mutation in the breast- and ovarian cancer susceptibility gene and no longer includes claims for diagnostic methods." [...]

The patent, '17q-linked breast and ovarian cancer susceptibility gene' was originally granted on 23 May 2001. Oppositions to the patent were filed by six different groups: the Institut Curie; Assistance publique – Hopitaux de Paris; the Institut Gustave Roussy; the Vereniging van Stichtingen Klinische Genetica, Leiden, the Netherlands; the Netherlands represented by the Ministry of Health; and Greenpeace Germany. Their concern was that the patent, with the others that had been granted to Myriad for the BRCA1 and BRCA2 genes), were too restrictive, giving a virtual monopoly on genetic testing to Myriad. Myriad were requiring that all samples be sent to their laboratories in the US for analysis at a fee of over \$2600 (approximately £1380). European laboratories had developed their own methods of BRCA1 testing and did not want to have to pay Myriad for analysis. In addition some argued that Myriad's test was not completely effective in finding large DNA deletions or rearrangements [...].

Whether in response to these arguments or other factors, the EPO has been backing off from its original decisions. Last year, the EPO revoked Myriad's first patent (EP 699754) for methods to diagnose a predisposition to breast or ovarian cancer using the normal BRCA1 sequence (as opposed to any mutated sequences) [...]. In February 2004, EPO granted a patent to Cancer Research UK for the BRCA2 gene, although Myriad also has a BRCA2 patent [...]. Now it appears that the broader community will be able to provide genetic tests for BRCA1 mutations without challenge, although Myriad is entitled to contest the opposition division's decision in this case."

The strength of patents can be increased with two policy levers: the duration of patents and their scope. In most patent systems patentees choose the patent duration. To do so, they have to pay renewal fees to extend the life of their patents up to a maximum of twenty years. The duration of patents could thus be increased by lowering the renewal fees or increasing the maximum duration. The scope of patents is determined by the formulation of the claims and their interpretation in court. For a given innovation, claims can be written in restrictive or in more general terms (see Box 3 for a case study), the latter providing exclusive rights on a wider range

of substitute or derived innovations. In case of patent litigation courts can in turn be more or less friendly vis-à-vis patent holders. For example, the *doctrine of equivalents* favors a general interpretation of the claims rather than a restrictive one (Merges & Nelson, 1990). In the U.S. the creation of the Court of Appeal of the Federal Circuit in 1982 has more generally resulted in decisions that were more frequently favorable to patentees against alleged infringers (Jaffe, 2000).

Economic literature does not permit to make a case for increasing patent protection. The theoretic findings emphasize the need to trade-off the incentive power of strengthened patents with the additional social cost that they may induce for consumers (Gilbert & Shapiro, 1990; Klemperer, 1990; Gallini, 1992). The empirical literature on the link between patent strength and innovation is scarce. It does not find clear evidence that an increase in patent strength would necessarily foster innovation (Jaffe, 2000; Gallini, 2002). Kortum and Lerner (2001) test empirically different possible causes for the surge in patent applications in the U.S. during the 1980's. They find that the increase in patenting is not due to the strengthening of patent protection during this period, but rather to a better productivity of R&D. In another empirical work Sakakibara and Branstetter (2001) find that the 1988 Japanese patent reforms did not foster innovation. These reforms expanded the scope of patent rights in an advanced industrialized economy. Sakakibara and Branstetter (2001), however, find no evidence of a statistically or economically significant effect of these reforms on firms' R&D spending or innovative output. Lerner (2001) studies how 177 policy shifts in 60 countries over 150 years have affected the number of patent applications. He measures patent strength with four indicators:

- whether protection existed in whole or in part for important technologies,
- the duration of the patent,
- the patent fee,
- the existence of various limitations on patent awards (for example, compulsory licensing).

He finds support for an inverted-U relationship between patent strength and innovation. This implies that beyond a certain threshold, increasing patent protection would actually be detrimental to innovation².

b) ... to patent effectiveness

Besides the scope and duration of patents, the incentives to innovate created by patents may depend on their effectiveness (Arora *et al.*, 2003). This includes the cost and delay of obtaining and enforcing patent protection, and the degree of certainty about the expected outcomes of

² The main reason why stronger patents may impede innovation is that early patents may dissuade follow-up innovations (Scotchmer, 1991). This point is developed in Section 4 of the Report.

patent litigation.

The costs of filing and enforcing patents are a first obstacle that may limit the incentive power of patents. An innovator’s decision to patent depends on a comparison between the expected benefits and the costs of obtaining a patent. Once the patent has been granted, the decision of suing an eventual infringer in turn depends on the comparison between the expected costs and benefits of litigation. Table 5 presents estimations of these costs in Europe and the United States. The fees paid to the patent offices are relatively low and symmetric. The legal and litigation costs are the main cost obstacle to the enforcement of patents. They are clearly higher in the United-States.

Table 5: Estimated Patent Costs in the United States and Europe

	United States	Europe
Application	\$34,000	\$22,903
Fees	\$4,000	\$4,624
Legal costs	\$30,000	\$5,914
Translation	NA	\$12,366
Renewal (10 years)	\$6,000	\$9,140
Re-examination/Opposition		
Fees	\$2,520	\$1,075
Legal costs	\$10,000-\$100,000	\$21,505
Litigation	\$0,5-\$3M	\$54K-\$540K

*These fees are for non-small entities

Numbers are in 2002\$, using an exchange rate of 0.93 euros to the dollar.

Source: Hall, Graham, Harhoff, Mowery, 2004.

Uncertainty about the validity and scope of patent rights is another factor that may weaken the incentives to innovate. Although the capability of patentees to enforce their rights depends on the cost of litigation, this cost shall not be incurred at all if patent protection were really effective. Economic theory indeed predicts that parties sharing the same expectations about the outcome of litigation will prefer to settle an agreement before incurring any litigation cost. As a matter of fact only a few patents are actually litigated and most of the cases are settled before the court has made a decision (see Box 1). Litigation may nevertheless occur when stakes are high – which explains why more patents are litigated in Pharmaceuticals and Biotechnology (Lanjouw and Schankerman, 2001) – or when parties have divergent expectations about the litigation outcome. Such divergent expectations are likely in new technology fields, but also when the validity or the scope of the patent is uncertain. Such uncertainty may weaken the patent premium expected by innovators. It may also favor the creation of undue market power, if firms settle “in the shadow” of weak patents (Shapiro, 2005). Therefore patent offices should minimize the granting of *probabilistic patents* (Bessen and Meurer, 2005). This can be done by enforcing carefully the patentability requirements, by delineating clear patent claims, and by

using efficient post-grant opposition mechanisms⁴. Note however that *ex post* invalidation of patents through post-grant opposition and litigation may be socially more efficient than *ex ante* examination: They concern only a small number of important patents, and therefore spare the cost of challenging a large number patents for a weak social benefit (Lemley, 2001). The duration of patent examination is another policy lever to reduce uncertainty, conditional of maintaining the quality of examinations. Until the patent has been granted the protection conferred is indeed uncertain and thus less effective. In Europe the existence of parallel national litigation circuits is a third factor of legal uncertainty, which the creation of a unified second degree jurisdiction could help to reduce.

⁴ Such mechanisms allow third parties to contest the validity of a patent just after it has been granted by the patent office. The patent is then re-examined by the office examiners who can be eventually invalidate it. Empirical studies find that the European post-grant opposition system is much more effective than the U.S. system (Graham *et alii*, 2002).

Chapter 2.

Information disclosure

2.1. Introduction

Although the emphasis is generally put on the protection conferred to innovators by patents, the disclosure of granted patents is another key function of the patent system. Patent law requires that patents be disclosed within a maximum delay of 18 months after application. The disclosure concerns the whole patent, namely the description of the invention and the formulation of the claims that delimit the scope of the exclusive rights. As a result at least four different types of information go public:

- information on the fact that the technology exists and has been patented;
- information on who developed and patented the technology;
- information on what is the technology;
- information on the scope of the protection.

According to Ordovery (1991), disclosure has not the same importance in all patent systems. Each patent system strikes a particular balance between exclusion and diffusion or, put differently, between the protection of information and the disclosure of information. This balance is defined by a set of rules that determine the scope and strength of patent protection on the one hand, and the timing, extent and quality of patent disclosure on the other hand. Ordovery (1991) compares and contrasts these rules in the Japanese and American patent systems in the early 1990’s. He shows that the Japanese system is geared towards diffusion in that it encourages quick patent filing and disclosure. In contrast, disclosure requirements are low in the American system while protection is very strong. Table 6 summarizes this comparison and extends it to the European patent system, which appears to be in an intermediate position between the 1990 U.S. and Japanese systems.

Table 6: Exclusion and diffusion in the U.S., European and Japanese patent systems in 1990

	American system	European system	Japanese system
Rule of priority_	First to invent	First to file	First to file
Disclosure deadline_	Patent grant	18 months after application	18 months after application
Scope of protection	Large	Medium	Narrow

_ The rule of priority determines who will obtain a patent in case two inventors apply for a patent on similar innovations. Under the first to invent rule, the patent is awarded to the applicant who was the first to develop the invention, while under the first to file the patent is awarded to the first inventor who filed a patent application at the patent office. While the first rule may seem fair, the second one encourages rapid patent filings. Therefore it favours an early disclosure of innovations.

_ In the Japanese and European patent systems, applicants are required to disclose their patent application 18 months after having filed the application. Before the American Inventors Protection Act of 1999, U.S. patent law stated that innovators had to disclose their patents only upon issuance of the patent, which both increased the delay of disclosure and limited the disclosure to accepted applications.

Why should a patent system be geared towards diffusion? The purpose of this chapter is to present a general view of the impact of patent disclosure on innovation. As presented in a first section the information disclosed through patents constitutes a public good that can benefit other

economic agents than the patentee. Such information is especially useful for firms to make strategic R&D decisions and can therefore improve the general efficiency of R&D investments. In a second section we present another economic function of patent disclosure, namely the use of patents as a signaling mechanism. In this case firms file patents to emit credible information, especially towards capital markets. We finally consider the policy implications of our findings and review the main policy initiatives that have been taken in this matter.

2.2. Patent disclosure as a public good

a) Theoretical insight

We have seen previously that innovations may be analyzed as information goods. Indeed they are ultimately made of *non-rival* information which, once disclosed, can be used indefinitely at no cost without being destroyed or exhausted. This feature of the patented innovation applies to the technology itself as well as to all other types of information that go public through patent disclosure, for instance the fact that the innovation exists and is patented.

Insofar as this information can be accessed to and used for free by other actors than the patentee itself, its value to the society is higher than its value to the patentee. This raises the classical economic problem of the provision of non-rival goods. Indeed there may be no benefit to the innovator in disclosing information. There may even be a loss for the patentee if competitors can use the disclosed information to circumvent a patent or copy its technology. As a result the innovator has no private incentives to reveal the information in a way that maximizes the benefit to society.

According to this perspective, patents can be seen as a contract between the innovator and the society, where the exclusivity conferred by the patent is the price paid to have the innovator disclose her innovation. The more protection granted, the more information innovators will accept to disclose (Denicolò and Franzoni, 2003).

b) Patent information and technology management

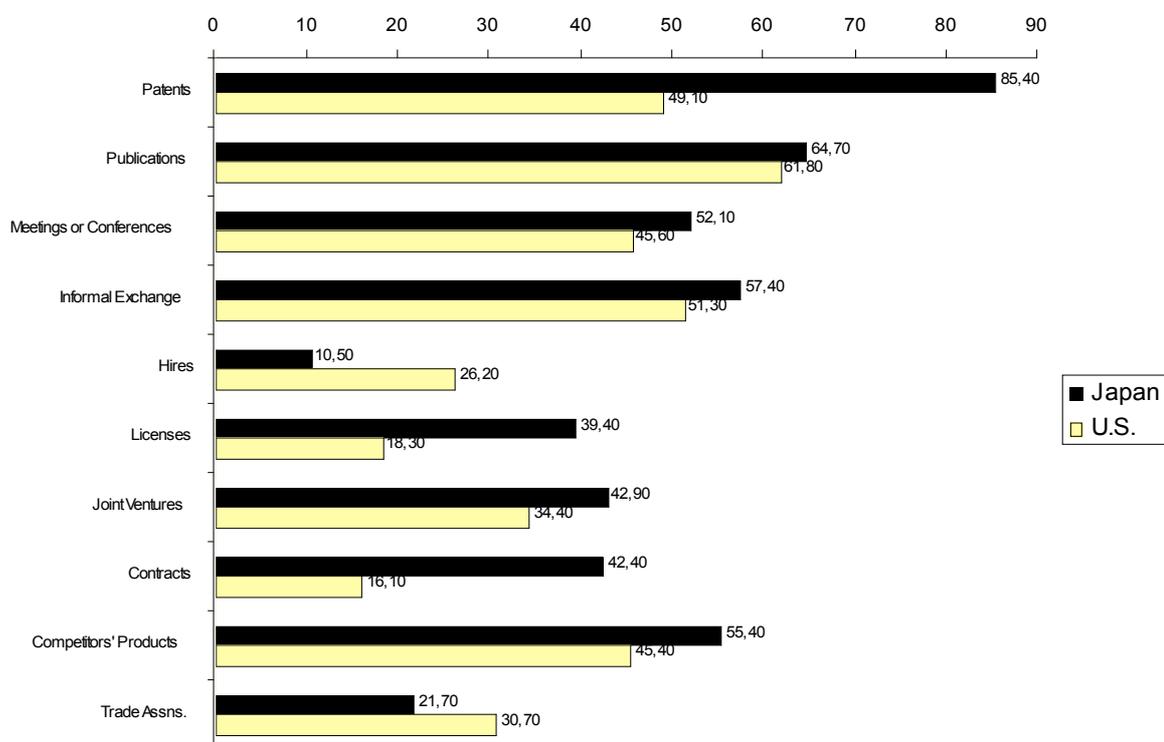
The information disclosed through patents is valuable to economic agents in that it helps them to make decisions. Firms can especially use patent information to improve their strategic planning of technology (Ernst, 2003).

Patent disclosure and strategic information

The results of a survey of 3240 U.S. and 1919 Japanese R&D performing firms highlights that firms largely rely on patents as a channel of information on rivals' R&D (Cohen *et al.*, 2002). Figure 7 represents the importance of the different channels of information on competitors as

perceived by the respondents. Patents are clearly the first information channel for Japanese respondents, 85% of which labeled it as ‘moderately’ or ‘very’ important. The ranking is different in the U.S., where respondents identified publications (62%) and informal exchange (61%) as their main information channels, patents coming third with 49%. The higher importance given to rival firms as an information source in Japan seems to reflect the higher ranking of patents as an information channel in this country. Most information flowing through patents is not market mediated. Indeed Figure 6 indicates that information circulates through patents much more than through licenses, which suggests that a large portion of information contained in patents is conveyed by public disclosure (Cohen *et al.*, 2002).

Figure 7: Importance of sources of information on rivals' R&D



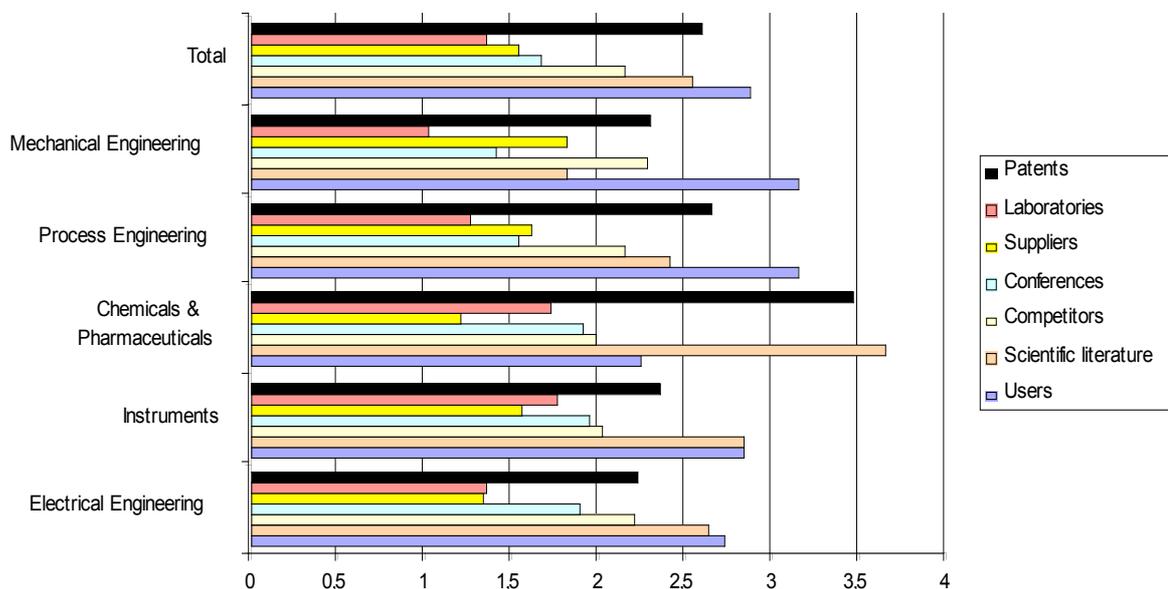
% of Respondents Indicating Source/Channel ‘Moderately’ or ‘Very’ Important. Source: Cohen *et al.*, 2002.

The same survey highlights the weight of such strategic considerations in decisions relating to R&D investments. Indeed 41% of American respondents and 48% of Japanese respondents reported using their competitors as information sources for suggesting new projects. There were also 13% (U.S.) and 51% (Japan) who reported using competitors as information sources for contributing to completion of existing projects. A large fraction of firms thus use information from competitors to make decisions on R&D investments, although the figures also suggest that Japanese firms have a more intensive use of such information than their American counterparts.

An OECD survey of 105 firms located in Europe, the U.S. and Japan confirm the role of patents as a source of strategic information (Guellec *et al.*, 2004). Among respondents, 88% report that

the information disclosed in other firms' patents are useful for designing and implementing their own R&D strategy. Moreover 44% believe that the usefulness of information disclosed in patents increased over the last decade, while only 5% think the opposite.

Figure 8: Importance of different sources of knowledge. Distribution by technological field



Source: Gambardella *et alii* (2003)

The PatVal survey of European patents highlights the importance of patent information in different technology fields (Gambardella *et al.*, 2003). Various source of knowledge are weighed according to a scale from 1 to 5 in function of their importance for respondents (Figure 8). Patents are always the second or third most important information channel behind users and/or the scientific literature. Patents are especially important in Chemicals and Pharmaceuticals, just behind scientific literature and far ahead the other channels. The rankings of information sources appear to be similar between different categories of respondents, except firms tend to rely more on patents than universities and other public research institutions.

Patent information improves the efficiency of R&D

How do firms use the information on rival's patents and how does it affect innovation? Although there is little empirical evidence available, the economic literature explores how patent disclosure can affect the organization of innovation. Information disclosed through patents can help firms make more efficient R&D investments, yet it may also have some adverse effects.

- Information on patents firstly allows firms to better orient their R&D investments. Lerner (1995) reports that U.S. biotech firms with high cost of litigation avoid research

areas where other firms already have patents, especially when the latter have low litigation costs. Early disclosure of patent applications also permits firms to avoid the risk of infringing *submarine patents*². In both cases firms can devote their R&D resources to research areas that remain unexplored. This, from a social efficiency standpoint, also permits to save useless duplications of R&D costs. To the contrary, patent information can also play a key role in selecting new investment opportunities in pioneer technology fields. Ernst (2003) develops, for instance, a methodology to identify future technological and commercial opportunities by mapping competitors' patent activities. However, firms can also use patent disclosure to mislead their rivals (Langinier, 2005). They can, for instance, file numerous useless patents and accumulate patent claims to hide where the valuable innovation lies.

- Firms can also use patent information to avoid investing in R&D when this is not necessary. Since the patent system allows them to screen the state of the art in a given field of science, they can use it to detect technologies which they need for their own R&D projects. If the price of such patented technologies is lower than the cost of developing equivalent solutions in house, they can save money by deciding to buy – through the acquisition of a patent, of a license or even through a merger – instead of innovating themselves. Such decisions increase the economic efficiency in two ways: they avoid useless R&D cost duplications, and they reinforce the profits, and hence the incentives to innovate, of innovators (Lévêque & Ménière, 2004).
- The technical knowledge that is disclosed through patents can finally be used by other firms without being market-mediated. Empirical evidence based on patent citations suggests that such *knowledge spillovers* are more likely when firms are geographically close (Verspagen & Schoenmakers, 2004) and located within the same country (Branstetter, 2001). Knowledge spillovers have a positive effect on innovation but they must be traded-off with patent protection and the incentives to innovate. In a survey of U.S. R&D managers (Cohen *et al.*, 2000) 46.7% of respondents report that disclosure is a reason not to patent some innovations and 24.3% of them consider that disclosure is the most important reason not to patent. In a theoretical model Aoki and Spiegel (1999) find that early disclosure rules can reduce the incentives to innovate and hence the number and quality of patented innovations, if they are not compensated by a stronger protection. Bessen (2005) also shows that in some cases technology diffusion may be stronger in absence of patent protection.

²Submarine patents are patent applications which are intentionally delayed by applicants until a similar idea is commercialized by someone else. See Aoki & Spiegel, 1999.

Box 4: Patent information in management of human resources and of knowledge

Besides informing firms about the innovative activities of their competitors, patents may help them monitor and manage their own inventive activities. Ernst (2003) identifies various ways in which patent information can facilitate human resources management and knowledge management.

Concerning the management of human resources, patent counts provide an indicator of the productivity of employees involved in innovative activities. They can therefore be used to set up a system of incentives where rewards are indexed on patents. Patent counts also permit to sort out different categories of employees in function of their productivity. They especially facilitate the identification of key inventors, who constitute a scarce human resource. In a study of more than 200 inventors in 43 firms, Ernst *et al.* (2000) concluded that 6.9 percent of them contribute to 25% of a firm's patenting output. Patents are a way to provide the right incentives to such innovators, but also extract, codify and store their tacit knowledge, and to facilitate early succession arrangement in case they are leaving. Moreover, patent information also provides a good tool for head-hunting such innovators.

2.3. Patent disclosure as a signal

The diffusion of patent information can be beneficial not only to third parties but also to patent holders. Indeed they can use the patent system as a certification mechanism to emit credible information towards other actors through patent disclosure (Long, 2002).

a) Theoretical insight

The lack of reliable information is a frequent cause of market failure. This is for instance the case with financial markets: when investors do not have enough reliable information to sort out good and bad investments projects, it is likely that they will not engage even into what would have been a good project. This *adverse selection* issue, whereby valuable transactions cannot take place because of asymmetries of information between parties, also applies to R&D and technology. It is indeed difficult to estimate the outcome, and hence the performance, of R&D investments, while firms may need to provide such information to financial or industrial partners.

Patents then provide a useful indicator of innovators' performance. This indicator is credible since patents are granted only to innovations that satisfy the legal patentability requirements and after examination by an independent body, namely the patent office. In this view the patent office can be compared with a rating agency in financial markets: it produces certified indicators that will help the firm to open a market by signaling its quality to potential partners.

b) Patents as signals towards financial investors

Firms use patents as a signal principally to attract financial investors (Long, 2002; Lemley, 2001). The value of patents as a signal, however, depends on the quality of the information emitted through patent disclosure.

Signaling financial value

Patenting the outcomes of their innovative activities is a way for firms to communicate vis-à-vis financial investors. Indeed capital markets use firms' patents as indicators of their inventive activities. They usually assume that patents are correlated with companies' capacity to innovate, but also with less observable characteristics such as the knowledge capital or the level and productivity of R&D spending (Long, 2002). Such assumptions seem reasonable. Hall *et al.* (1986) find a strong correlation between R&D expenditures and patenting in the U.S. manufacturing sector during the 1970's. In another empirical study of 120 firms between 1968 and 1975, Pakes (1985) finds that 76 percent of the variances in the size of patent portfolios among firms in the same industry can be explained by research-related events that cause changes in the market value of the firms. This implies that patent portfolios can be used as a benchmark to compare firms' research activities within an industry.

Since capital markets use patents as indicators, patents become a determinant of the firms' value. Pakes (1985) finds that an unexpected addition of one patent to a firm's patent portfolio induces an \$810,000 increase in the market value of the firm. In a more recent empirical study on 4800 U.S. manufacturing firms in the period 1957-1995 Hall *et al.* (2000) find that "an increased yield of one patent per million of R&D is associated with a two percent increase in the market value of the firm".

Attracting venture capital

Although there is little empirical evidence on that subject in the literature, patents also seem to constitute a key condition for start-up firms to attract venture capitalists (Lemley, 2000; Long, 2002, Kamiyama *et al.*, 2006). Venture capitalists consider high-value patents as one of the most important factors in investment decisions, especially at an early stage (Hayes, 1999; Kamiyama *et al.*, 2006). The filing of patents indeed indicates that the start-up has reached a certain stage of development (Martinez *et al.*, 2006). It signals good management and the fact the start-up has "defined and carved out a market niche" (Lemley, 2000). In this context, start-ups have specific incentives to file patents. This may explain why, in two empirical studies led respectively in the U.S. semi-conductor industry (Hall & Ziedonis, 2000) and in the U.S. manufacturing sector (Mansfield, 1986), start-ups appear to have a higher propensity to patent than other firms (Long, 2002).

Box 5: Case study (exerpts from WIPO at http://www.wipo.int/sme/en/case_studies/fk_biotec.htm)

"In 1999, FK Biotecnologia S.A. became the first Brazilian biotechnology firm to receive venture capital for the development of its innovative technologies. Since then, the company has grown at a steady pace and is considered a pioneering example of a successful biotech start-up in Brazil. Patent protection and patent information have been important elements of [the company's] business strategy.

FK [Biotecnologia S.A.] was established in CIENTEC, a technology incubator in Southern Brazil, and focuses on research, development, production and distribution of immunodiagnostics kits. In May 2001, the company received authorization from the Health Ministry to begin the commercialization of its immunodiagnostics kits, and its product line currently comprises over 70 items. Fernando Kreutz, Medical Doctor with a Ph.D. in Biotechnology and founder of [the company], estimates that the Brazilian market for immunodiagnostics currently amounts to US\$1 billion and depends almost exclusively on foreign imports or licensed foreign technology. This represents a great opportunity for future expansion.

But [the] most important technological development of [FK Biotecnologia S.A.] has been in the field of vaccines for cancer. The company is currently developing "an experimental vaccine composed of cancer cells, that work as medical treatment as they are capable of stimulating the immunological system to fight against cancer", says Kreutz. The technique is similar to the one used in many countries for the development of vaccines against melanomas and was developed in cooperation with local hospitals and universities. While the treatment is still at an experimental stage and Kreutz believes it will be some time before it may be commercialized, it has already been the object of an international patent application via the Patent Cooperation Treaty (PCT).

Kreutz believes his company's know-how, ability to develop new technology and its patent application have played a crucial role in motivating investors, government funds and venture capitalists, such as the Companhia Riograndense de Participações (CRP) and an unnamed Canadian venture capital investor, in investing in FK biotec. To a large extent, it is a high-risk enterprise. The treatment must still undergo clinical trials before it can be commercialized, but the promising results obtained in the laboratory and the exclusive rights granted by a patent are the basis for investing in the development of the new vaccine.

Fernando Kreutz is also an avid user of patent databases. "I am very surprised with the amount of knowledge I am getting from patent documents" he points out. "Knowing the legislation and regulations has been a differential for my company. Access to the information has been my biggest problem, but with the Internet things have become easier." FK relies significantly on patent information for identifying new technologies, niche markets and potential licensors from which to acquire leading technologies."

2.4. Policy issues

The efficient diffusion of patent information depends on patent offices at two levels. First, patent offices manage the disclosure and diffusion of information to users. Second, patent examiners also control the quality of patent information.

a) Ensuring access to disclosed information

It is the role of the patent offices to ensure the dissemination of information on a large scale and in good conditions. The context and modalities of this dissemination have deeply evolved during the last decades. On the one hand, information has become more difficult to manage. It has become more complex, thus necessitating more sophisticated methods (Schoch-Grübler, 2004). With the explosion of the number of patents, the quantity of information to deal with has also increased (Philipp, 2006). On the other hand, information users have evolved. In a context

of global competition and innovation, inventors have to know the state of art in the most remote areas (Schoch-Grübler, 2004). With increasing patenting from universities in the trail of Bay-Dole Act-type regulations and a more widespread use of patents in general, the users of patent information have also increased in variety.

Information technologies have proved a powerful tool to tackle these challenges (MacMaster, 2005). Before the 1980's, patents were disclosed in paper version only. During the 1980's commercial service providers began disseminating patent information by providing on-line bibliographic and full-text searchable access. In turn, major patent offices started cooperating at an international scale in order to improve patent processing and information dissemination through standardized IT tools. Such investments proved successful in the 1990's as patent examiners and users became widely equipped with PCs. Finally, the deployment of the World Wide Web and high speed wide-area networks permitted patents offices to offer free of charge Internet based information and search services to the public. During this process the conversion of patent information into digital data has required large investments, which have now been completed (MacMaster, 2005). The new priority of the offices shall thus be to adapt patent information diffusion to the specific needs of their users.

As a consequence of the increased use of information technologies to disseminate patent information, the technical competences required from users have also increased. Experienced users like large companies can afford investing in such competencies or buying the services of private sector information providers. In a cross-section survey of the use of patents as information channels in Europe Arundel and Steinmueller (1998) find that the probability of using patent databases increases with firm size and R&D investments and that it is higher among firms that consider patents as an effective appropriation mechanism. In contrast, smaller users, mostly small and medium enterprises, still have difficulties to access patent information under good conditions (Ebersole, 2003; Pilch & Shalloe, 2005). This problem has to be addressed by patent offices.

- Patent offices must strike a balance between their diffusion activities and the more innovative activity of private sector information providers (Ebersole, 2003). Patent offices generally diffuse free of charge information, while private sector providers supply complementary information with value-added services. When the value-added services proposed by providers are not affordable to all categories of users, patent offices can restore the balance by supplying their own services free of charge. The problem is that such a competition may discourage private providers' investments. Patent offices must thus set clear perspectives and maintain a close coordination with private sector providers (Ebersole, 2003). They could also apply differentiated tariffs in

function of the users or even contract directly with private sector providers to promote a wider access to the latter's services.

- A complementary policy consists in improving the capacity of small users to manage patent information. Patent offices have already developed training programs in this purpose. In a comprehensive survey of the patent offices best practices in intellectual property information dissemination, MacDougall (2003) shows that such training policies principally target small and medium enterprises.

Box 6: Patent translation and information diffusion

The current European patent system, as defined by the 1973 Munich Convention, principally consists of a European patenting circuit allowing innovators to file a unique patent application at the European Patent Office. If the application is accepted, the innovator can claim a patent for each European country, without any additional examination. This system was meant to reduce the cost of patenting by suppressing the duplication of examinations. However it remains costly because innovators have to translate their patents in national languages. Applications at the European Patent Office (APO) must be written in one of the three official languages of EPO, namely, English, French and German. If they are accepted, patents must also be translated in the two other official languages, and in the official language of each country where the innovators claims a patent. As a result, an average European patent (activated 7 in countries) costs 7,000 euros in translations (EPO, 2006). This is also the main reason why a European patent costs on average 24,100 euros (including in house and external costs) to its holder, against 10,250 euros for a U.S. patent and 5,460 for a Japanese patent (Roland Berger, 2005).

Several reform projects, such as the project of Community Patent and the London Protocol, aim at reducing the cost of translation of European patents in national languages. From an economic standpoint, this question must be tackled in terms of information diffusion (Lévêque & Ménière, 2006). The cost of translating a patent into another language should be incurred only if it is outweighed by a larger social benefit in terms of information diffusion. This does not seem to be the case for most translations, not to say all, are not read. In fact, translations are only available several years after the patent issuance. This delay is too long relatively to the path of the technological change. The monitoring of innovations from competitors is made through the reading of European patent applications and European patent grants in the original language, mostly English.

b) Quality of disclosed information

Besides the dissemination of patent information, patent offices have to ensure the quality of the disseminated information. Indeed the information disclosed through patents is economically worth only if the patentability requirements are rigorously applied.

The patent surge that took place during the last two decades corresponds partly to an increase in the number of patents for a given amount of R&D spending (Jaffe, 2000; Hall & Ziedonis, 2001). Since the additional patents protect minor inventive steps, they tend to dilute the informational value of patent disclosure. This can weaken the signaling function of patent disclosure by loosening the correlation between the number of patents and the innovativeness of firms (Long, 2002). This can more generally weaken the social benefit of patent disclosure. In case of litigation courts are likely to invalidate doubtful patents. The rights they confer are only probabilistic (Lemley & Shapiro, 2005), which blurs the information firms would like to rely on when making strategic R&D decisions. In some cases firms may even find it profitable to file

and disclose weak patents in order to mislead their rivals (Choi, 1998; Langinier, 2005).

Maximizing the value of patent disclosure necessitates producing credible information by examining patent applications rigorously. This is especially true in the U.S., where the non-obviousness patentability requirement has been enforced loosely since the 1980's (Jaffe, 2000; Barton, 2002; FTC, 2003). Moreover the low quality of patent information may in turn become a cause of the low quality of patent examinations, thereby feeding a vicious circle (Philipp, 2006). Indeed the quality of patent examination largely depends on the knowledge of prior art, which mainly consists of previous patents in the technical fields.

Chapter 3. Technology transfers

3.1. Introduction

Facilitating technology³ transfers is a major economic function of the patent system. As any property rights, patents can be exchanged. They also provide the legal framework for trading technologies via licensing contracts. The resulting transfers allow a wider diffusion of innovations. They also generate additional revenues to licensors, which in turn increases the value of patents, and therefore the incentives to innovate.

We discuss in this chapter the links between patents, technology transfers and innovation. For simplicity of exposure, we focus as a first step on transfers that are directed to simple users, who do not use the technology as an input for their own innovative activity. We will discuss separately, in Chapter 4, the role of technology transfers in the organization of R&D when innovation is cumulative.

The chapter is organized in three Sections. We firstly present the main theoretic insights on patents, technology transfers, and innovation. We then review the relatively scarce empirical literature on the functioning of markets for technology, and present empirical evidence of their expansion in different technology fields. We finally discuss policy issues.

3.2. Theoretical insights

The legal exclusivity conferred by patents on innovations is the necessary condition for their trade.

a) Patents allow disclosure for marketing purpose

Technology consists mostly of information, and it can therefore be traded in a disembodied form. The trading of disembodied technology is however compromised by the *non-rivalry* of information. Indeed, once the valuable information has been disclosed, potential buyers can use it directly and do not need to buy it anymore. And still, disclosing information to potential buyers is necessary to let them assess its value prior to any transaction. Paradoxically, information disclosure is at the same time the condition and the obstacle to its trade (Arrow, 1962).

Patent law solves this paradox by conferring exclusive rights on innovations. A clear definition of property rights allows the patentee to disclose her innovation to potential buyers without the risk of being robbed of it. Patents thereby prevent the transaction failure. Recall moreover that the disclosure of patents informs potential buyers about the availability and nature of

³ We use here the terms “technology” and “innovation” indifferently, although an “innovation” can be understood in a more restrictive way as a newly-developed technology.

innovations⁴. Finally the patent provides the legal basis for the transfer of innovations, either through a licensing contract or through the sale of the patent itself.

b) Technology transfers improve static and dynamic efficiency

Technology transfers can improve economic efficiency in two ways. Firstly, markets for technologies are a factor of static efficiency in that they facilitate the diffusion of innovations and the division of labor. Secondly, they improve dynamic efficiency. Indeed licensors can appropriate a part of the profit generated by the static efficiency gains of licensing, which in turn reinforces their incentives to innovate.

The economic literature has identified various ways in which licensing innovations or selling patents can improve static efficiency and, as a result, the licensor's profits and incentives to innovate. Here are some general examples:

- Licensing can save R&D cost duplications (Gambardella, 2002). Firms facing a specific need for a given technology can identify a patented technology that performs the same function. They can then license it instead of developing an equivalent technology in-house. In this case the licensor will accept to pay any price below the expected cost of duplicating the technology. The saved duplication costs represent a first static benefit. The licensor's additional profits in turn constitute a dynamic benefit, because they increase her incentives to innovate.
- Licensing facilitates specialization and the division of labor (Arora & Gambardella, 1994). This is the case when the firm that developed an innovation does not have the capability to exploit it at the least cost. Delegating the exploitation of the innovation to a specialized firm via a licensing contract can then be a way to create an additional profit which both firms will share. Since this division of labor reduces the cost of exploiting the innovation, static efficiency is improved. Moreover the share of the additional profit that goes to the licensor via the royalties paid by the licensee increases the incentives to innovate.
- Licensing also facilitates the exploitation of a technology as a commodity, at a larger scale than if the patentee did it alone. This is for example the case when a firm licenses a patented process to competitors or to firms in another industry. Since a more efficient technology is more widely diffused, this improves static efficiency to the benefit of firms and, eventually, of consumers. Licensing also allows the exploitation of a technology on a larger geographical scale, in countries or regions where the patentee does not operate. In both cases, static efficiency improves. As a result the product will be supplied to a larger number of consumers, which also enhances static efficiency.

⁴ See Chapter 2, Section 2.

In all these examples, the increase in incentives to innovate created by technology transfers depend on the licensor's capability of appropriating the static benefit of the transfer. Incentives can in particular be reinforced by the licensor's ability to discriminate the licensees by tailoring specific contracts for each of them. An important part of the literature explores how the design of licensing contracts can be fine-tuned to maximize the expected profit of the licensor – and hence her incentives to innovate – in various circumstances⁵.

3.3. Functioning and expansion of technology transfers

Empirical evidence confirms that patent protection is an important condition for technology transfers to take place. To our knowledge, there is no literature on direct evidence of the impact of such transfers on the level of innovation. Empirical studies, however, show that the trade of technology is expanding, thereby improving the diffusion of innovations in many industries, and increasing the innovator's profits.

a) Impact of patent protection on technology transfers

Empirical evidence confirms that a strong patent protection facilitates technology transfers. However, it also shows that transaction costs remain which still limit patent-based technology transfers.

Effective patent protection can facilitate transactions and vertical specialization

Although it is not always the case, the strength of patent protection may positively influence an innovator's decision to license new technologies. Strong patents reduce the risk of opportunistic behavior by the licensee (Merges, 1998, Arora and Merges, 2003). They also reinforce the licensor's bargaining power and therefore enable him to appropriate a larger share of the total surplus generated by the licensing deal. In an empirical study of 11 839 alliances with licensing content in the OECD area, Vonortas and Kim (2004) find that a strong intellectual protection in the primary line of business of the licensor has a positive impact on her propensity to engage in licensing agreements. In an empirical study based on the European PatVal survey Gambardella *et al.* (2006) find similarly that the probability of licensing is greater when patents offer a greater protection.

The positive effect of patent protection on licensing actually seems to be conditional on the type of technology. In an empirical study based on a 1994 survey of U.S. R&D managers, Arora and Ceccagnoli (2005) find that this effect is ambiguous and depends on whether the innovation is

⁵ See, for instance, Kamien (1992) or Sen (2005) for a survey.

also protected by complementary sales or manufacturing (see Figure 3 in Chapter 1). If it is not the case, the innovation consists of *pure* disembodied knowledge and can be protected only by intellectual property. Arora and Ceccagnoli (2005) find that an increase in the effectiveness of patent protection⁶ increases the inventor's licensing propensity when few or no complementary assets are necessary to bring the technology to market. In other words, there is more licensing of *pure* disembodied knowledge when firms consider patent protection as effective. In contrast, an increase in the effectiveness of patent protection rather decreases the inventor's licensing propensity when complementary assets are necessary to bring the technology to market. In this case, the technology is already protected by complementary sales or services. Firms then react to an increase in patent protection by filing more patents and they prefer direct commercialization to licensing.

Box 7: Technology transfers in the chemical industry

Before WW1, the chemical industry was dominated by German firms, principally organic dyestuff companies. These market leaders used combined patent and secrecy to deter entry and preserve their dominant positions in their domestic and foreign markets. After WW1, the emergence of new competitors such as Du Pont and ICI did not really increase competition. Firms organized in cartels at a global scale. Such "gentlemen's clubs" were market- or technology-based. They were often initiated by patent holders which, like Solvay with its ammonia-soda process, used licensing contracts with cartel members to maintain market shares, deter entry, and obtain the grant-back of improvements on their processes.

Due to the inter-firm diffusion of technology promoted by governments during the WW2, markets were much less concentrated in the post war. The post-WW2 era also witnessed other important changes that led to the development of large markets for technology.

A new type of firm appeared that specialized in plant design and the development and sale of process technologies. Such specialized engineering and construction firms (SEFs) were initially sub-contractors of oil companies. They have been particularly active in areas such as catalytic processes and engineering design improvement. They did not have the assets required to commercialize their innovations themselves, and therefore used to license their innovations. For the period 1960-66, SEFs accounted for about 30% of all licenses for processes. (Freeman, 1968). For the period 1970-90, the largest 110 SEFs accounted for over half of the total licenses granted in refining and petrochemicals (Arora & Gambardella, 1992). The activity of SEFs has affected the market structure of the chemical industry in two ways. By relying on patents to license their innovations, they firstly initiated a division of labor in process innovation (such a division of labor in product innovation was more difficult since innovators needed close link with downstream buyers and capabilities to undertake market development). By supplying complete packages of core technology, engineering design and know-how, and contract construction services, they also facilitated the entry of new firms in the industry, thereby increasing competition on product markets.

Chemical producers reacted to the SEFs' licensing activity by developing their own licensing strategies. For the period 1980-90 the share of plants involving an explicit reported licensing transaction varies from about 60% for Petrochemicals to about 15% for Pharmaceuticals. More than 80% of these transactions concern firms that are not linked through ownership ties. Besides SEFs, chemicals producers account for more than half the licenses sold to unaffiliated firms. The main licensors include large Chemicals companies such as ICI in ammonia, Union Carbide in polyethylene/polypropylene and air separation technologies, Montecatini in polypropylene and Mitsui in polypropylene, and oil companies like Shell, Mobil, BP and Amoco in refining and petrochemical technologies. Licensing seems more frequent in sectors with large scale production facilities, with relative homogenous products and a large number of new plants. Indeed, it seems that chemicals producers had to increase their licensing activity to adapt the entry of new competitors licensed by SEFs. They could thereby balance their losses in price-margins with an increase in the market share of their proprietary technologies.

Source: Arora (1997)

⁶ In the survey, the effectiveness of patent protection is estimated directly by respondents.

When patent protection is effective, licensing can affect the market structure of the industry, by facilitating the division of intellectual labor (Arora and al., 2001; Gallini, 2002; Arora & Merges, 2003). The link between technology transfers and the division of labor has been explored in the case of the chemical industry. The emergence of firms specialized in the provision of technology has in turn induced an increased licensing activity of large chemical producers since the 1950's (Box 7). Licensing helps small firms and start-ups specialize into research activities which intellectual output is sold to producers. This is the case in the U.S. semi-conductor industry where, after patent protection had been strengthened in the 1980's, firms have specialized in chip design and outsourced manufacturing tasks (Hall & Ziedonis, 2001). In their empirical study based on the PatVal survey of European patents, Gambardella *et al.* (2006) find that firm size is by far the more important variable which affects the probability of licensing in comparison with other factors such as patent value and the scientific nature of patents. Small firms appear to be much more active on markets for technologies than large firms. They indeed license 26% of their patented technologies against 9% only for large firms.

Transaction costs still limit technology transfers

Although an effective patent protection significantly reduces transaction costs, those costs do not disappear entirely and keep impeding technology transfers. In a survey of 229 U.S. and Canadian firms Razgaitis (2004) finds that only 4% of licensable technologies end up in a license. Indeed, of 100 licensable technologies, a potential licensee is found in only 25 cases. Partners then enter into negotiations in 6 to 7 cases, 3 to 4 of which end up in a license. In an empirical study based on the PatVal survey of European patents Gambardella *et al.* (2006) similarly find that firms do not succeed in licensing valuable patented technologies that they are willing to trade. Small firms appear to license 26% of their patented technologies while they are willing to license 37%. Large firm are willing to license 16% and actually license 9%.

Both Razgaitis (2004) and Gambardella *et al.* (2006) attribute small rates of success to various transaction costs incurred by potential partners. Firms may initially incur search cost to identify potential partners. Licensing deals may also be blocked by difficulties in getting internal approval or by disagreements concerning exclusivity or geographical restrictions. Licensors may especially fear opportunistic behavior by their partner in negotiations. Indeed, patents do not necessarily protect the whole information disclosed to potential licensees, especially if the transfer of information also concerns tacit knowledge such as know-how (Arora, 1995). Partners may thus be tempted to appropriate the disclosed information without buying a license. Moreover licensing contracts are complex and often incomplete (Merges, 1998), which reinforces the risk of opportunism by partners. Finally, it may be too costly for the patentee to enforce his patents in case of opportunistic behavior, which can dissuade her from engaging into

a licensing deal.

The existence of transaction costs explains why firms having prior relationships engage more easily into licensing agreements. Indeed repeated interactions reduce information asymmetries and increase trust between the partners. In an empirical study of 1365 licensing contracts and alliances involving U.S. participants between 1990 and 1993 Anand and Khanna (2000) find for instance that 30% of licensing deals were signed between partners that had previously signed other licensing contracts. Vonortas and Kim (2004) study a sample of 11 839 alliances with licensing content in the OECD area. They also find that prior licensing contracts and prior independent experience with licensing are significant positive factors in the probability that two firms sign a licensing contract.

b) Measuring markets for technology

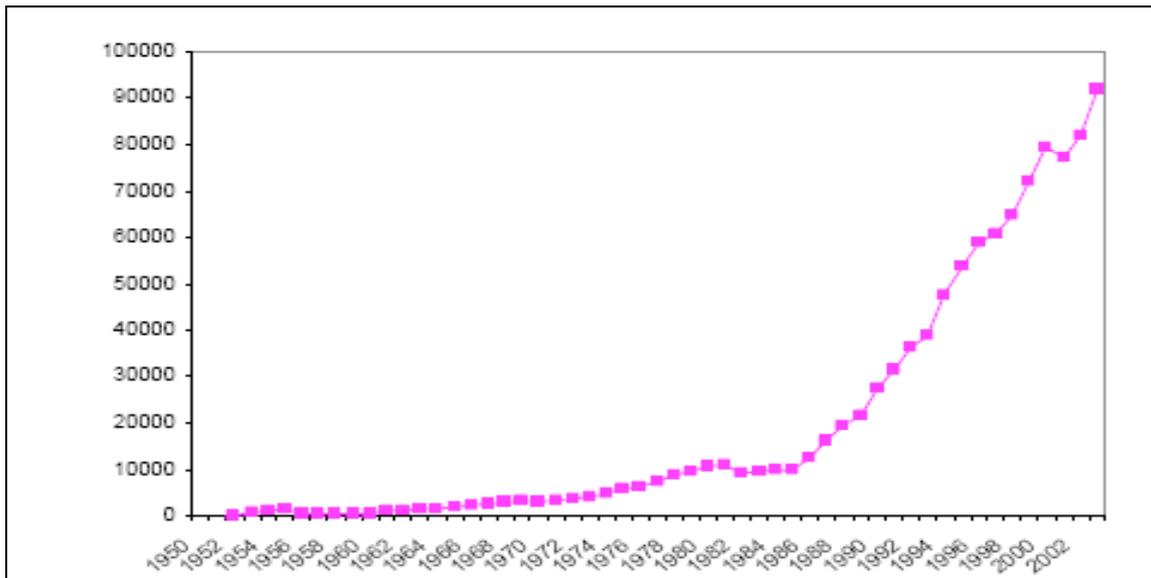
Markets for technologies can be defined as the sum of technology transfers in a given geographic area and time period. Empirical measures of these markets are scarce but available information suggests that they are large and growing (Kamiyama *et al.*, 2006). A conservative estimate indicates that the global market for technology averaged \$ 36 billion between 1990 and 1997, which is far above the \$ 5.6 billion estimate for the 1980's (Arora *et al.*, 2001; see also box 8). Estimated patent licensing revenue in the U.S. increased from \$ 15 billion in 1990 to more than \$ 100 billion in 1998; and it is expected to top half-trillion dollars annually by the mid-2010's (Rivette and Kline, 2000).

Box 8: The expansion of international markets for technology

Figures on international royalties and licensing fees between 1950 and 2003 show an impressive expansion of international markets for technology. The graph below represents the global amount of international royalties and licensing fees between 1950 and 2003 (Athreye & Cantwell, 2005). The data are extracted from national balance of payments statistics and do not distinguish between in-house and external licensing. This is problematic in that recorded in-house transactions may not entirely reflect true technology transfers but also accounting operations. Still, the graph clearly indicates a positive trend of development of international markets for technologies over the period, which becomes exponential in the 1980's.

Empirical evidence suggests that the degree of patent protection, measured by various indicators, has an important impact on international transfers of technologies. MacCalman (2001) finds that the 1994 TRIPS agreement has induced important monetary transfers from developing to industrialized countries, as a counterpart to technology transfers from industrialized to developing countries. However, these increased North-South transfers do not necessarily benefit to developing countries (Maskus, 2000). Using data on U.S. firms, Smith (2001) shows that the effect of increased intellectual property protection in developing countries actually depends on capacities of firms in these countries to appropriate and imitate the technologies that were transferred. When developing countries have good imitation capacities, increasing patent protection fosters technology transfers because firms in industrialized countries feel more confident about the risk of imitation. When imitation capacities are weak, additional protection is not necessary. Then more patent protection simply reinforces the market power of technology owners, without increasing technology transfers.

International royalties and licensing fees, 1950-2003 (Millions USD)



Source: Athreye & Cantwell (2005)

Stronger intellectual property rights also affect the channels of technology transfers. Smith (2001) finds that increased protection results in more immaterial forms of technology transfers: foreign direct investments tend to be substituted to product exportations, while licenses contracts tend to be substituted to foreign direct investments. Indeed, Branstetter *et al.* (2006) find that stronger intellectual in non-U.S. countries increase transfers of technology from U.S. firms to their foreign affiliates. Conversely, Nagaoka (2002) finds that Japanese firms prefer to direct technology transfers towards subsidiaries rather than license them to other firms when intellectual property rights are weak.

Markets for technologies seem to be less developed in Europe than in the U.S. and in Japan, although available evidence is scarce and incomplete. Table 7 summarizes the results of two surveys that permit to compare firms' licensing revenue and spending with their R&D spending. A survey of 133 companies from Europe, the U.S. and Japan in the mid-1990s (Gambardella, 2004) allows comparing the royalty spent to R&D ratios in the three regions. It shows a gap between Europe – where the ratio is close to 5% – and Japan and the U.S. which ratios are at least twice as much as the European ratio. The second survey was carried out in 2004 on 732 EPO patent applicants from the E.U., the U.S. and Japan (Roland Berger, 2005). It shows similar results on the lag of European firms vis-à-vis American and Japanese EPO applicants concerning both licensing in and licensing out.

Table 7: Markets for technologies in Europe, the U.S. and Japan

	Royalties spent/R&D (BTG)	Royalties spent/R&D (EPO)	Royalties received/R&D (EPO)
EU firms	5%	0.8%	3.1%
US firms	12%	5.5%	6.0%
Japanese firms	10%	22.0%	5.7%

An OECD survey of 105 firms in Europe, the U.S. and Japan in 2003 confirms both the trend towards the expansion of markets for technologies and the relative lag of Europe (Sheehan *et al.*, 2004). Approximately 60% of respondents reported increased inward and outward licensing

over the past decade. This response is more frequent in the U.S. and Japan than in Europe. Almost 40% of firms also reported increased cross-licensing with other firms during the past ten years. Finally, approximately 65% and 70% of respondents reported that they were expecting respectively outward and inward licensing to become more important in the next five years.

The results of several surveys show that licensing practices differ across industries. Licensing seems to be more frequent in Pharmaceuticals and Information Communication Technologies (ICT). Anand and Khanna (2000) use the SDC strategic alliances databases to compare licensing contracts involving U.S. participants between 1990 and 1993. They find that 80% of licensing contracts occur in three industry classes, namely Chemicals and Drugs (46%), Electronic and Electrical Equipment (22%) and Industrial Machinery (12%). Within these classes, some subclasses account for the most of licensing deals: Drugs (37% of all deals), Electronic Components and Accessories (14%), Computer and Office Equipment (9%), Communications Equipment (6%), and Medical Instruments (6%). The OECD survey confirms these results and provides more information on licensing patterns in different industries (Sheehan *et al.*, 2004). Pharmaceuticals, other Chemicals and ICT appear as the sectors where licensing activities increased the most. In Chemicals, firms report equivalent increases in outward and inward licensing, which denotes a division of labor between producers and firms specialized in R&D (see Table 8). In Pharmaceuticals, 80% of firms report an increase in outward licensing. In contrast, 60% of firms report an increase in inward licensing in ICT industries. These contrasted licensing patterns denote different organizations of innovation in both sectors, which we discuss more extensively in Section 4.

Table 8: Industry breakdown of licensing deals

		Deals	Percentage of industry class	Percentage of all deals
Chemicals	Drugs	511	81.4 %	37.4%
	Other	117	18.6%	8.6%
Industrial and Commercial Machinery	Computer and Office Equipment	118	74.7%	8.6%
	Other	40	25.3%	2.9%
Electronics and Electrical Equipment and Components	Communications Equipment	80	25.5%	5.9%
	Electronic Components and Accessories	197	62.7%	14.4%
Other	Other	37	11.9%	2.7%
	Surgical and Medical Instruments and Supp.	86	32.4%	6.3%
Total	Other	179	67.5%	13.1%
		1365	–	100%

Source: Anand and Khanna (2000)

3.4. Policy issues

The promotion of technology transfers represents an important stake for European innovation policy. However, it largely depends on the emergence of institutions that do not directly depend on public policies. Such policies should thus principally focus on creating the conditions for the emergence of such institutions.

a) Expanding markets for technology to promote innovations

A further expansion of markets for technology in Europe would represent an important opportunity to increase both the production and diffusion of innovations. Empirical evidence suggests that there is a potential for a further expansion of markets for technology in the coming years, especially in highly innovative sectors such as Pharmaceuticals and ICT (Sheehan *et al.*, 2003; Gambardella *et al.*, 2006). As already mentioned, some studies also find that markets for technologies are currently underdeveloped in Europe with respect to the U.S. and Japan (BTG, ; Sheehan *et al.*, 2003; Roland Berger, 2005).

The promotion of technology transfers does not result from a top-down impulse but rather from the emergence of *ad hoc* supporting institutions that facilitate their functioning (Arora *et al.*, 2001; Gambardella *et al.*, 2006). Such institutions comprise standard contract forms or transfer protocols which emergence contributes to reduce transaction costs. They also include the rise of specialized intermediaries that facilitate the meeting of technology buyers and sellers. They cannot result directly from public policies, although appropriate policies could facilitate their emergence.

b) Improving patent effectiveness and patent information to reduce transaction costs

Patent policy can contribute to reducing transaction costs by ensuring an effective patent protection to innovators and by facilitating the access to valuable patent information. The economic literature suggests that patent protection can secure licensing transactions by reducing the risk of opportunism by the buyer. Therefore the promotion of technology transfers requires that valid and clearly delineated patents be granted and that they can be enforced easily. An efficient functioning of patent information systems would also contribute to this goal, by facilitating access to information on potential technology suppliers, and more generally by raising awareness about the business opportunities relating to technology transfers.

Chapter 4. Cumulative R&D

4.1. Introduction

In some cases licensing does not concern ready-to-use innovations but rather intermediate results that will facilitate the licensee's own research activity. This is especially frequent in modern industries like Biotechnology and Information and Communication Technologies, where innovators often build upon each other's achievements. It is likely that innovating firms in these sectors depend on, or infringe upon, each other's patents. Patent infringement can therefore represent a threat on R&D investments, while patent licensing represents a necessary condition for efficient R&D investments.

We explore in this chapter how patents affect innovation when the inventors' R&D efforts are cumulative. We present the main theoretical insights into this question. We then review the empirical literature describing how patents influence the organization and the rate of innovation in Medical Biotechnology and in Computers and Electronics. We finally discuss relating policy issues.

4.2. Theoretic insights

Economic theory uses two concepts to analyze the problems raised by patents when innovations are interdependent, namely the concepts of *cumulative* innovation and of *complementary* innovation.

a) Organizing cumulative innovation

Economists call innovations that result from other innovations *cumulative* (Scotchmer, 1991). Some improve the quality of an existing product or reduce the cost of a recent production process. Others are new applications of an existing invention. Research tools, which are innovations that are used to produce other innovations, are another type of cumulative innovation. Cumulative innovations are particularly common in Information Technology and Biotechnology. The sequential nature of innovation in such fields implies that research may involve various actors at different stages. The problem is thus to organize R&D in an efficient way, by allocating the right incentives to innovate to the right actors. Patent law plays an important role in that matter: it determines which innovative steps are patentable and to whom patents rights on subsequent innovations must be allocated.

The optimal patenting of cumulative innovations is still a matter of debate amongst economists. Theoretical arguments nevertheless permit to sketch some conclusions in favor of a relative broad patent scope assuming that firms can sign early licensing agreements (Gallini & Scotchmer, 2002).

By granting the first innovator exclusivity over a technological lead, a broad patent gives him the power to organize research efficiently (Kitch, 1977). The threat of litigation for infringement is reduced as well as patent races and the excessive investments that go with them. In addition, because the patent is published, other firms can identify new applications, which they can propose to the patent owner. The owner has every interest in licensing the technology or creating research partnerships, when he can benefit from them. The problem is, however, to preserve the incentives to innovate for subsequent innovators. If upstream patent holders demand an excessive share of the expected benefits, subsequent innovators may under-invest or even renounce investing. This may dry up the innovation lead and, paradoxically, reduce the value of upstream patents (Merges & Nelson, 1990; Green & Scotchmer, 1995). Ensuring continued innovation thus requires that downstream innovators have a sufficient bargaining power vis-à-vis upstream patent owners.

The fine-tuning of patent law and early licensing are two ways to improve the rewards to downstream innovators.

- Granting patents on downstream innovations helps to level the bargaining positions of upstream and downstream innovators, because both parties then own an exclusive property right. Moreover theoretical results suggest that severe patentability requirements that exclude minor innovations from patentability and a broad forward protection permit to reinforce the incentive to innovate of downstream innovators (Denicolò & Zanchettin 2002)⁷.
- Even in the case wherein downstream innovators are entitled with patent rights, they may be deprived from most of their innovation profit if they negotiate licensing contracts with upstream patent holders after having sunk their R&D investments (Green & Scotchmer, 1995). To avoid this, licensing should take place *ex ante*, e.g. before the downstream innovator invests in R&D.

b) Navigating patents when innovations are complementary

The concept of complementary innovations captures the fact that a complete technology may embody several patented elements which, unlike cumulative innovations, do not necessarily result from each other (Shapiro, 2001). By the end of 2002 the MPEG standard for digital video compression contained for example 525 patents belonging to 22 companies. In agrobiotechnology, Golden Rice – a genetically engineered rice variety bred to help combat vitamin

⁷ Denicolò and Zanchettin (2002) show that forward protection is generally superior to severe patentability requirements. Indeed the two rules are equivalent if the level of protection is low, because both would prevent the development of small subsequent innovations. As the level of protection increases, a greater forward protection allows the development and sharing of bigger innovations, while a more stringent novelty requirement would block them. Finally, Denicolò and Zanchettin conclude that novelty should be used only as a complement to forward protection when the level of protection is very high.

A deficiency – encompasses more than 70 patents from 5 different technological fields. Generally, most products in electronics, telecommunications and biotechnology encompass several patents.

The scattering of patented elements of a given product between different owners generates specific costs:

- Since each patent holder has the exclusivity on one component of the product, they are likely to behave unilaterally as a monopolist, which may trigger a *multiple marginalization* issue. Indeed each patentee tends to fix a high price for its component, which reduces the overall demand for the technology and, therefore, the demand for the other components. According to the Cournot theorem, the final product is thus supplied at an excessive price, and it would be profitable for both consumers and for patent holders that the prices of all components be reduced simultaneously.
- More generally, the scattering of patents on complementary technologies generates transaction costs. These costs include the cost of identifying the patent owners, and the cost of bargaining, designing and enforcing licensing contracts.

Multiple marginalization and transaction costs reduce the benefit from innovation, and therefore the incentives to innovate. Heller and Eisenberg (1998) qualify this issue as a *tragedy of anticommons*. Indeed the well-known *tragedy of commons* qualifies the overuse and depletion of scarce resources (like fisheries, for instance) when they are in free access. In contrast, the fragmentation of patent rights creates a situation in which several individuals can block the exploitation of a non-rival resource such as a technology, which leads to an under-use of this resource.

When patents on complementary innovations are scattered, various types of initiatives can help address the problems of multiples marginalization and transaction costs. The merger of firms owning complementary patent portfolios – or the mere transfer of all complementary patents into the same hands – is a first option. Various collective institutions also help to “navigate the patent thicket” (Shapiro, 2001). Such institutions range from the observance of informal licensing rules, to cross-licensing agreements, to the creation of patent pools and standard setting organizations.

4.3. Case studies: Biotechnology and Computers and Electronics

Although cumulative and complementary innovations can be found in most sectors, they are particularly frequent in Biotechnology and Information and Communication Technologies, where patents may therefore raise specific issues regarding the organization of R&D. In this

Section we review the literature relating to these two technology fields in order to highlight the way patents intervene in the organization of R&D. We discuss successively the cases of Medical Biotechnology, and Computer and Electronics.

a) Drugs and biotechnologies

Patents can protect two broad categories of Biotechnology inventions. The first category includes the discovery and isolation of particular genes or proteins. The second category of patentable inventions includes the discovery of a method of use for a particular gene or protein, as a method for treating a particular disease or a research tool.

Patent protection and innovation

Patents play a key role in providing the necessary incentives to invest in the development of Biotechnology inventions. Innovation in Biotechnology is very costly. As stated by an FTC panelist, “R&D spending in biotechnology is more than double the average of the pharmaceutical industry (both on a per employee basis and as a percentage of sales)” (FTC, 2003).

Table 9: Net patent premium and elasticities

	Expected Patent Premium_	Conditional Patent Premium_	Elasticity, with respect to a 10% change in the patent premium, of:		
			R&D	Patent Applications	Patent Applications per R&D \$
Biotech	+ 20% + 34%	+ 79% + 145%	10.6%	14.3%	3.6%
Total	- 48% - 10%	+ 75% + 125%			

_ The expected and conditional patent premium are expressed as a percentage of the value of the unpatented innovation. Source: Arora *et alii*, 2003.

In an empirical work based on the Carnegie Mellon survey, Arora *et al.* (2003) calculate that the value of patents represents 22% of R&D expenses in Biotechnology, which is close to the average of all sectors (24%)⁸. However, Arora *et al.* (2003) find that patent protection has a strong effect on innovation in Biotechnology. According to their estimations, the expected patent premium (i.e. the average additional benefit resulting from patenting an innovation) is positive in Biotechnology, while it is negative on average in all sectors (Table 9). Hence it is generally very profitable to patent an innovation in Biotechnology, which is not the case in other industries. Conditional on being positive the patent premium represents between 79% and 145% of the value of the unpatented innovation, which is slightly higher than in the other sectors. Finally, Arora *et al.* (2003) find that the firms would react to a 10% increase (or

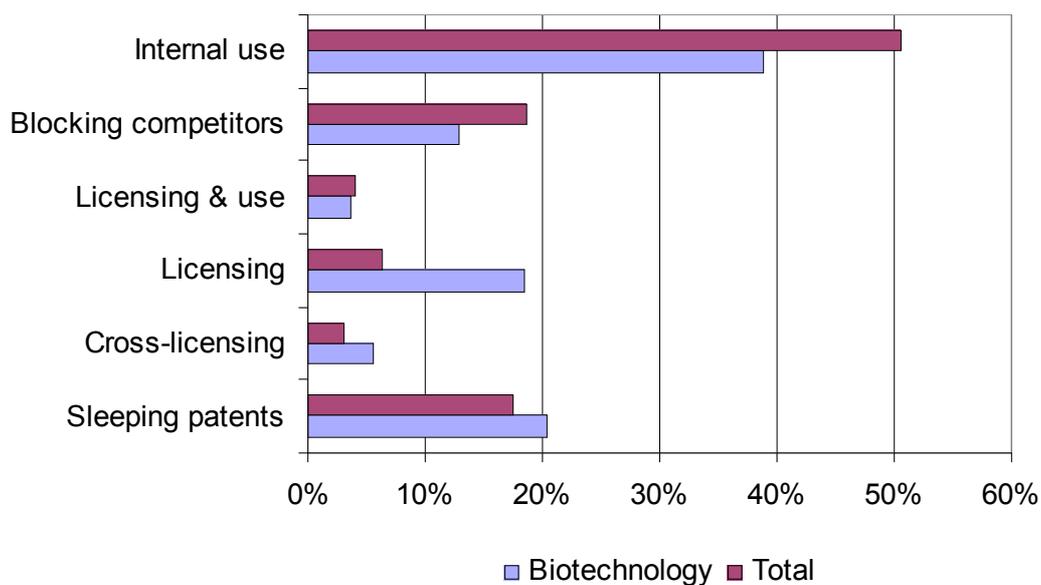
⁸ See Chapter 1, Section and 3 and Box 2 for a more complete presentation of this work and its methodology.

decrease) of the patent premium by increasing (respectively, decreasing) their R&D expenses by 10.6%. This is higher than the average of all sectors (6%) and suggests that patent protection has a positive and important impact on innovation.

The market for technology in medical Biotechnology

Patents also play an important role in the division of innovative labor between upstream research in Biotechnology on the one hand, and the development of new drugs by Pharmaceutical firms on the other hand. Genetic innovation has initially been introduced into Pharmaceuticals by new actors at an upstream level (Arora *et al.*, 2003). The number of small innovative Biotechnology firms has grown quickly in the 1980’s, preceding the growth in Biotechnology patenting (Cockburn *et al.*, 2000). Universities have also become major sources of both patented biomedical inventions and start-up firms. These specialized actors generally license their patented discoveries to the pharmaceutical industry, which explores and tests them in a more conventional way to develop new drugs.

Figure 9: Patent uses in Biotechnology



Source: Gambardella *et alii* (2005).

Empirical surveys show that the market for technology in Biotechnology is one of the most developed and that it is still growing quickly (Anand & Khanna, 2000; Sheehan *et alii*, 2004). This is confirmed by the results of the PatVal survey (Gambardella *et alii*, 2005) regarding the use of European patents (Figure 9). Compared with other fields patented inventions in Biotechnology are less used internally or in order to blocking competitors. In contrast, firms license them much more frequently. Such licenses generally originate from universities and small Biotechnology firms towards large Pharmaceutical companies.

Table 10: Sharing of the profit from \$100 million in sales of pharmaceutical product

	Value	Share of profits
University	\$ 3.7 M	7%
Biotechnology	\$ 14.3 M	29%
Big Pharma	\$ 32 M	64%

Source: Edwards *et alii* (2003).

Table 10 summarizes the results of a survey of 112 licensing agreements involving U.S. universities, biotechnology firms and pharmaceutical companies over a 25-years period. It shows how the profits generated by biotechnologically engineered drugs are finally allocated between universities, biotechnology firms, and large pharmaceutical companies. This distribution determines their respective incentives to invest at different stages of the development of the drugs. In an empirical study of more than 800 licensing contracts mainly disclosed by US biotechnology firms, Nakamura and Nagaoka (2006) in turn highlight how the design of such licensing contracts facilitates the vertical division of R&D:

- Contracts with exclusivity provisions and/or a high level of royalties appear to be less frequent at the discovery stage than at the downstream stage and when they concern research tools rather than product technology. In both cases this may be due to the need to encourage follow-on research on innovations that are still far away from commercialization, so that the licensee will incur higher risk and R&D costs to reach the commercialization stage.
- Exclusivity provisions are more frequent when licensing takes place *ex ante*, before the licensee makes any investment. Such *ex ante* contracts are a way for the licensee to reduce the risk of being unable to appropriate the benefit of its innovation because of the hold-up problem. They also allow the licensor to ensure a quick and secure exploitation of its technology.
- Finally, universities appear to impose exclusivity more frequently than private companies when they license their innovations *ex post*, which may reflect their financial constraints (Nakamura & Nagaoka, 2006).

Do biotechnology patents impede innovation?

Several authors have expressed concerns that the multiplication of patents on research tools and genes might actually impede innovation in Biotechnology (Heller & Eisenberg, 1998; Mazzoleni & Nelson, 1998; Henry *et al.*, 2003). The development of new products such as diagnostic kits requires the use of a large number of patented genes or gene fragments. In this

case transaction costs and royalty stacking could therefore dissuade innovators and create a *tragedy of anticommons* (Heller and Eisenberg, 1998). Mazzoleni and Nelson (1998) also warn that the generalization of exclusive licensing contracts can block valuable research projects by forbidding the access to the required research tools.

Available empirical evidence however suggests that there is no *tragedy of anticommons* in medical Biotechnology. Arora *et al.* (2003) conducted 70 interviews with scientists and executives employed by firms, intellectual property practitioners, and university and government personnel. They report that defensive patenting has increased recently, as a way for the firms to accumulate bargaining power to obtain an access to other firms' patents. Yet they also find that these patenting strategies have not created a tragedy of anticommons due to negotiation breakdowns, royalty stacking or excessive royalties. A reason might be that the number of patents involved per research project is relatively low, while there is a very large set of valuable innovation opportunities, only some of which are actually carried out. Arora *et al.* (2003) find indeed that most research projects do not require initial licensing of existing patents, although some projects may potentially infringe up to one hundred patents. A survey implemented in 2004 on access to patented research tools by 68 Japanese pharmaceutical and biotechnology firms confirms these findings (Onishi & Nagaoka, 2006). Respondents seldom abandon a research project after having discovered the existence of a patent on a research tool. They most often buy a license either immediately or after continuing their research without a license until they have obtained some results. Otherwise they use alternative methods, challenge the validity of the patent or simply ignore it.

A recent survey of 1125 academic researchers (including university, non-profits and government labs) and 563 industry researchers confirms that patenting does not limit research activity significantly, except in some specific cases (Walsh *et al.*, 2005). No academic researcher has stopped a project due to a problem of access to patents on knowledge inputs and only 1% of them reported suffering a project delay of more than a month for the same reason. However this situation seems to result from their ignorance of the risk of patent infringements rather than from the absence of such risks. [JE1]Researchers tend to use disclosed knowledge without noticing whether it is patented or not. In this context, the difficulties experienced by researchers mostly concern the access to tangible research inputs which must be delivered by other researchers.

Access to patented research inputs seems to be more difficult for industry scientists and in some specific technology fields. Industry scientists check more frequently for patents, and it may be the reason why they are also more likely to be faced with restrictive terms for access to material research inputs, and to face research delays while the terms are negotiated. Similarly, they are more likely to refuse others' requests in order to preserve the commercial interests of their

companies. Walsh *et al.* (2005) finally carried out a complementary survey focusing on high-stake research on signaling proteins. They found that commercial activities and problems of access to material research inputs tend to be more frequent in this area.

Box 9: Patents in the seeds industry

The rise of Biotechnology has deeply changed the seeds industry. Innovation in this industry traditionally consists in obtaining new plant varieties by breeding old ones. Varieties are protected by Plant Breeder's Rights (PBR) that confer exclusivity on their commercialization but allow their research use for breeding new varieties. Biotechnology has changed this pattern by allowing the introduction of new traits into plant varieties at the genetic level. This type of innovation requires a costly technology platform comprising patented plant genetic transformation tools, patented genes, and elite crop germplasm (Graff *et al.*, 2003b). Some technologies may finally encompass a very large number of patents. For instance, the beta-carotene-enhanced GoldenRice embodies more than 70 patents belonging to 31 different institutions (Kryder *et al.*, 2000).

This technology shift has modified the organization of innovation in the seeds industry. Besides the traditional seeds company, the industry is now characterized by the development of networks of alliances around large chemical companies, and by the important weight of public research patents:

- Large chemical companies had entered the industry of agricultural seeds during the 1970's, and absorbed many of the former seed companies. Chemical firms such as Monsanto, Dow and Dupont acquired for instance seeds firms such as Pioneer, DeKalb or Asgrow. The emergence of Biotechnology has in turn triggered the entry of small innovative companies during the 1980's. In the 1990's, frequent patent litigation between innovators resulted in the concentration of patent portfolios and research alliances around the large chemicals firms (Graff *et al.*, 2003b). In the early 2000's, the ten biggest actors in the seeds industry represented around 40% of global sales, and most of them were coming from the agrochemical industry.
- Universities and other public research institutions used to play an important role in traditional research on seeds, and their activity has to a large extent be redirected towards Biotechnology (Knight, 2003). They account for a quarter of US and European patents in this field, and 14% in Japan (14%), which is much higher than the proportion of public sector patents in all fields (2.7% in the U.S.) (Graff *et al.*, 2003a).

To our knowledge there has been no systematic evaluation of the impact of patents on innovation in the specific field of agriculture Biotechnology. In this context the economic literature principally highlights the risk that patent protection of genetically modified seeds may reduce diversity and impede innovation to the benefit of some categories of users, especially in developing countries (Barton *et al.*, 2002; Henry *et al.*, 2003). Research in genetically engineered crops has so far principally focused on the creation of standardized models, often compatible with herbicides (Harhoff *et al.*, 2001). Since they are protected by patents, these widely diffused varieties cannot be used freely for breeding new varieties in the traditional way. Public research, which represents a major source of innovation aimed at developing countries, also seems to be impeded by its fragmentation and by the exclusive collaborations it has often contracted with agrochemical groups (Graff *et al.*, 2003a). Several initiatives have been launched during the last years to change licensing practices and create more freedom to operate on patents owned by public research institutions (Graff, 2001; Atkinson *et al.*, 2003; Delmer *et al.*, 2003; Graff *et al.*, 2003a; Van Overwalle *et al.*, 2006).

b) Computers and electronics

Technology fields related to Computers and Electronics, including Semi-conductors and Telecommunication Equipments, are very innovative and characterized by highly cumulative and complementary innovations. Hardware equipments such as computers, monitors, servers or routers usually embody a large number of patented elements, forming a *patent thicket* which the firms have to navigate. Shapiro (2001) reports for example that, in the semi-conductor industry, firms receive “thousands of patents each year and manufacturers can potentially infringe on hundreds of patents with a single product”. A panelist auditioned by the FTC in 2002 similarly stated that in the U.S. more than “90,000 patents generally related to microprocessors are held

by more than 10,000 parties.” Likewise, he reported, “there are approximately 420,000 semiconductor and systems patents held by more than 40,000 parties” (FTC, 2003). A similar situation can be observed in the software industry (Box 11).

Impact of patents on innovation

Available evidence suggests that patents globally have a positive effect on innovation in Computers and Electronics. Empirical studies find substantial Equivalent Subsidy Rates (measured by dividing the value of the firms’ patents by their R&D expense to produce those patents) in these industries (Lanjouw, 1998; Schankerman, 1998; Arora *et al.*, 2003)⁹. Such high ESR reveal that the value of patents represents a significant share of R&D expenses, without however proving that patent protection really spurs these expenses.

Table 11: Net patent premium and elasticities

	Expected Patent Premium_	Conditional Patent Premium_	Elasticity, with respect to a 10% change in the patent premium, of:		
			R&D	Patent Applications	Patent Applications per R&D \$
Semiconductors	- 61%	+ 79%	4.8%	11.9%	7.1%
	- 13%	+ 125%			
Electronic components_	- 99%	+ 70%	4.1%	13%	8.9%
	- 28%	+ 111%			
Communication equipment	- 51%	+ 66%	5.4%	10.3%	4.9%
	- 11%	+ 111%			
Computers and other office equipment	- 17%	+ 79%	7.3%	11.6%	4.3%
	+ 0%	+ 138%			
	- 48%	+ 75%	6%	12.3%	6.3%
Total	- 10%	+ 125%			

_ The expected and conditional patent premium are expressed as a percentage of the value of the unpatented innovation. _ Excluding semiconductors.

Source: Arora *et al.*, 2003.

With a more elaborated methodology Arora *et al.* (2003) find evidence of a limited but positive effect of patents on innovation in various fields of Computers and Electronics¹⁰. Their main results are summarized in Table 11. The expected and conditional patent premium¹¹ appears to be slightly below the average of all industries, except for Computers and other Office Equipment where they are slightly higher. Arora *et al.* (2003) find a positive elasticity of R&D with respect to the patent premium, which implies that patent protection has a positive effect of R&D. Indeed, firms would react to a 10% increase (or decrease) of the patent premium by increasing (respectively, decreasing) their R&D expenses by 4.1% to 11.6% (respectively in Electronic Components and in Computers and other Office Equipment). Interestingly, the

⁹ For a complete comparison, see Table 2 in Chapter 1.

¹⁰ See Chapter 1, Section and 3 and Box 2 for a more complete presentation of this work and its methodology.

¹¹ The Expected Patent Premium is defined as the average additional benefit resulting from patenting an innovation. It is negative on average, meaning that it would not be profitable to patent all innovations. Since only innovations with positive patent premium are patented, the Conditional Patent Premium denotes the actual additional benefit that can be expected from patents.

elasticity of patent applications with respect to the patent premium is higher than the elasticity of R&D, which reflects the fact that Computers and Electronics tend to react to a strengthening of patent protection by pursuing more aggressive patenting strategies.

Cross-licensing and freedom to operate

The *patent thickets* observed in Computers and Electronics result to a large extent from aggressive patenting strategies. Hall and Ziedonis (2001) find for example that the propensity to patent (the number of patent filed by million of dollars invested in R&D) doubled between 1982 and 1992 in the U.S. semi-conductor industry, while it was stagnant in other manufacturing industries and even decreasing in Pharmaceuticals. They date back this change from the evolution of U.S. patent law towards the easier granting of more protective patents. A monography by Bekkers *et al.* (2002) highlights a comparable increase of the patenting propensity in European Telecommunications Equipment during the 1980's and 1990's.

Aggressive patenting strategies are not only motivated by the mere protection of innovation. Patents are also used to obtain an access to the other firms' patents and technologies (Hall & Ziedonis, 2001). Besides patents pools and standard setting (see Box 10), there are two principal ways of securing freedom to operate on other firms' patent portfolios:

- Patent portfolios are firstly used to prevent hold-up. The risk of patent hold-up is high in Computers and Electronics, because it is difficult to identify which patents could be infringed before investments are sunk. Since firms operate under the threat of being sued for infringement by competitors, their best answer then consists in being able to threat back competitors with their own patents, thereby reaching an equilibrium where it is in the interest of no firm to start a litigation¹². When litigation nevertheless occurs, a broad patent portfolio will still guarantee a favorable settlement, generally a cross-licensing agreement.
- The broad cross-licensing of patent rights between manufacturers is an old practice in industries such as semi-conductors and electronics (Grindley & Teece, 1997). Since separate negotiations for each patent would be practically unfeasible, such transactions consist for the parties in licensing each other all current and future patents in a given field of use. The bargaining power in such negotiations depends on the size and quality of the patent portfolios. Thus firms have an incentive to accumulate the largest possible portfolio in order to secure an access to other firms' portfolios at the lowest cost.

¹² Such strategies have been labelled Mutual Assured Destruction Strategies by commentators, because they ultimately rely on the reciprocal threat of being ruined in litigation expenses in case a series of patent trials starts (FTC, 2003).

Box 10: Standard setting and patent pools

Besides bilateral cross-licensing agreements, standard-setting organizations and patent pools are multilateral institutions that allow firms to organize freedom to operate in a given technology field, generally relating to Information and Communication Technologies.

A patent pool is a consortium of at least two companies agreeing to license as a package their patents and other intellectual property rights relating to a particular technology. Patent pools have existed since the sewing machine pool in 1856 and became less frequent after WW2 because of a more hostile antitrust environment (Gilbert, 2004). They number recently increased in Hardware, Software and Biotechnology where they were seen as a way to tackle the “patent thicket” issue. Famous current examples include the patent pools that back the MPEG, DVD or GSM technology standards, or the Golden Rice in Agri-Biotechnology.

Patent pools can benefit both patent holders and consumers, provided they include patents that are complementary or blocking (Shapiro, 2001; Lerner & Tirole, 2004). Patent pools reduce transaction costs since the licensing of all complementary patents is delegated to a unique organization, which redistributes the royalties to patent holders as a second step. They moreover permit patent holders to coordinate their pricing strategies, and thereby to avoid the setting of an excessive price for the package of complementary patents, due to royalty stacking and multiple marginalization problems. However patent pools may also be an opportunity for patent owners to collude when their patents are not complements but substitutes. To prevent this, antitrust rules generally require that only *essential* patents, i.e. patents without substitute, be included in the pool (Gilbert, 2004). Allowing members of the pool to license their patents independently also seems to be sufficient to ensure that the patent pool will not be collusive (Lerner & Tirole, 2004; Lerner *et al.*, 2005).

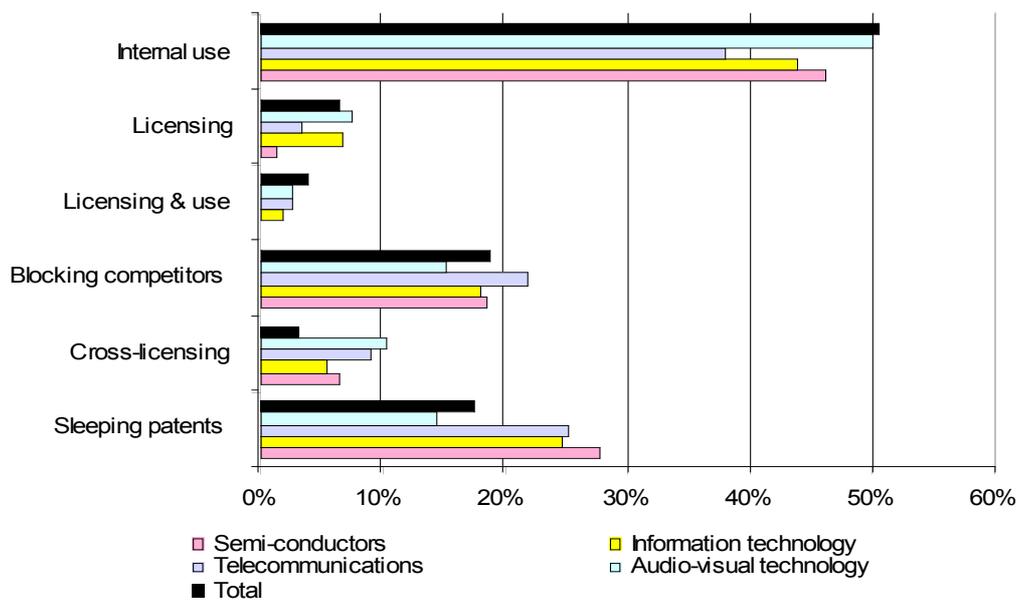
Standard Setting Organisations (SSO) are especially frequent in Computers and Semi-Conductors¹³, where they facilitate the definition of collective technology standards and their diffusion towards a large number of users (Shapiro, 2001; Lemley, 2002; Chiao *et al.*, 2005). Intellectual property rights intervene at an early stage of the Standard Setting process, as basic bargaining chips that are used to define the content and the perimeter of the norm, and to establish the respective weight of each member in the norm (Lemley, 2002). It is important to ensure at this stage that all holders of relevant patents will disclose them early enough, in order to prevent the risk of hold up for future standard users (Shapiro, 2001; Lemley, 2002). Since such standards can embody a large number of patents¹⁴, patent pools are an efficient way to manage their licensing. Lemley (2002) finds that out of 21 SSO, 17 required “some form of licensing... [m]ost commonly... on ‘reasonable and non-discriminatory terms.’” In an empirical study of 60 Standard Setting Organizations, Chiao *et al.* (2005) find that SSO that are oriented to technology sponsors have better quality standards and more restrictive licenses.

Empirical studies provide evidence of these specific uses of patent portfolios in computer and electronics. In a survey of U.S. R&D managers Cohen *et al.* (2000) find that the main reasons why Computers and Electronics firms file patents are to block other firms, prevent law suits, and negotiate licences, rather than to prevent imitation. The European PatVal survey similarly shows that patent uses differ between hardware and other technology fields (Figure 10). The internal use of patents and their licensing appear to be less frequent in hardware industries, while patents are more frequently cross-licensed or *sleeping*, i.e. they can be activated in case of litigation.

¹³ For lists of Standard Setting Organisations, see Lemley (2002) and Chiao *et al.* (2005).

¹⁴ At end-2002, MPEG patent pool contained 525 essential patents (Lévêque & Ménière, 2003); at the beginning of 2004, 6,872 patents were declared essential to the WDCMA 3G cellular norm (Goodman & Myers, 2005).

Figure 10: Patent uses in hardware industries



Source: Gambardella et al. (2005).

In their survey of U.S. licensing deals Anand and Khanna (2000) highlight the specific pattern of licensing in Computers and Electronics. They confirm a higher frequency of cross-licensing contracts and of contracts with related firms (39% in computers and 35% in Electronics, compared with 28% in Chemicals and 23% in other industries). *Ex ante* technology transfers also appear to be less frequent (less than 6%), while licensing contracts involve less exclusive transfers (respectively 18% and 16% in Computer and Electronics, compared with 38% in other industries).

Impact of patents on the industry structure

Evidence suggests that systematic patenting strategies affect the organization of innovation. In the U.S. semiconductor industry the accumulation and cross-licensing of large patent portfolios principally concerns capital intensive manufacturers (Hall & Ziedonis, 2001). Using data on Japanese manufacturing firms, Nagaoka and Kwon (2006) find that cross-licensing occurs principally between large and symmetric firms, especially in the Electrical Machinery industry. Because of their large sunk costs, capital intensive firms are indeed more exposed to patent hold up. A recent empirical study (Galasso, 2006) confirms that capital intensive firms tend to sign cross-licensing agreements, while firms with low capital intensity do not.

Box 11: Patents in the software industry

The software industry differs from hardware industries in many respects. Software programs are pure information goods. Innovation in such programs is mostly incremental and requires less capital than in hardware industries. Technological change is rapid and technology leaders can be easily replaced. The software industry has initially developed under a copyright intellectual property regime only, and it is still featured by original innovation regimes such as open source software (FTC, 2003).

Aggressive patenting strategies and “patent thickets” can be observed in the software industry too, especially in the U.S. where a large number of software patents have been granted (FTC, 2003). In a study on U.S. software patenting during the 1980’s and 1990’s, Graham and Mowery (2003) show that the aggregate patent propensity of the top 15 U.S. packaged software firms has increased between 1987 and 1997, from less than 2 to more than 5 patents per \$100 millions of R&D spending. They also find that Electronic Systems firms account for an increasing share of software patenting, which reached 50% in the end of the 1990’s.

As in Computers and Electronics, it seems that building patent portfolios is a way for large and deep-pocket firms to prevent hold up. Several observers have expressed concerns about the poor quality of information disclosed through software patents, and about the lack of clear prior art information, which implies that trivial and undue patents can be granted, and that it may be difficult to anticipate potential infringements (Hall & Ziedonis, 2001; Arundel *et al.*, 2002; Graham & Mowery, 2003; FTC, 2003). Some firms, called “patent trolls” even seem to specialize in using patents to hold up large companies. In this context, large incumbent firms have a higher propensity to patent than new entrants (Graham and Mowery, 2003). So far, small software firms do not seem to pursue specific strategies to navigate a patent thicket, and they rather use patents to raise capital and protect their market (Mann, 2005).

Empirical evidence on the effects of software patents on innovation is still scarce. An empirical work by Bessen and Hunt (2003) concludes that software patents are principally filed for strategic purpose and actually tend to impede innovation. This work and its methodology have been criticized by Hahn & Wallsten (2003) and Mann, (2005). A more recent empirical study evaluates the impact of *Lotus v. Borland* decision that resulted in a decrease of copyright protection of software in the U.S. (Lerner & Zhu, 2006). It finds that firms reacted by increasing disproportionately their patenting. The results of the study suggest that the increased use of patents does not seem to have negative effects on innovation, and is to the contrary correlated with growth in R&D expenditures, sales, total assets and the number of business lines. Another recent empirical study explores the effect of events impacting the strength of software patents such as U.S. court decisions and the issuance of USPTO guidelines (Hall & MacGarvie, 2006). It shows that the initial extension of patentability to software has reduced the stock market value of some software firms, especially those producing applications and services, which indicates a negative a priori perception of the impact of patents by shareholders. However, since this first event, software patents have been positively valued by markets. The value of patents is however dual depending on the firms. In hardware firms, patents seem to be valued as strategic assets that can be used as a threat and as a bargaining chip in cross-licensing negotiations. In software firms, the financial value of patents seems more to reflect the intrinsic value of inventions.

Since they do not own large patent portfolios, smaller firms are not in a position to negotiate good terms for the access to large firms’ patents. As stated by an industry executive, new semiconductor manufacturers must, for instance, pay \$100million to \$200 million to license manufacturing principles that have become common-knowledge. In this context, new semiconductor manufacturers face barriers to entry. Empirical evidence shows that firms with intermediate capital intensity have a stronger propensity to litigate (Galasso, 2006). These growing firms must indeed assert their patent portfolio and build a reputation that they will be able to leverage in future negotiations about cross-licensing deals. This strategy, however, requires important investments in the accumulation of a patent portfolio and its assertion before courts.

In contrast, small firms with low capital intensity are not an interesting target to hold up. Therefore they seem to use patents only to enter and develop in niche markets. Hall and

Ziedonis (2001) report that small semi-conductor firms tend to specialize in niche markets, such as the design of semiconductor products, in order to avoid infringing other producers' portfolios. Unlike manufacturers, their strategy then consists in filing a limited number of strong patents to protect their core activity. They do not seem to license these patents frequently, but rather to use them to prevent imitation and raise capital.

4.4. Policy issues

As for the expansion of markets for technology, the efficiency of cumulative R&D depends on the adoption of appropriate patenting and licensing strategies and on the emergence of supporting institutions rather than on a particular policy lever. Still, policy initiatives can facilitate the emergence of appropriate institutions and regulate their functioning. A better functioning of the patent system can also help prevent perverse effects of patents on innovation.

a) Good practices and supporting institutions

As illustrated by the cases of Medical Biotechnology and Computer and Electronics, the way in which patents and licensing affect the organization and the pace of innovation varies considerably between sectors. It would therefore be irrelevant to make precise recommendations independently of the technology field that is concerned. Some general principles can nonetheless be formulated concerning good practices and supporting institutions.

Initiatives to identify and promote good practices in a particular sector may be an effective way to promote innovation when innovators can be collectively harmed by their own private strategies. This is for example the case in Biotechnology when researchers – especially in public research institutions – license their patents under exclusive or very restrictive terms although it is not justified, or, in contrast, when they take unconsidered risks of being sued because of their ignorance of patents. Public organizations such as the U.S. National Institute of Health or OECD have therefore issued specific guidelines for licensing in Biotechnology (NIH, 1999; OECD, 2006). Patent Offices can similarly contribute to raise awareness about good practices among users of the patent system, through seminars and the issuing of guidelines.

Supporting institutions created by innovators themselves can also help spread good practices and clear the way for innovation. They should therefore be encouraged, provided they are not anticompetitive. We have presented above how patent pools and standard setting organizations contribute to innovation by clearing “patent thickets” in ICT industries. In the software field, organizations such as the Open Source Development Lab¹⁵ or Open Invention Network¹⁶ are sponsored by large software and hardware companies and develop initiatives, e.g. patent

¹⁵ <http://www.osdl.org/>

¹⁶ <http://www.openinventionnetwork.com/>

commons, to reduce the risk of patent hold up for innovation in open source software (Lévêque and Ménière, 2006). In agricultural Biotechnology, the Cambia IP Resource¹⁷ provides innovators with information on the patent landscape in particular fields, and with tutorial and support for licensing negotiations. Another initiative, Pipra¹⁸, creates a clearing house for licensing transactions between public research institutions (Delmer *et al.*, 2003; van Overwalle *et al.*, 2006).

b) Ensuring an effective functioning of the patent system

An effective functioning of the patent system itself can reduce the negative effects of patents on innovation. As highlighted by Hall and Ziedonis (2001), the strengthening of patent law in the U.S. triggered for instance more aggressive patenting strategies that increased the size of the “patent thicket” in the Semiconductor industry (FTC, 2003). In Biotechnology, excessively broad patent claims may also constitute an impediment rather than a spur for innovation (Merges & Nelson, 1990). In this context, the enforcement of tight legal standards for patentability and effective mechanisms to challenge the validity of patents and patent claims can prevent the negative effects of patents on innovation (FTC, 2003). In several countries, patent systems also include exemptions to patent law for experimental use on drugs or on research tools in Biotechnology (OECD, 2006). Some authors also suggest that the creation of similar exemptions should be considered for experimentation or interoperability purposes in the software field (Burke & Lemley, 2006).

The quality of disclosure and the creation of prior art databases can constitute other means to mitigate the negative effects of patents on innovation. An easy access to prior art in a given technical field facilitates the application of the non-obviousness and novelty tests by examiners in Patent Offices. The need for better information on prior art has for instance been expressed in the case of software, which development initially occurred under the copyright protection only (FTC, 2003). Complete and accessible information on prior art can also reduce the transaction costs incurred by innovators to detect the patents which their projects might infringe. It can thereby help them sign *ex ante* licensing agreements.

¹⁷ <http://www.cambia.org/daisy/cambia/home.html>

¹⁸ <http://www.pipra.org/>

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