

# **The economics of patents: from natural rights to policy instruments<sup>1</sup>**

David ENCAOUA (EUREQua, CNRS & University Paris I)  
Dominique GUELLEC (OECD) and  
Catalina MARTÍNEZ (OECD)

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<sup>1</sup> The opinions expressed in this paper are the sole responsibility of the authors and do not necessarily reflect any position or policy of the institutions to which the authors are affiliated.

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## Summary

The patent system has gone through major changes in most countries over the past two decades, aiming in general at strengthening the role of patents: expanding the patent subject matter and endowing the patent holder with broader rights. This paper uses the latest advances in the economic theory of patents for examining these changes, and beyond that, for rethinking the rationale of the patent system.

Economic theory does not see patents as a *natural right* that should be systematically granted to inventors whatever the conditions. Instead, the economic approach sees patents as a *policy instrument* aimed at fostering innovation and diffusion which can be used or not depending on the economic and technological conditions, and which should be suited to this task. Major implications from economic theory regarding current policy debates are as follows:

- The extension of the patent subject matter to new areas, such as software, business methods, and scientific discoveries in recent years, should not be taken for granted. Patents should not be seen as the solution by default. In industries where imitation is costly, where first-mover advantages are important, where innovation is sequential, in the sense that each further invention is built on previous ones, or where basic discoveries can be considered as ‘essential facilities’, patent protection might do more bad than good for innovation.
- The patentability requirement, a minimal ‘inventive step’ required for a patent to be granted, should be high enough in order to avoid the grant of patents for low-valued inventions, in order to reduce the social cost of the patent system.
- Exemptions for research use should be protected, as restricted access to basic knowledge hampers cumulative technical change.
- Rather than the statutory patent life, what matters is effective patent life, which can be affected by the instruments of patent policy, especially the breadth of patents and renewal fees. Broad protection increases effective patent life. Imposing higher fees to obtain broader protection should encourage larger patent breadth only for highly valuable inventions. Similarly, a system where renewal fees increase steeply allows a selection of inventions whose value justifies longer protection.

Beyond these currently debated issues, economic theory pleads for an in-depth reshuffling of the patent system, for transforming it into a self-selection mechanism, whereby patentees reveal the economic characteristics of inventions, compensate society for the protection they are granted and obtain sufficient incentives to innovate. Optimal patent protection should differ across inventions, but there is imperfect information about the relevant economic characteristics of each invention. Thus optimal patent policy has to take into account this imperfect information framework and use an optimal mechanism design approach to design patents. In the case of an isolated innovation, the notion of optimal patent refers to a degree of

protection that minimises the discounted value of the deadweight loss created by the patent under the constraint that the discounted profit from the most valuable innovations provides enough incentives to invest. In the case of sequential innovations, the optimal degree of patent protection takes into account in addition the effect of the patent breadth on the pace of innovation.

If the system were to be radically changed, an optimal patent policy should be based on a multidimensional menu of different degrees of patent protection with corresponding patent fees, submitted to patent applicants, so that they can choose the degree of protection they wish to obtain and pay for – higher protection would correspond to higher prices. The feature of the current system that comes closest to this idea is the system of renewal fees, as patentees choose the duration of the protection they want to receive and pay accordingly. Such a system could be extended to other characteristics of patents, notably linked to breadth (e.g. the number of independent claims), so that patentees seek for a protection level that corresponds to the value of their invention. The introduction of a system by which the patentee agrees on a price at which he commits himself to sell his rights once granted (i.e. a buyout mechanism) in the context of such menus is thus envisaged.

## **1. Introduction**

There have been tremendous changes in Intellectual Property Rights (IPRs) and patent law over the past two decades, all going in the same direction: expanding and strengthening protection. The patent community has been a major driving force behind this evolution, namely attorneys, judges, Patent and Trademark Offices (PTOs), as well as business intellectual property associations. This is unfortunate, as patents should not be an instrument for enhancing the rights of inventors and their agents, but for promoting invention and diffusion of knowledge. In this context, economic analysis has been essentially absent from the debate. Economists can provide policy makers with analysis that would shed a different and unique light on the debate. It is the purpose of this paper to show that.

The extension of subject matter to basic scientific discoveries, especially in biotechnology, to software and to business methods is one of the major recent changes currently debated. Empirical evidence shows that patents are not the most effective means of protection for inventions in all fields of technology. When imitation is costly and first mover advantages are important, market-based mechanisms alone can provide enough reward to inventors to recover their innovation costs. This is the case for financial innovations, which can now be protected by business methods patents in some jurisdictions, notably in the US. The controversy surrounding the patentability of software and basic scientific discoveries is based on the different means of access to knowledge for follow-on innovations in a context of sequential innovations. Patent protection for research tools in biotechnology may seriously hamper innovation, given that the exclusive rights on first generation innovations may restrict their use in a broad range of applications that may be unknown at the time they are granted.

Patent holders have been increasingly endowed with broader rights in recent years. PTOs have been granting patents covering a broader scope of products and applications, and courts have validated this trend. Moreover, exemptions to the rights conferred to patent holders have become scarcer, with antitrust authorities rarely interfering with the statutory market power conferred by patents by requiring compulsory licensing, and with research exemptions being subject to more restrictive conditions.

International harmonisation of IPR regimes, in particular the extension to developing countries of the string IPR systems that prevail in developed countries (e.g. 1995 TRIPS agreement) has fostered the application of uniform standards across inventions and markets, without allowing for differences that might have called for distinct measures. Patents seem to have become the default policy to promote innovation and economic growth, rather than a policy instrument whose evolution is carefully examined and led by policy makers.

The main argument behind these changes has been that providing stronger rights to inventors should reinforce their incentives to invest in research, and then boost technical change. But is such a strengthening of IPR really beneficial to technical change and economic growth? Economists have a cautious approach in this regard. Even if stronger patents might actually reinforce the incentives given to firms to invest in research, they could also have detrimental effects on market competition, the allocation of resources, the process of cumulative innovation and the diffusion of knowledge.

Patents allow inventors to get a monopoly rent, paid by customers, which generates a distortionary static effect, whose cost might well overtake the benefit that society gets from further inventions. In addition, the apparent laxity of patentability requirements has led to the proliferation of low-quality patents, at least in the US, and especially in new patentable areas such as business methods. This has induced rent-seeking behaviour among patent applicants, where the incentive to patent originates much more in the eventual use of patents as a *bargaining tool*, rather than as a means to recoup invention costs.

From a dynamic perspective, technical change is a cumulative process where inventions are built on previous ones conforming to the prior art. In this context, patents are a double-edged sword, giving stronger rights to upstream inventions might mean that downstream inventors are faced with further obstacles, such as difficult access to the protected prior art, limitations in the allowed use of existing knowledge, or reduced share in the revenue generated by follow-on inventions, since the upstream inventor can claim most of the profits.

The aim of this paper is to shed light on currently debated policy issues, drawing on the latest advances in economic theoretical and empirical research. The next section analyses the question of whether IPR are needed for all inventions, considering arguments for and against the use of patent protection for all inventions. Section 3 analyses the multiple dimensions of patents as policy instruments and the lessons that can be drawn from economic theory models to improve current patent policy. Section 4 addresses radical policy changes that could improve the current system and get closer to an optimal patent policy design.

In what follows, we focus on the analysis of patents, highlighting differences with other IPR (copyrights, trade-secret, *sui-generis*, etc.) when needed.

## **2. In what economic contexts are IPR needed?**

The corner stone of the traditional argument in favour of patent protection is the non-rival character of knowledge, and more generally the idea that an invention can be imitated with no additional cost apart from the cost of the factors used in the production process. Economists have long challenged this idea, notably from the evolutionary school (Nelson and Winter 1982), but arguments against the traditional view have only been recently formalised (Boldrin and Levine, 2002, Quah, 2002, Hellwig and Irmen, 2000, Bester and Petrakis, 1998). If imitation is as costly as invention, or if firms have economic means of protecting their inventions then, the argument goes, there is no need for further legal protection which is only a source of market distortions and associated rents.

### **2.1. Traditional arguments for and against IPRs**

Let us begin by recalling the usual argument in favour of intellectual property protection as it appears in the seminal works of Arrow (1962), Nordhaus (1969) and Romer (1990). The innovation process amounts essentially to the production of knowledge or informational assets. Even if knowledge is generally embodied in new physical products or new technologies, the main point is that knowledge presents some features that distinguish it from usual private goods.

Whereas private goods belong to the class of rival goods, knowledge is inherently non-rival. This means that, once produced, knowledge can be subsequently used by others without its value being reduced. In other words, consumption of knowledge does not require any additional resources than the ones devoted to its initial production. This non-rivalry property, satisfied by public goods, is to be contrasted with the rivalry property satisfied by private goods for which the quantity produced must be at least equal to the total number of consumed units. Knowledge is also a non-exclusive good, in the sense that everyone can use it unless a specific property right legally protects it. Thus, as long as the production of knowledge requires a fixed cost in terms of R&D investment, and the goods and services in which the knowledge is embedded can be reproduced and distributed at low marginal cost, perfect competition in the product markets does not allow the innovator to recoup his initial investment. Whereas the production of knowledge is socially valuable, its non-rivalry and non-exclusivity features make it questionable for a competitive market mechanism to perform properly and public intervention is needed to re-establish private incentives to engage in R&D activities.

IPR, as an ex-ante incentive mechanism giving the inventor the exclusive right to use or sell its invention, have been generally considered as being a valid policy instrument to overcome those problems. By imposing a legal exclusivity to the use of knowledge, society encourages ex-ante investment in research

and thus the production of knowledge and innovation. However, whereas for rival goods strong property rights lead to efficient market outcomes, for non-rival goods an IPR involves a trade-off. Weak rights may lead to under provision of R&D effort, while strong rights may lead to a monopoly distortion (deadweight loss) and to a reduction in the pace of technical progress, since further innovations are confronted with the obstacles raised by previous innovators (Shapiro, 2001, Encaoua and Hollander, 2002). IPR appear thus as a second best solution given that the first best, characterised by a socially desirable level of innovation without market power, appears to be unreachable.

In this context, IPR correspond to an ex-post decentralised solution with many virtues. First, by giving some exclusionary rights to an inventor, society delegates the R&D decision to the innovator and leaves him the responsibility of recovering its R&D investment. Not only do individual agents have better information on the costs and benefits of R&D than the government, but delegation has also the positive effect of avoiding the moral hazard problem on the part of the researchers. Second, the assignment of costs is made to users rather than to tax payers. Third, the implementation of the patent system by the government does not require economic information that is only privately known (R&D cost, value of the innovation). The reward resulting from a patent is linked to the private value of the innovation, so that innovative firms will compare the cost and the value when deciding whether to invest. Finally, the disclosure rule to which granted patents are submitted favours in principle the diffusion of knowledge.

But they also have many drawbacks. First, patents create static distortions corresponding to the classical deadweight loss that results from inefficient monopoly pricing. Not everyone who values goods above their marginal cost can buy them. Second, the market reward of the patent is not directly linked to R&D cost. Moreover, so long as inventors cannot fully capture the consumer surplus or the positive spillovers of their ideas to other researchers, they do not capture the social value of their invention. Therefore, incentives for socially valuable inventions may be insufficient. Third, the patent system does not avoid some duplication of resources, for instance through patent races. Fourth, patents also distort the direction of research by creating too much incentive to develop substitutes for patented goods and too little to create complements, since by developing substitutes, firms can steal rents from existing patent holders (Eswaran and Gallini, 1996). Fifth, IPRs require a large amount of financial resources devoted to their enforcement (infringement, suits, trials, etc.), resources that are diverted from the process of innovation. Finally, private information on individual research efficiency is in general disseminated among heterogeneous firms and the patent system does not lead to a useful aggregation of this disseminated information for efficient decision-making.

## **2.2. Non-rivalry and market-based means of protection for inventions**

The view that no profit can be made from an invention if it is not protected by legal means, or that market forces are not sufficient to compensate inventors, has been challenged on different grounds for the past two decades in a series of empirical works (Levin et al. 1987; Cohen et al. 2000). Broad empirical evidence supports the view that knowledge used in economic processes is to a large extent difficult or costly to imitate, which contrasts with the traditional view that knowledge is a public good. If knowledge was like any other ordinary rival asset, there would be no need for special protection and competitive rents would provide sufficient incentives to innovate. Companies would be able to charge customers for the additional cost incurred in R&D for the production of new knowledge embedded in their products and processes, without being undercut by lower cost imitators. The market power enjoyed by firms in this context would thus be justified by the nature of technology itself, not by any specific economic or legal device.

### ***2.2.1. Empirical evidence on the effectiveness of patents across sectors***

Several industrial surveys have illustrated the fact that patent protection is not always an essential prerequisite for invention in some sectors. Mansfield (1986) asked firms what fraction of inventions they would not have developed in the absence of patents in 1981-83, finding out that it was generally very low (less than 10% for firms in electrical equipment, primary metals, instruments, office equipment, motor vehicles and others), except for pharmaceuticals (60%) and fine chemicals (40%).

In contrast, first mover advantages, secrecy and the existence of complementary assets seem to be effectively used by firms to protect their inventions without necessarily relying on legal means of protection such as patents.

- *First mover advantage and costly imitation.* Replicating an existing invention is costly and time consuming because knowledge is to a large extent embodied in individuals, in firms, and in physical goods and equipment. The characterisation of knowledge as blueprint is to a large extent irrelevant in many technology areas, although it might apply to science where many discoveries can be summarised in formulas. Certain industries like pharmaceuticals are more science-based than others and might be characterised by more codified and hence more easily imitated knowledge. However, much knowledge is not codified. This entails delays and limits imitation, giving rise to first mover advantages that could allow inventors to recoup their cost in general. Providing protection when imitation is costly is unjustified, not only because the innovator has enough incentive to create a new product without creating deadweight loss but also because protection often creates barriers to entry. Lead-time in the market can be sustained if there is further learning, which guarantees the initial inventor permanent advantage over followers.

- *Secrecy*. Even if it is non-rival, knowledge can be protected by secrecy. Secrecy can lengthen the duration of the first mover advantage and reduce the ability of competitors to improve upon initial inventions. In addition, secrecy is to a certain extent protected by law (e.g. trade secrets). Secrecy is particularly efficient for process innovation, which cannot be reverse engineered and in many instances leaves no visible mark on the product.
- *Complementary assets*. Obtaining profits from an invention requires the use of complementary assets, which might act as barriers to entry. Such complementary assets include marketing (e.g. distribution networks, brand name and reputation etc.), manufacturing facilities and specific competencies. Firms that are not endowed with these assets face barriers to enter the market and compete with the initial inventor.

The 1983 Yale Survey and the 1994 Carnegie Mellon Survey, both administered in the US, show that firms use private appropriation mechanisms such as exploitation of lead time and the use of complementary sales, manufacturing and service capabilities in addition to secrecy and patents to capture and protect the competitive advantage provided by innovations (Levin *et al.*, 1987; Cohen *et al.*, 2000). Results also show that firms commonly employ a variety of mechanisms to protect the same invention, and that the frequency of reliance on a certain mechanism differs across sectors. Patents are unambiguously reported to be the least central of the major appropriability mechanisms in all industries, significantly below complementary sales and services, but relatively more effective in industries such as medical equipment and drugs, special purpose machinery, computers and auto parts (Cohen *et al.* 2000).

Moreover, by using data from the 1994 Carnegie Mellon Survey, Arora *et al.* (2003) show that the additional payoff obtained from a patented innovation relative to an unpatented innovation (patent premium) differs largely across industries and is positive only in a few manufacturing industries: drugs, biotech, medical instruments, machinery, computers and industrial chemicals.

However, it seems that patents are often devoted to other purposes than appropriating returns from innovation, such as an instrument to increase bargaining power (patent portfolios) and to facilitate entry of SMEs in markets (intangible assets of start-ups). To illustrate the former, there is evidence that firms in the semiconductor industry rely much more on lead-time, superior manufacturing and design capabilities rather than on patents as protective devices. Despite this, one observes an increasing propensity to patent in this industry. Hall and Ziedonis (2001) explain this patent paradox by arguing that the important portfolio of patents amassed by firms are best viewed as *bargaining chips* that give credibility to the threat that

others will be effectively sued for infringement. Similarly, this portfolio also serves to reduce the risk of being held by other patent holders, since they enhance one's capacity to bargain under better conditions for access to technology developed elsewhere.

Patents also facilitate entry by start-ups in high-technology fields through cooperation agreements with incumbents via licensing agreements, strategic alliances or mergers. Gans, Hsu and Stern (2002) find that patents contribute to create technology markets, especially in emerging fields, such as biotechnology, where capital markets are imperfect: "*start-up innovators tend to earn their returns from innovation through the market for ideas, acting as upstream suppliers of technology.*" This argument could be used to favour entry of firms with highly-valuable innovations through patent protection.

### ***2.2.2. Theoretical arguments in favour of market-based mechanisms***

From the theoretical point of view, a key question to start with is whether market-based mechanisms are sufficient for inventors to recover innovation costs. This question is at the heart of the debate opened by recent research. It has been argued that the discounted value of the stream of revenues generated by selling the first unit is sufficient to allow inventors to recover the sunk cost associated with initial R&D investments. Some leading economists have recently tried to formalise this argument in theoretical models (Bester and Petrakis, 1998; Hellwig and Irmen, 2000; Boldrin and Levine, 2002).

Boldrin and Levine (2002) define the *right of first sale* as the property right allowing an inventor to use his intellectual asset for a productive purpose or to sell the prototype, which is the first unit of the tangible good incorporating the intangible knowledge, to a third party. As for any other good, this property right is perfectly legitimate and commanded by economic efficiency. However, patent protection goes beyond this right of first sale since it also involves the right to control and limit the usage of the intellectual property after sale. This second right is the one conferred by patent protection and corresponds to what Boldrin and Levine call *downstream protection* or *intellectual monopoly*. They argue that the right of first sale may be sufficient to allow a creator to recover his R&D investment by obtaining a revenue reflecting the full market value of the invention, *i.e.* the net discounted value of the future stream of consumption services generated by the first unit produced. At each date, consumers are confronted with the following choice: either they buy and consume the product; or they buy and replicate the product, withdrawing revenues from the inventor. Subsequent replication usually involves *non-increasing returns to scale*, because it takes time to replicate the original prototype and only a limited number of units can be replicated per period. The inventor internalises this loss in the expected revenues he can capture. Since the technology of production of the owner of the prototype is characterised by non-increasing returns, it generates infra-marginal rents or

competitive rents that can be sufficient to recover the R&D sunk cost. Thus, even without intellectual monopoly, innovators have incentives to undertake R&D investments.

To what extent is this argument correct? The problem is that due to the indivisibility of the initial R&D investment, the market value of the prototype may be too low to recover this indivisible cost. Competitive markets would thus not provide enough rents to inventors when initial R&D costs are too large (Boldrin and Levine, 2002). This result has also been obtained by Bester and Petrakis (1998) in a partial equilibrium framework and by Hellwig and Irmen (2000) in a general equilibrium framework.

Moreover, the assumptions underlying the assertion that products embodying ideas may be produced, reproduced and distributed under the conditions of perfect competition, without intellectual monopoly, are not totally innocuous. First, for competitive rents to be sufficient, demand has to be elastic. When demand is elastic, if the cost of copying the new product decreases over time, due to the introduction of a more competitive technology of reproducing and diffusing the copies of the prototype, output increases more than prices decrease at each date, so that the revenue appropriated by the innovator increases. Second, the inventor is supposed to anticipate the residual demand for its product at each date, without any informational constraint, which is a rather stringent assumption. Finally, a paradoxical feature of this model is that a decrease in the cost of imitation generates an increase in the rent of the initial inventor: the easier it is to imitate an invention, the less protection it needs.

Despite the restrictive assumptions underlying their model, the mechanism proposed by Boldrin and Levine is nevertheless backed up by empirical evidence on the extended use of secrecy to protect inventions: the inventor does not diffuse its invention, which is protected by secret law, but once it is sold embedded in a product, customers have the right to reverse engineer the product to duplicate the invention. Trade secret law permits reverse engineering, which is the advocated diffusion technology in their model. The key question is whether patents are preferable to secrecy. On the one hand patents favour the diffusion of knowledge because of disclosure requirements, but they also involve many drawbacks (deadweight loss, etc). On the other, secrecy prevents disclosure but allows the working of competitive markets. Empirical evidence shows that the balance might be different across sectors. In what follows the special case of financial innovations, traditionally protected by secrecy and recently included in the realm of patentability, is analysed.

### ***2.2.3. Informational advantages: the case of financial innovations***

Research undertaken to date indicates that patents are not essential to promote innovation in this field. Banks and other financial institutions have been developing financial innovations over the past four

centuries in the absence of legal protection mechanisms, and patent subject matter was only extended to financial and other business methods in the US with the State Street Bank decision in 1998.<sup>2</sup> The question is how innovators recoup costs in a sector where innovation costs tend to be high and imitation occurs relatively rapidly. Empirical work on the incentives to innovate in financial markets has shown that underwriting spreads on first offerings had not been much larger than on late offerings for a sample of financial services introduced by investment banks between 1974 and 1986. Lead-time was relatively short for innovators, although they usually enjoyed higher market shares than followers (Tufano, 1989).<sup>3</sup>

Consistent with these empirical findings and additional information from interviews with credit derivatives dealers and developers in investment banks, a theoretical model developed by Herrera and Schroth (2000) shows that the incentive of investment banks to launch new financial products comes from the *informational advantage* provided by being the first in the market. Lead-time is important because it specifically provides an informational advantage in a setting where learning by doing is essential, not because of short-term monopoly profits an innovator may obtain until competitors enter the market. In fact, they argue that the threat of imitation prevents the innovator from charging monopoly profits in the learning stage, when he is the only supplier. The innovator is able to recoup investment costs because his informational advantage and expertise enables him to charge higher prices and enjoy larger market shares than their competitors at the competitive stage. Information is essential in a market where profit depends on risk management, so although the design of a financial product is fairly easy to imitate, its optimal exploitation can only be imperfectly imitated because it requires some expertise that is carefully protected by the innovator with secrecy.<sup>4</sup>

### **2.3. Sequential and complementary innovations: the case of software**

Not only may patents not be needed to recover innovation costs when imitation is costly, as described above, but the exclusive rights they provide, might hamper follow-on innovations. Indeed, when innovation is sequential, patents may impede access to previous inventions and slow down progress. Even if the initial rents earned by an innovator in the absence of patents are lower than with patents, the benefits

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<sup>2</sup> Since then USPTO has issued patents on financial inventions on asset valuation, debt management, education finance, mortgages, privatisation, risk assessment, stock picking and working capital finance, among others (Thomas, 2001).

<sup>3</sup> Recent empirical findings by Carow (1999) confirm that leaders tend to have larger market shares than followers but show that prices decrease as the number of competitors increases when the reputation of sellers and specific characteristics of the products compared is introduced into the analysis.

<sup>4</sup> One of the persons interviewed by Herrera and Schroth, a J.P. Morgan credit derivatives trader, explained that the economic value of a financial product lies in information about its performance, rather than in its design: "*Everybody can see the laid-out contract but what I am very careful not to disclose are the positions in my book. With this information you could track down the logic and see where I make money. Without it you could not price correctly the product, break down the risks involved, and understand what the components are. New ideas are not easily imitated: the developing process is a set of complex skills that are not easy to acquire*".

that accrue to him when he is allowed, in his turn, to build around the next innovation made by a competitor outweigh the current loss.

An example of an industry where these features are present is software. Innovation in the software sector has been characterised as sequential and complementary, so that the probability of achieving a certain research goal within a given time increases with the number of research lines followed. In this setting, Bessen and Maskin (2000) argue that the exclusive rights conferred by patents may play a negative role because the costs of precluding cooperation to facilitate further innovation may be higher than the benefits of the monopoly profits conferred by patents, so that although “*patents preserve innovation incentives in a static world; in a dynamic world, firms may have plenty of incentives to innovate without patents and patents may constrict complementary innovation.*”<sup>5</sup> They use the fact that R&D intensity of top US software patentees after the expansion of patent subject matter in the US to software in the 1980s remained “*roughly steady or declined*” to illustrate that patents are not *per se* the best instrument to spur innovation in the software industry.

More recently, using a regression model of the cost of patenting, Bessen and Hunt (2002) have shown that “*the growth of software patents is associated with significantly lower R&D intensity, consistent with strategic patent portfolio behaviour*”, because patents constitute more a substitute for R&D than a complement in this area. They claim that manufacturing firms, which are patenting relatively more software inventions, have imported patent portfolio strategies from their traditional sectors of activity to the software sector. They also argue that this is one of the main reasons behind the increase in software patents. This behaviour corresponds to the one observed in semiconductors industry, as noted above.

An additional factor to take into account in this area is the emergence of the open source software initiative at the end of the 1990s. In its early years, the open source software community aimed at keeping software innovation away from business interests and patents by using a set of rules to guarantee access to the source code and allow modifications and derived works.<sup>6</sup> Market-based mechanisms such as the offering of complementary assets and sales seem to be the most successful way to recoup investment costs associated with software invention in this environment, as evidenced by the successful entry of big firms as sponsors of open source software models.<sup>7</sup>

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<sup>5</sup> (Bessen and Maskin, 2000, p.20).

<sup>6</sup> <http://www.opensource.org/docs/definition.php>

<sup>7</sup> “*Like all big shifts, the Linux phenomenon will include winners and losers. Likely winners include IBM, which specializes in high-performance computing and is selling twice as many Linux servers as any other computer company. Processor maker Intel is riding Linux’ coattails into the world of high-powered computing. And Dell is*

#### **2.4. Scientific discoveries as ‘essential facilities’: the case of biotechnology**

The extreme case of sequential innovations appears when a particular innovation lacking economic value in itself is essential as a research input for highly valuable innovations in the future. Basic discoveries, genetic material and research tools in general, which can be considered as ‘essential facilities’ for follow-on innovations, come under this category.

Research tools in biotechnology, and basic scientific discoveries in general, were introduced in the patent debate with the Bayh-Dole Act and the expansion of patent protection to biotechnological and genetic inventions at the beginning of the 1980s in the US. The Bayh-Dole Act reinforced patenting and licensing incentives for federally funded research to promote its commercial exploitation (Mazzoleni and Nelson, 1998). The underlying principle seemed to be that although federal funds were still necessary for fundamental research, its development into commercially applicable research and inventions needed additional private research that would only be incurred by firms if patent protection allows them to appropriate the economic return of its exploitation.

A recent paper by Walsh, Arora and Cohen (2002) provides empirical evidence on the impact of patenting and licensing research tools in the field of biomedical innovations. They note that advances in molecular biology, automated sequencing techniques and bio-informatics have made biomedical research depend *“more heavily than before on previously developed research tools, particularly prior scientific discoveries”*. They also note that the role of universities has become more important in the past two decades, *“as sources of both patented biomedical inventions and start-up firms that are often founded on the strength of university-origin patents.”* Despite the obstacles posed by patents in this area, where scientific discoveries used to be placed in the public domain two decades ago, the general conclusion seems to be that *“firms have been able to develop ‘working solutions’ that allow their research to proceed. These working solutions combine taking licenses, inventing around patents, infringement (often informally invoking a research exemption), developing and using public tools and challenging patents in court.”* The question is whether the benefits of patenting outweigh the waste of resources needed to find such a working solution.

There are several examples of patents for research tools being used to block follow-on innovations in biomedical research, such as the patent on the OncoMouse granted by USPTO to Harvard University in 1988. Due to the existence of an exclusive license granted by Harvard University to DuPont, the National

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*pumping out low-priced Linux servers and selling them directly to companies via the Net.”* Business Week, “The Linux”, Special Report, March 3, 2003.

Institutes of Health (NIH) only obtained access twelve years after, under restrictive conditions and after years of negotiations.<sup>8</sup>

To sum up, broad patents on research tools may be an obstacle to further innovation when patent holders license research tools exclusively and use their patents anti-competitively. Not only should PTOs avoid granting excessively broad patents on basic inventions that may be used on a wide range of applications in the future, but also competition authorities should monitor licensing agreements involving patents in order to avoid their use as an instrument to block R&D by competitors. Research exemptions or compulsory licenses on essential inputs for research could be envisaged as the solution, in the same way as competition authorities request open access to essential facilities in other fields.

## **2.5. Conclusion: patents should not be the solution by default**

Patents are not needed as an incentive mechanism for all inventions. A series of characteristics of technologies and markets such as the degree of non-rivalry, ease of keeping secrecy, the sequential character of innovations and the technological opportunity rate determine whether market-based means of protection provide sufficient incentives for innovation. As a result, the optimal protection regime may differ across fields, with different solutions applying to industries as diverse as pharmaceuticals, software and finance.

For economists, the key question is whether there exist types of inventions or technology fields for which the social cost of patenting clearly exceeds its social benefit, and whether, in that case, inventors should be prevented from using patents even though they may find them privately profitable. This raises the question of what should be accounted as social costs and benefits of patenting. But, one must recognize that a full appraisal of the impact of patents needs to take into account other purposes than exclusion from the market. Patents serve private purposes when used as an argument in negotiations for cross-licensing agreements, as a signalling mechanism for shareholders, banks, venture capitalists, competitors or customers. They also contribute to social welfare by facilitating the diffusion of knowledge through information disclosure requests and allowing the development of markets for technology. To a large extent, economic theory falls short of addressing these other private and social motives for patenting.

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<sup>8</sup> It is worth noting that the Canadian Supreme Court found the patent for the OncoMouse to be invalid in Canada in 2002, although the decision was mainly based on ethical grounds about the patentability of higher life forms, such as mammals.

### 3. Instruments of patent policy design

In what follows, we consider some policy issues in the current patent debate. Although they do not exhaust all the problems raised by the evolution of the patent system, they are nevertheless of prime importance. Recent trends in the patent system show a decrease of the patentability requirement and a broadening of patent breadth. The purpose of this section is to inquire whether these trends are justified from an economic perspective.

#### 3.1 Patentability requirement: non-obviousness or inventive step

PTOs grant patents to inventions provided they comply with the patentability criteria of utility, novelty, and non-obviousness.<sup>9</sup> Non-obviousness is a technical concept meaning that the invention should not be obvious to somebody skilled in the relevant art. In particular, it should not be a combination of existing techniques that is obvious to the person skilled in the art.

There is some evidence that the non-obviousness criterion has been deteriorated over the past two decades. In the US, the effective grant rate (including continuing applications) lay in the range between 82% and 96% in the mid 1990s (Quillen and Webster, 2001). The problem seems to be especially important in new areas such as software and business methods. Software experts argue that patents have been granted on inventions that were neither obvious nor novel. Examples include the patent on hypertext links granted to British Telecom in 1989 and the 1997 patent on anti-virus protection for computer networks.

Moreover, new IPRs with lower non-obviousness requirements and providing weaker protection than patents have been introduced, such as petty patents and a number of *sui generis* rights. Illustrations include the 1984 US Semiconductor Chips Protection Act and the petty patents introduced in Australia in 2001 that are intended to provide protection to “*incremental and lower level inventions that would not be sufficiently inventive to qualify for standard patent protection.*”<sup>10</sup>

In order to analyse the effects of the lower patentability requirement, one must begin by emphasising one of the main differences between PTO practice and economic research approach. Non-obviousness is defined according to the technical character of the invention by the former, whereas economists define it as a threshold under which the reduction in costs for process innovations or the degree of quality improvement for product innovations would be insufficient for the patent to be granted. The scheme is a one-dimensional scale on which all techniques of the relevant domain can be measured, according to some performance feature (e.g. cost, quality). In addition, whereas the technical characteristics of an invention

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<sup>9</sup> Utility is called ‘industrial application’, and non-obviousness is called ‘inventive step’ in Europe.

<sup>10</sup> [www.ipaustralia.gov.au/patents/P\\_innvopat\\_about.htm](http://www.ipaustralia.gov.au/patents/P_innvopat_about.htm)

are usually known *ex-ante*, economic features are only known *ex-post*, after the technique has been actually implemented, giving rise to products sold on the market. For instance, a new technical device, which does not improve performance with respect to a currently used technique, may satisfy the patentability requirement on the examiners scale, but it would not be acceptable *prima facie* on the economists' scale because it provides no direct or immediate gain to society. Nevertheless, both approaches could be reconciled by taking a broader view, accepting that although a new technique may not outperform incumbent techniques in its early stage it might do so after a few improvements have been made, and as such it deserves protection. PTOs have recently started to take into account economic criteria for granting or holding patents, instead of relying solely on technical factors, as has traditionally been the case.

The traditional tests of non-obviousness were primarily based on the following technical features: i) scope and contents of prior art; ii) differences between prior art and patent claims; iii) level of ordinary skills in the relevant art. However, in the US, a set of secondary factors such as commercial success, failure of others and long felt need, previously considered as subordinate, was elevated by the CAFC to the same status as the primary factors set out above and is now used as part of the patentability requirement by the USPTO and US courts. In Europe, commercial success is also considered as relevant information by the EPO, but still subordinate to the technical criteria: “*Commercial success alone is not to be regarded as indicative of inventive step, but evidence of immediate commercial success when coupled with evidence of a long-felt want is of relevance provided that the examiner is satisfied that the success derived from the technical features of the invention and not from other influences (e.g. selling techniques or advertising).*”<sup>11</sup>

However, Merges (1992) argues that patents should be used to encourage firms to engage projects with low certainty of commercial success, as inventions with more certain gains would be implemented even without a patent. Increasing the patentability requirement encourages larger and riskier inventions, something that is socially desirable when markets tend to favour smaller and less riskier inventions.

### **3.1.1. The effect of patentability requirements on R&D and innovation**

What is the advantage of restricting the number of patents by imposing non-obviousness requirements? In other words, why not grant patents to all inventions? The answer is that strong patentability requirements provide higher incentives to innovate by extending the effective life of patents, the length of market incumbency for the inventor.

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<sup>11</sup> EPO guidelines, Part C, Chapter IV, page 72.

To analyse the effect of the patentability requirement on the pace of innovation, Hunt (1999) considers a situation where successive quality improvements occur and research activity has uncertain outcomes. At each point in time, only the highest quality product is profitable ('the winner takes all') and for an improvement to be patented, it must exceed some threshold value, which corresponds to the patentability requirement. In addition, unless it is patented, an invention is in the public domain, so that a non-patented product would be immediately copied by all firms and therefore would have a zero return. A patented technology is fully disclosed and serves as a basis for further improvements. A number of firms are racing to improve existing products and it is assumed that decreasing returns on R&D prevail for each firm.

In this setting, the net effect of an increase of the patentability threshold on the pace of innovation depends on the magnitude of two opposing effects. The short-term effect is negative. Indeed, increasing the patentability requirement lowers the probability that an innovation is qualified for a patent, reducing therefore the short-term incentive to innovate. In contrast, the long-term effect is positive for two reasons. First, an increase of the patentability requirement leads to a longer effective patent life of an innovation, since it will be replaced by improved techniques later. Second, it also leads to a higher average profit flow from a patented discovery. Hunt (1999) shows that there exists an inverted U relationship between the increase of the patentability requirement and the rate of innovation. Innovation is positively affected by the height of the patentability requirement but, after a certain level, the relationship changes and innovation decreases. Moreover, simulations show that the optimal patentability requirement is relatively high and increases with the arrival rate of innovative ideas.

### ***3.1.3 What factors should determine the optimal patentability requirement?***

The above analysis has shown that the optimal patentability requirement would be higher when technical change is more rapid. The reason is that the opportunity cost of not winning the patent race is smaller, as the incumbency period decreases with the arrival rate of innovative ideas.

An implication of this finding is that factors affecting the optimal level of the patentability requirement are technology specific, whereas the current patent system is characterised by uniform rules, following the principle of 'one size fits all'. Thus, the reduction in the patentability requirement experienced in certain countries over the past two decades might have favoured industries where technical change is low at the expense of industries with high technological opportunities (e.g. IT, biotechnology). This is all the more important as the reduction in the patentability requirements seems to have been particularly large in these new fields, especially software.

The relaxation of one crucial assumption in Hunt's model would reinforce the positive effect of increasing patentability requirements on innovation. If imitation were assumed to be costly even for a fully disclosed invention, the optimal patentability requirement would be higher. Indeed, when the incumbent cannot freely capture a non-patented technology, an innovator needs more incentives to undertake an R&D project. Increasing the patentability requirement would give such an incentive by increasing the effective life of the incumbent.

To conclude, the economic characteristics of inventions should be taken into account whenever the information is available before granting a patent. That might even justify some delay in the granting process when deemed useful by patent examiners. Examiners of patents and courts should then consider inventions with greater value more favourably than others.

### **3.2. Patent breadth**

The breadth of a patent is defined as the set of products that courts would find to infringe the patent, i.e. products that no other firm can make, sell or use without a license from the patent holder. In principle, patent breadth is determined by the claims accorded by the patent examiners to the patentee, defining the boundaries between what is protected and what is not, and by the Courts interpretation of these claims during litigation procedures. Courts in different countries increasingly rely on the *doctrine of equivalents*, meaning that essentially equivalent products not explicitly included by the patentee in the stated claims could be judged to have infringed the patent. Such a doctrine leads to a higher patent breadth than the *enablement doctrine*, according to which only what is disclosed is protected. Research exemptions also affect patent breadth. Exemptions to the application of patent rights, notably for research use, have a narrowing influence on the breadth of patents as they allow inventions to be used by third parties without any compensation to patent holders. However, a recent US Court decision has rendered these research exemptions more stringent. Thus, a trend towards broadening patent protection can be observed. The question is whether this trend is justified from an economic point of view.

Different notions of breadth have been developed by economists, according to whether innovation is examined in isolation or as a component of sequential innovations. In the context of isolated innovations patent breadth is identified with *lagging breadth*, which specifies the set of inferior products that would infringe the patent and limit the behaviour of imitators. In order to distinguish between infringement coming from imitation or improvement, economists also introduced the concept of leading breadth, which specifies the set of superior products that are protected by the patent and limit the behaviour of future innovators. One can also have some more sophisticated, albeit implicit, notion of breadth. Endogenous growth theory exemplifies such an approach, in which any invention is split into two components. First, the

product sold on a market, which is protected by a patent and sold with a premium that covers research cost. Second the idea itself, which will be used later in other inventions as the state of the art from which new inventions are discovered. The question is whether the protection of the idea itself, besides the protection of the product, is justified or not.

Since the effects of patent breadth differ according to whether an innovation is considered in isolation or not, we separately analyse single and sequential innovations. Moreover, for sequential innovations, it is important to distinguish two sub-cases according to whether only two successive innovations or an infinite number of successive innovations are considered.

### ***3.2.1 Isolated innovations***

The literature on patent design examines isolated innovations by emphasising the traditional trade-off between creating incentives to conduct R&D and the deadweight loss resulting from strong patents. Optimal patent breadth is defined by minimising the discounted value of the deadweight loss created by the patent under the constraint that the discounted profit provides enough incentives to invest (Nordhaus, 1969, Scherer, 1972, Tandon, 1982, Gilbert and Shapiro, 1990, Klemperer, 1990, Waterson, 1990, Gallini, 1992, Denicolo, 1996). In most of these models, patent breadth is to be understood as lagging breadth, in the sense of the protection accorded against imitators. Thus for a product innovation, breadth defines the minimal differentiation that must exist between a patented product and an inferior product so that the second one does not infringe the patent on the first one. For a process innovation leading to a cost reduction, breadth defines the maximal cost reduction allowed to a non-infringing inferior process.

Patent length and patent breadth affect the value of the invention as they determine the extent of the protection. A broad patent allows its holder to set a higher market price, while a longer patent allows its holder to get the innovation rent for a longer period of time. But these two dimensions of patents work in different ways, with different effects on the economic behaviour of the patent holder and its potential competitors. Larger breadth makes it more difficult to imitate or improve the protected invention, whereas increasing the duration of patent protection enhances the incentives to imitate or to improve the invention (Gallini 1992). The results of the different models on the optimal mix depend heavily on the relationship between deadweight loss and breadth.

Gilbert and Shapiro (1990) define patent breadth as the minimum price that provides the patentee a pre-specified reward allowing him to recoup the R&D cost (participation constraint). In this case, minimising the deadweight loss under the participation constraint calls for a *long and narrow patent*, where the breadth just allows the specified reward. This result crucially depends on the fact that deadweight loss increases

more than proportionally with breadth (i.e. it is a convex function of breadth). Tandon (1982) obtains the same qualitative result in the context of compulsory licensing.

However, Klemperer (1990) obtains different results by developing a model with horizontal product differentiation, linear disutility costs and price competition. In his model, patent breadth is defined as the set of characteristics in the product space that infringe the patented product, so that consumers may be deprived of their ideal products if these products happen to infringe on an existing patented product. In this context, Klemperer shows that two combinations of patent length and breadth can be optimal: long and narrow patent or short and broad patent protection.

Short and broad patents are also found to be optimal in Gallini (1992). If an innovator introduces a new patented technology, reducing unit cost by a certain amount, breadth is defined as the maximal cost reduction that an imitator can achieve to avoid infringement. Larger breadth is associated with higher imitation cost. With imitation, the social cost of patents has now two components: deadweight loss and duplicative waste resulting from imitation. Gallini shows that broad and short patents are optimal because they lower socially wasteful imitation. This result has been criticised by Maurer and Scotchmer (1998), who note that the introduction of a compulsory license regime in the model would reverse the optimal design: *"whatever the market outcome without licensing, the innovator and potential entrants can achieve the same market outcome (price and number of entrants) through a licensing agreement with appropriate royalties and other fees"*.

To sum up, there is no conclusive result on the optimal mix between length and breadth for isolated innovations. However, there is a strong presumption that narrow and long protection is a preferable alternative when introducing more realistic features in the model, for instance, patent races and richer descriptions of competition in product markets (Denicolo, 1996).

### ***3.2.2 Two successive innovations: first and second generation***

When there are only two successive innovations, the main question is how patent breadth affects infringement and licensing, and how the distribution of profits between first and second-generation innovators is determined.

If the initial innovation gives rise to a follow-on marketed product, one source of revenues for the first generation innovator (upstream) may be the transfer paid by the second generation inventor (downstream) via licensing. In this case, a broad patent to the initial invention will reduce the incentives of the follow-on application. Therefore, the incentive of the first innovator will decrease because its expected revenues

depend on the use of its innovation by the next innovator. But, another dimension is opened if the first and second innovators introduce some collusive agreements before the second innovator commits to its R&D investment (Scotchmer and Green, 1990, Merges and Nelson, 1990, 1994, Green and Scotchmer, 1995, Scotchmer, 1991, 1996, Chang, 1995, Matutes *et al.*, 1996, Eswaran and Gallini, 1996, Van Dijk, 1996, Denicolo, 2000).

As in the case of isolated innovations, analytical results are heavily dependent on the availability of licenses: *ex-ante* licenses for sequential innovations as opposed to *ex-post* licenses for isolated innovations. *Ex-ante* contracting, before R&D costs are incurred, can reproduce the situation where a single firm develops both upstream and downstream innovations. This is a simple application of the Coase theorem, which states that in the absence of transaction costs, the distribution of property rights among market participants has no effect on the social outcome. With *ex-ante* contracting, subsequent innovations occur if they provide additional profit, and the role of breadth is to determine how the profit is divided. However contractual agreements raise serious concerns from the viewpoint of competition policy.

Chang (1995) develops a model of two successive innovations "*to determine how courts should set legal standards for patent improvement so as to encourage the invention of valuable improvements on a patented product or process*". Measuring the patent breadth of the first invention as the share of the second-generation value that must be appropriated by the first innovator, Chang shows that the optimal patent policy is to allow a patent breadth that is non-monotone on the value of the first innovation. "*Courts should set infringement standards so as to extend the broadest protection not only to a basic invention with a very large stand-alone value relative to all possible subsequent improvements, but also to the patent with very little stand-alone value relative to the improvements that it may inspire. This rule differs from that proposed by the leading textbook on patent law, Merges (1992), and by Merges and Nelson (1990), who suggest that courts decline to find infringement when the value of the original invention is small relative to the value of the improvement*".

Moreover, Chang re-examines the question of the effects of a collusive licensing policy, a question that leads to two opposing views. "*Whereas Scotchmer (1991) and Green and Scotchmer (1995) suggest that courts should permit collusive licensing between competing patentees, Kaplow (1984) has argued that such an antitrust policy rewards innovation only at an excessive social cost*". The results obtained by Chang provide only very limited support in favour of collusive licensing, since such a policy creates incentives for inefficient entry by imitators who invent around the original patent. Thus a policy favouring collusion between a patentee and competitors who improve the product but still infringe the patented product is unappealing.

Finally, Chang addresses the issues arising from the design of an ideal compulsory licensing policy. He shows that under the impossibility of reaching a first best solution, only a third best solution can be achieved with the limited set of policy instruments combining patent breadth and antitrust regulation. In this setting, Courts can only decide whether the second invention infringes or not the first patent, and allow collusive licensing or not. He argues that a second best solution can be achieved under a compulsory licensing regime by regulating the price of the license.

Denicolo (2002) suggests a more lenient policy against collusion between successive patent holders. In a model involving patent races for two successive innovations in which the winner of the first race can participate in the second one, he shows that when social value differs from private value collusion may be socially beneficial under more limited circumstances than in Chang's model. In particular, if the second-generation innovation contributes to consumers' surplus more than the first, collusion between successive innovators must be permitted since it encourages the first invention. However, "*the reverse may hold if the second innovation contributes little to consumers' surplus, but in this case ruling that the second innovation infringes on the first patent may be a more effective way of stimulating initial investment. A policy regime in which the second generation does not infringe and collusion is banned may then be optimal only for intermediate values of the model's parameters*" (Denicolo, 2002).

As a conclusion, it appears that in the two-generation-framework, the first innovation is an essential facility to the second one. In such a situation, two policies are possible. One is to let the two innovators enter into *ex-ante* contractual agreements and decide how to share the joint profits between them. Such a solution gives incentives to the realisation of both innovations. But, besides the practical difficulty of this solution, due to the fact that the second innovator is generally unknown to the first one, the cost of this first policy may be relatively high in terms of anti-competitive behaviour. The second solution is to introduce a compulsory licensing regime, as in the second best solution advocated by Chang (1995), in which the first innovator commits *ex-ante* to sell a license at a predetermined price. This corresponds to a buyout mechanism to which we return later.

### ***3.2.3 Infinite sequence of successive innovations***

In a cumulative innovation context, current innovations benefit not only current inventors and consumers, but also future innovators who are offered the opportunity to build on them. The main research question in this setting is how to increase the pace of innovation while minimising monopoly distortions (O'Donoghue *et al.*, 1998, O'Donoghue, 1998, Bessen and Maskin, 2000, O'Donoghue and Zweimuller, 2000).

As in the previous section, profitability depends on the *effective life* of patents, which is itself determined by patent breadth. But now, with infinite sequence of innovations, it is the leading breadth that matters and not the lagging breadth. Suppose indeed that lagging breadth is complete, in the sense that an innovator obtains a protection for inferior products between the previous state of the art and the new improved state of the art. Even then, lagging breadth alone does not provide sufficient incentives for R&D because it offers protection only against imitators and not against future innovations. Lagging breadth alone leads to sub-optimal R&D investment in a cumulative innovation framework.

A specified rate of innovation can be achieved by choosing between two policies: the first characterised by a long statutory patent life and a modest leading breadth, and the second characterised by a short statutory patent life and a broad leading breadth. Under the first policy, the effective patent life is determined by the time elapsed until a sufficiently better product is invented. In this case, leading breadth acts as a non-obviousness requirement. Under the second policy, the effective patent life coincides with its statutory length. The comparison between these two policies depends on the rate at which new ideas emerge (O'Donoghue *et al.*, 1998). When the hit rate of ideas (supposed to be exogenous) is low, the first policy (long statutory patent life with modest breadth) is superior to the second because it lowers the effective patent life and favours the rhythm of technical progress. Conversely, when the rate of innovation is high, the second policy (large leading breadth and short length) is more effective since it gives higher incentives for R&D and it reduces market distortions. Moreover, a substantial rate of innovation increases the turnover of innovators.

These results can be understood by recalling the two interpretations of leading breadth. The first interpretation is that since previous patent holders have not discovered all the subsequent quality improvements, it would be unjustified to give them a protection against all these improvements. This interpretation supports the first patent policy with modest patent breadth and long statutory patent life. The second interpretation is that each subsequent innovation uses the previous technology as its basic knowledge input. This second interpretation supports the second patent policy with large leading breadth and short length.

Another important conclusion emerges from endogenous growth literature. Suppose that in an industry there are two firms competing both in research and the product market. At each date, both firms may be either neck-to-neck competitors or asymmetric players, where one is the technological leader and the other a technological follower. Encaoua and Ulph (2000) distinguish the technological frontier from the technological knowledge available to a laggard. When the idea underlying the current technological frontier is protected, a technological laggard who has no access to this knowledge may at best catch-up

with the technological leader. This corresponds to a step-by-step process of innovation (Aghion *et al*, 1997). Alternatively, when the idea underlying the current technological frontier is not protected, the laggard firm leapfrogs the previous leader when it succeeds. Encaoua and Ulph (2000) show that the rate of growth of the economy is higher when access to the current technological knowledge is not protected. They also show that product market competition has a positive impact on the incentives to innovate when protection of the idea is absent. These results support the view that intellectual property would protect the product and not the idea or the knowledge incorporated in the product. In other words, diffusion of ideas must be considered as a pure spillover that must not be appropriated. This objective can be achieved by reinforcing the role of patents as an information disclosure tool.

### ***3.2.4 Policy implications for patent breadth***

A conclusion that emerges from the surveyed literature on patent breadth is that economic models introduce more instruments than are available in the real world. While the economic literature emphasises the trade-off between patent length and breadth, in practice one of these instruments is fixed. Statutory patent length is uniform across industries and countries. The fine-tuning of patent policy that can be reached in economic models is more difficult to reach in reality. Under the constraint on the uniform statutory patent life, broad patents may do more bad than good to innovation. From this perspective the trend towards broadening patent protection is not economically justified.

Can it be justified on technical grounds? The answer seems to be negative. Indeed, several observers worry about the discrepancy between the real scope of discoveries and the claims granted by patent protection. Examples abound, notably in biotechnology. The claims made by inventors in patent applications, and often accorded by PTOs, go beyond their actual discoveries. This shows that patents are applied much more to serve strategic purposes than as an R&D incentive. Therefore patents are, in general, broader than can be justified on technical grounds.<sup>12</sup>

Broad patents distort incentives and allocation of research funds. While broad patents increase the rents accruing to inventors, they might generate rent-seeking behaviours if the PTO is not entirely successful in screening the legitimate claims of each patent application. In other words, broad patents increase the social cost of imperfections in the management of the patent system. In addition, broad patents tend to skew the

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<sup>12</sup> The example of the patent that originated the CellPro case (My-10 antibody) shows that patent claims can be much broader than claims at a scientific symposium for the same invention. The patent claimed all monoclonal antibodies that bind to CD34, although the actual discovery was one such monoclonal antibody only: “*If Civin had claimed at a conference of molecular immunologists that he had discovered all monoclonal antibodies that bind CD34, his reputation would have been permanently damaged for claiming findings beyond his own data.*” (Bar-Shalom and Cook-Deegan, 2002, p. 641-642).

reward distribution associated with research. Large breadth makes research resemble more a winner take all game, as modelled in patent races. One drawback of such a scheme is that it distorts the allocation of research funds which may concentrate in some areas and lead to duplication of efforts at the expense of insufficient investment in other areas where patents happen to be narrower.

Another conclusion emerging from this literature is that the trade-off between patent breadth and length depends on some industrial characteristics, such as the level of technological opportunities or the rate at which new ideas appear. We have shown that broad patent protection combined with short patent length could be the best policy in industries where technological opportunities are high. But even in this case broad patent protection alone is not justified.

What other lessons can be drawn from the previous economic literature? Given the current constraint of a uniform statutory patent life, other policy instruments can be envisaged without seeking to be exhaustive.

The first lesson is that a deeper coordination between patent policy and competition policy could improve the system. US Antitrust Guidelines for the Licensing of Intellectual Property issued in 1995, have taken a step in that direction. They recognise that cross-licensing or patent-pooling arrangements may provide *"pro-competitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions and avoiding costly infringement costs"*. However, the guidelines also make clear that, since these arrangements may restrain competition, they must be challenged under the rule of reason, so that authorities *"will consider whether the restraint is reasonably necessary to achieve pro-competitive efficiencies"*. The antitrust treatment of restrictive conditions included in licensing contracts is thus crucial (OECD, 1998).

The second lesson is related to the importance of research exemptions that favour knowledge diffusion. Reinforcing their role could reduce the drawbacks of the patent system. However, it appears that in practice research exemptions are rarely implemented and their scope has recently been seriously restricted in the US. In October 2002, the CAFC decided in *Madley v Duke University*, that the experimental use must be *"solely for amusement, to satisfy idle curiosity, or for strictly philosophical inquiry."*<sup>13</sup> It was also argued that if the use is in any way commercial in nature or if its purpose is to further improve the alleged infringer's legitimate business activities, it cannot be experimental. Insofar as universities are in the business of providing education and research, their use of patented knowledge for research would not be considered as experimental. Although this measure appears to be consistent with the policies encouraging universities to patent and licensing their research results, that is, to undertake profit-making activities

(Bayh-Dole Act), it might have long term negative effects and hamper cumulative innovation, especially in biotechnology where university research plays a very important role.

The third and fourth policies, which seem to be more promising but require a reform of the patent system, are related to renewal fees and compulsory licensing. They are the subjects of the next section.

#### **4. Rethinking the patent system: patents as an incentive mechanism**

From an economic point of view, the question of how public authorities should design patent policy to stimulate research, development and innovation is always considered from an *ex-ante* perspective. The relevant economic question is how to induce private agents to devote sufficient efforts and resources to research and development so that social welfare is maximised. The *ex-ante* economic perspective is an important aspect to keep in mind, particularly because legal scholars and lawyers often have a different approach. A lawyer would rather take an *ex-post* perspective, the relevant questions being how and when an inventor must be rewarded for his invention, according to the intellectual protection statutes, regardless of the effects this may have on the market allocation of resources and social welfare. Despite these apparently different perspectives, some attempts have been made to deepen the understanding of the relative virtues and shortcomings of the different incentive systems to stimulate innovation in order to draw policy implications. (Merges and Nelson, 1990, 1994; FTC-DOJ Hearings to Highlight the Intersection Between Antitrust And Intellectual Property Law and Policy, 2002; Sideri and Giannotti, 2003).

The main problem for public authorities is that neither the cost nor the value of an invention is perfectly observed. With perfect information, intellectual property would not be the best incentive mechanism. Other mechanisms better fulfil such a role by avoiding *ex-post* market distortions. Public sponsorship or prizes allow the public authority to choose the projects that present the largest net social benefits, either by subsidizing them *ex-ante* or by paying them a prize *ex-post* on delivery (Wright, 1983, Shavell and Van Ypersele, 2001, Chiesa and Denicolo, 2002). Thus, only the existence of asymmetric information between firms and public authorities on the cost and value of research programs could justify the existence of intellectual property protection.

Economists have attempted to show under what conditions patents can be considered as an efficient mechanism and by doing that, they have also sought to design patents that elicit socially beneficial inventions while minimising distortions in the allocation of resources. Two major results emerge from this literature. In the isolated innovation case, *renewal fees* can be used for implementing an optimal

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<sup>13</sup> *Madey v. Duke University*, No. 01-1567 (Fed. Cir. October 3, 2002)

mechanism (Scotchmer, 1999, Cornelli and Schankerman, 1999). In the sequential innovations case, a *fee on breadth* combined with a *buyout price* implement incentive mechanisms (Llobet *et al.*, 2000). These systems are designed in a way that allows *self-selection* by innovators. In the first case, the task of the regulator is to define a menu of choices involving application and renewal fees so that the chosen patent life increases with the value of the innovation. In the second case, the regulator defines a menu of choices involving an application fee and a buyout price at which an innovator commits to license its innovation to anyone willing to pay this price. The chosen patent breadth that results from this mechanism increases with the value of the innovation. In what follows we develop the description and the properties of these two mechanisms. They rely on specific assumptions regarding technology and informational structures.

#### **4.1. Renewal fees as an incentive mechanism for isolated innovations**

In many countries, besides the lump-sum patent application fee, it is necessary to pay renewal fees in order to keep the patent in force. A renewal fee system exists in the European patent systems and was introduced in the United States in 1982 (See Lanjouw, 1998, Pakes, 1986). The level of the application fee and subsequent renewal fees could be used as essential instruments of patent policy, even though at present they are mainly used to cover the costs of PTOs. Recent works have deepened our understanding of the patent fees and renewal fees as regulatory instruments (Cornelli and Schankerman, 1999, Scotchmer, 1999, Pakes 1986).

Suppose that a single firm has an idea for an innovation and must decide whether to invest in it or not. The characteristics of this idea, namely its cost and value, are observed by the firm but not by the government. Scotchmer (1999) shows that in this framework, the only *feasible incentive-compatible mechanisms are equivalent to patent renewal mechanisms*, where the transfer from the public authority to the innovator can be either positive (subsidy) or negative (lump-sum fee). This is an important result for two reasons. First, it gives a theoretical justification to the patent system since it presents an economic environment in which the patent system turns out to be optimal. Second, it opens the way for rethinking how patent fees and renewal fees should be calibrated for an economic efficiency purpose. Let us clarify the problem.

Consider a patent system where an applicant is confronted with a trade-off between a fee depending on the desired patent life to be paid and the monopoly profits to earn in return during the chosen effective patent life. This has two related consequences. First, at each period high value innovations will be more profitable than low value ones. Second, high value innovations will be renewed for longer, unless benefiting from a longer protection is made more costly. From the point of view of social welfare, this scheme could be justified only if the R&D cost increases more than proportionally with the value of the innovation or, in other words, only if the cost is an increasing and *convex function* of the value of the innovation. This is

exactly the context in which the patent system is optimal. A *patent system is an incentive-compatible mechanism if and only if the maximal cost supporting an R&D project is a convex function of its value.*

In a *direct revelation mechanism* where the firm is asked to report the value of its invention to the public authority, the patent office would have to decide on a rule specifying the amount of the fee (or subsidy) that the firm would have to pay (or receive) in order to obtain a legal protection for a specified time length. During this period of time, the firm is allowed to sell the patented product at the monopoly price. Suppose that a *social outcome* is defined by a *decision rule* prescribing that the firm invests in an innovation if and only if its R&D cost is lower than some threshold varying with the value of the innovation. This threshold defines a *cut-off function* that gives the *maximum R&D cost that can be supported in order to undertake the specified value project.* The firm is compensated for its R&D cost by capturing the discounted flow of profits during the length of protection obtained by paying the corresponding fee.

The first question is whether social outcomes could be implemented by a *direct revelation mechanism.* The firm must have incentives to both participate and report truthfully its parameters. In the jargon of the theory of mechanism design, this means that the mechanism must be *individually rational* and *incentive compatible.* Individual rationality means that what the firm receives from the mechanism must at least reimburse the cost. Incentive compatibility means that, whatever its actual cost and value, the firm must obtain at least as much by truthfully reporting the parameters than by lying. Mechanisms that are individually rational and incentive compatible are *feasible* mechanisms

Scotchmer (1999) shows that a social outcome is implementable by a feasible mechanism if, and only if, the cut-off function is a convex function. This means that the patent system is an incentive compatible mechanism only when the R&D cost function increases more than proportionally to the value or, to put it in another way, when the returns to R&D are decreasing. In this case, for each truthfully reported value, the *assigned patent life* has a discounted value equal to the slope of the cut-off function.

Since the cut-off function is convex, both the patent length and the fee to be paid by the innovator are increasing functions of the reported value. This means that higher-value innovations will receive longer patent life and will pay higher fees, which sounds reasonable. Note that if the effective R&D cost is lower than the cut-off value, the mechanism lets the firm capture an *extra-profit* corresponding to the *informational rent*, whereas if the R&D cost is larger than the cut-off value, the project is not patented.

When the R&D cost is just equal to the cut-off value, the mechanism just compensates for the cost and does not leave the innovator any extra-profit.<sup>14</sup>

This mechanism can be implemented by using existing features of the patent system. The lump-sum payment to obtain a patent for a desired length defines a *patent fee mechanism* in which the regulator offers a menu of different patent fees associated to different patent lives. The main result in Scotchmer (1999) is that every feasible mechanism is equivalent to a patent fee mechanism. This means that for any given social outcome with a convex cut-off function, there always exist *lump-sum patent fees* that implement the given social outcome. The lump sum fee is a non-decreasing function of the patent life.

A *renewal fee mechanism* involving *flow payments fees* could be used instead of lump-sum fees to obtain the same results. Defined as a function of time, these flow payment fees are also non-decreasing, which means that to obtain an extension of the patent protection for one more period, the innovator has to pay an increasing renewal fee. Thus the *renewal fee* system is an important instrument for an optimal patent policy. The fees correspond to an option-based view of patent valuation (Pakes, 1986) in the sense that as long as the patent is renewed, the firm reveals the expected valuation of its discovery. Raising renewal fees may thus act as a “sorting device”: only the most valuable innovations would have the incentive to pay these fees and extend their effective patent life. Both application fees and renewal fees correspond to an optimal *differentiated* policy.

Cornelli and Schankerman (1999) use a simpler framework than Scotchmer (1999) and by simulation they compute the welfare gains that would be reached with an optimally differentiated patent policy relative to an optimal *uniform* patent policy<sup>15</sup>. The comparison is made for various countries: France, Germany and the United Kingdom. In the current system, renewal fees are required for patent ages 2-20 in France, 3-18 in Germany and 5-16 in the United Kingdom.

As regards patent length, simulations indicate an optimal uniform patent length of between 15 and 19 years, which is close to the statutory patent length in most countries. But, optimally differentiated patent lengths appear to be much more contrasted. First, there is a minimum length of about 7 years, even for very low R&D productivity parameters. Second, for the bulk of the distribution of the R&D productivity

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<sup>14</sup> By contrast, when the R&D cost is a concave function of the value of the project, there is no incentive mechanism that reimburses the firm's cost

<sup>15</sup> The model of Scotchmer corresponds to an adverse selection problem involving two unknown parameters, the cost and the value, whereas the model of Cornelli and Schankerman combine adverse selection and moral hazard dimensions, each one with a single unknown parameter. The moral hazard dimension is related to a productivity parameter that depends on the unobserved cost.

parameter, the range of optimal patent lives is between 8 and 15 years. Third, for very high productivity parameters corresponding to projects with the greatest contribution to welfare, the optimal lives are much longer than existing statutory lives.

Concerning welfare gains, simulations indicate an average welfare gain of 5%, which may exceed 10% for some R&D productivity parameters. Finally, simulations of optimal patent fees indicate that they rise sharply with patent life and more rapidly than the associated profits from the patent. According to the authors "*this important feature of the optimal mechanism is violated by existing renewal schedules*". By using the estimates of the value of patent rights from Schankerman and Pakes (1986), Cornelli and Schankerman (1999) show that the equivalent tax rates (ratio between actual cumulative renewal fees and the profits from patent protection) implied by statutory patent fees in the three countries decline sharply with the effective patent life, leading to a *regressive tax*. In turn, the equivalent tax rates that derive from the optimal patent mechanism would increase with the chosen patent life, leading to a *progressive tax*.

#### **4.2. The buyout mechanism for sequential innovations**

We previously argued that a main feature of the innovation process is that it is cumulative. In this case, the problem of designing an optimal mechanism is much more complex, since a promise of patent rights to one innovator might be in conflict with offering another patent to a future innovator, discouraging future innovations<sup>16</sup>.

Llobet, Hopenhayn and Mitchell (2000) have made an important contribution in this area. They characterise the optimal mechanism as a patent, with no statutory expiration date, that provides some 'amount of protection' against future improvements. As in Scotchmer (1999) for isolated innovations, the mechanism proposed by Llobet *et al.* offers a 'higher patent protection' in exchange for a higher fee, the difference being that in the cumulative innovation context protection is defined in terms of *breadth* rather than in terms of *length*. This means that a patent only expires when a new discovery comes along which does not infringe on the products protected by the breadth its holder can afford. Thus, even with an infinite statutory patent life, effective patent life is finite. The proposed mechanism is defined as a *menu* that offers patent applicants a variety of patent breadths corresponding to different prices. Larger breadth comes with a higher price. If the mechanism works well, larger improvements over previous inventions would get more protection.

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<sup>16</sup> We have discussed in the previous section the optimal patent breadth for sequential innovations in the perfect information framework. See O'Donoghue, Scotchmer and Thisse (1998)

The main contribution made by Llobet *et al* (2000) is to show that an incentive-compatible mechanism can be implemented in a very practical way, namely through a *mandatory buyout price* which is the minimum price at which a patent holder commits to sell his rights if he is proposed to do so, in addition to a *patent breadth fee* depending on the desired breadth of protection. By offering a menu of *buyout prices* and *patent breadth fees*, public authorities are able to generate information on the innovations. The levels of the buyout price and patent breadth fee are positively correlated. An inventor with a more valuable invention will seek a broader patent, even at the cost of a higher fee, as reporting an underestimated value would expose him to having his invention purchased by a third party at a lower buyout price. In other words, the compulsory licensing fee determines the breadth of the patent. The higher the fee the greater the patent implied breadth, since future innovators will need substantial improvements to be willing to pay a higher buyout price.

To sum up, in order to obtain a patent and exercise his monopoly power, a subsequent innovator must pay the initially agreed amount to the prior innovator, choose the buyout fee for his own invention, and make the appropriate payment to the government as prescribed by the menu. The menu of contracts offered by the government has a simple form. It is a list of posted prices for patents with a corresponding buyout price level for each. The main virtues of this patent system are twofold. First, it delegates to the firms the choice of their patent breadth and it does so in an efficient way. Second, "*it generates enough information to solve the infringement problems through the self-selection of a menu of patents. This is in contrast to current policy, where the courts must determine more than just if two innovations are quality improvements over the other, but also how much of an improvement has been made*" (Llobet *et al* ,2000). In the proposed mechanism where innovators choose the desired breadth by paying an appropriate fee and commit to a buyout price, infringement is determined by innovators, lowering the burden on the patent system.

Once more it appears that, even in the more complex context of sequential innovations, the introduction of a mechanism that gives the innovators the incentives to reveal their private information could lead to a substantial improvement relative to the 'one size fits all' principle that currently characterises the patent system.

## 5. Conclusions and policy recommendations

This overview of the economics of patents and patent policy has underlined a series of practical issues that deserve further attention from policy makers. A list of such issues is given below.

- Patents are a double-edged sword, with a positive and a negative side. Patents often contribute to enhancing incentives to invent, to disclose and trade technology, but they also generate costs to society in terms of monopoly rents and barriers to access and use of knowledge. When there is no clear evidence or strong presumption that the advantages of patents exceed their disadvantages in a certain field, the default solution should be ‘no patent’. Patents should not be seen as a natural right of inventors, but as a policy instrument with its virtues and drawbacks.
- Competitive rents, in the absence of IP protection, might be sufficient to compensate innovators when secrecy is a feasible means of protection, when the cost of imitation is high or when first mover advantages are important. In those cases, patents may not be necessary to encourage innovation. However, patents may also serve other functions, such as disclosing knowledge or allowing the development of a market for technology.
- Broad patents, with broad and vague claims should not be granted as they stifle competition and improvement over the protected product. This could be the case especially in emerging fields, such as software and biotechnology, where there is not yet an established tradition of patent examination that allows clear mastering of the breadth given to each grant. Patents given to ‘ideas’, regardless of whether they are computer implemented or not, are detrimental to innovation.
- Patent fees should reflect the cost of patents to society, rather than PTOs examination costs. Patent fees should be used to encourage patent applicants to screen their applications: for instance a tax could be established on some quantitative measure of breadth, such as the number of claims, or the number of independent claims, or the number of pages of the patent. Such a tax already exists; it is partly explicit (a special fee is applied to applications with more than **X** claims at EPO, more than **Y** pages at USPTO), partly implicit (as certain expenses related to patents, such as translation, are proportional to some characteristics connected with size). However, such taxes are designed for compensating the PTO for a higher cost of processing the application: if the aim was changed to compensate society for a broader exclusion right put in private hands, the fee structure would probably have a different shape.

- Renewal fees should be made steeper. As noted above for breadth, this is part of an endeavour aimed at using application and renewal fees as self-selection mechanisms to encourage high valuable inventions to be patented and discourage the least valuable ones.
- The funding structure of PTOs should be changed. Although some connection between their volume of work and their budget is necessary, the current system of direct funding by patentees might lead PTOs to follow strategies that do not completely serve the interest of society. Some observers argued that current patent examination and granting procedures act as profit-making activities, while PTOs should be restricted to the public administration of property rights for intellectual creations.
- Patentability requirements should be higher and strictly applied. Low value patents can have a detrimental effect on innovation and competition. Patentability requirements should be effectively enforced by a post-grant opposition system, similar to the one in place in Europe, allowing information coming from private hands to be collected and used in the process.
- Exemptions for research use should be strengthened or even re-established where they have been restricted or dropped. Patents should not be used as an obstacle to basic research performed in universities, although it is fair that fees be paid when inventions are commercialised.
- Patent applicants and patent examiners should be allowed to use as much information as possible to improve their knowledge about the economic value of inventions, in order to reduce the number of low-quality patents granted. This could be implemented by increasing the ‘flexibility’ of the administrative process for granting patents, as it is happening in many countries, so that patent applicants can have the option, at several stages in the process, to withdraw their application and not incur the cost of pursuing it.
- The patent system is currently built on a “one size fits all” principle. Economic theory shows that the optimal patent design differs significantly across technology areas and industries. Factors such as the cost of replication relative to the cost of invention, the possibility of keeping an invention secret or not, the availability of alternative means of protection, the degree of cumulativeness of technology, etc. affect the relevance of patents. A differentiation of the patent system would be necessary to achieve, although it would not be easy to design and implement. This should be carefully reviewed, especially in the context of the current negotiations at WIPO.

- Governments should facilitate the creation and functioning of markets for patent licenses and encourage markets for technology. Competition policy and patent policy should be consistent so that licensing agreements promoting innovation and economic efficiency are not blocked on antitrust grounds.

The main conclusion from this overview is that a good patent system should be flexible, offering menus rather than “one size fits all” rules, and making intensive use of the price mechanism, in order to have patentees self-selecting their desired protection according to the characteristics of their invention. Patent policy should be under the control of policy makers rather than the patent community so that the interests of society would be the leading motive for patent reform.

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