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# Patents and patent policy

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**Abstract** A patent is the legal right of an inventor to exclude others from making or using a particular invention. This right is sometimes termed an 'intellectual property right' and is viewed as an incentive for innovation. This article surveys the evidence on patent effectiveness in encouraging innovation and reviews the current controversies in patent policy.

**Key words**: patents, intellectual property, incentives

**JEL classification**: K11, L4, O34

## I. Introduction

An inevitable consequence of the growth of the 'knowledge' or 'information' economy is the increased importance of instruments designed to protect the property rights associated with these intangibles. Chief among the formal means of such protection is the patent, defined as the legal right of an inventor to exclude others from making or using a particular invention. This right is customarily limited in time, to 20 years from the date of application submission in most countries. The principle behind the modern patent is that an inventor is allowed a limited amount of time to exclude others from supplying or using an invention in order to encourage inventive activity by preventing immediate imitation. In return, the inventor is required to make the description and implementation of the invention public rather than keeping it secret, allowing others to build more easily on the knowledge contained in his invention.

Given the increased salience of intellectual property rights (IPR) broadly and especially of patents to firms competing in the knowledge economy, it is perhaps not surprising

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that this increase has been accompanied by increased criticism and controversy over the functioning of patent systems throughout the world. In fact, a number of government and quasi-governmental agencies have issued reports calling for patent reform in the very recent past, in some cases as part of a broader agenda of IPR reform.[1] The recommendations offered have ranged from procedural reforms specific to individual jurisdictions, all the way to calls for reductions in the enforcement of the TRIPS (Trade-related Aspects of Intellectual Property Rights) agreement in developing countries.[2] They include recommendations that patent and IPR policy operate in tandem with competition policy, that impediments to basic scientific research using patented inputs be reduced, and that the patent systems in individual countries and regions work towards harmonization in order to reduce the transactions costs of the system.

This article sets the stage for a discussion of current trends in patenting and patent policy with a brief history and guide to the current operation of patent systems around the world. It then reviews the economic rationale for patents and the evidence that patents provide or do not provide appropriate incentives for innovation. I then discuss why the system has been under strain recently and review the arguments for various policy reforms.[3]

## II. A brief history and guide

Patents have a long history, although some of the earliest patents are simply the grant of a legal monopoly in a particular good, rather than protection of an invention from imitation. Early examples of technology-related patents are: Brunelleschi's patent on a boat designed to carry marble up the Arno River, issued by the Florentine government in 1421; the Venetian patent law of 1474; and various patent monopolies granted by the English crown between the fifteenth and seventeenth centuries. The modern patent, which requires a working model or written description of an invention, dates from the eighteenth century, first in Britain (1718) and then in the United States (1790), followed closely by France (in both the latter two cases one of the consequences of a revolution).[4] Many other Continental European countries introduced patents during the 19th century, as did Japan (JPO, 2006) and India (James, 2007). During the twentieth century, the use of patent systems became almost universal and the signing of the TRIPS agreement has ensured that all countries who are members of the World Trade Organization (WTO) will have at least a minimal level of patent protection.

In 1883 the Paris Convention for the Protection of Industrial Property guaranteed national treatment of patent applicants from any country that was a party to it. Its most important provision gave applicants who were nationals or residents of one member state the right to

[1] For the UK, see Gowers (2006). For the USA, see Federal Trade Commission (FTC, 2003); National Academies' Board on Science, Technology, and Economic Policy (2004); the Reply to the National Academies Report by the American Intellectual Property Law Association (2004); Maskus (2006). Elsewhere, see Commission on Intellectual Property Rights (2002); Japanese Government (2004); Danish Board of Technology (2005); and IBM (2006). For a set of papers reporting recent economic research on patents, see OECD (2003).

[2] For example, in February 2007, US Congressman Henry Waxman called on Novartis not to challenge India's denial of a patent on a new cancer drug, Glivec, as a violation of TRIPS (*MIP News*, 19 February 2007, available at http://www.managingip.com/default.asp?page=8)

[3] For an excellent contemporary survey of the impact of changes in IPR systems on management and strategy, see Ziedonis (2007).

[4] Ladas and Parry (2003). See also the EPO and USPTO websites (EPO, 2007*a*, and USPTO, 2007).

file an application in their own country and then, as long as an application was filed in another country that was a member of the treaty within a specified time (now 12 months), to have the date of filing in the home country count as the effective filing date in that other country (the ‘priority date’). This is an important feature of the patent system, as it enables worldwide priority to be obtained for an invention originating in any one country, in addition to ensuring that in principle all inventors are treated equally by the system, regardless of the country from which they come.

Although the process for granting a patent varies slightly according to the jurisdiction for which protection is desired, the adoption of the TRIPS agreement in 1995 ensures that it is approximately the same everywhere in the world. This agreement requires its member countries to make patent protection available for any product or process invention in any field of technology with only a few specified exceptions. It also requires them to make the term of protection available for a period of not less than 20 years from the date of filing the patent application.

The World Intellectual Property Organization (WIPO) has almost 200 member states and lists an equivalent number of national patent offices and industrial property offices on its website. In general, the patent right extends only within the border of the jurisdiction that has granted it (usually but not always a country). An important exception to the one country–one state rule is the European system, where it is possible to file a patent application at the European Patent Office (EPO) that will become a set of national patent rights in several European countries at the time of issue (EPO, 2006). A similar situation exists with respect to the African Regional Intellectual Property Organization (ARIPO). The exact number and choice of countries is under control of the applicant. Patents granted by the EPO have the same legal status as patents granted by the various national offices that are party to the European Patent Convention (EPC).

The Patent Cooperation Treaty (PCT) came into existence in 1978, and now has 133 countries as contracting signatories. Any resident or national of a contracting state of the PCT may file an international application under the PCT that specifies the office which should conduct the search. The PCT application serves as an application filed in each designated contracting state. However, in order to obtain patent protection in a particular state, a patent needs to be granted by that state to the claimed invention contained in the international application. The advantage of a PCT application is that fewer searches need be conducted and the process is therefore less expensive. Thus, although application and search are to some extent standardized across offices, grants are not. In fact, 87 per cent of the PCT applications go to one of three patent offices for search: those in the United States, Europe, and Japan (WIPO, 2007). Most of the other systems rely on these offices for the search process and follow them in a number of other areas. Therefore, much of what follows focuses on these three major systems.

Many patent offices have a provision for challenging patents following their issue. In the United States, any third party may request re-examination of a patent during its lifetime, although for various reasons related to potential subsequent litigation this opportunity is rarely taken up.[5] In Europe and Japan, robust patent opposition systems with limited time frames operate, and these systems are often used by rival firms as an alternative to more expensive litigation (Hall *et al*., 2003; Harhoff and Reitzig, 2004). In Europe this avenue of

[5] Users of this procedure are stopped from raising any issues of validity that might have been raised in re-examination in subsequent litigation. In practice, fewer than 1 per cent of US patents are re-examined, and almost half of those re-exams are requested by the patent-holder or the USPTO itself (Graham *et al*., 2003).

challenge is particularly attractive because it is the last opportunity to attack the validity of a patent at the Europe-wide level rather than in individual national courts.

Patents are valuable only if they can be enforced and this fact has a number of implications for their use. First, the ability of the courts to reach the ‘correct’ verdict with respect to infringement and validity will matter; in situations or jurisdictions where there is a great deal of uncertainty about the outcome, and even if both parties agree as to the merits of the case, it may be worthwhile for one or both of them to pursue the issue further or, in some cases, to reach a private financial settlement to avoid a random outcome in the courts.[6] Second, the costs of litigation will matter: where parties with deep pockets can threaten those with less access to financial resources, or where the opportunity cost of paying attention to a patent suit is high, as in small entrepreneurial firms. On the other hand, smaller parties with little to lose can also hold up firms with large sunk investments at risk (Hall and Ziedonis, 2001). Finally, the threat of litigation may discourage firms from even entering certain areas, thus providing a disincentive rather than an incentive for R&D. Lerner (1995) documented this phenomenon for biotechnology.

The degree to which these kinds of threats matter depends to a great extent on the costs and extent of litigation, both of which tend to be higher in the United States than in many other countries. However, there are signs that concerns about litigation cost have been increasing elsewhere, notably in Europe where there is active debate over proposals to reduce enforcement costs by creating a supranational patent court system of some kind. At the time of writing, the current proposal, which is the European Patent Litigation Agreement (EPLA), has not yet been ratified by enough countries to make it legally binding. EPO (2006) gives the rationale for such an agreement along with some estimates of patent litigation cost in Europe and EPO (2007*b*) reports on the current state of all legislative initiatives in Europe.

Research on patent litigation is difficult because of the data collection problem (it frequently requires accessing the records of courts in several different jurisdictions), but in recent years there has been series of studies of US patent litigation (Moore, 2000; Lanjouw and Schankerman, 2001; Bessen and Meurer, 2005) and at least one of the German system (Cremers, 2004). All of these studies document the fact that litigated patents tend to be the more valuable patents, as one might have expected. The US studies also show that only about 5 per cent of such suits go to trial, with the remainder being settled before going to trial. They also show that whether patent litigation has increased depends on whether it is measured in aggregate or per patent. That is, the increase in patent litigation has roughly paralleled the increase in patenting, at least in the United States, although there is some indication that the litigation rate has risen in the very recent past (Bessen and Meurer, 2005).

## III. Do patents encourage innovation?

The economic view of patents is that they offer a bargain between society and the inventor: in return for a limited period of exclusivity, the inventor agrees to make his invention public rather than keeping it secret. Two questions immediately arise from this: first, what is the optimal design of such a policy instrument? and, second, are patents effective at accomplishing this task? Much of recent economic research on patents has been directed to attempting to answer these questions and has found that the trade-off between a ‘short-term monopoly’ and

[6] See Farrell and Shapiro (2007) for detailed models of this process.

**Table 1:** The patent system trade-offs

| Effects on: | Benefit | Cost |
|---|---|---|
| **Innovation** | creates an incentive for R&D; promotes the diffusion of ideas | impedes the combination of new ideas and inventions; raises transaction costs |
| **Competition** | facilitates entry of new small firms with limited assets; allows trading of inventive knowledge, markets for technology | creates short-term monopolies, which may become long-term in network industries |

'innovation incentive' is much more complex than the usual textbook treatment, making the optimal design problem extremely difficult.

Table 1 presents a framework for thinking about the costs and benefits of the patent system in two dimensions, innovation and competition. The plain boxes represent the traditional trade-off between negative effects for competition arising from market power and the positive effects for innovation, while the shaded boxes represent newer views of the ways in which patents might actually discourage innovation but enable and encourage competition.

Thus this table suggests that, in addition to the familiar arguments that patents increase innovation via incentive effects and diffusion, and decrease competition because they create temporary monopolies, there are offsetting effects in both cases, effects that have become more apparent in recent years.[7] These offsetting effects are the tendency of patents to increase the costs of subsequent innovators, especially when these innovators need to combine inventions from many sources, as well as the fact that patents may help competition by facilitating the vertical disintegration of knowledge-intensive industries and helping new entrants. The next two sections of the article review the evidence, both theoretical and empirical, on the effectiveness of the current patent systems in achieving their goals. This is followed by a discussion of the theoretical literature on optimal design of innovation incentive systems.

## (i) Theoretical evidence

As is often the case with models that admit the complexity of the world, the theoretical literature in this area produces ambiguous results with respect to incentives provided by patents. In the simplest case, where a patent corresponds to a single product and knowledge is not particularly cumulative, it is clear that patents will encourage innovation. Offering individuals the short-term right to exclude others from practising an invention provides the inventors with the opportunity to earn rents or supranormal profits when they innovate that

[7] This is not to say that these effects have gone completely unrecognized in the past. Consider the following quotation from a sugar manufacturer in Great Britain during the nineteenth century: 'In the manufacture with which I am connected—the sugar trade—there are somewhere like 300 or 400 patents. Now, how are we to know all these 400 patents? How are we to manage continually, in the natural process of making improvements in manufacture, to know which of these patents we are at any time conflicting with? So far as I know, we are not violating any patent; but really, if we are to be exceedingly earnest in the question, probably we would require to have a highly paid clerk in London continually analysing the various patents; and every year, by the multiplication of patents, this difficulty is becoming more formidable.' (R. A. Macfie, quoted in 'Is the Granting of Patents for Inventions Conducive to the Interests of Trade?', *Transactions of the National Association for the Promotion of Social Science* (George W. Hastings, ed., 1865, p. 666).)

are higher than those they would earn if there were immediate free entry into imitation of their invention.

The early theoretical industrial organization literature on patent races even seemed to suggest that patents produced *too much* innovation (Wright, 1983; Reinganum, 1989). However, models that incorporate the cumulative nature of innovation or dispersed ownership of the patents required for producing a new good yield more ambiguous results (Judd, 1985; Scotchmer 1991; Bessen and Maskin, 2006). A modest theoretical literature pioneered by Scotchmer (1991) has developed that analyses a number of such models. Two main cases and their variations have been considered: those where two innovative stages are required to produce the product (the 'research tool' case) and those where there is a sequence of products, each of which is an improvement over the previous product (the cumulative or 'quality ladder' case). In either case, it is possible that any particular invention uses one or more other inventions as input, or is an input to one or more future inventions. This type of analysis has increased in importance because of the complexity of modern technology and also because of growth in patent use in sectors that traditionally had regarded patent protection as relatively unimportant. Briefly described, the new setting is one where a single product involves hundreds of patents, and where one innovation builds directly on many others. Neither feature is really new, but both have assumed increasing importance in a number of technology areas, such as information technology and biotechnology.

When development of an innovative product requires multiple patent inputs, Heller and Eisenberg (1998) have argued forcefully that the licensing solution may fail because of transactions costs if a large number of patent-holders are involved. One consequence of this fragmentation threat may be increased defensive patenting by the product developer in order to be able to threaten a counter suit if attacked. Empirical evidence for this proposition has been provided by Ziedonis (2004) in the context of the semiconductor industry.

A recent paper by Bessen and Maskin (2006) develops a model of sequential (cumulative) and complementary innovation in a differentiated product setting and analyses the effect of patent protection in two settings, non-sequential and infinitely sequential (that is, where each invention builds on the preceding invention). The results are somewhat complex but intuitive: in the static non-sequential case, having patents generally yields higher welfare than not having them. But in the fully sequential case, the equilibrium without patents has higher welfare and innovation than the equilibrium with patents if the upper tail of the distribution of innovation values is sufficiently thick. They show that the two commonly used distributions for innovation value, lognormal and Pareto, satisfy this condition.[8] They also show that, in some cases, even the original innovator may benefit from the absence of patents in the dynamic case, because he receives spillovers from follow-on innovation. Empirical evidence that suggests some positive value to this kind of spillover has been offered recently by Belenzon (2006) using sequences of patent citations to measure knowledge flows in and out of the firm.

## (ii) Empirical evidence

The question posed at the beginning of this section has also proved difficult to answer empirically, largely because of the absence of real experiments, at least since the nineteenth century. Some researchers have looked at historical eras when there were changes to the

[8] Grabowski and Vernon (1994), Hall *et al*. (2005), and Harhoff *et al*. (1999) provide evidence on the distribution of innovation and patent value.

system and examined the consequences for subsequent innovative activity, measured either by patenting in a jurisdiction not affected by the changes to the system or by invention counts obtained independently (Lerner, 2002; Moser, 2005). A second widely used approach is to survey firm managers, asking about their patent use and the use of patents in their industry (Mansfield, 1986; Levin *et al*., 1987; Cohen *et al*., 2002; Arundel, 2003). Using these kinds of survey data matched to R&D spending and innovation outcomes, more econometric model-based approaches have been pursued by Baldwin *et al*. (2000), Arora *et al*. (2003), and Bloom *et al*. (2005), among others.

A few conclusions have emerged from this body of work. First, introducing or strengthening a patent system (lengthening the patent term, broadening subject matter coverage or available scope, improving enforcement) unambiguously results in an increase in patenting and also in the use of patents as a tool of firm strategy (Hall and Ziedonis, 2001; Lerner, 2002). This is to be expected, but it is much less clear that these changes result in an increase in innovative activity (Lerner 2002; Baldwin *et al*., 2000), although they may redirect such activity toward things that are patentable and away from those than can be kept secret within the firm (Moser, 2005). Sakakibara and Branstetter (2001) studied the effects of expanding patent scope by allowing multiple claims in Japan in 1988 and found that this change to the patent system had a very small effect on R&D activity in Japanese firms.

Exceptions to this conclusion are two studies based on cross-country data: Park and Ginarte (1997) and Kanwar and Evenson (2003). Park and Ginarte (1997) use aggregate data for 60 countries during 1960–90 and an index of the strength of IPR (subject matter coverage, term length, etc.) which they developed. Using a simultaneous equations model of economic growth, investment, schooling, and R&D investment, they found that the strength of IPR was positively associated with investment and R&D investment in countries with above median income but not for the less-developed countries. IPR had no independent effect on growth above and beyond that contributed by investment and R&D. However, Park and Ginarte (1997) also show that the strength of IPR in high-income countries (but not in low-income countries) can be predicted by prior R&D intensity, which raises some questions about the simultaneity of IP protection and a country's orientation towards R&D and innovation. That is, it is possible that the demand for IP protection increases when a large share of the industrial base is engaged in innovative activities.

The study by Kanwar and Evenson (2003) looks at the variation across country in R&D spending as a function of the Ginarte–Park index over the 1981–95 period and finds similar results, with stronger IP protection related to higher R&D intensity. Although well done in many respects, this study makes no attempt to explore the potential endogeneity of the relationship, nor does it control for the level of development of the countries, which arguably drives both R&D and the development of IP institutions.

In contrast to the two results cited above, Qian (2007) performs a similar analysis for pharmaceutical patents in 85 countries over the period 1978–99, but using matched sampling and also fixed country-effect estimators. She finds that national patent protection does not stimulate domestic innovation activities, except at higher development levels, and that above a certain level of patent protection, innovation activities are actually reduced.

A third finding from the empirical literature is that if there is an increase in innovation due to patents, it is likely to be centred in the pharmaceutical, biotechnology, and medical instrument areas, and possibly specialty chemicals. This conclusion relies mostly on survey evidence from a number of countries which shows rather conclusively that patents are not among the important means to appropriate returns to innovation, except perhaps in pharmaceuticals, medical devices, and some specialty chemicals (Mansfield, 1986; Levin *et al*., 1987; Arora *et al*., 2001; Cohen *et al*., 2002). Using a structural model that combines survey responses with accounting data on R&D, Arora *et al*. (2003) found that increasing the patent premium, which they define as the difference in pay-offs to patented and unpatented inventions, can be expected to increase R&D in most manufacturing sectors, with the greatest increase in medical instruments, followed by biotechnology and pharmaceuticals.

Fourth and finally, the existence and strength of the patent system affects the organization of industry, by allowing trade in knowledge, which facilitates the vertical disintegration of knowledge-based industries and the entry of new firms that possess only intangible assets (Hall and Ziedonis, 2001; Arora *et al*., 2003; Arora and Merges, 2004). The argument is that, by creating a strong property right for the intangible asset, the patent system enables activities that formerly had to be kept within the firm because of secrecy and contracting problems to move out into separate entities. Although limited, research in this area supports this conclusion in the chemical and semiconductor industries.

Thus the bottom line from the empirical evidence is that the patent system provides clear incentives for innovation in only a few sectors, but that firms and industries do respond to its presence, both by making use of the system and by sometimes tailoring their innovative strategies to its presence. As Edith Penrose said in 1951 when speaking to the same question,

> If national patent laws did not exist, it would be difficult to make a conclusive case for introducing them; but the fact that they do exist shifts the burden of proof and it is equally difficult to make a really conclusive case for abolishing them. (Penrose, 1951)

One possible interpretation of this remark is that history matters, in the sense that industrial organization and firms adapt to the institutional regime in which they operate and changing this regime, whatever it is, involves substantial short-term costs that may not be outweighed by the long-term benefits.

## IV. Optimal patent design

As has been noted by many others (for example, Wright, 1983; Shavell and van Ypserele, 2001), there are alternative means of providing incentives for innovation, such as prizes or research contracts, but these tend to be of limited value when the goal of the inventive activity is unknown or hard to identify *ex ante*. See Scotchmer (2005, ch. 2) for an excellent discussion of the alternative incentive systems.

The seminal work on optimal patent design was Nordhaus (1969), which considered two policy instruments: the length of the patent term and the breadth of the patent, i.e. the range or scope of the inventions covered. The broader the scope of a patent, the larger the number of competing products and processes that will infringe the patent, and the larger the market power of the patentholder. The greater the length of a patent, the longer the period over which the firm can earn monopoly profits. Later work by Gilbert and Shapiro (1990) and Klemperer (1990) built on and extended his method of analysis. Unfortunately, even though all three sets of authors simplified the problem by assuming that a patent corresponds to a product and that there is no uncertainty, the welfare conclusions still turn on assumptions about the nature of the product market (how competitive it is) and the existence of close substitutes for the patented product. The principal conclusion from this line of work is that optimal patent design is likely to depend on the nature of the product market and the technology, which is inconsistent with long-standing practice and policy in most patent systems. Historically, the only important exception to the homogeneous treatment of technologies is the extreme case of excluding some of them (such as pharmaceutical products, medical practices, or disembodied software, at various times and in various countries) completely from the system.

The design of patent-based incentive systems has now been extended in two directions: the first looks at the sequential innovation problem and the second focuses on incentive-compatible schemes for eliciting the private information of inventors about value. Green and Scotchmer (1995) analyse the case of sequential innovation with two innovators, showing that it is difficult, if not impossible, to set incentives at the correct level for both the first and subsequent innovators. In general, they find that *ex ante* agreements between the two innovators have the potential to enhance innovation, and that in the case where the first technology is basic, *ex ante* agreements are welfare enhancing because they allow profit to be transferred to the first innovator. This in turn compensates him for the shortened patent life and allows the overall patent life to be kept to a minimum given the need for both innovators to cover their costs. Of course, the difficulty with this analytic set-up is the fact that subsequent innovators can rarely be identified at the time the first innovation is undertaken.

O'Donoghue *et al*. (1998) studied the length–breadth trade-off in the sequential innovation case with licensing. In this case, follow-on innovations can shorten the effective life of a patent, so length and breadth are interrelated rather than being two separate policy tools. They find that very broad but finite-lived patents improve innovation and diffusion, but that long and narrow patents (which are easily displaced by similar but not identical inventions) can lower R&D costs by encouraging effort toward larger innovative steps.

A promising line of work in this area is the development of incentive-compatible patent renewal or compulsory licensing mechanisms designed to elicit information from inventors about the approximate real value of their innovation. These models assume both that there is uncertainty *ex ante* about value and the R&D effort that will be undertaken and that the inventor has more information about value *ex post*. Cornelli and Schankerman (1999) show that in this case it is optimal for the government to offer firms a menu of patent lives and associated lump-sum patent fees. When there is no post-patent learning by the firm, this mechanism is equivalent to offering a schedule of annual renewal fees. Even in the usual case where the value of the invention is revealed over time, renewal fees may be a useful mechanism for encouraging the release of inventions into the public domain. Using simulation, Cornelli and Schankerman show that existing patent renewal fee schedules rise much too slowly with patent life given the likely distribution of invention value.

Hopenhayn and Mitchell (2001) showed that such a scheme may be dominated by a menu that trades off the breadth and length of a patent, with the inventors of more fertile innovations choosing to receive broader but shorter patents. However, because of the difficulty of producing a workable definition of breadth in practice, this idea is far more difficult to implement than a set of menus involving only renewal fees and patent terms. Recently, Hopenhayn *et al*. (2007) have developed a more complex information-revelation scheme in the setting where innovation is cumulative.

## V. Recent patenting trends

### (i) Policy changes

As with (almost) all governmental institutions, patent systems have evolved and continue to evolve in ways that are ultimately driven by forces related both to a perception of increased global competition, especially in knowledge-intensive sectors, and also to technological change itself. Such changes as the expansion of subject-matter coverage, strengthening of enforcement systems, and the encouragement of patenting by upstream actors can all be seen as driven by these forces. As is often the case with innovation, it is also true that many of the changes in patenting strategy observed around the world have originated in the United States and then diffused elsewhere, both via imitation and also via the process of intergovernmental negotiation. This section of the paper discusses these trends and their implications.

Unfortunately (from the perspective of optimal policy), many of the changes in patent policy in the United States during the past two decades have been as a result of court decisions, especially those of the Court of Appeals of the Federal Circuit (CAFC), and to a lesser extent by the Supreme Court. Addressed as they are to the features of individual cases, these decisions do not always consider the broader policy implications as they set precedents. As a result of a series of court decisions by these bodies, the subject matter eligible for patenting has been extended to new technologies (biotechnology), technologies not previously subject to patent protection (business methods, software), and to upstream scientific research tools, materials, and discoveries (Madey *v*. Duke, 2002). The rights of patentholders *vis-à-vis* alleged infringers have been strengthened by such decisions as Polaroid *v*. Kodak (1986/1991), which yielded a major damage award to Polaroid and shut down the instant camera business of Kodak. However, recent decisions by the Supreme Court have reversed this trend to some extent.[9]

Of course, in many ways these court decisions were the consequence of legislative changes in 1982, during which the CAFC was created, and the position of patent holders strengthened by a number of procedural changes in the courts. In a comparison of appeals cases from 1953 to 1978 and from 1982 to 1990, the share of District Court decisions finding validity and infringement that were upheld by the higher court increased from 62 to 90 per cent. Decisions of invalidity and no infringement were reversed 12 per cent of the time before the Federal Circuit's creation and 18 per cent afterwards (Lerner, 1995). Moreover, the rate of preliminary injunctions increased dramatically (Lanjouw and Lerner, 1998). In a recent study using modern time-series methods and taking account of the sequence of appeals decisions, Henry and Turner (2006) found robust evidence that the CAFC was less likely to invalidate patents than earlier courts, but no less likely to affirm or reverse infringement findings. Some commentators have argued that a specialized patent court is more likely to be 'captured' by the patent bar and those whose interests are served by strong patents of any kind, and that the potential for this outcome should be borne in mind when considering creation of a similar court for European patents.

The early 1980s was also the period when the well-known Bayh–Dole Act passed into the law, leading to the emergence of new players,such as universities and public research institutions, as well as an increase in activity at institutions that had already been patenting some of their research results. Although the impact and importance of this Act remain controversial in the United States (see, for example, Mowery *et al*., 2004), it has been seen as a model by many other countries who are anxious to improve their record of commercializing university research and a number of them have experimented with similar changes (Geuna and Nesta, 2006). A full discussion of the issues associated with the patenting of university

[9] *KSR International v Teleflex Inc*. (No. 04-1350) 119 Fed. Appx 282, on non-obviousness, and *eBay Inc, et al. v. MercExchange, L. L. C.* (No. 05-130) 401 F. 3d 1323, on the four-factor test for injunctions.

research outputs is beyond the scope of this article and the reader is referred to Siegel *et al*. (2007, this issue).

As discussed earlier, the economic view of patents is that they represent a trade-off between the costs of granting limited market power to firms versus the benefits of encouraging innovation, in much the same way that competition policy is designed to maintain a balance between the costs of increased market power from concentration and the benefits of scale efficiencies. It should come as no surprise, then, that patent policy and competition policy are occasionally misaligned, and increasingly need to be looked at simultaneously.

In the area of competition policy, from 1981 onwards there has been a marked evolution in the attitudes of the US Justice Department's Antitrust Division and the Federal Trade Commission (FTC) towards business conduct involving patents, resulting in a much more nuanced and pro-patent position (FTC, 2003). Following changes to practice in 1981 and 1988, in 1995 the Justice Department and the FTC jointly issued Antitrust Guidelines for the Licensing of Intellectual Property, declaring that 'the Agencies do not presume that intellectual property creates market power in the antitrust context' and intellectual property licensing is 'generally pro-competitive'. Similarly, new licensing guidelines were issued by the European Commission in 2004 that provide a safe harbour for many licensing agreements, especially those involving firms with low market shares. For useful comparisons of the two sets of provisions and a discussion of the differences, see Gilbert (2004) and Delrahim (2004). The Korean and Japanese Fair Trade Commissions also have what amounts to a 'rule of reason' approach to the regulation of such agreements.

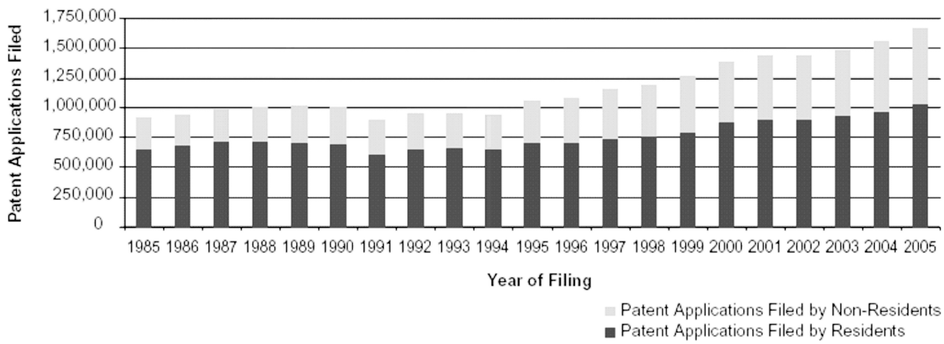
Taken together, these changes add up to a considerable strengthening of patent holder rights and a broadening of the reach of the patent system. As I summarize in the next section, the response to these changes on the part of private firms has been dramatic.

## (ii) Strategic response

The most obvious response to these changes in the US patent system was the increase in patenting across many sectors, leading to a doubling of US patent applications and grants during the 10-year period between 1992 and 2002. In Hall (2005), I used a simple time-series analysis to show that the time series of aggregate patent applications in the USA displayed a structural break in 1984, with the annual growth rate increasing from zero to over 6 per cent. Such a growth rate will produce a doubling in 12 years. I also showed that most of the growth was due to increased patenting by firms in the information and communication technology (ICT) sectors, which is consistent with the view that much of it is for defensive reasons (Arora *et al*., 2001; Hall and Ziedonis, 2001; Hicks *et al*., 2001). At the same time, the contribution of increased university and public research institution patenting to growth was relatively small, not because such patenting did not increase, but because the share remains small. From a regional perspective, over half the growth was due to inventors in the United States, one-third to those in Asia, and the small remainder to inventors in Europe. Thus the growth in patenting at the USPTO through 2002 was driven by the behaviour of the ICT sector in the USA and Asia.

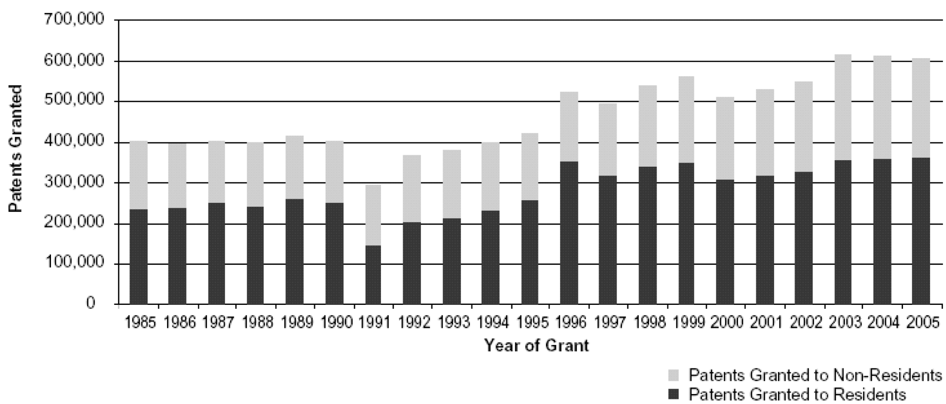
Recent data from WIPO confirm that this growth trend is worldwide (WIPO, 2007). Applications at the EPO tripled in the 20 years between 1985 and 2005, while those at the Japanese Patent Office grew somewhat earlier, at 10 per cent per annum between 1980 and 1985 and then 50 per cent between 1985 and 2005. Figures 1 and 2 show that applications worldwide have doubled between 1994 and 2005, whereas grants have only grown by 50 per

**Figure 1:** Worldwide patent filings




*Source:* WIPO Statistics Database.

**Figure 2:** Patents granted worldwide




*Source:* WIPO Statistics Database.

cent during the same period, probably because of increased backlogs in patent offices around the world.

A number of other behavioural changes have accompanied this increase in patenting: slightly higher renewal rates, more frequent assertion of patents, a doubling of US District Court patent suits between 1988 and 2001, and some evidence that the probability of a suit per patent has increased recently (Bessen and Meurer, 2005). The complexity of patents in terms of number of claims and citations of prior art has grown, and patentees tend to invest more in the processes of application and examination. In testimony before Congress, the current director of the USPTO, Jon Dudas, reported that more than 100,000 of the 355,000 patent applications filed in 2004 were continuations of applications that had been previously reviewed by an examiner. He also reported on the problem of 'super-sized' applications submitted by a minority of applicants (7 per cent of the applications account for 25 per cent of the claims examined; some are submitted on CD-ROMs with thousands of claims).

The super-size phenomenon has also been documented elsewhere by van Zeebroeck *et al.* (2006), who report that applications of over 1,000 pages are now frequently filed at the EPO and other patent offices around the world, and several applications have even reached 100,000 pages or up to 20,000 claims. They looked at the sources of the surge in the number and size of patent applications and conclude that a major factor driving the growth is the diffusion of the US patent application model via the PCT. Nagaoka (2006) reported that the number of claims per patent application in Japan tripled between 1990 and 2003.

In addition, many critics have argued that the sheer volume of patent applications threatens to degrade the quality of issued patents, or lengthen the backlog, or both. On the backlog there is no doubt. In April 2005, Dudas reported that pendency in data-processing technologies stood at three years and growing, and that without intervention, the current backlog of applications awaiting first review could double from 500,000 to a million in the next 5 years. The EPO grant lags were already long and are getting longer. During the 6 years between 1998 and 2006, the waiting time for examination at the Japanese Patent Office increased from 19 to 26 months (Nagaoka, 2006).

Finding hard evidence of a decline in quality is more difficult, although a number of legal scholars and practitioners have been vocal on the subject (for example, Hunt, 1999; Barton, 2000; Kingston, 2001; Lunney, 2001; Jaffe and Lerner, 2004). There are several reasons to believe that quality (especially the application of the non-obviousness and novelty criteria of patentability) has suffered as the number of applications has grown. First, the number of patent examiners has not kept pace with the increase in workload represented by the increased number and growing complexity of the applications. Second, in the United States there does seem to have been a dilution of the application of the non-obviousness standard in biotechnology (due to court decisions) and some limitations on applying it properly to business-method patent applications, for, among other reasons, the absence of adequate written prior-art documents. Recent changes in the treatment of genomic and business-method applications were introduced at the USPTO (the second pair of eyes for business-method patents and the requirement of a specific application or use for a new gene sequence) that resulted in a slowing down of patent grants in those fields, suggesting that the previous bar may have been set too low.

During the US FTC/Department of Justice hearings on the patent system and antitrust policy in 2002, a number of industry representatives expressed concerns about the difficulty of negotiating the patent thicket in their area and the risk of being ‘held up’ *ex post* by a patent on a technology that was only a small component of their product. This complaint was heard largely from those in the complex product industries (the ICT sector), such as Robert Barr, then Vice-president for Intellectual Property and Worldwide Patent Counsel at Cisco Corporation. He described two types of problems faced by firms in the sector: the first being the large stockpiling of patents necessary as a defensive measure against others in the industry, and the second the threat posed by small entities that have nothing at risk themselves and may not even be producers. On the first, Barr says the following:

> My observation is that patents have not been a positive force in stimulating innovation at Cisco. . . . Everything we have done to create new products would have been done even if we could not obtain patents on the innovations and inventions contained in these products. . . . The only practical response to this problem of unintentional and sometimes unavoidable patent infringement is to file hundreds of patents each year ourselves, so that we can have something to bring to the table in cross-licensing negotiations. . . . The time and money we spend on patent filings, prosecution, and

> maintenance, litigation and licensing could be better spent on product development and research leading to more innovation.[10]

On the second problem (that of being attacked *ex post* by a small entity that does not face much risk of infringement itself):

> stockpiling patents does not really solve the problem of unintentional patent infringement through independent development. If we are accused of infringement by a patent holder who does not make and sell products, or who sells in much smaller volume than we do, our patents do not have sufficient value to the other party to deter a lawsuit or reduce the amount of money demanded by the other company.[11]

The first of the problems Barr describes is clearly a case of mutually assured destruction that leaves the firms in question no better (and no worse) off than if they were not accumulating massive numbers of patents for defensive purposes, and yet at the same time is a very costly strategy. Increasing the administrative costs of patents to firms or reforms within the industry itself to discourage this behaviour would seem to be the obvious solution, since it would be in the interest of all firms involved to reduce spending on this activity. However, the second problem is more controversial: the small entities that assert patents in this way may have legitimate claims to ownership of some of the technology in a large firm's product. Some observers have even questioned how common this kind of patent assertion is. Nevertheless, the IT industry in general has been very concerned about these kinds of threats and their consequences for the incentives to invest in complex technologies that might potentially incorporate a piece of technology which leads to a dispute that cannot be resolved by cross-licensing.

Concern over patent hold-up is especially relevant in the case of standards technologies, which are difficult to invent around and which are very important in this sector (Shapiro, 2001). This problem has caught the attention of many firms worldwide because of the highly publicized and controversial litigation over DRAM standards initiated by Rambus against firms such as Hynix, Samsung, and Micron Technology. The litigation is over patents whose applications were filed while Rambus was participating in the standards-setting committee (JEDEC). The EPO overturned one of the relevant patents in an opposition case and the US FTC initiated a successful complaint over their behaviour in this case, but some of the cases are still in the courts.[12] Nagaoka (2006) reported that the practice of applying for patents after a standard has been chosen is widespread: using US and worldwide patent family data, he showed that 50 per cent of the essential patents covering the MPEG2, DVD, and W-CDMA standards were applied for after the specifications were set.

The final area where changes in patenting practice and IP management have raised concern in policy circles is the increased patenting of 'research tools' and the consequences of this. Walsh *et al*. (2003) interviewed some 70 players in the biotechnology research area and found that, by and large, IP in biotechnology is being managed relatively successfully. Because of increasing patent assertion and the extension of patentability to life-forms and gene sequences, the associated costs of research are somewhat higher and research can sometimes be slowed, but it is rarely blocked altogether. There are, however, occasional cases of restricted access

[10] Barr (2002, pp. 675–7).
[11] Barr (2002, pp. 679–80).
[12] *MIP Weekly News*, 15 February 2004 (EPO) and 8 August 2006 (FTC), available at http://www.managingip.com

to foundational discoveries and to some diagnostic genetic tests. A number of ‘working solutions’ have evolved, including negotiated licences and royalty payments. Patents are also circumvented by inventing around them, using substitute research tools, and locating research activity offshore. Institutional responses include the National Institutes of Health guidelines encouraging research grantees to facilitate access to patented research tools and the steps taken by several research organizations to place results in the public domain, where they become patent-defeating prior art.

## VI. The TRIPS controversy

The TRIPS agreement that was incorporated into the charter of the WTO in 1994 essentially sets uniform patent standards throughout the membership of the WTO, although in the case of developing countries it allows considerable delay in adopting these standards.[13] The agreement was negotiated without a great deal of economic input, and the idea of uniform standards has proved very controversial among economists. The most obvious argument against the principle behind TRIPS is that the trade-off between the costs of market power granted by a patent and the benefits of the innovation incentive is not likely to be uniform across different development levels, so that a one-size-fits-all rule is far from optimal. A secondary argument is that for a small less-developed country, the fixed cost of operating a patent office takes resources and trained personnel away from more productive activities. Analysis is also complicated by the fact that the optimal policy needs to be determined in an open-economy setting, where costs are incurred locally but benefits may spill globally.

Grossman and Lai (2004) analysed a simple version of the problem, with only two countries (developed, or North, and less developed, or South). In a non-cooperative equilibrium, North will choose a stronger patent policy under reasonable conditions (North’s market is at least as large as South’s and its R&D capability is greater). The global welfare optimum has multiple outcomes, but, without transfers, the outcomes which favour the North are those with longer patents in the South. Using a similar set-up, Scotchmer (2004) shows that harmonization generally strengthens IP protection in all countries, and that because there are no similar institutions to manage the benefits of public support for innovation, the tendency is towards too much protection and too little public spending with respect to a (global) social optimum.

A useful survey of the empirical evidence on the incentive effects of patents in the developing-country context is provided by Branstetter (2004). He finds that there is little evidence of a strong incentive effect for domestic innovators, but some acceleration in the diffusion of advanced technology by multinational firms (who feel more protected in the presence of a functioning patent system). Although this result suggests that spillover effects from foreign direct investment may be enhanced, it also means that the monopoly rent from a given innovation has been enhanced, essentially promoting innovation in the developed world rather than the developing world.

There is also the previously cited evidence of Qian (2007) with respect to pharmaceuticals, which shows that the incentive effects of patents depend on the development level of the country. The historical experience of the USA in the early nineteenth century (when national treatment was not available to foreign inventors) and Taiwan in the twentieth century (where

[13] Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, Agreement on Trade-related Aspects of Intellectual Property Rights, 15 April 1994, 33 I.L.M. (1994) 81.

patents were unimportant until the mid-1980s, after a certain level of industrial development had been reached) confirms that where technology imitation is an important tool of catching up, it may be optimal to wait before introducing strong patent protection.

## VII. Conclusion

This article has offered a brief tour of patent systems, past, present, and immediate future. As one reflects on the results of economic research in this area, one is struck by the not inconsiderable tension between what we know about patents as an innovation incentive and the general thrust of contemporary patent policy. This tension is visible in two main areas: the expansion of patenting activity in several dimensions (subject matter coverage, type of patenting entity, and geographic) and its 'one-size-fits-all' nature.

Thus, although the research I have surveyed does not indicate an overwhelmingly important role for patents in encouraging innovation except in a few sectors, there is no doubt that the general policy stance of many governments is to encourage firms, individuals, and research organizations to learn about the patent system and apply for patents. To cite one example, the European Union has had an initiative in place for several years designed to educate small and medium-sized enterprises in the use of the patent system. A number of countries have adopted measures to encourage patenting and technology licensing by universities and governmental research organizations, modelling them on the well-known Bayh–Dole Act in the United States (Geuna and Nesta, 2006). And, of course, the TRIPS agreement clearly was intended to raise the level of patenting activity in developing countries by guaranteeing a minimum level of protection throughout the global economy. At the level of the individual agent, this is undoubtedly the right strategy, even if social welfare is not necessarily increased by a massive increase in patenting activity.

Given the importance of knowledge assets in modern-day economies, some of the increase in patenting and its importance that we have observed is obviously due to increased inventive activity. It is unlikely that patent systems will disappear or be completely replaced by alternative incentive systems for eliciting this kind of activity. Nevertheless, one has to ask whether the marginal scientist/engineer is best employed doing R&D or examining patents. That is, would society as a whole be better off if the inventive step requirement for a patent were raised, leading to fewer patents but without discouraging real innovations?

The evidence surveyed here also leads inexorably to the conclusion that a significant problem for policy-makers is the heterogeneity of responses to the system, a heterogeneity that is firmly grounded in the heterogeneity of technology and its development. The debate presently taking place in the United States over patent reform highlights the problem: pharmaceutical firms, among others, find that the present system works well for them and are opposed to any changes designed to improve its operation for firms in 'complex' technology industries such as telecommunications and computing. ICT firms, on the other hand, seem to view the system as a necessary evil, requiring costly investments in patent portfolio building for defensive purpose while using other methods to secure returns to their own innovations. Many of these firms support reforms to the system that are designed to mitigate the problems which arise when a product contains many minor inventions and relies on a number of standards that may be covered by patents.

In spite of the fact that the cost and nature of invention clearly varies across technological field, patent law and international agreements essentially agree that the same level of patent protection should be available for all technologies without discrimination. However, as Burk and Lemley (2002) point out, application of the law by patent offices and the courts can lead to substantial variation across technologies in practice. Given the likely response of firms and inventors to attempts to define statutory differences in treatment across technologies, this type of flexibility is perhaps the best we can do. But the problem of heterogeneity and whether there is something that can be done about it remains a subject for future policy research.

## References

Arora, A., and Merges, R. P. (2004), 'Specialized Supply Firms, Property Rights, and Firm Boundaries', *Industrial and Corporate Change*, **13**, 451–75.

— Ceccagnoli, M., and Cohen, W. (2003), 'R&D and the Patent Premium', Working Paper No. 9431, Cambridge, MA, NBER.

— Fosfuri, A., and Gambardella, A. (2001), *Markets for Technology: The Economics of Innovation and Corporate Strategy*, Cambridge, MA, MIT Press.

Arundel, A. (2003), *Patents in the Knowledge-based Economy: Report of the Know Survey*, Maastricht, MERIT, University of Maastricht.

Baldwin, J. R., Hanl, P., and Sabourin, D. (2000), 'Determinants of Innovative Activity in Canadian Manufacturing Firms: The Role of Intellectual Property Rights', Working Paper No. 122, Ottawa, Statistics Canada.

Barr, R. (2002), Testimony at the US Federal Trade Commission/Department of Justice Hearings on Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy, University of California at Berkeley, 28 February.

Barton, J. H. (2000), 'Reforming the Patent System', *Science*, **287**, 1933–4.

Belenzon, S. (2006), 'Knowledge Flow and Sequential Innovation: Implications for Technology Diffusion, R&D and Market Value', Nuffield College, Oxford University, available at http://www.economics.ox.ac.uk/Research/wp/pdf/paper259.pdf

Bessen, J., and Maskin, E. (2006), 'Sequential Innovation, Patents, and Imitation', Working Paper, Boston University School of Law and Princeton University.

— Meurer, M. (2005), 'The Patent Litigation Explosion', Law and Economics Working Paper No. 05-18, Boston University School of Law.

Bloom, N., Van Reenen, J., and Schankerman, M. (2005), 'Identifying Technology Spillovers and Product Market Rivalry', Discussion Paper No. 3916, London, CEPR.

Branstetter, L. G. (2004), 'Do Stronger Patents Induce More Local Innovation?', *Journal of International Law*, **7**(2), 359–70.

Burk, D., and Lemley, M. (2002), 'Is Patent Law Technology-specific?', *Berkeley Technology Law Journal*, **17**, 1155–206.

Cohen, W. M., Goto, A., Nagata, A., Nelson, R. R., and Walsh, J. P. (2002), 'R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States', *Research Policy*, **31**, 1349–67.

Commission on Intellectual Property Rights (2002), *Integrating Intellectual Property Rights and Development Policy*, London, Commission on Intellectual Property Rights, September.

Cornelli, F., and Schankerman, M. (1999), 'Patent Renewals and R&D Incentives', *Rand Journal of Economics*, **30**(2), 197–213.

Cremers, K. (2004), 'Determinants of Patent Litigation in Germany', Discussion Paper No. 04-72, Mannheim, Centre for European Economic Research (ZEW).

Danish Board of Technology (2005), *Recommendations for a Patent System of the Future,* report by a working group under the Danish Board of Technology, June.

Delrahim, M. (2004), 'US and EU Approaches to the Antitrust Analysis of Intellectual Property Licensing: Observations from the Enforcement Perspective', US Department of Justice, available at http://www.usdoj.gov/atr/public/speeches/203228.pdf

EPO (2006), 'Assessment of the Impact of the European Patent Litigation Agreement (EPLA) on Litigation of European Patents', European Patent Office, available at http://www.european-patent-office.org/epo/epla/pdf/impact_assessment_2006_02_v1.pdf

EPO (2007*a*), 'Patent System', European Patent Office, available at http://www.epo.org/topics/patent-system.html (accessed 3 December 2007).

— (2007*b*), 'Legislative Initiatives', available at http://www.epo.org/patents/law/legislative-initiatives.html (accessed 3 December 2007).

Farrell, J., and Shapiro, C. (2007), 'How Strong are Weak Patents?', paper presented at the Conference on the Economics of Competition and Innovation, October, University of California at Berkeley.

FTC (2003), *To Promote Innovation—The Proper Balance of Competition and Patent Law and Policy*, Washington, DC, Federal Trade Commission, October.

Geuna, A., and Nesta, L. J. J. (2006), 'University Patenting and its Effects on Academic Research: The Emerging European Evidence', *Research Policy*, **35**(6), 790–807.

Gilbert, R. J. (2004), 'Converging Doctrines? US and EU Antitrust Policy for the Licensing of Intellectual Property', *Antitrust*, **19**(1), 51–7.

— Shapiro, C. (1990), 'Optimal Patent Length and Breadth', *RAND Journal of Economics*, **21**, 106–12.

Gowers, A. (2006), *Gowers Review of Intellectual Property*, London, HMSO, December.

Grabowski, H., and Vernon, J. M. (1994), 'Returns to R&D on New Drug Introductions in the 1980s', *Journal of Health Economics*, **13**, 383–406.

Graham, S. J. H., Hall, B. H., Harhoff, D., and Mowery, D. C. (2003), 'Post-issue Patent "Quality Control": A Comparative Study of US Patent Re-examinations and European Patent Oppositions', in W. Cohen and S. Merrill (eds), *Intellectual Property in the Knowledge-Based Economy*,. Washington, DC, National Academies Press.

Green, J., and Scotchmer, S. (1995), 'On the Division of Profit in Sequential Innovation', *Rand Journal of Economics*, **26**, 20–33.

Grossman, G. M., and Lai, E. L.-C. (2004), 'International Protection of Intellectual Property', *American Economic Review*, **94**(5), 1635–53.

Hall, B. H. (2005), 'Exploring the Patent Explosion', *Journal of Technology Transfer*, **30**, 35–48.

— Ziedonis, R. H. (2001), 'The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry, 1979–1995', *RAND Journal of Economics*, **32**, 101–28.

— Jaffe, A. B., and Trajtenberg, M. (2005), 'Market Value and Patent Citations', *RAND Journal of Economics*, **36**, 16–38.

— Graham, S., Harhoff, D., and Mowery, D. C. (2003), 'Prospects for Improving US Patent Quality via Postgrant Opposition', *Innovation Policy and the Economy*, **4**, 115–43.

Harhoff, D., and Reitzig, M. (2004), 'Determinants of Opposition against EPO Patent Grants: The Case of Biotechnology and Pharmaceuticals', *International Journal of Industrial Organization*, **22**, 443–80.

— Narin, F., Scherer, F. M., and Vopel, K. (1999), 'Citation Frequency and the Value of Patented Inventions', *Review of Economics and Statistics*, **81**, 511–15.

Heller, M. A., and Eisenberg, R. S. (1998), 'Can Patents Deter Innovation? The Anticommons in Biomedical Research', *Science*, **280**, 698–701.

Henry, M., and Turner, J. L. (2006), 'The Court of Appeals for the Federal Circuit's Impact on Patent Litigation', *Journal of Legal Studies*, **35**, 85–117.

Hicks, D., Breitzman, T., Olivastro, D., and Hamilton, K. (2001), 'The Changing Composition of Innovative Activity in the US—A Portrait Based on Patent Analysis', *Research Policy*, **30**, 681.

Hopenhayn, H., and Mitchell, M. (2001), 'Innovation Variety and Patent Breadth', *Rand Journal of Economics*, **32**(1), 152–66.

— Llobet, G., and Mitchell, M. (2007), 'Rewarding Sequential Innovators: Prizes, Patents, and Buyouts', *Journal of Political Economy*, **114**(6), 1041–68.

Hunt, R. M. (1999), 'Nonobviousness and the Incentive to Innovate: An Economic Analysis of Intellectual Property Reform', Federal Reserve Bank Working Paper No. 99-3, Federal Reserve Bank of Philadelphia, Economic Research Division.

IBM (2006), *Building a New IP Marketplace*, A Global Innovation Outlook Report, September.

Jaffe, A. B., and Lerner, J. (2004), *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It*, Princeton, NJ, Princeton University Press.

James, T. C. (2007), 'Patent Protection in India: Policy Trends', presentation to the Conference on Intellectual Property Rights, Globalisation and Related Issues, Delhi School of Economics, India, November.

Japanese Government (2004), *Intellectual Property Strategic Program*, May.

JPO (2006), 'A History of System of Industrial Property Rights', Japanese Patent Office, available at http://www.deux.jpo.go.jp/cgi/search.cgi?query=history&lang=en&root=short (accessed 19 December 2006).

Judd, K. L. (1985), 'On the Performance of Patents', *Econometrica*, **53**, 567–95.

Kanwar, S., and Evenson, R. (2003), 'Does Intellectual Property Protection Spur Technical Change?', *Oxford Economic Papers*, **55**, 235–64.

Kingston, W. (2001), 'Innovation Needs Patents Reform', *Research Policy*, **30**(3), 403–23.

Klemperer, P. (1990), 'How Broad should the Scope of Patent Protection Be?', *RAND Journal of Economics*, **21**, 113–30.

Ladas and Parry LLP (2003), 'A Brief History of the Patent Law of the United States', available at http://www.ladas.com/patents/uspatenthistory.html (accessed 19 December 2006).

Lanjouw, J. O., and Lerner, J. (1998), 'The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature', *Annales d'Economie et de Statistique*, **49–50**, 223–46.

— Schankerman, M. (2001), 'Characteristics of Patent Litigation: A Window on Competition', *RAND Journal of Economics*, **32**, 129–51.

Lerner, J. (1995), 'Patenting in the Shadow of Competitors', *Journal of Law and Economics*, **38**, 463–95.

— (2002), 'Patent Policy Shifts and Innovation over 150 Years', *American Economic Review*, **92**, 221–5.

Levin, R. C., Klevorick, A. K., Nelson, R. R., and Winter, S. G. (1987), 'Appropriating the Returns from Industrial Research and Development', *Brookings Papers on Economic Activity*, **3**, 783–831.

Lunney, G. S., Jr (2001), 'e-Obviousness', *Michigan Telecommunications Technology Law Review*, **7**, 363–422.

*MIP News* (various dates), *Managing Intellectual Property News*, available at http://www.managingip.com

Mansfield, E. (1986), 'Patents and Innovation: An Empirical Study', *Management Science*, **32**(2), 173–81.

Maskus, K. (2006), *Reforming US Patent Policy*, Council on Foreign Relations, November.

Moore, K. A. (2000), 'Judges, Juries, and Patent Cases—An Empirical Peek Inside the Black Box', *Michigan Law Review*, **99**(281), 365–409.

Moser, P. (2005), 'How do Patent Laws Influence Innovation? Evidence from Nineteenth-century World Fairs', *American Economic Review*, **95**, 1214–36.

Mowery, D. C., Nelson, R. R., Sampat, B. N., and Ziedonis, A. A. (2004), *Ivory Tower and Industrial Innovation: University–Industry Technology Transfer Before and After the Bayh–Dole Act*, Stanford, CA, Stanford University Press.

Nagaoka, S. (2006), 'Reform of Patent System in Japan and Challenges', paper presented at the Conference on 21st Century Innovation Systems for Japan and the United States: Lessons from a Decade of Change, Tokyo, Institute of Innovation Research, Hitotsubashi University.

National Academies' Board on Science, Technology, and Economic Policy (2004), *A Patent System for the 21st Century*.

Nordhaus, W. (1969), *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change*, Cambridge, MA, MIT Press.

O'Donoghue, T., Scotchmer, S., and Thisse, J.-F. (1998), 'Patent Breadth, Patent Life, and the Pace of Technological Progress', *Journal of Economics and Management Strategy*, **7**(1), 1–32.

OECD (2003), *Patents, Innovation and Economic Performance, OECD Conference Proceedings*, Paris, Organization for Economic Cooperation and Development.

Park, W. G., and Ginarte, J. C. (1997), 'Intellectual Property Rights and Economic Growth', *Contemporary Economic Policy*, **15**, 51–61.

Penrose, E. T. (1951), *The Economics of the International Patent System*, Baltimore, MD, Johns Hopkins University Press.

Qian, Y. (2007), 'Do Additional National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment', *Review of Economics and Statistics*, forthcoming.

Reinganum, J. F. (1989), 'The Timing of Innovation: Research, Development, and Diffusion', in R. Schmalensee and R. D. Willig (eds), *Handbook of Industrial Organization*, vol. 1, Amsterdam, North-Holland.

Sakakibara, M., and Branstetter, L. (2001), 'Do Stronger Patents Induce more Innovation? Evidence from the 1988 Japanese Patent Law Reforms', *RAND Journal of Economics*, **32**, 77–100.

Scotchmer, S. (1991), 'Standing on the Shoulders of Giants', *Journal of Economic Perspectives*, **5**(1), 29–41.

Scotchmer, S. (2004), 'The Political Economy of Intellectual Property Treaties', *Journal of Law, Economics, and Organization*, **20**, 415–37.

— (2005), *Innovation and Incentives*, Cambridge, MA, MIT Press.

Shapiro, C. (2001), 'Navigating the Patent Thicket: Cross Licenses, Patent Pools, Standard-setting', *Innovation Policy and the Economy*, **1**, 119–50.

Shavell, S., and van Ypserele, T. (2001), 'Rewards versus Intellectual Property Rights', *Journal of Law and Economics*, **44**, 525–47.

USPTO (2007), United States Patent and Trademark Office, available at http://www.uspto.gov (accessed 4 January 2007).

Van Zeebroeck, N., and Van Pottelsberghe de la Potterie, B. (2007), 'Filing Strategies and Patent Value', paper presented at the Second Annual Meeting of EPIP, Lund, Sweden.

— — Guellec, D. (2006), 'Claiming More: The Increased Voluminosity of Patent Applications and Its Determinants', CEPR Working Paper No. 5971, London.

Walsh, J. P., Arora, A., and Cohen, W. M. (2003), 'Effects of Research Tool Patenting and Licensing on Biomedical Innovation', in W. M. Cohen and S. A. Merrill (eds), *Patents in the Knowledge-based Economy*, Washington, DC, National Academies Press, 285–340.

WIPO (2007), 'Patent Statistics', World Intellectual Property Organization, available at http://www.wipo.int/ipstats/en/statistics/patents/ (accessed 30 January 2007).

Wright, B. D. (1983), 'The Economics of Invention Incentives: Patents, Prizes, and Research Contracts', *American Economic Review*, **73**, 691–707.

Ziedonis, R. H. (2004), 'Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms', *Management Science*, **50**, 804–20.

— (2007), 'Intellectual Property and Innovation', forthcoming in S. Scott (ed.), *Blackwell Handbook on Technology and Innovation Management*, Oxford, Blackwell.