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Research Paper

The Use and Value of Patent Rights

Bronwyn H. Hall

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1. Overview of issues

Accompanying the growth of the knowledge sector in many economies is an increased interest in property rights for the knowledge being created by firms and individuals, that is, in the protection of those rights via Intellectual Property Rights (IPR). IPRs include patents, trademarks, copyrights, trade secrets, and a number of more specialized instruments such as plant patents. Because these rights are a creation of legislation and government regulation, the increased focus on their use also leads to increased interest in their design and function on the part of policymakers. The present paper is designed to review the various ways these rights are used today, to draw some lessons for policy, and to suggest areas where further research is needed. The paper focuses on patents, arguably the most important form of intellectual property for business firms, although other rights will be discussed to the extent that they substitute for patents in various contexts.

When the governing authority grants a patent, it trades off short term exclusive (monopoly) rights to the use of an invention in return for two things: 1) an incentive to create the invention and 2) early publication of a description of the invention rather than the use of secrecy to protect its misappropriation. But with the increasing importance to enterprises of their investments in knowledge and the accompanying increase in the use of the patent system, it has become apparent that things are far more complex than the bargain suggested by the simple tradeoff. In addition, as the importance of the IP system grows, clever strategists use it in ways not contemplated by its designers. Hence the timeliness of this review of the use and value of IP rights, especially patents.

The first observation on ways in which reality departs from the simple one invention, one patent picture is that invention is cumulative, with each discovery today building on discoveries in the past. Therefore the incentive created for one invention or innovation via the patent right can act to slow down the creation or

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[1] University of California at Berkeley and University of Maastricht. *bhhall@econ.berkeley.edu* I am grateful to the organizers of and participants in the Forum for useful comments and to the UK Intellectual Property Office for financial support.

increase the cost of a subsequent invention that builds on the first. This fact suggests that the overall effect on innovation may not be as strong as suggested by the allocation of exclusivity to the inventor. The second observation is that firms and individuals that are given such a rather complex legal instrument will learn to use it strategically in ways that may not serve the intent of the original legislation. For example, the benefits of publication may be limited by careful drafting of the patent or the omission of essential (tacit) know-how. Or a patent may be taken out and then kept "sleeping" solely to disadvantage a competitor and to preserve a (temporary) monopoly in a particular market.

A final observation is that knowledge-intensive firms face a number of problems associated with the fact that their assets are largely intangible and patents can help to mitigate these problems. In particular, clear title to at least some of these assets facilitates obtaining financing, at least from those willing to provide risk capital such as venture capitalists. In principle, the existence of secondary markets for patent assets, which are still in their infancy (Ocean Tomo, Yet2, Intellectual Ventures, etc.) should facilitate entry into knowledge-intensive sectors, by increasing the salvage value of a firm that ultimately fails. Patents can also serve as a focusing device for the trading of expertise and know-how between firms.

Before discussing what we know about the use and value of IP rights by firms, two broader issues deserve mention. The first is to emphasize the perspective from which this paper is written, which is a consideration of how the IP system could be improved to increase or even maximize social welfare. That is, it does not start with a premise that strengthened intellectual property rights are necessarily better for innovation or social welfare, beneficial as they may be for individual firms. Understanding that intellectual property rights are not the same as ordinary property rights on physical assets is key to understanding that policy can and should be different in this area. The most obvious difference between the two types of property is non-rivalry: in the absence of strong IP rights, one person's use of a piece of knowledge still leaves it free for another to use, a characteristics not shared by ordinary tangible property. Another difference between the two types of property is due to what Bessen and Meurer (2008) call insufficient notice, a lack of clarity about the boundaries of the property, a problem which appears to have worsened recently in the case of patent rights.[2] Taken together, both arguments suggest that a policy

[2] One reason for this may be an increase in creative drafting of applications, especially in the business method and software areas, where obfuscation may confer a benefit on the patentee in subsequent litigation. The difficulties of patent clearance can be extreme in such cases.

maker's approach to the regulation of IP rights may and should be quite different from his or her approach to the regulation of ordinary property rights.

The second observation about the workings of the IP system and how it affects firms and innovators was hinted at by Edith Penrose in 1951:

> "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."

I interpret this statement to describe a phenomenon that we can observe happening throughout the history of various changes and experiments with IP systems: firms and the structure of industry adapt to the systems with which they find themselves. A leading example is the rise of firms specializing in knowledge creation following the strengthening of the U. S. patent system in the early 1980s (Hall and Ziedonis 2001; Arora et al. 2001). That is, there is path dependence in industry structure, which makes it difficult to compare the performance of a system that is in place with one that may involve radical change in the way things are done. Another implication is that existing systems create rents for some firms and individuals, who then resist strongly any changes that might destroy these rents.

With these two points in mind, I turn to the economic theory and evidence on the use and value of patents.

2. Economic theory and evidence

2.1 Do patents encourage innovation?[3]

As is so often the case with economic models that admit the complexity of the world, the theoretical literature on patents produces ambiguous results with respect to incentives that they provide. In the simplest case, where a patent corresponds to a single product and knowledge is not very cumulative, it is clear that patents will encourage innovation. Offering individuals the short-term right to exclude others from practicing an invention provides them with the opportunity to earn rents or supranormal profits when they innovate which are higher than those they would earn if there were immediate free entry into imitation of their invention. This is expected to stimulate their inventive activity. The early theoretical industrial organization literature on patent races even seemed to suggest that patents might produce too much innovation (Wright, 1983; Reinganum, 1989).

[3] Parts of this section of the paper are drawn from Hall, B. H. (2007), "Patents and Patent Policy," *Oxford Review of Economic Policy* 23 (4): 568-587.

However, models that incorporate either 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 analyzes a number of these 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. For example, Lemley and Shapiro (2007) reports that 177 patents held by seven firms deal with recordable DVD media, and that the 802.11 WiFi standard is underpinned by several hundred patents held by over 30 companies. As these authors also report, the 3G telephony standard is covered by thousands of patents.

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 patentholders are involved. If these patents are essential complements, a royalty stacking problem will occur: in effect, each patent holder is able to hold out for the entire surplus value associated with the invention and it can be difficult to reach a bargaining solution (Lemley and Shapiro 2007).

A recent paper by Bessen and Maskin (2006) develops a model of sequential (cumulative) and complementary innovation in a differentiated product setting and analyzes the effect of patent protection in two settings, nonsequential and infinitely sequential (that is, where each invention builds on the preceding invention). The results are somewhat complex but intuitive: in the static nonsequential case, having a patent system generally yields higher welfare than not having one. But in the fully sequential case, the equilibrium without patents has higher welfare and more 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 so that social welfare is expected to be higher without a patent system. 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. He finds that the market value of a firm is enhanced when it cites others' patents that have cited its patents in turn. That is, knowledge that flows back to a firm from others enhances profitability.

Thus economic theory yields an inconclusive answer to the question of whether patents encourage innovation in general. We therefore turn to the empirical evidence on this question, which comes in several flavors: survey evidence, cross country studies, and studies within individual patent systems. Here there are several conclusions.[4] The first is that introducing or strengthening a patent system (lengthening the term, broadening subject matter coverage, etc.) unambiguously results in an increase in the use of the system (Lerner 2002; Hall and Ziedonis 2001).

Second, it is much less clear that these changes also result in an increase in innovative activity, although they may redirect such activity toward things that are patentable and/or are not subject to being kept secret within the firm (Moser 2001; Lerner 2002; Baldwin et al 2000). Third, if there is an increase in innovation due to patents, it is likely to be centered in the pharmaceutical and biotechnology areas, specialty chemicals, and possibly medical and scientific instruments as well as small-scale machinery (Levin et al 1987; Cohen et al 2001; Arora et al 2001). Fourth and finally, the existence and strength of the patent system does affect 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. 2001; Arora and Merges 2004).

2.2 How do firms actually use patents?

We actually know a reasonable amount about this topic, thanks to a series of firm- and inventor-level surveys. In the U. S., there were important surveys of innovation conducted in the mid-1980s by researchers at Yale University (Levin et al. 1987) and in the mid-1990s by researchers at Carnegie-Mellon University (Cohen et al. 2002). These first large efforts were followed by similar surveys in a number of European countries and Japan, and then by the Community Innovation Surveys

[4] I have surveyed the empirical evidence in more detail in several recent papers: Hall (2007); Hall(2009a); Hall (2009b).

which have been conducted in most European countries since the late 1990s. Then in 2004 the new PATVAL survey of the inventors named on patents was conducted by researchers in 6 European countries (Giuri, Mariani et al. 2007; Gambardella et al. 2007).[5] This initiative sparked a new wave of inventor surveys, which have now been conducted for the U. S., Japan, and Korea, and with a successor European survey in the offing (Nagaoka and Tsukada, 2007; Nagaoka and Walsh 2009). This section of the paper reviews the results of these surveys.

Innovation surveys

The first group of surveys asks firm representatives (usually R&D managers) by which means they secure returns to their innovative activity, providing a menu that includes patents, trade secrecy, lead time, superior sales and service, and so forth. Sometimes the question is phrased as what share of their innovations are protected by the various means. Table 1 summarizes the results of a number of such surveys, simply using whatever importance ranking is available from the published reports; it is necessarily fairly approximate given the lack of exact comparability across the surveys. However, it does document rather clearly the fact that for the majority of firms, patents are seldom among the most important means for appropriating returns to product innovation, with lead time and superior sales and service generally considered more important.[6]

Table 1
Appropriating the Returns to Product Innovation

			Ranking of means across all industries			
Survey	*Year*	*Country*	*1*	*2*	*3*	*4*
Yale	1982	US	sales & service	lead time	**patents**	secrecy
Harabi	1988	Switzerland	sales & service	lead time	secrecy	**patents**
Dutch CIS	1992	Netherlands	lead time	retaining employees	secrecy	**patents**
Carnegie-Mellon	1993	US	lead time	secrecy/mfg	sales & service	**patents**
Japan C-M	1993	Japan	lead time	**patents**	sales & service/ mfg	secrecy
SESSI/INSEE EFA	1993	France	lead time	**patents**	secrecy	complexity
StatCan Innovation	1999	Canada	confidentiality agreement	trademarks	**patents**	secrecy
CIS 3 2000*	2000	EU12	lead time	secrecy	trademarks	complexity

*Patents not shown in table, Eurostat 2004, KS-NS-04-001, Theme 9: Innovation output and barriers to innovation.

[5] The countries were Italy, Germany, France, Spain, the Netherlands, and the UK.

[6] In most surveys, similar questions are asked for process innovations. Here patents rank even lower, and secrecy higher, as one might have expected.

Table 2 presents a rough ranking of the industries in which patents are considered the most important. In almost all cases where it is broken out separately, the pharmaceutical industry ranks at or near the top, followed by specialized machinery and instruments, other chemicals, and occasionally transport equipment including motor vehicles and parts. Note that, in general, these sectors contain technologies that are relatively well-defined by a patent document, and where an innovative product can be covered by one or a few patents. For example, in the case of transport equipment, it is the parts manufacturers that find the patent system effective for protecting their innovations (Cohen et al. 2000; Levin et al. 1987).

Finally, it is important to note that there is wide dispersion across firms in the answers to these questions and therefore in the relative rankings of protection methods within the manufacturing sector and even within an industry. For a small but nontrivial share of firms in most sectors, patents will still rank very highly as a means of appropriating returns to innovation, making it difficult to generalize completely. In addition, when the wording of the question concerns the share of innovations that are protected by patents, the answers are almost always a non-negligible share, regardless of industry.

Table 2
Appropriating the Returns to Product Innovation by Sector

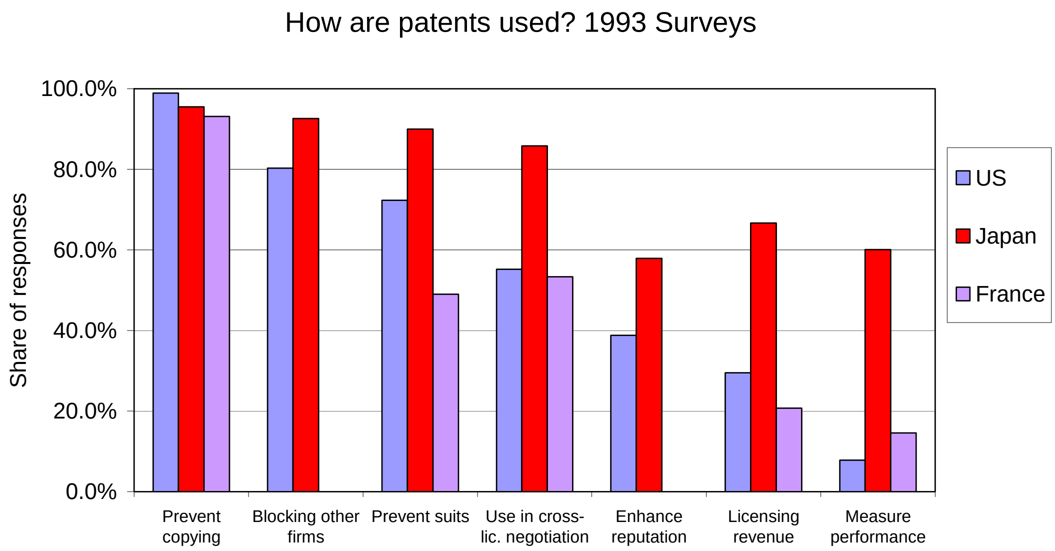
Appropriating the Returns to Product Innovation

Survey	*Year*	*Country*	Industries preferring patents in descending order of preference
Yale	1982	US	pharmaceuticals; plastics; chemicals; steel; oil
Harabi	1988	Switzerland	research labs; machinery; chemicals; watches; paper*
Dutch CIS	1992	Netherlands	pharmaceuticals, chemicals, instruments, rubber&plastics, oil
Carnegie-Mellon	1993	US	pharmaceuticals, medical inst; special machinery; computers; chemicals
Japan C-M	1993	Japan	
SESSI/INSEE EFA	1993	France	pharmaceuticals, instruments; transport equip.; chemicals; machinery; paper
StatCan Innovation	1999	Canada	machinery; elec equip.; pharmaceuticals; comm eq; instruments; chemicals; motor vehicles
CIS 3 2000*	2000	EU12	transport equip.; instruments; chemicals*

* Pharmaceuticals not broken out from chemicals

In some cases these survey questionnaires have also asked why the firms patent or how they use patents – to prevent copying, to avoid infringement suits, to block competitors from patenting, for licensing revenue, and so forth. Figure 1 presents some representative results from the three 1993 surveys conducted in the U.S., Japan, and France. It is apparent from the figure that the traditional use of patents, preventing imitation, is the most important use. However, a nontrivial share of the firms, especially in the U.S. and Japan, use patents to block other firms from patenting or to prevent infringement suits. Cohen et al. (2002) deepen this analysis and are able to show that the use of patents varies substantially depending on the type of technology that is being protected, discrete (one or a few patents per product) or complex (many patents per product). This finding has important implications for the ways in which patenting strategy has evolved over the past 20 years and I therefore discuss the issue at greater length in the next section, after a brief discussion of the inventor survey results.

Figure 1



Inventor surveys

Samples for the typical inventor survey are drawn from the inventors named in patent documents. Taking the pioneering EU Patval survey as an example, the questions asked are designed to elicit information about inventor characteristics, their motivations, the sources of their knowledge, types of collaboration, and the actual use and economic value of their patents, including licensing and commercialization.

With respect to the use of their patents, overall the EU inventors report that about half of them are used internally by the firm, 13 per cent are licensed, and approximately 35 per cent are unused, either sleeping or blocking competitors (Giuri, Mariani et al. 2007). Answers for the US and Japan are similar, but with a somewhat larger share used in cross-licensing agreements (Nagaoka and Walsh 2009), doubtless reflecting the greater importance of ICT sectors in these economies. Because of the way the questions on use are asked, it is difficult to compare the answers directly with those given by the R&D managers of the firms in the innovation survey. The inventor survey questions are about individual patents and the innovation survey questions are about the firm's patents in general; nevertheless the answers are qualitatively similar.

The inventor surveys also contain questions about individual patent value, but I will defer the discussion of the results to section 2.4 of the paper, on patent value.

2.3 Complex vs. discrete technologies

The distinction between complex and discrete technologies has turned out to be important in understanding the different ways firms use the patent system and also their attitudes toward reform of the system (Cohen et al. 2002; Hall 2005, 2009b; von Graevenitz Wagner, and Harhoff 2008). The commonly accepted definition of a discrete technology is one where the typical product is covered by one or a few patents, usually held by a single firm. In contrast, a complex technology is one where a product is covered by many patents, usually held by several firms. It is the dispersion in ownership that creates most of the problems we observe, and such dispersion is more likely when there are many patented technologies in a single product. Table 3, drawn from Cohen et al. 2002 and von Graevenitz et al. 2007, 2008, shows a classification of industries and technologies according to their product type, along with a summary of the patent strategies generally associated with their technology type.

Table 3

Taxonomy of industries, technologies, and patent uses

	Discrete	*Complex*
Industries (based on Cohen et al. 2002, divided at ISIC 2900)	food&tobacco, textiles&apparel, wood&paper, chemicals including oil and plastics, pharmaceuticals, non-metallic mineral prods, metals, and metal products	machinery, computers, software, electrical equipment, electronic components incl. radio/TV, med & sci instruments, and transportation equipment
Technologies (from von Graevenitz et al. 2008, based on OST classes)	measurement & control, pharmaceuticals, medical, coatings, materials processing, organic chem, materials, mechanical elts, nuclear and chem eng, machine tools, biotech, ag & food chem & mach, environmental, thermal processes, space&weapons, consumer goods, civil eng, mining	high complexity: audiovisual, telecommunications, semiconductors, info technology, optics, electrical medium complexity: handling&printing; engines, basic chemistry and petrol, polymers, transport
Patent strategy (from von Graevenitz et al. 2007)	*Portfolio optimization*	*Portfolio maximization*
	used to exclude, and sometimes for licensing; also to prevent litigation	used in negotiations (cross licensing and other), and to prevent litigation
Volume of applications	high	very high
Use for blocking *only*	frequent	infrequent
Use of opposition	above average	below average
Applications with shared priorities	above average	average

The industry classification shown partitions the manufacturing sector into industries where the products are "materials" that rely on only a few technologies and industries where the products are "systems" relying on the assembly of various components, each of which may use several technologies.[7] The technology classification uses the ideas developed by von Graevenitz et al. 2008, applied to EPO patents classified by the OST-INPI/FhG-ISI 30 technology classification system.[8] These authors compute a complexity measure for patents in each of the 30 technology classes that is based on a count of cases where three firms own patents that mutually block each other.[9] Arranging the classes in descending order of this measure, six exhibit very high complexity measures, 19 exhibit very low (often zero) measures, and five are in between these two. With a few exceptions (notably some chemical subsectors), it is clear that the technology classification maps fairly well to the industry classification.

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[7] This split is the one used by Cohen et al. 2002, and is defined by choosing industries with ISIC less than 2900 (discrete) and greater than or equal to 2900 (complex). The definition is based in turn on work by Kusunoki, Nonaka, and Nagata (1998).

[8] See OECD (1994) for an earlier version.

[9] Blocking is defined as an X or Y reference to each other's patents at the EPO. See the von Graevenitz et al. paper for details of the construction of this measure.

Cohen *et al*. 2002 used the industry classification together with the results of the Carnegie-Mellon innovation survey to show that important differences across the sectors in the *reasons* for using patents emerge. Firms in industries with discrete products report that they patent for the traditional reasons of excluding competitors and preventing litigation, whereas those in complex product industries are significantly more likely to report patenting for cross-licensing and trading/ negotiation purposes, as well as to prevent litigation. This last finding is consistent with the work of Hall and Ziedonis (2001) on semiconductor firms and their patent portfolio races, which are designed to prevent hold-up and improve their bargaining position in cross-license negotiation. Hall 2005 shows that the patent explosion in the U. S. is essentially due only to firms in the electronics, computing, instruments and electrical equipment sector (complex technologies).

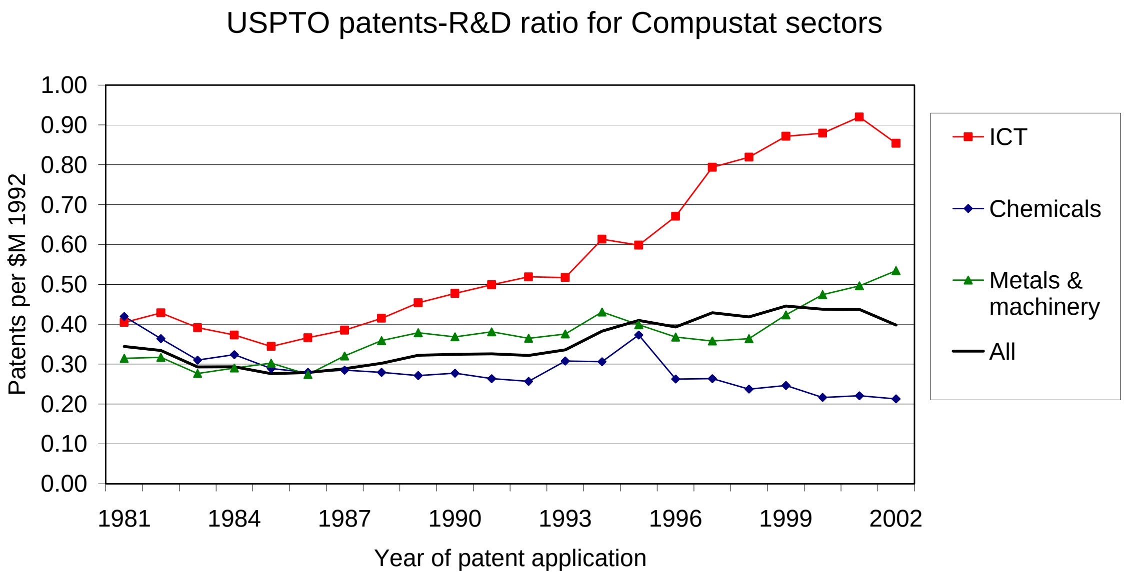
The entries in the bottom half of Table 3 characterize two broad patent strategies pursued by firms in the two technology sectors, discrete and complex. The descriptions and the data on which they are based come from von Graevenitz et al. (2007), a report to the European Union on strategic patenting. In that report, we described the discrete technology strategy as "portfolio optimization": this involves active patenting, largely for traditional exclusion reasons, proliferation of applications with a single priority date, and applications that correspond to high value innovations or innovations that threaten competitors, as indicated by high opposition. The quintessential technology that displays this behavior is pharmaceutical including biotechnology and cosmetics.

On the other hand, we have the complex technology strategy of portfolio maximization, where patents are used primarily defensively, in cross license negotiations and to prevent litigation. Here the volume of applications has increased greatly during the recent past, individual patents are rarely opposed, probably because any single patent is not worth much, and the proliferation from a single priority is much less. The quintessential technologies with these characteristics are the information and communication technologies (ICT), who pursue the patent portfolio arms races that were described by Hall and Ziedonis (2001) for the semiconductor sector. When negotiating a cross license agreement with a competitor, the quality of the individual patents does not matter as much as the fact that one possesses a large portfolio that can potentially threaten the opponent.[10]

[10] Although some licensing agreements are negotiated using a list of the firm's "proud patents" (Grindley and Teece 1997), according to the industry representatives with whom we met, firms occasionally find patents so difficult to value that some cross-licensing negotiations are conducted using patent *counts* as the unit of currency (Hall and Ziedonis 2001). Von Hippel's interviews of semiconductor firms revealed a similar tendency: "[when] threatened by an infringement suit, a firm will typically send 'a pound or

The increase in the importance of patents in the ICT sector over the past 20 years is illustrated in Figure 2, drawn from data at the USPTO on firms that are traded on U.S. stock markets (so that data on their R&D spending is available). This figure shows the aggregate patent grants (by date of application) per million constant R&D dollars for all of manufacturing and three major sectors separately: ICT, Chemicals including pharmaceuticals, and Metals and machinery including transport equipment. The patent yield for all of manufacturing has risen slightly from 0.3 to 0.4 per million 1992 dollars of R&D during the twenty year period shown. For chemicals, the yield fell slightly, whereas for ICT, the yield tripled from 0.3 to 0.9. This is unlikely to be to due to true increased productivity of R&D in that sector; the explanation is the perceived need of firms in those sectors to amass large patent portfolios for defensive purposes and use in cross-licensing negotiations with other firms whose technology they are using. This situation was probably exacerbated by a patent office struggling to deal with the rapid increase in patent applications in this area; most observers think that a number of patents of dubious quality issued during the period of the rapid increase.

Figure 2



two' of copies of patents germane to the business to the potential plaintiff and suggest that it is they who are the real infringers, culminating in a cross-licensing" (von Hippel 1988, p. 53; cited in Cohen et al. 2000). Clearly, to the extent that this practice has become more widespread, there is a considerable incentive to apply for patents on minor innovations that have no other intrinsic value.

Noting the changed patenting behavior of ICT firms and following on several well-known international disputes in the sector during the past 20 years or so (Texas Instruments asserting integrated circuit patents; Rambus asserting patents on memory technology; Qualcomm's patents on the CDMA standard), a number of scholars have studied the problem of patented standards components, royalty stacking, and patent holdup when there are many patent owners of technologies in a single product.[11] Obviously these kinds of problems are more severe in complex technology sectors, especially when these sectors rely heavily on standards in producing their products (as they inevitably do).

Reitzig et al. (2007) present a model of inadvertent infringement where the *ex ante* alternative is to invent around the patent and where the patent covers a relatively small piece of the final product. They show that because courts do not consider this alternative and what it means for the licensing costs if they were negotiated *ex ante*, a profitable strategy for patentholders is to wait to be infringed rather than offering a license before the costs of developing the product have been sunk. The usual royalty and damage rules change the threat point for *ex post* settlement between the parties and mean that the patent holder can make many times more from infringement settlements than from *ex ante* technology licenses.

Farrell and Shapiro (2007) have pointed to the fact that even weak patents (patents that probably should not have been issued) are problematic when there is downstream competition, because the incentives to challenge patents are sub-optimal if patents are probabilistic. When there are many firms competing, the firm that challenges the patent bears the full cost of the challenge, whereas all the firms benefit if the patent is overturned.[12] They are therefore able to show that weak (low probability of validity) patents licensed to non-rival downstream firms will command low royalties, but that weak patents licensed to rival downstream firms can command large running royalties. This problem is worse in the case where a product requires many complementary technologies because the profit at issue is much larger than the contribution of a single patented technology.

The conclusion is that strong patents (certain validity) are better than weak patents, but that even weak patents can be used anti-competitively. They are especially powerful given the threat of injunction, which shuts down production of the entire product line. The possibility of an injunction shifts the threat point in

[11] Simcoe et al. 2009 find that patents disclosed to Standard Setting Organizations by participants have a relatively high litigation rate, especially if they are owned by small firms, who tend to increase their litigation rates following a standard's adoption.

[12] An interesting new endeavor, PatentFreedom, has been undertaken to try to mitigate this problem. See McCurdy and Reohr (2008).

bargaining over license terms considerably: Under damages based on reasonable royalties, with a patent of uncertain validity, a firm chooses whether to pay for a license now or to pay later with a probability $p<1$. Under an injunctive threat, the loss later may be much greater, even though $p<1$, especially in complex technology industries.

Coupled with the observation that many such patents are asserted by non-producing entities, the above considerations presumably lie behind some of the support for preliminary injunction test recently articulated in the *MercExchange v. eBay* case in the United States.[13] In May 2006, the Supreme Court ruled that a four factor test must be used to decide whether to issue a permanent injunction in a patent case. A patent owner must show (1) it has suffered irreparable injury; (2) monetary damages are inadequate compensation; (3) a remedy in equity is warranted; and (4) the public interest would not be disserved. Applying this test should make it more difficult for patent holders that do not offer a product embodying the invention in question to obtain injunctions against those who do.

A note on non-producing entities

Recently, due to the activities of a number of pure patent holding or "knowledge producing" firms, controversy has developed over the role of these entities (sometimes called "trolls") in asserting patents that they own but whose technology they have no plans to develop. There is no doubt that such activity is increasing, and that much of it is directed against firms in the ICT sector, whose patent portfolio defense is useless when the litigant has no production that can threatened. As shown by Farrell and Shapiro and discussed above, it may not be worthwhile fighting such suits even when the patent being asserted is weak. In addition, in the case of complex technologies, the threat of a preliminary injunction may increase the bargaining threat point of the plaintiff disproportionately relative to his contribution to the product (Reitzig et al. 2007)

However, it is important to stress that non-producing entities can also play an important rule in encouraging entry into innovation, as they offer a way to salvage some of the intangible assets created by failed new entrants. That is, innovation, especially innovation that involves creating a new firm, is a highly uncertain and risky activity and frequently fails, leaving behind mostly intangible assets, which may have value in another use. Absent property rights and a market for these assets, they may be lost, and the salvage value of a failed innovative firm would therefore be close to

[13] http://www.supremecourtus.gov/opinions/05pdf/05-130.pdf

zero (barring a few desks and computers). A secondary market for IP assets can ensure that some value is retrieved from the failure, and therefore lowers the initial cost of entry. Whether this story is really true or has any real impact on entry probability is a matter for further research.

2.4 The value of patents

What do we know about patent value? The first step is to define what is meant by the term. The two main possibilities are the following: 1) the value of the underlying invention that the patent protects – such value could be private (the present discounted profits or licensing fees received by the inventor) or social (including any spillovers and the value of inventions that build on this one, as well as any consumer surplus not captured by the firm via markup pricing); and 2) the value of the patent right, which is the private incremental value of taking out a patent, above and beyond any profits that might be earned on the invention without patent protection. The latter is the incentive effect of patenting, whereas the former is often what interests us from a welfare perspective, or when we use patents as indicators of innovative activity.

Empirically there are two broad strategies for measuring the value of patents. The first values the patent portfolio held by a firm using a regression of firm market value on various firm characteristics (tangible assets, R&D spending, etc.) and including a measure of the patents owned by a firm, possibly weighted by the citations they have received. The second values a single patent using two very different methodologies: either by observing the owner's willingness to pay renewal fees on the patent or by surveying its owner or inventor and attempting to elicit an estimate of its value. In the former case, one obtains a measure of the value of the patent right (as opposed to the underlying invention), while in the latter case, one often obtains the combined value of the invention and the property right on that invention. There is also one effort that values the grant of a single patent using the event study methodology.[14]

The market value or portfolio approach relates the financial market valuation of a firm to its assets: tangible (plant, equipment, inventories, etc.) and intangible (knowledge capital, patent stocks, reputation, etc.). The coefficients in such a regression are the shadow value of the various assets in the market; they are not structural parameters and can and do vary over time and space. Note also that

[14] This methodology looks at the share price reaction around the time of news for a firm. Austin (1993) applied it to young biotechnology firms, where the issue of a single patent can be considered big news that might move the value of the firm. Because this is not generally true, and because patent issue is not always a surprise, it is difficult to justify applying the method more broadly.

financial markets will value patents both as indicators, because they are correlated with the success of innovative activity, and as instruments that secure returns to that activity by excluding competitors. The two are correlated within firms and difficult to separate, although conceptually they are different. Controlling for R&D will help to some extent to account for variations in innovative activity, but not for variations in its success. So market value approaches will generally measure a combination of part of the value of the underlying inventions and the patent rights associated with them.

The literature on the relationship between market valuation and the firm's patent portfolio is too extensive to survey in detail here, so I briefly review of the results of what has been learned.[15] A first observation is that much of the evidence is for Anglo-Saxon economies (US, UK, Australia, Canada) plus Japan, because those economies have thick financial markets on which most medium to large R&D-doing and patenting firms are traded, making the exercise possible. The results can be summarized as saying that patents are usually valued above and beyond the R&D done by the firm, that the value of patent protection is higher in pharmaceutical firms, and possibly somewhat higher in chemicals, computers, and machinery (Hall et al. 2004; Bessen 2006). A typical quantitative result is that of Hall et al., who find that one additional patent per million (1992) dollars of R&D increases a firm's market value by 3 per cent.

Measures of the quality of the portfolio, in particular the number of citations received by the patents, are even more strongly associated than patents with firm market value (Hall et al. 2007; Czarnitzki et al. 2006; Hall et al. 2005). This reflects a basic underlying fact about patents that has been found by all three approaches to studying patents: most of them are worthless and are few are worth a great deal. Therefore even very imperfect measures of quality help to explain value. For example, Hall et al. 2005 found that no additional value was attached to the U. S. patent citations received by a firm's patents unless they received more than the median cites per patent and that if the firm was in the top 5 per cent of the cites per patent distribution, their market value was 50 per cent higher, other things (including R&D and patents themselves) equal.

Inventor surveys and their predecessor surveys undertaken by Harhoff, Scherer and co-authors are directed at valuing a single patent right rather than a portfolio, but they find similar results. The following is a typical question asked in one of these surveys:

> "If at the time the patent issued you knew what you now know about the profit history of the invention abstracted here, what is the *smallest*

[15] For a somewhat dated survey of this literature, see Hall (2000). Also see Czarnitzki et al. (2006).

> amount for which you would have been willing to sell this patent to an independent third party, assuming that you had a bona fide offer to purchase and that the buyer would subsequently exercise its full patent rights? (Harhoff et al. 1999, page 512).

The answers to this kind of question always confirm the basic point first made long ago by Grabowski and Vernon (1990) in the context of new chemical entities and confirmed by Scherer and Harhoff (2000) using a number of data collections: the distribution of individual patent value is extremely skew, generally more skew than a log-normal distribution. Most patents are worth very little and a few are worth a lot. Of course, this does not imply that most are not needed or should not have been issued, but it does suggest that the uncertainty at the time of issue is very large.

Gambardella et al. 2008 present a comprehensive study of the patent value distribution elicited by the PATVAL surveys. They find that the mean value reported by inventors for their patents is 3 million euros (in mid-1990s euros) with a median that is one tenth that value. They correlate that value with commonly used indicators such as citations, number of claims, and the number of countries in which the patent is taken out, finding that these indicators explain only 2.7 per cent of the variance in value, 11.3 per cent when country, industry, and technology are controlled for. The implication is that there is still a great deal we do not know about patent value, calling for future research.

Using renewal data to estimate the value of a patent right is in many ways the preferred way to analyze the problem if the main focus is on the value of obtaining a patent rather than on the value of the underlying invention. The idea of this approach is to note that in most cases, the fees for renewing a patent rise over time, so that one can get an idea of the distribution of the value of patent coverage in a particular jurisdiction by looking at how many patents are renewed at different lifetimes. The methodology was pioneered by Schankerman and Pakes (1986) and has been applied to European patents (Schankerman 1998; Lanjouw 1993), Finnish patents (Groenquist 2007), and U.S. patents (Bessen 2007), among others. The findings can be summarized as confirming several points: 1) the distribution of patent rights value is skewed; 2) chemical and pharmaceutical patents are worth more on average, followed by electronics, computers, and communication equipment; and 3) most learning by the patentee about the value of his patent takes place in the first 5 years or so.

Under a set of fairly heroic assumptions, one can use the information provided by the renewal model to compute the size of the subsidy to R&D spending provided by the patent system. These authors find a range of answers, mostly in the

10-25 per cent range, but Bessen concludes that the implicit subsidy is much lower, on the order of 3 per cent. However, appealing though this approach to measuring the value of patent rights is, it has one major drawback: patent renewal fees are usually too low to reveal much about the truly valuable patents, those which are always renewed to term. And it is these patents that create most of the value in the system. The renewal approach relies on extrapolation of the distribution into a range where no data is actually observed (typically above values of $20,000-$30,000), and if the chosen distribution is wrong, the error in the subsidy estimate can be quite large.[16]

2.5 Use of patents to secure financing

As I alluded to in my discussion of non-producing entities, one of the chief arguments in favor of legal IP rights is their ability to protect the intangible assets of new entrants who have no other means of appropriating returns to their investments, thus encouraging entry. This is as true of copyright for the creation of new works by unknown authors as it is for patents in the case of new innovative firms. In this section of the paper I review what we know about the use of patents to secure financing, in particular, their use by Venture Capital-backed firms.

Among others, Hall and Ziedonis (2001) report informal evidence that individuals in the high-technology sector view patent applications as high on the list of questions asked by a prospective VC investor. Empirically this has been shown to be true in a number of ways. Kortum and Lerner (2000) use thirty years of data in the United States along with a "natural" experiment in the availability of VC funds to demonstrate that increases in industry VC activity spur patenting in that sector. That is, VC investment increases innovation when compared to ordinary R&D investment, or at least, increases the use of patents. Recently Haeussler et al. (2009) have shown that patent applications, especially those of high quality, speed the arrival of VC financing for British and German startups.

Owning or having applied for patents also seems to increase the valuation of startups during their initial phases of VC funding. In a paper that was primarily concerned with entrepreneurs preference for VC affiliation, Hsu (2004) found that having no patents reduced a startup's pre-money valuation by about 17-20 per cent. In a careful study of 370 startups in semiconductors, Hsu and Ziedonis (2008) find that doubling the patent application stock of a new venture increased its valuation by 28 per cent. T. Hall (2006) conducted his own survey of startup managers and found

[16] It would be useful to survey the exact magnitudes of the fees and how they vary across these various authors' papers, to get a picture of how sensitive the results might be to this problem.

that patents described by the managers as "useful for generating barriers to entry" increased pre-money valuation by about 20-30 per cent on average. In general, about one third of the firms in his sample had such patents, and another 10 per cent had patents that were not considered useful. An interesting result was that the valuation effect was essentially zero in early-stage rounds, but 50 per cent in expansion rounds (later-stage financing). So having patent applications clearly increases valuations and the probability of obtaining VC funding.

One point hinted at in the T. Hall (2006) results should perhaps be emphasized: there is a great deal of heterogeneity even within VC-backed startups and across sector, with many firms receiving financing in spite of having no patent applications. A few studies specific to particular sectors also exist. For example, Munari and Toschi (2007) look at a global sample of nanotechnology startups and find that although patent applications in general do not increase the value of these firms, patent applications that were actually in the nanotechnology class increase the financing amount received at the initial round by 15 per cent. However, the average number of such patents held by their firms is 0.2, which implies that at least 80 per cent of their sample have no nanotechnology patents at the initial round.[17]

The same situation prevails in software, a sector that has been better studied than some others in this area. Mann and Sager (2007) find that only one in four venture-backed software firms have patents even several years after their first round of financing, compared to over half of biotechnology firms, and that the rate of patenting differs substantially within the software sector, with the applications sector having substantially fewer patents than the internet, systems, and communications/ networking sectors. In spite of the rather low number of patents in this sector, having patents is significantly related to the firm's progress in terms of number of financing rounds, longevity, and total investment. The size of the portfolio does not seem to matter. Cockburn and MacGarvie (2007) confirm that having patents pending (whether or not they have already been granted) significantly raises the probably that a firm will obtain initial funding.

Hall and MacGarvie (2008) shed a different light on these rather nuanced results, finding that the market values of firms in the applications part of the software industry were more negatively impacted by the widespread introduction of software patents, presumably because these firms are more likely to have to license in technology components if they are patented, without an additional corresponding

[17] It is important to note that although the sample of firms Munari and Toschi use is global, the patents considered are only those applied for at the EPO. So there may be firms with patent applications at other offices in the sample. However, the valuation regression does include a US dummy, so this fact is of less concern for that regression.

revenue stream of their own. Hall and MacGarvie also found that for software firms, the quality of the patent portfolio was relatively more important than its size, when compared with hardware firms. That is, patent portfolio racing is not yet a feature of this sector.

Cockburn and MacGarvie (2007) also study the interaction between the presence of patent thickets in a subsector (measured as the concentration of ownership of patents citing the patents in the relevant market) and the financing and exit of early-stage software firms. They find that entry into a market with dense patent thickets is delayed, but once they are present in such a market, they are more attractive to investors, stimulating IPOs. These effects seem to be weak, however, and related to other characteristics of the firms that are difficult to control for.

Although consistent and very interesting in itself , the accumulated evidence is in some ways not surprising. Having applied for patents is a signal that a new or young firm has some technology worth protecting, but we don't know whether it is the patent or the technology that is creating the value.

2.6 Patents versus trade secrecy

There is a limited amount of work on this topic, beginning with Moser (2005), who shows that 19th century variations across countries in the existence of patent systems influenced the innovation strategies of inventors in the country. Absent a patent system, they tended to focus on inventions that could be protected with trade secrecy. She does not offer evidence on whether this fact had an overall impact on economic performance, but if economies are fairly integrated, one would not expect a big effect, because international trade would ensure that inventions of either type would diffuse across the region.

Hussinger (2004) shows that patents are a more important form of protection in present day Germany when the firm has a large share of new products on the market. However, secrecy is also used and considered important by such firms. So the main conclusion is the unsurprising one that protecting IP is more important for firms that innovate more, especially if their innovations are products rather than processes. It is probably safe to say that both means of protection are useful and important, but in different contexts.

Lerner (1994) uses a large sample of Intellectual Property cases from Middlesex County, Massachusetts to show that the frequency of litigation over trade secrecy is roughly the same as the frequency of patent litigation during the early 1990s, but that smaller firms tended to favor litigating trade secrets over patents. Size is in fact the only thing that predicts a preference for patents over trade secrecy. From this he concludes that secrecy is an important means of protection, more widely used among small firms because its fixed cost relative to patenting is lower.

One area where we have seen a shift away from secrecy (possibly accompanied by copyright) towards patenting is in software. This shift is essentially a consequence of a series of court decisions in the United States during the 1990s that enabled the patenting of "pure" software, accompanied by the introduction of the world wide web and its rapid growth. One of the features of code written for the internet is that much of it is written in languages that are readable by anyone who downloads the web page, in contrast to traditional compiled package software. In practice, this fact makes it less suitable for trade secret protection, and copyright without trade secrecy is not very attractive for protecting software, as it leaves the ideas exposed even as the expression of those ideas is protected.

The availability of patents for software has led to a shift towards patents from copyright on the part of the larger package software firms (Graham and Mowery 2004). Nevertheless, the largest software patenters, accounting for 50 per cent of software patenting, are still electronics multinationals.[18] In addition, a large part of the software sector, especially firms producing package software for niche markets, still relies on copyright plus trade secrecy due their inexpensive cost when compared to patents.

3. Policy implications

It may seem that the central patent policy question should be whether the patent system increases innovative activity on net, recognizing that it has both costs and benefits for this activity.[19] But the extensive study of the system that is partially documented here has revealed that this question is too simplistic. It is clear that patents encourage innovation in many areas, and also that they have beneficial effects for industry structure, knowledge markets, and the financing of new innovative firms. The policy questions at the forefront now bear on how best to design a system with these benefits without at the same time hampering innovation in other areas.

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[18] Graham and Mowery look at a narrow definition of software patents (excluding software embedded in hardware) and find that 12 large electronic systems and component firms account for half of the U.S. patents granted in 2007. The firms are IBM, Intel, Hewlett-Packard, Motorola, National Semiconductor, NEC, Digital Equipment Corporation, Compaq, Hitachi, Fujitsu, Texas Instruments, and Toshiba. Bessen and Hunt (2004), using a wider definition of software patents, find that only 5-7 per cent are issued to firms in the software sector, and 75 per cent to firms in the manufacturing sector. Hall et al. 2007 find that over 60 per cent of European or U.S. software patents are taken out by firms in electrical machinery and electronics including computers, only 2 per cent by software firms.

[19] A secondary question might be whether the patent system increases innovative activity so much that it rises above the social optimum. Most scholars and policy makers seem to agree that this is an unlikely possibility in general, although it may occur in specific cases, such as the search for a "me too" pharmaceutical.

A clear implication of the foregoing for policy is that optimal design is likely to differ across technologies and sectors. Many firms in the ICT sector view the current system as a tax on their innovative activity, whereas firms in pharmaceuticals and biotechnology are strong supporters of the existing system. Differences in the pace of technological change and product development across sectors suggest that optimal patent life may also differ. But most analysts have recognized that tailoring the system to technologies now available would inevitably leave it unable to adapt to new technologies as they arrived, and would also lead to substantial strategic behavior on the part of patent applicants to place their technology in such a way as to secure the best possible protection for their particular invention. The difficulty is that technological change moves much faster than legislative change, which means that fine-tuning of the patent system is inevitable out-of-date by the time it is in place.

Thus the most feasible ways to move away from a one-size-fits all system are for the courts to deal differently with different technologies (as suggested by Burk and Lemley 2009) or for incentive compatible rules to be articulated that encourage firms to truthfully reveal the kind of patent protection that would be useful. One way to deal with the latter problem has been suggested by Cornelli and Schankerman (1999). Higher renewal fees can help to weed out some patents that clog up the system.[20] The prior research on renewal behavior surveyed here (Pakes 1986; Schankerman and Pakes 1986; Lanjouw 1993) has revealed that firms often do not know the value of the invention protected by a patent value until about three to six years after its issuance. Higher renewal fees would encourage patents found to be of low to moderate value to be placed in the public domain sooner. Among other benefits, this guarantees that the patent cannot later be resurrected and reinterpreted to cover technology that was not originally contemplated.

Another problem for innovating firms that has been identified is the problem of inadvertent infringement when there are many minor patents, not always clearly written. As noted above, this problem is exacerbated by the imbalance in bargaining power between a potential infringer and patentee, especially a non-producing patentee. Shapiro (2007), among others, has proposed that prior user rights or an independent invention defense be available. There are obvious costs to this proposal as it would doubtless lead to more discovery in litigation, but also a substantial benefit that is aligned with policy goals, given that the fact of independent invention suggests that the invention was not "non-obvious" to persons having ordinary skill in

[20] de Rassenfosse and van Pottelsberghe (2008) have recently produced convincing evidence that patent applicants are sensitive the cost of applications, with a price elasticity of approximately -0.4. That is, demand for patents is inelastic, but price sensitive. There is no reason to think that this finding does not also apply to renewal fees.

the art and that the patent should therefore not have been issued. Shapiro goes on to show that social welfare is almost always higher if this defense is allowed. Lemley (2007) provides a more modest proposal incorporating some of the same ideas.

4. Priorities for further research

Based on the preceding survey and policy discussion, this final section of the paper suggests a few areas where further research might be beneficial, and then goes on to argue that in some areas, it might be advisable to ensure access to data that is currently only available via spotty news reporting or via the partial reporting by firms in their annual reports.

Modern empirical research in economics largely adheres to a version of the scientific method, with a focus on testing particular hypotheses rather than on the measurement of magnitudes, or integration of results on a single topic or question. This fact means that much of the research output surveyed here is not quite as useful as one would like for drawing clear policy conclusions or answering particular questions. As one reads through the literature on valuing patents, it becomes clear that each author has pursued the question using different specifications from different time periods and different countries, to say nothing of different technological classification systems. While in itself this is a good thing, it does make it difficult to compare the results and form an accurate picture of what has changed, and what is common across systems. So the first need for research might be to review these studies in somewhat more detail and to try to produce a best practice summary of their results (augmented with new analysis as needed). In particular, the various patent renewal studies would benefit from such an undertaking. If the question is "by how much is the patent system subsidizing R&D and innovative activities?", then renewal studies seem the most promising approach.

A second area of increasing concern is the "patent explosion." Although the rate of growth in patent applications has abated somewhat due to the financial crisis, application-grant lags are still unacceptably long and patent offices around the world have been struggling with the flood. As I have asked in an earlier paper, is the marginal scientist or engineer in an economy best employed doing R&D or examining patents? (Hall 2007). One reason for the flood is clearly the cross-licensing behavior of large manufacturers in ICT. As long as the inventive bar for a patent is fairly low and especially if it is uncertain, there are incentives to flood the offices with patent applications. We need research on ideas for incentive-compatible ways to change firm behavior. The obvious one is to raise fees of course, but one needs to consider how that plays out for smaller entities, who may in some cases be important sources of real inventions. The other area of concern is the use of continuation/divisional strategies and whether they are truly necessary to obtain adequate returns to innovation (especially in pharmaceuticals/biotechnology). Overall, there are many reasons to want to raise the patenting bar (novelty standard), but how do we get there?

I have raised the issue of non-producing entities earlier; there is considerable evidence that such entities are able to raise costs for ICT firms under many current legal systems and there is no doubt that the firms in question have been very vocal on the subject (Hall 2009a, among others). Some questions for research have emerged in this area: first, how should damage computations in litigation be modified in order to correctly reflect the possibility of *ex ante* license negotiation at much lower costs to the firms involved, that is, rather than using "rule-of-thumb" royalty rates, can we develop methods to compute royalty rates that truly reflect the contribution of the potentially infringed patent to the product? And to what extent is this a problem in jurisdictions outside the United States, where most of the problems seem to have occurred?

A second topic concerning non-producing entities that needs greater study is their role in ensuring salvage value for failed innovative firms. That is, we know that firms like Intellectual Ventures buy hundreds of such patents, but do we have any idea at what price, and whether the value is significant enough to affect the ability of firms to enter at lower cost. Research has shown that patents help secure financing for entry, and that they increase the amount of financing firms can obtain, but we do not know how much of that is due to the quality of the underlying invention, and how much to the patent right itself.

Finally, study of the full administrative costs of operating a patent system combined with the costs borne by the firms that participate or are impacted by it (legal, opportunity, fees, etc.) is somewhat limited, but necessary in order to perform a true welfare computation. That is, we might form a guess about how much additional R&D is elicited by the existence of patent protection, but evaluating the societal benefit also requires knowing how much it costs to operate. This is a very tall order, as it involves what is in effect an economy-wide computation of something which is in fact only a small part of the economy.

4.1 Data on litigation and licensing

Given the extreme heterogeneity of patenting behavior and value, one can always find a case study in the patent area to support any particular policy position. This is especially true in the litigation area. Therefore, evaluating the importance of many proposed problems with the system depends on looking at the data more broadly. However, much of the relevant data is either difficult to come by, or very selective due to differences in firm reporting practices.

Two types of data would be especially desirable for obtaining an adequately informed picture of litigation threats and settlements that never see the light of day. First, we need better and more consistent litigation data including the terms of financial settlements in patent suits. Firms that rely on the court system and public services to settle disputes should be obligated to report the details of any settlement reached. Such a requirement might encourage settlements (which can be kept secret) to be reached before a suit is filed, lowering the cost of suits, but at the expense of losing public information. In this case, it may be useful to introduce a two or three year lag before reporting is required.

A second desirable set of data is the financial data related to licensing contracts, some of which are of course the outcome of litigation. These data are essential both to encourage markets for technology (Lemley and Myrhvold 2008) and also if we are going to understand these markets more fully. It may be useful to require reporting of patent licenses in some standardized way, again with a substantial lag so that firm strategy is not compromised.

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Concept House
Cardiff Road
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