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THE U.S. PATENT SYSTEM IN TRANSITION: POLICY INNOVATION AND THE INNOVATION PROCESS

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ABSTRACT

This paper surveys the major changes in patent policy and practice that have occurred in the last two decades in the U.S., and reviews the existing analyses by economists that attempt to measure the impacts these changes have had on the processes of technological change. It also reviews the broader theoretical and empirical literature that bears on the expected effects of changes in patent policy. Despite the significance of the policy changes and the wide availability of detailed data relating to patenting, robust conclusions regarding the empirical consequences for technological innovation of changes in patent policy are few. Possible reasons for these limited results are discussed, and possible avenues for future research are suggested.

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I. Introduction

Starting in the early 1980s there began a series of changes to patent policy and practice in the U.S. that have had the generally perceived effect of strengthening the protection that patents provide, and extending the applicability of that protection institutionally, geographically, and technologically. Roughly coincident in time with these significant changes in the legal and institutional environment, there has been a dramatic, historically unprecedented surge in patenting by U.S. inventors. This confluence of events provides a major challenge and opportunity for scholars of technological change and for science and technology policy. On the one hand, significant changes in property-rights regimes do not happen very often and provide, at least in principle, an unusual set of "natural experiments" that ought to greatly improve our ability to understand how different regimes affect behavior. On the other hand, policy-makers have a right to expect that social scientists can analyze these developments and provide vital input regarding the economic and social consequences of policy changes of this sort.

In this survey, I will highlight the major policy changes that have occurred and review the existing analyses by economists that attempt to measure the impacts these changes have had on the processes of technological change. I will also review the broader theoretical and empirical literature that bears on the expected effects of changes in patent policy. To give away the punch line: despite the significance of the policy changes and the wide availability of detailed data relating to patenting, robust conclusions regarding the empirical consequences for technological innovation of changes in patent policy are few. The primary reasons for these disappointing results appear to be:

1. many aspects of the environment for innovation are changing at the same time, making it difficult to distinguish the effects of policy changes from the effects of other contemporaneous developments;

2. patents are only one among many determinants of the returns to innovative behavior, so that even significant changes in patent policy may have only limited effects; and
3. economic theory makes predictions about the effects of policy parameters that are sometimes quite sensitive to model assumptions, and it is often difficult to connect specific changes in patent rules and practices to the theoretical constructs.

The paper begins with a brief overview of the major changes in patent law and policy that have occurred. It then proceeds to review the literature. This review is organized around empirical and analytical issues rather than the specific policy changes, but the connections should be clear. Next I discuss a few current policy debates in light of the existing literature. I conclude with some summary comments and the traditional observations about what kinds of additional research would appear to be most needed.

As with any review, there are many things omitted. The most important category of omissions is that this paper is primarily about patent policy in the U.S. Although I will discuss to some extent the international harmonization of patent rules related to the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations, I do not consider in any detail many important differences between the U.S. patent system and those of other countries. Even within the U.S., there have been a number of additional changes in patent rules that I will not consider, either because their applicability is relatively narrow, because there has been little analysis of their effects, or simply because I didn't get to them. Finally, there is a voluminous legal literature that is closely related to the economic analysis that I describe, and many of the changes that I discuss have complicated and subtle legal nuances that I do not understand. Readers interested in those aspects of these issues should consult Merges (1997).

II. Important Policy Developments

The changes in patent policy that I will discuss can be grouped into four broad categories: (1) the creation of a new court to review patent decisions and the apparent associated improvement in the likelihood of success in court for patentees; (2) the extension of patenting and licensing privileges to inventors in universities and government laboratories who create commercially exploitable inventions partly or wholly with the use of federal research funding; (3) the extension and clarification of the applicability of patent rights to new technological areas, particularly software and gene research; and (4) the agreements under the Uruguay Round of the GATT negotiations to extend and harmonize patent protection around the world.

Although framed by the issues of international competitiveness that have come to the fore in the last several decades, recent debates over patent policy contain many echoes of earlier debates. For reviews of this historical background, see Kaufer, 1989, Merges (1997) or Penrose (19zz).

A. *Creation of the Court of Appeals for the Federal Circuit (CAFC)*

At the end of the 1970s, the U.S. patent system was widely perceived to be weak and ineffective. The U.S. Patent and Trademark Office (PTO) was overworked and understaffed; in 1979 they simply stopped granting patents for a while. In fast-moving technological fields, the general perception was that an invention would be obsolete before the PTO would get around to granting a patent on it. The Justice Department, the Federal Trade Commission and the Courts took a rather dim view of patents, often interpreting efforts to enforce patent rights through a lens of antitrust law and concluding that many patent and licensing practices were anticompetitive. Most patents whose validity was litigated were eventually held to be invalid (Koenig, 1980; Merges, 1997).

Beginning in 1980, this situation was essentially reversed. The Supreme Court issued a series of decisions that stated that monopoly power was the purpose of the patent grant, so that efforts to enforce patents and extract the monopoly rents they generate were not, in and of themselves, violations of antitrust laws. Congress passed a series of laws that strengthened and streamlined the patent office. Most importantly, Congress passed the Federal Courts Improvements Act in 1982. This law created a new Court of Appeals for the Federal Circuit (CAFC) to which were assigned appeals from the many district courts of all patent cases. This was described as a procedural reform, designed to standardize patent law across the country and eliminate the incentives for "forum shopping" in which patentees would try to bring cases in court circuits sympathetic to patents while alleged infringers would seek out circuits believed hostile.

This change in procedure is widely believed to have had a profound impact on the substantive outcomes of patent litigation. Before 1980, a district court finding that a patent was valid and infringed was upheld on appeal 62% of the time; between 1982 and 1990 this percentage rose to 90%. Conversely, before 1980 appeals courts overturned only 12% of district court findings of patent invalidity or non-infringement; that percentage rose to 28% in the later period (Koenig, 1980; Harmon, 1991). As a result, the overall probability that a litigated patent will be held to be valid has risen to 54% (Allison and Lemley, 1998).[1] Patentees asserting infringement are also now more likely to be granted a preliminary injunction barring the sale of the alleged infringing product during the litigation (Lanjouw and Lerner, 1998).

B. Changes affecting universities and government labs[2]

Although the fraction of U.S. R&D funded by the federal government has been declining over the last two decades, in 1997 it was still the source of

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[1] It is important to emphasize that these probabilities are *conditional* on the patent being litigated. The decision to litigate is itself endogenous. One would expect that a Court more friendly to patentees would induce patent holders with more marginal cases to file infringement actions, and also induce some of the clearer infringers to settle rather than face the Court. This endogeneity suggests that the increase in the conditional probability of success is likely to understate the extent to which the Court has become more favorable to patentees. Research on patent litigation is discussed further below.

[2] This section is adapted from the discussion in Jaffe and Lerner, 1999, and Henderson, Jaffe and Trajtenberg, 1998. The part based on Jaffe and Lerner was originally written by Josh Lerner.

approximately 30% of all R&D expenditure. Further, in the university sector, where federal funding now accounts for about 60% of all research expenditure, federal funds provide part of the support for the vast majority of projects, so that the rules governing the patentability of Federally-supported research essentially control university patenting.

A substantial literature discusses federal policies towards the patenting and commercialization of the innovations whose development it has funded.[3] Even a casual review of these works, however, makes clear how little the debate has changed over the decades. Many advocates have consistently called for government to take title to innovations that it funds, in order to ensure the greatest diffusion of the breakthroughs. Others have argued for a policy of allowing contractors to assume title to federally funded inventions, or alternatively allowing the exclusive licensing of these discoveries.

While questions concerning the federal government's rights to patent the results of publicly funded research were the subject of litigation and Congressional debate as early as the 1880s, the debate assumed much greater visibility with the onset of World War II. The dramatic expansion of federal R&D effort during the War raised questions as to the disposal of the rights to these discoveries. Two reports commissioned by President Roosevelt reached dramatically different conclusions, and framed the debate that would follow in the succeeding decades.

The first of these was the National Patent Planning Commission, an *ad hoc* body established shortly after the Pearl Harbor attack to examine the disposition of the patents developed during the War. In its January 1945 report, the Commission highlighted the tradeoffs associated with the practice

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[3]This issue was the topic of over forty congressional hearings and reports and four special commissions between 1940 and 1975 (U.S. Energy Research and Development Administration, 1976). Three helpful overviews of the historical debates are Forman (1957), Neumeyer and Stedman (1971), and Hart (1998).

of the government's taking title to new inventions and issuing royalty-free non-exclusive licenses. (This was the general policy prior to the War in all non-defense agencies.) While this practice assured the rapid diffusion of easily commercialized innovations, the Commission cautioned that:

> It often happens, particularly in new fields, that what is available for exploitation by everyone is undertaken by no one. There undoubtedly are Government-owned patents which should be made available to the public in commercial form, but which, because they call for a substantial capital investment, private manufacturers have been unwilling to commercialize under a nonexclusive license (U.S. House, 1945, p. 5).

Rather than recommending a uniform policy, the commission urged that the practices be allowed to vary across agencies. It urged the creation of a central body to monitor the patent policies of the various agencies, and to ensure that these policies appropriately reflected the national needs.

A second report, completed in 1947 by the Department of Justice, took a very different tack. It argued that "innovations financed with public funds should inure to the benefit of the public, and should not become a purely private monopoly under which the public may be charged for, or even denied, the use of technology which it has financed" (U.S. Department of Justice, 1947, p. 2). The report urged the adoption of a uniform policy forbidding both the granting of patent rights to contractors and exclusive licenses to federal technology in all but extraordinary circumstances.

Shortly after the report's release, the Justice Department was asked to draft a new policy, which was issued by President Truman in 1950 as Executive Order 10096. This new policy largely reflected the Department's recommendation: it called for a centralized policy across the federal government, to be implemented by a Government Patent Board. While there is little statistical evidence about how the Board implemented its charter, Forman's (1957) review of its unpublished decisions indicates that it was far more supportive of awarding and licensing patents to contractors and government employees than might have been anticipated from the circumstances around its creation. Furthermore, some evidence suggests that some agencies clandestinely persisted in policies that were quite different from those promulgated in the Executive Order (Neumeyer and Stedman, 1971). In 1963, President Kennedy's "Statement of Government Patent Policy" explicitly allowed agencies to adopt different policies, and in some cases to grant "greater rights than a nonexclusive license" to contractors or third parties.

From this time until the 1980s, there was no comprehensive federal policy regarding patenting of results from publicly funded research. A few universities patented fairly actively. University patents during this period represented either (1) the fruits of university research with no federal funding; (2) patents sought for the public or professional prestige that they confer, rather than any desire for commercial exploitation; or (3) inventions from federal research for which a title rights waiver was received from the federal agency funding that research. Some agencies negotiated blanket agreements with specific universities permitting them to patent and exploit the results of research funded by that agency, and other agencies routinely granted waivers allowing universities to exercise property rights in particular patents. Other agencies rarely or never granted such waivers.

In the late 1970s, the argument that exclusive property rights were necessary if inventions derived from public research were to be developed resurfaced, and won new attention in a time of increasing concern about the country's overall technological performance. The ultimate result was a series of statutory and administrative changes that eventually made virtually all public research subject to the possibility of private patents and/or exclusive licensing. The Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480) explicitly made technology transfer a mission of all federal laboratories and created a variety of institutional structures to facilitate this mission. Among other steps, it required that all major federal laboratories establish an

Office of Research and Technology Applications to undertake technology transfer activities. The law required all facilities with an annual R&D budget of at least $20 million to devote at least one full-time employee to this office.

At about the same time, the Bayh-Dole Act (technically the Patent and Trademark Laws Amendment of 1980, or P.L. 96-517) allowed universities and other non-profit institutions automatically to retain title to patents derived from federally funded R&D, removing the need to get an explicit waiver from the funding agency in order to exploit patent rights. In addition, Bayh-Dole explicitly recognized technology transfer to the private sector as a desirable outcome of federally financed research, and endorsed the principle that exclusive licensing of publicly funded technology was sometimes necessary to achieve that objective. The passage of P.L. 98-620 in 1984 expanded the rights of universities further, by removing certain restrictions contained in Bayh-Dole regarding the kinds of inventions that universities could own and the right of universities to assign their property rights to other parties.

The Bayh-Dole Act also explicitly allowed government-operated laboratories (such as the National Institutes of Health) to grant exclusive licenses on government-owned patents. Over the course of the 1980s, a series of initiatives extended and broadened the possibilities for patenting by federal laboratories. A variety of implementing memoranda, executive orders, and legislative clarifications in the 1982 through 1987 period extended many of these provisions to government-owned, contractor-operated (GOCO) facilities, which include the large facilities such as Los Alamos, Brookhaven, Oak Ridge, and Lawrence Livermore, that are typically known as National Laboratories.

This wave of legislation and administrative action did not resolve the debate concerning the extent to which ownership of government-funded R&D ought to be transferred to private sector entities. Congressional and agency investigations of inappropriate behavior during the commercialization process—particularly violation of fairness of opportunity and conflict of interest regulations during the spin-out and licensing process—continued to be commonplace. The view that no one should be excluded from enjoying the fruits of public research is still expressed. As discussed further below, these controversies have, in recent years, impinged on the patenting activities of the federal labs and have led to continued debate about the desirability of at least some forms of university patenting. Nonetheless, we have witnessed a general transformation of the system from one in which patenting of inventions derived from public funding was the exception to one in which such patenting is widespread.

C. Expansion of the realm of patentability[4]

Roughly concurrent with these statutory changes in *who* could acquire patent rights, there were significant changes in *what* could be patented. These changes were not brought about primarily by Congressional action, but rather by the re-invigorated patent office, which has taken a series of fairly narrow Court decisions regarding new subject matter and generally interpreted them quite broadly. There are now patents for genetically engineered bacteria, genetically altered mice, particular gene sequences, surgical methods, computer software, financial products, and methods for conducting auctions on the Worldwide Web. For each of these, there would have been prior to 1980 at least serious doubt as to whether or not they would be deemed by the PTO and the courts to fall within the realm of patentable subject matter. It is probably not accidental that these expansions in the realm of patentability prevented patents from being irrelevant to several of the most important and dynamic technological sectors of the current era.

[4] The question of what constitutes patentable subject matter is a complex one. I intend in this section to convey only the basic tenor of the expansion of patentability. For a detailed discussion of these issues, see Merges (1997).

Particularly important and controversial has been the expansion of patentability of software and financial service products and processes for offering them. Historically, these were viewed as difficult to patent because algorithms and methods of doing business had been held to be unpatentable. But these presumptions have gradually been either overturned or found to be irrelevant. Beginning in 1981, the Supreme Court held that software that was part of manufacturing system or process was patentable (*Diamond v. Diehr)*. Later decisions held that a wide variety of software that was in some way supportive of physical processes was patentable. In 1998, the CAFC upheld a patent on a software system that performs real-time accounting calculations and reporting for use by mutual fund companies (*State Street Bank & Trust Company v. Signature Financial Group).* This decision explicitly rejected the notion that "business methods" were inherently unpatentable, and appeared to place very few limits on the patentability of software and financial service products.

D. Changes related to the GATT Agreement

Part of the Uruguay Round of negotiations on the GATT was an agreement reached in late 1993 on Trade-Related Aspects of Intellectual Property ("TRIPs"). In addition to committing the U.S. to making some important changes in its patent system (discussed below), the TRIPs agreement achieved major changes desired by the U.S. in the patent policy of other countries. The most important provisions are:

- Virtually all commercially important technological areas must be included within the realm of patentable technology. The most important effect of this agreement is to prohibit the practice, common in many developing and some developed countries, of not recognizing patents on drug products. Prior to TRIPs, some countries also did not grant process patents.
- Patents must be granted for 20 years.
- Patent applications must be tested for non-obviousness and utility as in the U.S. patent system.

- Patent holders must have the right to prohibit the importation of infringing products.
- Limitations are placed on the circumstances under which governments can order compulsory licensing of patents. Compulsory licensing can be required in the U.S. only in very special circumstances, but some other countries had much broader compulsory licensing policies.

Overall, these provisions are seen as constituting a major strengthening of patent protection around the world, if and when they are fully implemented.[5]

The changes to the U.S. patent system brought about by TRIPs are contained in P.L. 103-465, passed in 1994. The most important of these is to change the patent term from 17 years from date of grant to 20 years from date of application. Certain patents already applied for but not yet granted were given a patent term equal to the greater of these two. As of this writing, Congress is also considering other changes that would make the U.S. patent system more consistent with those of other countries. One of these is changing the procedure for determining priority of inventions from our “first to invent” rule to the “first to file” rule used in most other countries. Another change under consideration would modify the U.S. practice of maintaining the secrecy of patent applications, by publishing all applications 18 months after they are filed.

[5] Some developing countries are allowed until 2005 to fully comply with the requirements to grant drug patents. As of 1995, however, they were required to accept applications for patents on new pharmaceutical products and to grant exclusive marketing rights for any of these products that obtain a patent grant in another GATT country.

III. The Theoretical and Empirical Literature

A. The overall trend in patenting and research

Figure One shows the dramatic increasing in U.S. patenting since the mid-1980s.[6] Patenting by U.S. inventors in the U.S. had been constant or declining for much of the 1970s and early 1980s. But beginning in 1984, and accelerating in 1988, patent applications by U.S. residents began to increase, with a corresponding increase in patents granted. Figure One also shows an upward trajectory for total R&D expenditure in the U.S. that began earlier, in the latter half of the 1970s. Thus at least part of the increase in patenting is likely to be the output of this increased R&D expenditure, although the approximate decade-long lag between the upturn in R&D and the upturn in patenting is too long to be consistent with microeconomic evidence suggesting that the there is little or no lag at the firm level between changes in R&D spending and changes in patent application rates (Hall, Griliches and Hausman, 1986).

In fact, domestic patenting had been more or less constant at 40 to 50 thousand patents per year for most of this century, corresponding to a gradually declining rate of patenting relative to the population or the size of the economy. To focus on the issue of patenting intensity, Figure Two shows the number of patents scaled in two ways. The lower line represents the total domestic patent grants charted in Figure One, divided by the U.S. adult population. The upper line is the number of patents that were assigned at time of issue to U.S. corporations (typically about 80% of domestic patents), divided by constant-dollar R&D performed by industry in the U.S. By either of these measures, patent intensity declined significantly over the 1970s,

[6] In Figure One and throughout the paper, I use the phrase "domestic patents" to refer to patents granted to individuals residing in the U.S. Patents with multiple inventors are considered domestic if the first inventor resides in the U.S. Below, I also look at data for patents assigned at issue to U.S. corporations. Approximately 80% of patents issued to domestic inventors are assigned to U.S. corporations. There are also a small number of patents with inventors residing abroad that are assigned to U.S. corporations.

with the decline relative to R&D being particularly large because the increase in R&D spending in the second half of the decade was not initially associated with any greater patenting. By the mid-1980s, however, both of these series are moving up, indicating that patenting is increasing faster than population or real R&D expenditure.

Thus a long-term secular decline in the intensity of patenting activity in the U.S. reversed in the mid-1980s, and the trend since that time has been steadily upward. In the 1990s, U.S. inventors have been receiving patents in record numbers, with the one-year total of over 80 thousand in 1998 more than double the number received in any year from 1979 through 1986. The Figures show that part, but not all, of this increase is associated with an increase in R&D expenditure.[7] I will return below to the increase in R&D expenditure and its connection to the patent surge, but I review first the literature that has looked at the patent surge itself in more detail.

This is a historic change in the U.S. innovation process that deserves careful scrutiny. The most thorough analysis to date is that of Kortum and Lerner (1998). They consider four possible explanations. The first they dub the "friendly court" hypothesis, by which they mean that the creation of the CAFC made patents more valuable, and hence increased the "propensity to patent" of U.S. inventors. Not all inventions are patented, and not even all potentially-patentable inventions are patented. Inventors balance the time and expense of the patent process, and the possible loss of secrecy that results from patent publication, against the protection that a patent potentially affords to the invention. The "friendly court" hypothesis is that the increased probability of success associated with the new court has shifted

[7] Indeed, because R&D expenditure increased for a decade before patenting started to increase, even the record level of patenting in 1998 is significantly less than the rate that would be predicted based on current R&D expenditures if the patent/R&D ratio had remained at its 1970 level.

that balance, causing a higher proportion of potentially-patentable inventions to be patented.

A variant of the "friendly court" hypothesis sees the changes of the 1980s as an example of "regulatory capture," in which the large firms that dominate the research and patenting processes in the U.S. managed to induce the government to change the rules in their favor. Under this hypothesis, the increase in patenting would be dominated by those firms, taking advantage of the new favorable environment that they had created.

The third hypothesis is that there has been a shift in "technological opportunity" that has made more invention possible. This "fertile technology" hypothesis points particularly to new areas such as biotechnology and information technologies as the source of the growth in patenting. The final hypothesis considered by Kortum and Lerner is that the process of research and invention has become more productive. Such an increase in research productivity might be attributed to changes in research technology (Arora and Gambardella, 1994), such as the application of information technology and computers to problems that had previously been handled heuristically, or to changes in the management of the research process, including an increasing emphasis on the kind of applied research that is likely to generate patents (Rosenbloom and Spencer, 1996).

To distinguish among these hypotheses, Kortum and Lerner look at the patent data in several ways. First, they argue that the *friendly court* hypothesis suggests that U.S. patents have become more valuable for all inventors, and so we should have seen an increase in patenting in the U.S. by foreigners roughly coincident to the increase by domestic inventors. Further, since this hypothesis suggests an increase in the propensity to patent but no increase in the number of inventions, it suggests that U.S. inventors should not necessarily have increased their rate of patenting in other countries. Neither of these implications is borne out by the data. Although patenting by foreigners in the U.S. has increased, it was increasing rapidly before the

1980s and there is no sign of acceleration during the *friendly court* period. Further, patenting by U.S. inventors has increased abroad. Put differently, an analysis of the U.S. and other industrialized countries as both "sources" and "destinations" for patent applications shows that the U.S. has become a significantly greater source, but has *not* become a more important destination. This clearly suggests that the *friendly court* effect is not the primary explanation for the increase in domestic patenting.[8]

Kortum and Lerner also show that the data do not support either the *fertile technology* or *regulatory capture* hypotheses. In particular, although there is significant variation in the rate of growth of patenting across technological areas, approximately 70% of all patent classes have exhibited an increased rate of patenting. While biotechnology and information technology classes have grown more rapidly than others, the overall increase in the patent totals is due to widespread increases across technological areas. Similarly, the increase is not confined to large firms. On the contrary, in recent years the fraction of patents going to new firms and the fraction going to firms that previously had relatively few patents have both increased.

Through this process of elimination, Kortum and Lerner conclude that there must have been an increase in the productivity of the research process, at least in terms of its ability to produce the kinds of innovation that lead to patents. They then ask whether an increase in the productivity of research is consistent with the observed behavior of the research expenditure series. They develop a simple model of research-driven endogenous economic growth, in which an unexpected permanent increase in the productivity of R&D is predicted to lead to a transitory increase in R&D as well as patents. The difficulty with fully reconciling this prediction with the data is that R&D began its increase so much sooner than patenting. If research productivity

[8] Kortum and Lerner also show that the fraction of applications that are successful has not dropped for U.S. inventors, as might be expected if a rising propensity to patent was leading to more marginal patent applications.

began to increase in the 1970s, there should have been an effect on patenting rates within a few years.[9]

Thus the surprising conclusion of Kortum and Lerner's careful analysis is that the explanation for the patent surge lies outside the patent system itself, despite the coincidence of timing with important changes in patent enforcement. This conclusion is, however, possibly reinforced by survey evidence that indicates that the usefulness of patents as a means for protecting the returns to innovation did not increase over the decade of the 1980s (Cohen, Nelson and Walsh, 1997). This survey, a follow-up to the so-called "Yale" survey administered in 1983 (Levin, Klevorick, Nelson and Winter, 1997) asked R&D managers across manufacturing industries about the effectiveness of diverse mechanisms for appropriating the returns to research. Despite the fact that firms are taking out many more patents, R&D managers, at least, do not perceive patents to be any more effective.

Cohen and his co-authors suggest that the reconciliation of the jump in patenting and lack of increase in perceived effectiveness may lie in the multiple ways that firms use patents. In particular, their survey shows that, in addition to protecting the returns to specific inventions, firms use patents to block products of their competitors, as bargaining chips in cross-licensing negotiations, and to prevent or defend against infringement suits. It is possible that respondents did not consider these benefits of patents when answering the question about the effectiveness of patents in protecting the returns to innovations. More fundamentally, firms using patents for these purposes are engaging to a significant extent in a zero- or negative-sum game. If all firms do more blocking, accumulating of bargaining chips, and patenting to fend off infringement suits, it could easily be the case that, in

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[9] Kortum and Lerner also note that the decline in R&D in the early 1990s as patenting continued to surge was puzzling. With several more years' data, the R&D dip in 1993-94 appears to be a short-term fluctuation, not necessarily an end to the gradual upward trend.

the end, none of them has succeeded in increasing their returns to innovation. Under this hypothesis, what has happened is that everyone is patenting more because the private, marginal return to patenting is high—but firms' actions largely offset each other so that the perceived value of patents overall is no higher.

This hypothesis is partially supported by Hall and Ham (1999). They analyzed in detail the patenting of semiconductor firms, and interviewed patent lawyers and intellectual property managers at semiconductor firms. They conclude that large firms do, indeed, use patents primarily in large portfolios that are used as the basis for negotiation of cross-licensing agreements. Because of the systems nature of semiconductor technology, it is virtually impossible to make products or processes that do not incorporate others' technology to varying degrees, and so everyone "needs" cross-licensing agreements in order to avoid risking infringement suits. Further, semiconductor fabrication facilities are large, capital intensive facilities, so even the remote threat of an injunction that could shut down production is viewed as an unacceptable economic risk. Although cross-licensing agreements have always been common in the industry, the strengthening of patent protection in the 1980s brought new attention to the value of patent portfolios.[10] The resulting "patent portfolio race" is consistent with rising rates of patenting and rising patent/R&D ratios without there being any perceived improvement in the net value of patents in protecting the value of innovations.

Hall and Ham also show, however, that part of the increase in patenting in this industry reflects a more traditional use of patents as the

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[10] In addition to the creation of the CAFC and associated legal decisions, the ability to protect chip designs was enhanced by the creation of a new property right covering chip layout by the Semiconductor Chip Protection Act of 1984. Semiconductor executives also mentioned the profound effect on industry thinking of Texas Instruments' vigorous and successful efforts in the late 1980s to extract royalties on its patents from many of its competitors.

means to protect the value of inventions. The period of rising patenting has coincided with a time of significant entry by new firms into the industry, many of which are so-called “fab-less” manufacturers who design chips and contract their manufacture to others. Presumably, this separation of design from manufacture, and the resulting reduction in the barriers to entry into chip design, would not be possible if the designing firm could not protect its creation from appropriation by the contracting manufacturer. Hall and Ham show that the pattern of patenting by small firms and new entrants is consistent with this hypothesis.

In summary, there is at best limited evidence that the upsurge in patenting resulted, at least directly, from the strengthening of patent protection in the 1980s. Much of the increase can be associated with an increase in real R&D spending that began much earlier. At the end of the day, it is extremely difficult to identify the causal effects of multiple interacting endogenous variables. It seems plausible that the combination of technological opportunities, the buildup in government R&D spending and defense procurement, increased international competitive pressure and other factors increased the returns to R&D in the late 1970s and early 1980s. It is likely that these increases would have led over some time horizon to more patenting, even if there had been no changes in the patent regime. But the strengthening of the patent system presumably reinforced these incentives. It is possible that the R&D boom would not have been so large or lasted so long without this reinforcement. It is disquieting, however, that there is so little empirical evidence that what is widely perceived to be a significant strengthening of intellectual property protection had significant impact on the innovation process.

B. Patenting by universities and federal laboratories.

Figures Three and Four are analogous to Figures One and Two, showing the increase in patenting for publicly funded research institutions.[11] Figure Three shows that both universities and National Labs significantly increased their patenting between the late 1980s and the mid-1990s, although the patenting in the Labs peaked in 1993, while university patenting has continued its rapid increase. In 1997, almost 5% of all patents assigned to U.S. non-governmental institutions were assigned to universities. It is worth noting that university patenting was also increasing throughout the 1970s and early 1980s; statistical tests do not reveal a significant "break" in the university patent series in the early 1980s (Henderson, Jaffe and Trajtenberg, 1998).

Figure Four shows the patent intensity (patents per million inflation-adjusted R&D dollars) for these two groups of institutions. University research spending was increasing strongly over most of this period, so that the increase in patent intensity is somewhat less than the increase in overall patenting. Nonetheless, between 1980 and 1997, university patents per dollar more than tripled. National Lab funding, on the other hand, increased more slowly in the 1980s, and in fact has been declining in real terms since 1989. Thus the patent intensity of the Labs more than quadrupled between 1980 and 1993, though it has declined somewhat since then.

More detailed analysis of these series appears in Henderson, Jaffe and Trajtenberg (1998) for university patents and Jaffe and Lerner (1999) for the Lab patents. Important observations about the university patents are:

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[11] The totals for the National Labs refer to the 23 Federally Funded Research and Development Centers ("FFRDC") owned by the Department of Energy and operated by outside contractors. The patent totals shown include both patents assigned to the government and those that are assigned to the lab contractor under their operating agreements. The procedure for identifying these patents is described in detail in Jaffe and Lerner (1999).

- The increase reflects in part the spread of active patenting to many more institutions. In 1965, 30 academic institutions received patents; this increased to about 150 in 1991 and over 400 in 1997.

- University patenting is disproportionately concentrated in technology classes related to the health sciences. The increase in university patenting is not, however, explained primarily by the growth of these fields. Universities have increased their patenting in all broad technological areas.

- The increase in university patenting has been associated with a decline in the apparent "quality" of university patents, as indicated by the frequency of citation by future patents. Prior to 1980, university patents were significantly more highly cited than other patents, controlling for technology fields. This difference had completely disappeared by 1988. Much of the change corresponds to a dramatic increase in university patents receiving no citations in the first 5 years, from 10% in 1975 to 43% in 1987.

- This decrease in citation-measured "quality" is partially due to the lower average quality of patents of institutions that had not previously patented. But there was also a measurable decline in average quality at the top patenting institutions.[12]

- The increase in university patenting cannot be causally attributed to the passage of Bayh-Dole; other contributing factors were an increase in industry research funding, an increased attention to applied research, and the growth of university technology offices. But the dramatic increases of the last two decades probably could not have occurred *without* the greater patenting freedom granted by Bayh-Dole.

Beyond the explosion in university patenting, there is accumulating case-study evidence that the desired economic benefits of technology transfer from universities have occurred. Studies of MIT (Pressman, *et al.*, 1995; Shane, 1999), the University of Minnesota (Severson, 1999), and Columbia, Stanford, and the University of California (Mowery, *et al.*, 1998; Mowery and

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[12] Mowery and Ziedonis (1999) provide a more recent and detailed look at this issue for the patents of Stanford and the University of California. They find no decline in average citation intensity for these two institutions. Interestingly, they do find a decline in licensing "yield," defined as the average licensing revenue per patent.

Ziedonis, 1999) have documented that new or expanded technology licensing offices in the post-Bayh-Dole period have licensed university technology to private firms that are investing significant resources in developing new products and process using those technologies.[13] Jensen and Thursby (1998), using both a theoretical model and survey results from many major universities, show that much of the technology being licensed is in the "proofs and prototypes" stage and would therefore never be developed commercially without exclusive licenses. They also argue that the assistance of the university inventors is necessary as the development process is carried out, and that patent royalties play an important role in inducing this cooperation from the academics.

The underlying story for the National Labs shows some similarities and some interesting differences relative to what happened in universities:

- Lab patenting is highly concentrated, with a handful of the largest labs contributing the vast majority of the patents.
- Labs with strong national security and basic science missions are less patent intensive, on average.
- There is some evidence that competition for the contract to operate a Lab stimulates patenting activity relative to those Labs with long-term stable contractual relationships.
- Unlike universities, the increase in Lab patenting does not appear to have been associated with any decline in quality, as measured by citation intensity. Whereas the universities appear to have increased patenting by looking harder for patentable inventions within the same research areas, it may be that the Labs had more incentive and ability to respond to the technology transfer incentives by refocusing their attention into new, commercially relevant areas.
- As in universities, the "institutionalization" of patenting through the creation and expansion of technology transfer offices played a key role. The decline in patenting in the Labs in the mid-1990s was associated with cutbacks in these operations in response to congressional criticism of these activities.

[13] See also U.S. General Accounting Office (1998).

- Controversy over the Labs' relationships with outside firms and alleged conflicts of interest have inhibited patenting and technology transfer from the Labs.

C. Patenting in new areas

As noted above, since 1980 patents have been granted in areas of biotechnology and computer software that were previously considered essentially unpatentable. Probably not coincidentally, these have also been areas of extraordinary technological fecundity.[14] As discussed by Kortum and Lerner, it is difficult to identify either biotechnology or software patents in the aggregate in a systematic way. They undertook a comprehensive analysis based on the international patent classification (IPC) system. On this basis, they show that biotechnology patents grew from 3% of all patents in 1969 to about 6% in 1991, and that software increased from about 4% to almost 7% over the same period (Kortum and Lerner, 1998, Figure 10). It is widely perceived that these trends have accelerated in more recent years.

To give some indication of what these trends might look like, Figure Five shows the number of patents over time in a few selected U.S. patent classes that are likely to be *indicative* of trends in biotech and software patenting. These classes surely contain patents that are not truly biotech or software, and they represent only a fraction of the relevant patents, so they should be treated merely as suggestive. If they are indicative, however, then these areas have experienced even more phenomenal growth in the 1990s than they did in the 1980s. For example, USPTO Class 435, Molecular Biology and Microbiology, accounted for about .5% of all patents in 1985 (about the same as in 1977). This rose to about 1% in 1990, 1.3% in 1995 and then grew dramatically to 2.5% in 1998. Classes 600, 601, 602, 603, 604, 606, 607 and 623, all of which deal with "Data Processing," accounted for about .4% of all patents in 1977, .7% in 1985, 1.2% in 1990, 1.6% in 1995 and

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[14] When I suggest that this is not a coincidence, I mean that the fecundity of these areas probably influenced the patent office to want to allow patents in these areas, not that the new patentability induced the technological fecundity.

2.6% in 1998. For both of these groups, the large percentage jumps between 1995 and 1998 occurred despite an overall increase in patenting in that interval of over 40%; both of these categories more than doubled in absolute terms in just 3 years. Thus it does seem to be the case that patenting is growing very rapidly in these categories, although Kortum and Lerner's conclusion that these technologies do not explain the growth in total patenting remains true.

D. Issues Related to Patent "Scope"

Patent scope is a crucial determinant of the value of the patent right. While the scope of any particular patent is, in principle, defined by the specific claims that the patent office permits the inventor to make, there is a generic policy issue or set of issues related to how broadly patent rights will generally be interpreted. Thus patent "scope" or "breadth" constitutes a potentially important lever for innovation policy. Indeed, the area of patent scope seems to be one in which the CAFC has had an important impact on patent doctrine. Further, issues related to patent scope have received significant theoretical attention by economists in the last decade, and there is also a small empirical literature. Hence this set of issues presents an interesting case study of the possible interactions among theory, statistical analysis, and legal and policy decisions.

At the most general level, patent scope or patent breadth refers to the size of the region of technology space from which a patentee may exclude others from operating. Clearly, a broader patent is more valuable to the patentee. It seems a natural step from this observation to conclude that a patent system that *generally* confers broader scope makes invention more valuable, and thereby provides greater innovation incentives. The problem, of course, is that *ex ante* an inventor also has to worry about producing an invention that will be judged to infringe someone else's patent; broader patent scope makes this more likely and hence makes research riskier and less valuable.

Because of this tension, analysis of the welfare consequences of patent scope involves more than just the classic tradeoff between the objective of encouraging innovation at the cost of creating (static) monopoly power. The rate of innovation itself is not necessarily increasing with increases in patent scope, because of actual or perceived constraints that increasing patent scope places on inventors' expectations regarding their ability to profit from their own inventions.

1. *Theoretical analysis of patent scope*

It is useful to distinguish three types of scope issues, based on the relationship between an invention and the other inventions that may or may not infringe depending on the patent scope that is awarded. The first situation is where the potentially infringing invention is developed independently of the patented invention. The second situation is that of "cumulative innovation," in which the potentially infringing invention builds upon the patented invention. The third situation is that of inventions that are research tools, useful only or primarily for the specific purpose of developing other inventions. In reality, of course, actual patent disputes may have elements of all of these, but the theoretical analysis tends to treat them separately.

Independent inventions. Waterson (1990), Gilbert and Shapiro (1990) and Klemperer (1990) analyze the issue of patent "breadth" in a context of non-cumulative innovation. The issue of breadth or scope is viewed in the context of the tradeoff between providing monopoly profits to the inventor to stimulate innovation versus the static efficiency losses of market power. This market power and associated losses are greater when the monopolist controls a larger region in product space. The welfare tradeoff with respect to scope is thus analogous to the welfare tradeoff related to the duration of patent protection, and the problem is to choose a combination of breadth and duration that minimizes the welfare loss associated with providing any given level of innovation incentive. Within this framework, a generalized increase in patent breadth or scope, holding all else equal, unambiguously increases the innovation rate, because it does not affect the incentives of subsequent potentially infringing inventors.

Cumulative invention. The case of cumulative invention has received considerable theoretical attention. Adopting Newton's powerful metaphor, economists have tried to develop models in which sequences of inventors all "stand on the shoulders" of the "giants" who came before them (Scotchmer, 1991). Kitch (1977) views this as a problem of optimal coordination among different researchers working on related technologies. In the absence of coordination, there will be wasteful duplication of effort, and possibly overinvestment as firms seek to beat each other to important results. Kitch argues that granting of broad patent rights to a pioneering inventor early in the development of a line of technology will allow that inventor to ensure optimal orderly development of the technology. To the extent that other inventors have ideas or capabilities that contribute to the development of the technology, the pioneering inventor would have an incentive to include them in the development process, via cross-licensing or other contractual arrangements.

Later work has brought the incentives of the potential follow-on inventors explicitly into the models. The question of scope or breadth can be characterized in terms of the magnitude of the improvement that an invention must represent before it will be granted a patent of its own, and/or before it will be held to infringe the patent of the previous inventor (Green and Scotchmer, 1995; O'Donoghue, 1998). This line of research generally confirms Kitch's view that broad patent protection should be afforded to the initial invention in a cumulative development line. The intuition behind this result is that the incentive to create broad "shoulders" for others to stand on is inadequate because this elevation of future inventors represents a positive externality (Chang, 1995; Green and Scotchmer, 1995; Scotchmer, 1996; O'Donoghue, 1998). Scotchmer (1996) even argues that "second-generation" products should not be patentable at all. This maximizes the research incentives for the first innovator. Further, *if* the first and second innovators can bargain over the terms of a licensing agreement before the (potential) second inventor sinks any of its research investments, the first innovator will have the incentive to license her technology to the second whenever it is optimal to do so, under terms that do not prevent the development of the second-generation invention.[15]

Hopenhayn and Mitchell (1999) explore the implications of the fact that inventions differ in the extent to which they spawn fertile lines of subsequent inventions. Ignoring the kinds of *ex ante* agreements that Scotchmer uses to ensure that infringing "second-generation" products will still be developed, they show that broad patent scope is more costly for more fertile inventions, because it may inhibit these subsequent developments; on the other hand it is important to provide good incentives to develop such "fertile" inventions to begin with, because they are socially very valuable. They show that overall innovation incentives can be improved by offering patentees a "menu" of combinations of patent duration and patent scope or breadth. Optimal construction of this menu induces patentees to reveal their private knowledge regarding the fertility of their inventions, and thereby achieves a better balance between the incentives of the initial and subsequent inventors than can be achieved with uniform patent scope. Hopenhayn and Mitchell suggest that a mechanism with properties such as theirs could be implemented by allowing patentees to choose different types of patents with different durations and different legal rights. As an example, they suggest that patentees might be required to accept shorter patent

[15] Of course, this approach presumes that the trajectory of innovation is known in advance. As emphasized by evolutionary economics (Nelson and Winter, 1982), it is more often the case, particularly early in the development of a new line of technology, that no one knows which directions of improvement are possible or desirable. This makes *ex ante* licensing seem unlikely.

durations in order to receive the benefit of protection against infringement under the Doctrine of Equivalents (discussed below).

Patented research tools. The case of patented research tools can be thought of as a special case of cumulative innovation in which the initial invention in the sequence has *no* value except as a platform for future invention (Scotchmer, 1996). I consider it separately, partially because it has gotten significant policy attention (Heller and Eisenberg, 1998). Unlike the typical situation of cumulative innovation, the research tool does not typically compete in the marketplace with the products developed using it. Thus the development of the downstream product does not reduce the profit stream of the research tool inventor. On the contrary, if the patented tool has no direct commercial market, its owner can profit *only* to the extent it is used in other inventions. This would seem to make this situation in some sense easier than that of cumulative innovation, because the incentives of the research tool inventor and the research tool user are more in line with each other: they both want the downstream product to be produced and sold; the only question is how much should the research tool inventor receive in royalties for the use of the tool.

Schankerman and Scotchmer (1999) investigate the enforcement of patents for research tools from the perspective of maximizing the incentives to develop such tools. They consider whether it is necessary to grant the patentee the right to an injunction preventing the sale of products developed with the tool, or whether the availability of damages for patent infringement is sufficient. They show that the current legal treatment of patent damages as a "reasonable royalty" is logically flawed, so that maximizing the incentive to develop research tools requires either that injunctions be available, or that the damage rule be changed to award to the research-tool patentee the profits earned by the infringer.

2. Empirical studies of patent scope

There has been relatively little analysis of the effects of different degrees of patent scope. Such studies are very hard to do, because it is very difficult to measure patent scope in a systematic way across large numbers of patents, and because there are very few natural experiments in which different degrees of patent scope can be observed.

Lerner (1994) examines whether patents that appear to have relatively broad scope are more valuable to the patentees than narrower ones. He examines biotechnology firms, whose value is closely tied to their intellectual property. He shows that firms whose patents span more International Patent Classes (IPCs) are valued more highly by venture capitalists. While this does not address directly the question of the effect of broad changes in patent scope, it provides threshold support for the underlying idea that broader scope increases value and thereby increases innovation incentives. On the other hand, Harhoff, Scherer and Vopel (1999) do not find that the number of IPCs is related to patent value, as measured in survey responses by patent owners.

Branstetter and Sakakibara (1999) estimate the impact of an apparent increase in the scope of Japanese patent protection. Prior to 1988, the Japanese patent system essentially allowed only one claim per patent. A complex invention, or one with many distinct applications, could be covered by many separate patents, leading this system to be referred to as the "sashimi" system, in reference to the thinly-sliced fish dish. All of these distinct patents had to be non-overlapping; you could not get a patent whose claim covered some of the same material as the claim of another patent, even your own. In 1988, Japan converted to a system much like the U.S. system, in which a single patent can have multiple claims. Beyond the change in how claims are packaged into a particular number of patents, the effect of this change is that it is now possible to stake out a set of *overlapping* claims. Branstetter and Sakakibara argue, based on discussions with Japanese companies and patent experts, that in many cases it is not possible to protect a complicated invention or one with several applications using a series of independent claims. Even the most complete set of independent claims leaves “holes” in technology space that can only be covered with overlapping claims. Therefore, the change to the multi-claim system effectively increased patent scope by permitting more effective protection of these inventions.

Branstetter and Sakakibara hypothesize, based on models such as those of Klemperer and Gilbert and Shapiro discussed above, that such an increase in patent scope would increase the return to inventive activity, which should be observable in two ways. First, R&D spending by Japanese firms should rise. Second, Japanese firms should produce more inventions; since the incentives created by the U.S. patent system did not change in 1988, this should lead to an increase in patenting by Japanese firms in the U.S. The paper shows that neither of these occurred, although it is worth noting that this was a period in which both Japanese R&D and Japanese patenting in the U.S. were rising; the negative conclusion is that there is no measurable increase in the rate of growth associated with the time at which the policy change occurred. It is possible that these negative results mean that, despite the impression of the managers that Sakakibara and Branstetter interviewed, the ability to file overlapping claims does not result in a significant increase in patent scope. It is also possible that there was an effect, but it is just to difficult to see it in data series that are changing rapidly for other reasons. Otherwise, these results suggest that changes in patent scope do not have significant effects on research incentives. This could be because scope doesn’t really matter, because it is too hard to anticipate *ex ante* what the consequences of different regimes might be, or because the conflicting effects on initial and follow-on innovators tend to cancel each other out.[16]

The only paper that I know of that presents evidence on how patent scope affects innovation in the U.S. is Merges and Nelson (1990). The evidence is not statistical, but rather an examination of the development of several historically important technologies. Based on these cases, Merges and Nelson question the conclusion of Kitch (and implicitly, the later work of Scotchmer, Chang, O'Donoghue and others) that broad patent protection for pioneering innovators is desirable. The analytical basis for the disagreement is that Merges and Nelson believe that *ex ante* uncertainty and disagreement among competitors about which lines of development will be most fruitful makes licensing agreements or other coordination mechanisms unlikely and/or ineffective. Examining the historical development of electrical lighting, automobiles, airplanes and radio, they argue that the assertion of strong patent positions, and disagreements about patent rights, inhibited the broad development of the technologies. While it is obviously difficult to know if these technologies would have developed more rapidly without the assertion of strong patent rights by early inventors, it is certainly clear that the different inventors did *not* succeed in reaching agreements to coordinate their activities. On the other hand, Merges and Nelson argue that semiconductor technology benefited greatly from broad licensing of the original AT&T patent, which was brought about largely because AT&T was prevented by its antitrust consent decree from exploiting the patent itself. Thus these case studies, while obviously not definitive, do raise doubts about both the underlying assumption (that different inventors will license their technologies to each other if it is efficient to do so) and the conclusion (that

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[16] It is probably just coincidence, but it is provocative that Branstetter and Sakakibara have a finding for Japan that is analogous to what happened in the U.S. They show that the "break" in the Japanese R&D series occurs in the early 1980s. Thus, just as in the U.S., there was an increase in R&D spending that *preceded* the change in patent policy.

strong property rights for pioneering inventors maximize innovation) of much of the theoretical work on cumulative innovation.

Overall, there is a noticeable gap between the highly developed theoretical literature on patent scope and the limited empirical literature. This is due partially to the infrequency of changes in patent regimes like the one examined by Sakakibara and Branstetter.[17] Part of the difficulty also lies in the weakness of the connection between the model constructs and quantifiable aspects of a patent regime.

E. The effect on LDCs of stronger intellectual property protection

The extension of product patent protection, particularly on drugs, to the less-developed world was clearly motivated by a desire of the U.S. and other technologically advanced countries to keep more of the profits from research. Implementation and enforcement of intellectual property protection is more likely to be carried out, however, if it brings some benefits for the LDCs themselves. Mansfield (1994) presents survey evidence that multinational firms are more likely to locate a research facility in a country that has strong IPR policies. Scherer and Weisbrod (1995) examined the effects of the institution of protection for drug patents in Italy on the Italian pharmaceutical industry. They found that pharmaceutical innovation was not stimulated, largely because the Italian industry was specialized in the exploitation of the previous property regime through the production of off-brand versions of drugs patented elsewhere.

Lanjouw (1998) and Lanjouw and Cockburn (1999) argue that, in addition to possibly stimulating domestic innovation, LDC patent protection for drug may induce more research throughout the world into treatments for diseases that are prevalent in the third world. Lanjouw and Cockburn show that this second effect is potentially very large, as there are a number of diseases that have huge worldwide effects that are relatively understudied by the world's drug companies. They generally conclude that it is too soon to tell if this will change, although they present some evidence of an upsurge in malaria research.

F. Patent litigation

Much of the theoretical literature regarding patent design assumes that a patent, once granted, allows the patent holder to prevent competition from infringing inventions. In practice, of course, infringement can sometimes only be prevented through costly litigation, the outcome of which is typically uncertain. This raises two important policy issues. Does the cost of enforcing patent rights significantly reduce the value of patents as an innovation incentive? And, does the risk of patent litigation from other parties reduce the incentive to engage in innovation even where the intention is not to infringe?

Analysis of these issues through the lens of data on patent infringement cases is complicated by the fact that we do not observe the patents that are successfully enforced without resort to litigation, and we generally do not know the outcome of cases that are settled out of court. Of course, the decisions to bring suit, to abandon an allegedly infringing product under threat of suit, or to settle out of court, are all endogenously determined by the parties' perceptions of their chances. Hence statistics regarding the observed outcomes must be interpreted with caution.

Lanjouw and Schankerman (1999) explore the determinants of patent litigation, by comparing patents that are litigated to a random sample of all patents. They show that patents that are litigated tend to have more claims and more citations per claim, which they interpret to mean that litigation is more likely when the stakes are high. They also show that litigation is more

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[17] Cross-sectional comparisons between countries with differing patent systems may provide some insight (Ordover, 1991). But in comparing different countries so many things differ that it is difficult to draw strong conclusions.

likely when a patent is part of a stream of related development work, as evidenced by the number of citations received from subsequent patents on related technologies owned by the same firm. Overall, the litigation rate is about 1% of all patents, which I consider surprisingly high, given the large numbers of patents that are granted that turn out to be worthless. There are large differences across technology fields in the likelihood of litigation, with the likelihood of litigation in the Drugs and Health field roughly double the overall average. Lerner (1995) finds that within biotechnology about 6% of all patents end up in litigation.

Siegelman and Waldfogel (1999) look at the determinants of litigation in the context of an explicit model of the parties' decisions leading to an actual trial. These decisions are affected by the stakes, by the magnitude of legal fees, by the expected probability of winning, and by the uncertainty about the outcome. Interestingly, they find that intellectual property cases (involving patents, trademarks or copyrights) appear to have a lower inherent outcome uncertainty than contract, labor, prisoner or tort disputes. They also find that the implied average expected likelihood that the plaintiff will prevail is about 35% for the IPR cases, which is higher than all of the other categories except contracts.

Allison and Lemley (1998) investigate the determinants of the outcomes of litigation over patent validity. They find that overall just over half of patents whose validity is litigated to final resolution are held to be valid. They find that validity is more likely to be upheld if the case is heard by a jury. They find that the probability of validity does not vary significantly by technological field or the nationality of the inventor. They also note that the average final validity finding occurs about 9 years after the patent was granted and about 12 years after the application date.

Both the implied expected success probability of Siegelman and Waldfogel and the empirical success probability of Allison and Lemley are conditional on the case being filed to begin with. Since such cases are presumably filed only after the patentee has been unsuccessful in stopping infringement without filing suit, and infringers are presumably less likely to give up without a fight in those cases where the patent is weaker, the *unconditional* probability of success is presumably higher than the probability of success conditional on the case having gone to court. Waldfogel (1998) attempts to estimate the unconditional probability by examining how the observed success probability varies with the duration of the court case. If parties learn about their chances over time, then the cases resolved most quickly reflect most closely the overall unconditional success probability. He finds that cases that are resolved within 3 months are won by the patentee 84% of the time and cases resolved within a year are won 61% of the time. This suggests that the fact that only half of cases carried to conclusion are won by the patentee greatly understates the likelihood that a random patent can be enforced.

On the question of whether the threat of patent suits might deter innovation, Lerner (1995) finds that firms with high litigation costs (proxied by small capitalization and lack of previous patent experience) are less likely to patent in patent classes with many previous awards by rival firms. Further, they tend to avoid those classes occupied by rivals that themselves have relatively *low* litigation costs. These results suggest that the perceived danger of patent litigation does affect firms' research decisions, and differentially affects those decisions depending on the firms' abilities to engage in litigation.

IV. A Sampling of Current Policy Debates

A. Policy debates related to patent scope

There are three current policy or legal debates that I will discuss in the context of patent scope. The first is a perceived decline in the standard for non-obviousness imposed by the patent office in examining patents; the second is the perceived expansion of the "Doctrine of Equivalents" under the

CAFC; and the third is a debate over the perceived increase in the enforcement of patents on research tools.

1. Perceived increase in granting of "obvious" patents

With respect to any given patent, there are often disagreements as to whether the "inventive step" embodied in the patent is large enough to justify a finding that the invention is not obvious and hence it is entitled to a patent. In recent years, however, there has been a widespread sense that the patent office is granting large numbers of patents on trivial inventions. I am not aware of any attempt to document this phenomenon systematically; indeed, it is not clear to me how it could be done. All of the measures of patent scope that have been used empirically, such as number of patent classes per patent, citations per patent, and claims per patent, are subject to variations over time in patent office practice. For this reason, they are typically thought of as *relative* measures, i.e., in any given year a set of patents with a higher average claims/patent is broader than a set with a lower average. It would be a much bigger leap to interpret changes over time in the *aggregate* averages for any of these measures as telling us anything meaningful about changing patent scope.[18]

Within the analytical framework of the theoretical models, a decline in the standard for non-obviousness would be interpreted as a decline in patent scope; if a subsequent inventor needs to take only a small step past me to get a patent, then the scope of my patent is narrow. It is unclear, however, whether this is really the correct interpretation of what is going on or perceived to be going on. An alternative interpretation would be that there has been a decline in the quality of the patent examination process. Patent examiners are simply making more mistakes, granting patents that should

[18] One possibility might be to look at the variance of these measures rather than the mean. On the assumption that the rate of generation of "big" inventions has been stable, then a lowering of the standard for non-obviousness could perhaps be interpreted as producing a greater spread in actual patent "size" as more very small inventions are mixed into the distribution of patents.

not be granted. Indeed, it is perhaps to be expected that the rapid increase in the number of patents examined, and, perhaps more importantly, the expansion of patenting to new fields of technology, would lead to greater variability in the examination process. Under this interpretation, it is not that patent scope has decreased, but just that more noise has been introduced into the system. Eventually, this should lead to an increase in the frequency with which patents are found to be invalid, but it could be that not enough time has passed for this to be observed.

2. The Doctrine of Equivalents

While the granting of arguably "obvious" patents implies a decline in patent scope, it is widely believed that patent scope has been increased in the U.S. in the last two decades as a result of more liberal application of the Doctrine of Equivalents. The Doctrine of Equivalents holds that an invention that does not literally infringe upon the claims of a patent should nonetheless be found to infringe if the differences are insubstantial. The idea behind the Doctrine is that to limit enforcement of the patent to literal infringement "would place the inventor at the mercy of verbalism and would be subordinating substance to form" (*Graver Tank & Mfg. v. Linde Air Prods., 1950).* To prevent this, the Supreme Court said that an invention that performs the same function, in the same way, with the same result, would be judged to infringe.

Using this function-way-result test, the CAFC has upheld a number of important findings of infringement. In the 1995 *Hilton-Davis* case, it upheld a jury finding of infringement of a patent describing a chemical process occurring in the pH range from 6 to 9 and a pressure range from 200 to 400 psig, where the infringement was by a related process that occurred at pH 5 and pressure of 500 psig.[19] In doing so, it held that the function-way-result test could be supplemented by other evidence that relates to whether the differences between the patent and the alleged infringing invention are "insubstantial." In particular, it found that evidence as to whether the potential infringer knew of and "designed around" the patent, while not directly relevant to the question of infringement, could be used as evidence regarding how substantial the differences were. It also confirmed that the question of infringement under the Doctrine was a factual one to be determined by the jury if the case was before a jury.

The extent of infringement under the Doctrine of Equivalents is clearly closely connected to the theoretical analysis of the effects of patent scope on cumulative innovation. Indeed, this connection was explicitly recognized in a concurring opinion by Judge Newman in the *Hilton-Davis* case:

> The principle of equivalency thus serves a commercial purpose, as it adjusts the relationship between the originator and the second-comer who bore neither the burden of creation nor the risk of failure. However, there is also the major consideration of the progress of technology. How does the existence of a "doctrine" that transcends the statutory purpose of legal notice of the patent's scope affect that progress? Does the doctrine of equivalents affect the research, development, investment and commercialization decisions of today's technologic industry, in a way that concerns the national interest? And if not, what's all the fuss about?
>
> Despite our national dependence on technologic advance, there is a sparseness of practical study of whether and how the doctrine of equivalents affects modern industrial progress and public welfare. (Concurring decision by Judge Pauline Newman in *Hilton-Davis v. Warner Jenkinson*, Fed. Cir. 1995, reproduced in Merges (1997), page 886)

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[19] This decision was reviewed by the Supreme Court in *Warner Jenkinson v. Hilton Davis* (1997). The Supreme Court remanded the case to the CAFC for reconsideration of certain issues, but did not fundamentally overturn the CAFC's holding. The Supreme Court decision emphasized that infringement under the Doctrine occurs when any differences between the patent and the alleged infringement involve elements that people skilled in the art knew were interchangeable.

This sounds like a clear and valuable challenge to the research community.

B. The patenting of research tools

The growth in biotechnology industries and the growth in patenting by universities have combined to create increasing concern about the consequences of the enforcement of strong patents on research tools. As stated by Heller and Eisenberg (1998), "Policy-makers should seek to ensure coherent boundaries of upstream patents and to minimize restrictive licensing practices that interfere with downstream product development. Otherwise, more upstream patent rights may lead paradoxically to fewer useful products for improving human health."

As noted above, at one level one would think that strong property rights on research tools do not create a dilemma. The creator of a research tool will not generally desire to suppress its use. It will be in all parties' interests to devise licensing agreements to ensure that socially valuable uses of research tools are not inhibited. Under this view, the current complaints about the enforcement of patents on research tools can be attributed to the elimination of the "free-ride" that previously existed because universities did not have clear patent rights. Enforcing these patent rights may cost downstream firms part of their profits, but this will create good incentives to develop new research tools, and will not inhibit their use because they will be licensed.

This logic can be questioned on two fronts. First, as was pointed out as far back as the 1947 Justice Department report discussed above, one can question on equity grounds why a subsequent researcher should have to pay a university to use technology that was developed with tax dollars. Second, Heller and Eisenberg question whether licensing will work well enough to ensure that research tools can be used. They note that the rapid advance of biotechnology, combined with the proliferation of patents on important research tools, puts a researcher in a position where she needs multiple licenses in order to market any given product. This creates a situation where the transactions costs necessary for this coordinated bargaining may cause the bargaining to break down completely. The result is what they call a "tragedy of the anti-commons," in which multiple overlapping and possibly ambiguous private property rights make it difficult or perhaps impossible for anyone to use the pool of research methods that have been developed.

Beyond the general statement quoted above, Heller and Eisenberg are not specific about how they would minimize the ability of research tool patentees to inhibit subsequent use. In an earlier paper, Eisenberg (1989) proposed that patents for research tools should not be entitled to injunctions that bar the sale of infringing products; they should be entitled only to a reasonable royalty on the use of the research tool. This would, in effect, implement compulsory licensing of research tools. Compulsory licensing has not historically played a prominent role in the U.S. patent system; as noted above, the U.S. bargained for limitations on compulsory licensing are part of the TRIPs agreement.

A more fundamental difficulty with the "reasonable royalty" approach is noted by Schankerman and Scotchmer (1999). Reasonable royalties have historically been interpreted to mean that the infringer pays as damages the royalty that the patentee and the infringer would have agreed to in a hypothetical licensing negotiation in which both parties knew that the patent was valid and a license was needed to avoid infringement. But, in the absence of a right to an injunction, the outcome to that negotiation itself depends on the damages that the two parties believe the patentee could demand if the negotiations fail and the infringement occurs. Hence it is circular to base the damages on that hypothetical negotiation.

It would seem that there are really two distinct issues here. In cases where the research-tool patentee is a private firm, it does not seem that the tradeoffs between that patentee's rights and incentives and the possible inhibition on subsequent invention is really very different than with respect to other patents. As recognized by Heller and Eisenberg, there are other industries where complex packages of patent rights have to be obtained, and the problems seem to be solved by patent pooling and cross-licensing agreements.[20] Certainly, no compelling case has been made for radical remedies such as eliminating patentability or effectively imposing compulsory licensing. Firms that develop new research tools already have the option of attempting to keep them secret instead of patenting them; if patents were made unavailable or less valuable, secrecy would become more attractive, making subsequent use of the tools by others less likely rather than more likely.

Patenting of research tools by universities and other publicly funded institutions arguably represents a different situation. It seems implausible that patent rights have much bearing on these entities' incentives to engage in research that develops new research tools.[21] The original argument for Bayh-Dole was that potential inventions from university research would lie unused in the absence of patent protection, because they needed a lot of subsequent development investment that would not be undertaken unless the patents could be licensed *exclusively* to a commercial firm. Research tools do not fit this model. They are not typically licensed exclusively, and we certainly wouldn't want them to be. But when they are licensed non-exclusively, the patent right and resulting royalties amount, in Heller and Eisenberg's phrase, to a "tollbooth" on the biotechnology development highway. This was not the argument made for Bayh-Dole, and it is not clear that it is socially desirable.

It is also unclear, however, if it is practical to selectively limit enforcement of research tool patents by public research institutions. A return to the pre-Bayh-Dole regime would also eliminate patents on other

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[20] Of course, these institutions may be quite inefficient. See Hall and Ham (1999).

[21] The availability of patent royalties may, however, affect researchers' incentives to cooperate in facilitating their commercial use. See Jensen and Thursby (1998).

commercial products, which seem to have been an important avenue of technology transfer. A prohibition on non-exclusive licenses would be likely to hinder broad technology transfer rather than facilitate it. An attempt to statutorily distinguish research tools from other inventions might be problematic. Thus it may be that the only practical approach is to use public scrutiny and moral suasion to encourage these entities to license research tools widely and easily.

C. Are software patents bad?

Despite (or perhaps because of) the rapid increase in software patenting, there is widespread debate about the desirability of software patents.[22] The arguments why software patents are undesirable include:

- Software products tend to be "systems" constructed from many different pieces. Allowing patents on pieces of software creates an untenable need to secure or at least consider many different licenses in order to market any given product.
- The above need for multiple licenses will favor large firms that can amass patent portfolios and thereby bargain for cross-licensing. The genius of the software industry is in small firms that will be driven under.
- In order to work, distinct pieces of software need to interface with each other, to provide inter-operability. Standards are needed. Patents on elements of standards or interfaces can provide very broad monopoly power.
- Software changes so quickly that it will have changed by the time a patent is issued. Many of the patents being issued are for software ideas that have been around a long time.
- It wasn't broke; we shouldn't have tried to fix it.

As we have seen, the first point is not unique to software. Other industries deal with these problems, although that does not mean that the outcome is necessarily socially desirable (Hall and Ham, 1999). With respect to the second point, it may be that small firms will have more difficulty

[22] As noted above, the expansion in the patentability of software has been part of a broader expansion that includes financial products and methods. Some, but not all, of the issues raised in this section apply to this broader category.

achieving cross-licensing agreements, but it is also true that small firms may have fewer other weapons besides patents to protect their inventions, and so in some cases may need patents more.[23]

The inter-operability problem is discussed by Merges (1999). He argues that the intellectual property system (including patents) will likely deal with it by using common-sense rules to prevent patents on "small pieces" of a system from controlling a disproportionately large market. On the fourth point, rapidly changing technology should not, in principle, lead to an increase in obvious patents; the obviousness of the patent is supposed to be judged as of the time of application. As noted above, however, applying consistent standards for patentability may be particularly difficult in new and rapidly changing fields. It is unclear how the courts will sort this out.

The last point should be taken seriously, at least by researchers. Although many things are changing at once, it would be useful to try to say something about the extent to which the greatly increased importance of patents in this industry has affected the innovation process. The challenge is to try to figure out ways to disentangle the co-evolution of innovation in this sector and the rules that govern it. Does the earlier period show that patents are unnecessary in this area? Is there some reason why patent protection became more necessary as the industry evolved? Or is the movement to patent protection killing the Golden Goose?

D. First to file versus first to invent and publication of applications

As noted above, the U.S. recently changed its patent duration from 17 years from date of grant to 20 years from date of application, in order to conform to practice in the rest of the world. We still differ from other countries, however, in (1) granting patent priority to the "first-to-invent"

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[23] Hall and Ham (1999) find that patents in semiconductors are used to a significant extent to amass patent portfolios to be used in negotiation. But they also find that design firms and new entrants rely on patents to protect their products when they contract with larger firms for manufacturing services.

rather than the “first-to-file,” and (2) keeping patent applications secret indefinitely pending the grant decision. Legislation has been introduced to change these as well. This legislation is generally supported by the large companies and the intellectual property bar (Blount, 1999), but has also generated significant opposition, including a letter signed by 10 Nobel Laureates in Economics and 16 Nobel winners in other fields.[24]

In addition to the desire to harmonize U.S. rules with the rest of the world, part of the motivation for these changes comes from perceived abuses of the patent review process, in which applicants manage to revise their original claims during the review period in light of subsequent discoveries. The extreme version of this takes the form of so-called “submarine patents.” These are patents based on old, allegedly vague applications, kept alive within the patent office by repeated continuations that modify the invention to reflect developing practice. Then, after the technology has ripened, the patent “surfaces” and other companies are surprised to learn that products that they have developed infringe the just-issued patent. While changing the patent duration so that it runs from the application date reduces this danger, publication of applications would make a bigger difference with respect to technologies for which 20 years is a very long time.

The most famous (or infamous) practitioner of the submarine patent is the late Jerome Lemelson, who held patents on components of VCRs, ATMs, cordless phones, fax machines, compact cassette players, welding robots and machine vision and image processing, which he used to extract significant royalties from companies that thought they were using only their own technologies. Blount (1999) shows that patents with very long pendancy periods are a very small fraction of all patents. Of course, because patents differ greatly in their importance, the fact that potential submarine patents

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[24] The letter was drafted by Franco Modigliani. See http://www.alliance-dc.org/aainews/nobel-S507.html.

are few in number does not necessarily mean that they are economically unimportant.

There has been relatively little systematic analysis of the consequences of changing filing and disclosure regimes. Scotchmer and Green (1990) show that the first-to-file rule generally leads to disclosure of more information. Aoki and Prusa (1996) consider the effect of the availability of information on competitors' pending applications on other firms' patent filings. They show that such disclosure induces firms to patent smaller inventions, and that firms' profits are greater under the open-disclosure system, because firms do not waste resources on developing products that are about to be precluded by someone else's patent. This analysis is taken further by Aoki and Spiegel (1998). They consider a model in which new products go through a "research" phase and a "development" phase. A firm that has successfully completed the research phase may apply for a patent. The patent may or may not be granted, and, if granted, may or may not ultimately be enforced by the courts. Once any firm completes the research phase, firms compete in the development phase, with the firm that originally succeeded in the research having a headstart on development; this headstart is reduced when the patent application becomes public.

Some of the results in this model depend on the strength of patent protection, i.e., how likely it is that a patent will be upheld and thereby protect the innovation from competition. In general, they find that early disclosure of applications reduces the rate of innovation, but raises the probability that any given innovation will be carried through the development phase and reach the product market. For some plausible parameter values, early disclosure makes consumers better off and raises total welfare.

Clearly, this is an issue deserving of more research, particularly if famous economists are going to write letters supporting or opposing particular statutory changes. The Aoki and Spiegel paper is attractive because it directly confronts the pending policy issue, and does so in a way that incorporates many features of the real world, including the uncertainty that always exists regarding whether a given patent will ultimately be enforced.

V. Conclusion

Economists have known for some time that patents are not the only—or in most industries the most important—mechanism for preserving incentives for innovation. Ironically, this understanding was solidified at approximately the same time as the apparent importance of patents began to rise. In the last two decades patents have arguably become stronger (in the sense of more likely to be upheld) and broader (the expanding Doctrine of Equivalents), become available for the first time in a significant way to the public research community, become available for a number of important categories of innovation that were previously largely unpatentable, and had their reach extended within the developing world.

I have taken the view that it would be surprising if major changes in the patent system did not affect the innovation process. This is consistent with the view of Judge Newman that encouraging innovation was (or ought to have been) the motivation behind the policy innovations. Unfortunately, it is not possible to make very many robust statements about the effects of these changes on the innovation process. The only clear set of conclusions is that the extension of patent protection to publicly funded research does seem to have had a significant impact in increasing technology transfer from this sector. Otherwise, we have fairly limited empirical results; the results we have generally suggest that the innovation process was not affected. This limited success is due partially to the difficulty of measuring the parameters of patent policy, and partly due to the difficulty of discerning statistically significant effects when many things have been changing at the same time. But it should surely be viewed as a challenge to researchers to try to do more.

An alternative view is that these negative results confirm what we thought we already knew, which is that patents are not central to appropriating the returns to R&D in most industries. In addition to the survey evidence discussed above, this view receives some support from statistical estimates of the value of the patent right. Such studies can be interpreted to measure the implicit or equivalent subsidy that the existence of the patent right provides to R&D. Such studies typically show that the magnitude of this subsidy varies by technological field, from as low as 5-10% of research spending to a high of maybe 35% in some industries (Schankerman, 1998; Lanjouw, Pakes and Putnam, 1998). For industries at the lower end of this range, at least, one could imagine that even a significant increase in the value of patent rights might still be too small relative to overall costs and returns to have a measurable impact on innovative behavior.

This broad review of where the literature stands suggests many avenues for potentially fruitful research. I would emphasize in particular the desirability of:

- efforts to understand how firms' perceptions about the availability of patents and the nature of their enforcement affect their research investment decisions;
- efforts to tie specific aspects of legal policy and practice to the theoretical constructs that embody patent scope or breadth in the theoretical literature;
- modeling and empirical analysis of the process of licensing and the extent to which transaction costs inhibit efficient bargaining between and among holders of potentially conflicting patent rights.
- efforts to understand how the apparent shrinking of the necessary inventive step for non-obviousness relates to and interacts with the broadening of patent scope represented by wider application of the Doctrine of Equivalents;
- analysis of what the growth in patenting in software, financial products and business methods really represents, and how it is affecting innovation.

There is a widespread unease that the costs of stronger patent protection may exceed the benefits. Both theoretical and, to a lesser extent, empirical research suggest this possibility. Economists have long understood that, at a theoretical level, technological competition can lead to a socially excessive level of resources devoted to innovation. The empirical literature is convincing that, for the research process itself, the externalities are clearly positive on balance (Griliches, 1992). But to the extent that firms' attention and resources are, at the margin, diverted from innovation itself towards the acquisition, defense and assertion against others of property rights, the social return to the endeavor as a whole is likely to fall. While the evidence on all sides is scant, it is fair to say that there is at least as much evidence of these effects of patent policy changes as there is evidence of stimulation of research.

These questions are closely related to a broader debate as to whether we are enjoying technological progress at a rate that is not adequately reflected in the productivity statistics. If history concludes that the end of the twentieth century was a time of rapid and sustained technological progress, it is likely also to conclude that the patent policy transition was a good thing. While we wait for this historical judgement, our failure to demonstrate real effects of the policy changes that have been made should make us very cautious about predicting that policy innovations affect the innovation process. At the same time, the dramatic increase in research expenditure and the apparent signs of technological progress all around us should make us cautious about concluding that the policy changes have had no effect.

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Figure One
U.S. Patent and R&D Trends

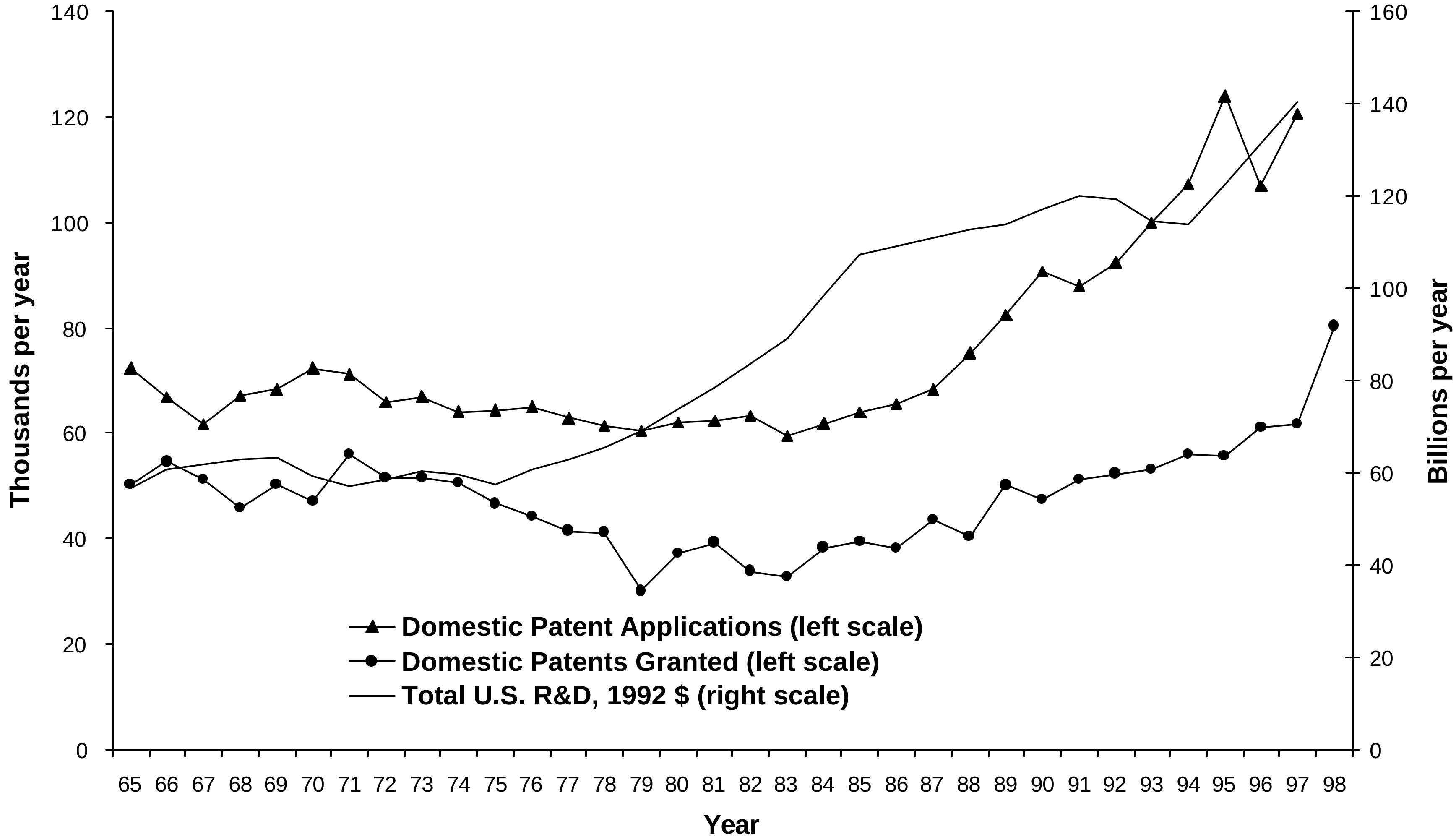

Figure Two
Patent Ratios Over Time
(5-year moving averages)

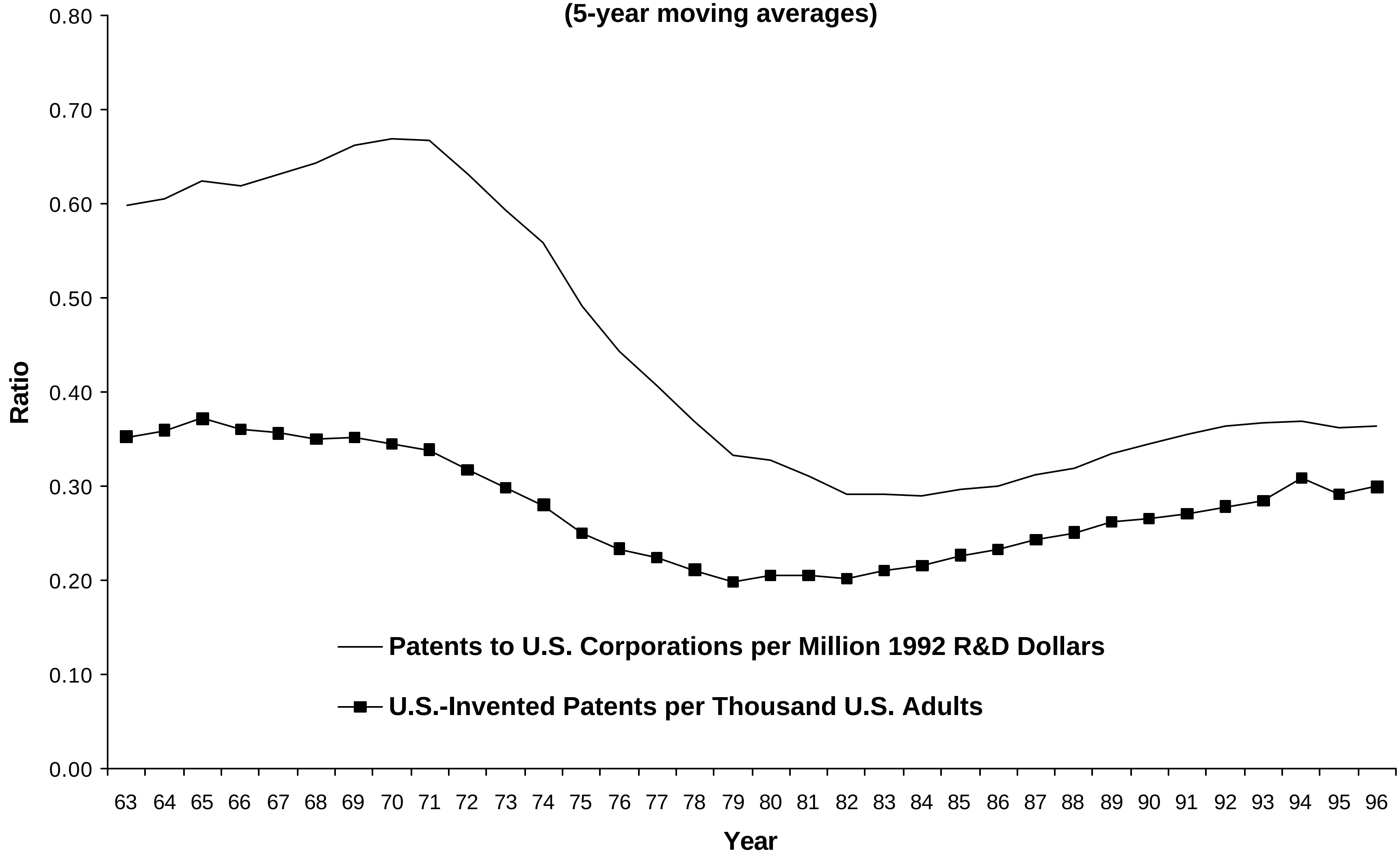

Figure Three
Patents from Publicly Funded Research

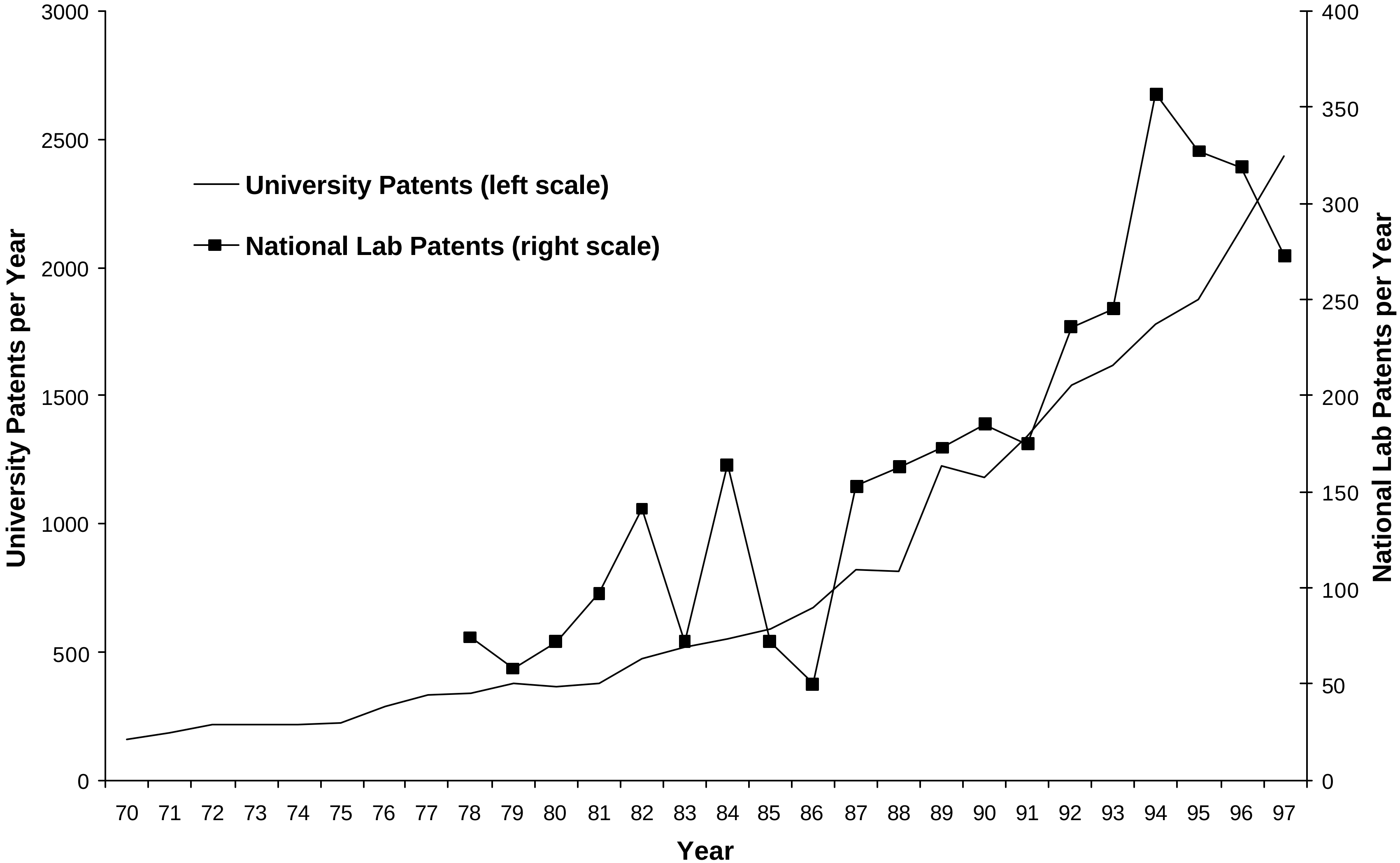

Figure Four
Publicly Funded Patents per Dollar of Research Expenditure

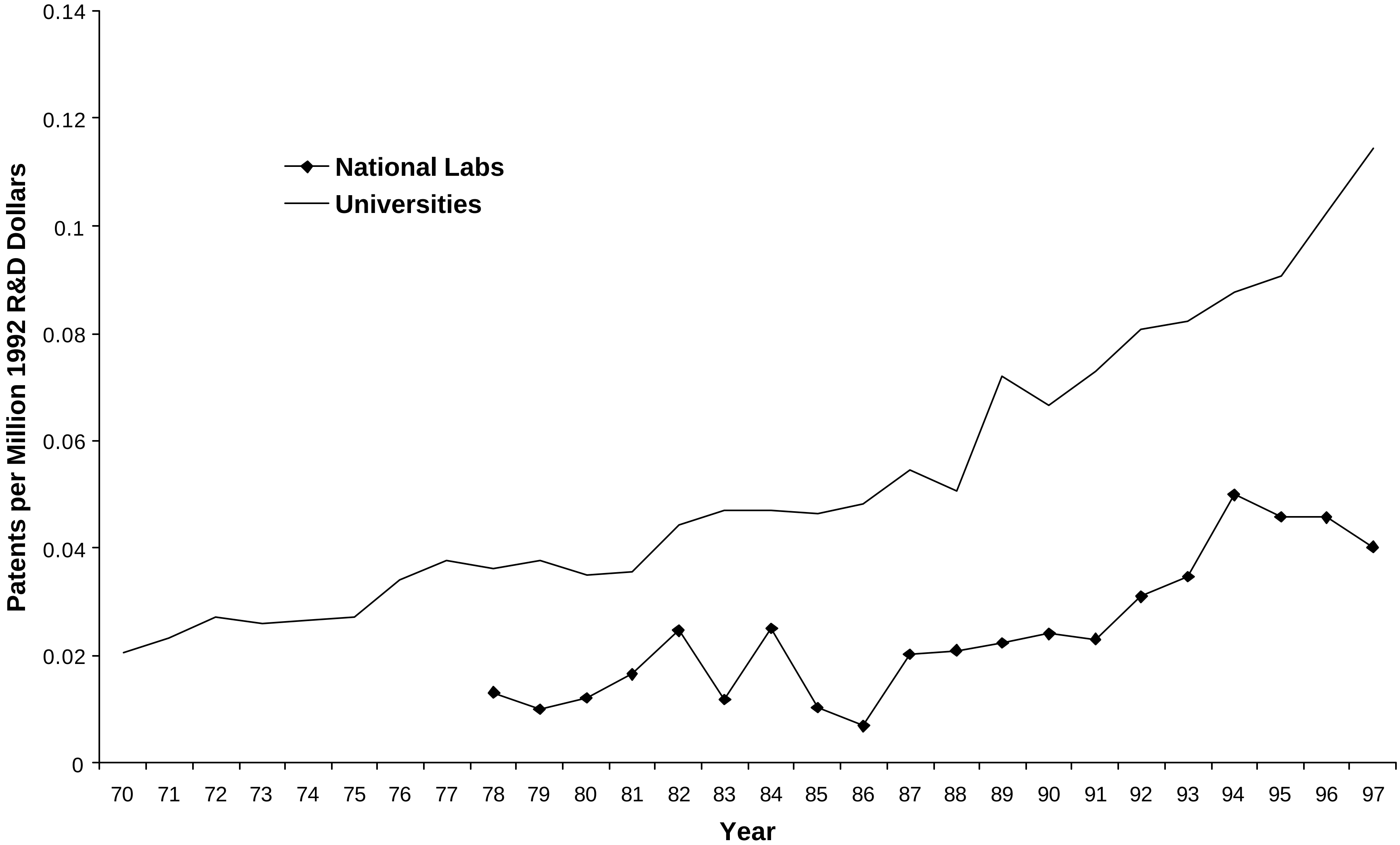

Figure Five
Biotechnology and Software Patents: Indicative Classes