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ON THE COMPLEX ECONOMICS OF PATENT SCOPE

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INTRODUCTION

The economic significance of a patent depends on its scope: the broader the scope, the larger the number of competing products and processes that will infringe the patent. Many theoretical papers have tried to assess the effects of fine tuning various aspects of the patent system to make it more efficient.[1] But only a few have focussed on patent scope,[2] even though scope decisions are subject to far more discre-

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1. For example, some years ago there was extensive discussion of the advantages of funneling patent claims through a special patent court. These discussions resulted in the establishment in 1982 of the Court of Appeals for the Federal Circuit. See, e.g., Dreyfuss, The Federal Circuit: A Case Study in Specialized Courts, 64 N.Y.U. L. Rev. 1, 25–26 (1989); Jordan, Specialized Courts: A Choice?, 76 Nw. U.L. Rev. 745 (1981).

2. An exception to the dearth of scholarly writing on patent scope is McFetridge & Rafiquzzaman, The Scope and Duration of the Patent Right and the Nature of Research Rivalry, 8 Res. L. & Econ. 91 (1986). In addition, a number of working papers published while this article was being written suggest that the academic neglect is ending. See R. Gilbert & C. Shapiro, Optimal Patent Length and Breadth (University of California, Berkeley, Department of Economics, Working Paper No. 89-102, Jan. 1989) (on file with authors); P. Klemperer, How Broad Should the Scope of Patent Protection Be? (Feb. 1988) (Notes for private circulation, on file with authors); S. Scotchmer & J. Green, Novelty and Disclosure in Patent Law (rev. ed. Nov. 15, 1988) (unpublished manuscript, on file with authors); see also J. Shoven, Intellectual Property Rights and Economic Growth, *in* Intellectual Property Rights and Capital Formation in the Next Decade 46, 49–50 (1988):

> As with the length issue, there are opposing factors in determining the optimal width of the protected intellectual property rights. The advantage of interpreting the properly [sic] narrowly is that it limits the monopoly power granted to the originator. . . . However, in addition to reducing the incentives faced by the originator of the real innovation, it has another potentially important adverse effect—the coexistence of 'neighboring' technologies, which can cause significant social waste because of the lack of standardization.

There is also a wide practice-oriented literature on patent scope doctrines. See, e.g., Noonan, Understanding Patent Scope, 65 Or. L. Rev. 717 (1986).

tion than most of the aspects more intensively studied.

Furthermore, most theoretical writing on patents is directed toward issues that as a practical matter are considered largely settled. For example, several economists have explored the question of optimal patent duration.[3] Their work did have a direct impact on the decision to extend patent terms on pharmaceuticals to compensate for regulatory lag.[4] But despite the scholarly attention to patent duration, the term of most patents remains fixed at seventeen years.[5] Likewise, there has been considerable debate over the years on the merits of compulsory licensing of patents under some circumstances,[6] yet the intellectual property community has repeatedly rejected the idea.[7] Thus, while the literature continues to generate interesting questions about bedrock assumptions and practices, it has little bearing on the everyday operations of the patent system. This Article is an attempt to redress this deficiency by analyzing the economic effects of patent scope.

The Patent Office and the courts are constantly making patent scope decisions. The Patent Office does so when it determines the claims it will allow on a specific patent. The courts do so in litigation, where questions of patent infringement are decided. In the former context, the applicant wants to claim as much as she can, and the Patent Office must decide what claims are allowable. While decisions regarding what to allow are constrained by a number of legal principles, and by the invention itself, in many cases the Patent Office has considerable room for discretion. Within that discretionary zone, the Office must

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3. See, e.g., W. Nordhaus, Invention, Growth, and Economic Welfare (1969); Scherer, Nordhaus's Theory of Optimal Patent Life: A Geometric Reinterpretation, 62 Am. Econ. Rev. 422 (1972); Tandon, Optimal Patents with Compulsory Licensing, 90 J. Pol. Econ. 470 (1982).

4. See Grabowski & Vernon, Longer Patents for Lower Imitation Barriers: The 1984 Drug Act, 76 Am. Econ. Rev. 195 (1986).

5. 35 U.S.C. § 154 (1988). See generally White, Why a Seventeen Year Patent, 38 J. Pat. Off. Soc'y 839 (1956) (describing historical basis for seventeen-year term and proposing shortened terms).

6. The debate is aptly summarized in Staff of the Subcomm. on Patents, Trademarks, and Copyrights of the Senate Comm. on the Judiciary, 86th Cong., 2d Sess., Compulsory Licensing of Patents—A Legislative History (Comm. Print 1958) (written by Catherine S. Corry). A good overview is provided by F.M. Scherer, Industrial Market Structure and Economic Performance 456–57 (2d ed. 1980) ("All in all, the substantial amount of evidence now available suggests that compulsory patent licensing, judiciously confined to cases in which patent-based monopoly power has been abused . . . would have little or no adverse impact on the rate of technological progress . . . .").

7. See F.M. Scherer, supra note 6, at 456 ("[E]very attempt to alter the U.S. law in this direction has been beaten down as a result of determined opposition from industrial groups and the patent bar.") (footnote omitted). For a brief time during the heyday of antitrust enforcement, compulsory licenses were routinely ordered. See Staff of the Subcomm. on Patents, Trademarks, and Copyrights of the Senate Comm. on the Judiciary, 86th Cong., 2d Sess., Compulsory Licensing Under Antitrust Judgments 1 (Comm. Print 1960) (written by Marcus A. Hollabaugh and Robert L. Wright).

decide which claims should be admitted and which ones pruned back or rejected.

After a patent has been issued, a patentee will often allege that her invention has been copied by competitors. In arguing the case, she will try to demonstrate that the accused infringer's product falls within the boundaries of her invention, as defined in her patent claims, or that any differences between the infringer's device and her invention are insignificant. The challenger, meanwhile, will argue first that the patent is invalid, and second that her invention or product does not infringe the patent—that it is different in some material respect from the invention claimed by the patentee. Again, the legal principles and objective evidence often leave considerable room for discretion. There has been surprisingly little theoretical discussion of how to exercise this discretion. This paper is concerned with the effects of these decisions, and with the policies that should influence them.

Several recent cases sigual the nature and complexity of the questions involved in patent scope decisions. In 1988 the Patent Office granted a patent to the inventors of a transgenic mouse.[8] The Office accepted the inventor's argument that their procedure could be used to engineer higher order animals, and thus allowed a claim to any "nonhuman mammal" made with their procedure.[9] Is such a generalization of specific results consistent with what is known about this area of technology? What are the likely consequences of accepting this broad claim? Should this claim cover other transgenic animals, even if it takes a major breakthrough to create them?

In another case a court ruled that a blood clotting protein made with recombinant DNA techniques violated a product patent held by an earlier inventor who had purified the same protein from human blood. But the court later found the original patent invalid on the grounds that the best mode of operation was not revealed by the patent.[10] Was the

8. U.S. Patent No. 4,736,866, issued Apr. 12, 1988, at col. 9, claim 1.

9. See id. The specification of the patent states that "the invention features a transgenic non-human eukaryotic animal (preferably a rodent such as a mouse) . . ." Id. at col. 10. The last two of twelve claims also narrow the invention to cover only rodents (claim 11) and only mice (claim 12). But most of the claims, along with the specification, describe the invention as pertaining to all nonhuman mammals, and unless claim 1 were invalidated the patent would undoubtedly extend to any nonhuman mammal. Interestingly, similar broad claim language was eliminated from the European version of this patent after a decision that the inventors had taught only enough to engineer transgenic mice, not nonhuman mammals in general. See In re President and Fellows of Harvard College (European Patent Office July 14, 1989), reported in 20 Int'l Rev. Indus. Prop. & Copyright L. 889, 895–96 (1989) (decision not final).

10. Scripps Clinic & Research Found. v. Genentech, Inc., 666 F. Supp. 1379, 1390, 3 U.S.P.Q.2d (BNA) 1481, 1488 (N.D. Cal. 1987) ("Scripps is entitled to claim purified Factor VIII:C having the characteristics of human Factor VIII:C, whether derived through its disclosed process or any other process achieving the same result."), patent invalidated, Scripps Clinic & Research Found. v. Genentech, Inc., 707 F. Supp. 1547, 1552–55, 11 U.S.P.Q.2d (BNA) 1187, 1191–94 (N.D. Cal. 1989) (patentee failed to dis-

first decision a reasonable one? The second? How will these decisions affect future inventions in this field?

Given the issues at stake, the question of appropriate patent scope has attracted surprisingly little attention. There has been some analytic writing on the subject,[11] but in our view most of the papers do not focus on the key issues. The well known paper by Edmund Kitch is an exception.[12] Kitch has argued that our system of granting a patent early in the development process allows an inventor to invest in development without fear that another firm will steal her work,[13] thus encouraging the inventor to coordinate her activities with other firms.[14] Kitch states that this "prospect function," which necessarily implies broad patents, explains many of the doctrines and practices of the patent system.[15] Another commentator has responded that for the most part the Patent Office and courts have resisted granting broad prospects.[16]

Our own exploration of the economics of patent scope has led us to focus on very much the same kinds of issues as raised by Kitch. We proceed as follows: We begin by considering the legal doctrines that define a patent's scope, then identify the room for discretion which often exists, and point out areas of consistency and inconsistency in current practice. Next, we develop an economic analysis that illuminates the central issues at stake in varying permissible patent scope. This analysis differs from standard economic models by moving beyond the two-dimensional analysis of incentives and deadweight loss.

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close best mode known to it of carrying out its invention). The first decision is premised on the rule that products such as Factor VIII:C that occur in nature are patentable if they are so transformed by the purification process that they constitute "for every practical purpose a new thing commercially and therapeutically." Parke-Davis & Co. v. H.K. Mulford & Co., 189 F. 95, 103 (C.C.S.D.N.Y. 1911) (L. Hand, J.) (patent on purified form of adrenalin), aff'd in part and rev'd in part, 196 F. 496 (2d Cir. 1912).

11. See supra note 2.

12. Kitch, The Nature and Function of the Patent System, 20 J.L. & Econ. 265 (1977).

13. See id. at 276–77. One comment criticizes this aspect of the prospect theory. McFetridge & Smith, Patents, Prospects, and Economic Surplus: A Comment, 23 J.L. & Econ. 197 (1980). The authors of the comment claim that the efficiency gains from delayed commercialization will be dissipated by competitive rivalry for the patent; even if a patent *were* an exclusive right to commercialize an invention, there would still be competition to get the patent which confers these rights. This would simply shift the competition back one stage, since there is no prepatent right to get a patent. See id. at 202. For Kitch's response, see Kitch, Patents, Prospects, and Economic Surplus: A Reply, 23 J.L. & Econ. 205, 206 (1980).

14. See Kitch, supra note 12, at 279.

15. Id.

16. See Beck, The Prospect Theory of the Patent System and Unproductive Competition, 5 Res. L. & Econ. 193 (1983) (arguing, contrary to Kitch, that patent law does not protect all or even many future developments of a technology). See generally F.M. Scherer, supra note 6, at 447 (describing under what conditions firms may find investment in innovation profitable even without patent protection).

Much of our discussion will center on the post-invention environment for development and subsequent improvements. By contrast, the work of Nordhaus and others is concerned with conditions surrounding the initial invention.[17] One way to describe our approach is to view it as a broadening of what counts as an incentive to invent or as a social cost of issuing patents. The concept of incentives, in our view, should embrace post-invention conditions favorable to the inventor, such as extension of an initial patent to cover subsequently-developed versions of the invention. Likewise, the notion of a patent's social costs should include its potential to reduce competition in the market for improvements to the patented technology.

Like Kitch, then, we see the important question as how patent scope decisions influence the *development* of a technology, both in the sense of an individual invention and that of a future line of improvements extending from it. However, contrary to what Kitch suggests, we do not *presume* that granting broad scope to an initial inventor induces more effective development and future invention. We regard this as an open question.

Our analysis differs from the existing literature on patents in a second way as well. This literature tends to assume that invention is the same in all technologies. In contrast, we develop several models of technical advance in industry, models that differ in terms of how various inventions are related to each other. These models are designed to highlight and capture the different ways in which technical advancement proceeds in different fields. One of our major objectives is to show that the issues at stake regarding patent scope depend on the nature of technology in an industry. This dependence includes two characteristics: the relationship between technical advances in the industry, and the extent to which firms license technologies to each other.

Theoretical argnment alone, however, cannot resolve the question of whether technical advance proceeds more vigorously and effectively under competition or under a regime where one person or organization has a considerable amount of control over developments. Therefore we follow our theoretical analysis with an empirical-historical examination of the course of technical advance in several industries, gnided by the various models we have developed. In each industry, critical rulings regarding the scope of important early patents significantly influenced the subsequent path of the technology. Our focus will be on those critical decisions and their consequences.

We conclude with an attempt to draw lessons regarding appropriate patent scope. Our basic conclusion is this: Without extensively reducing the pioneer's incentives, the law should attempt at the margin to favor a competitive environment for improvements, rather than an en-

17. See generally W. Nordhaus, supra note 3, at 3–15; McFetridge & Rafiquzzaman, supra note 2.

vironment dominated by the pioneer firm. In many industries the efficiency gains from the pioneer's ability to coordinate are likely to be outweighed by the loss of competition for improvements to the basic invention. Throughout the article we suggest ways that patent doctrine can be applied to carry out this goal.

I. PATENT LAW DOCTRINES

A. *Patent Prosecution: Threshold Issues*

During prosecution of a patent, a Patent Office examiner reviews an application to determine what is patentable. To be patentable an invention must meet all the statutory requirements for patentability: novelty,[18] utility[19] and non-obviousness.[20] The claims are crafted to meet these requirements. But another requirement relates more directly to the scope of the claims—enablement, which largely concerns how the invention is described and claimed in the patent.

A patent application has two main parts. The first is a specification of the invention, which is written like a brief science or engineering article describing the problem the inventor faced and the steps she took to solve it. It also provides a precise characterization of the "best mode" of solving the problem.[21] The second part of the patent application is a set of claims, which usually encompass more than the material set out in the specification.[22] Claims define what the inventor considers to be the scope of her invention, the technological territory she claims is hers to control by suing for infringement.

The specification and claims serve quite different functions. The specification is used by the Patent Office to determine whether the inventor has made a patentable invention and, if so, whether others can make and use it. This fundamental principle—that legal protection is

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18. See 35 U.S.C. § 102 (1988).

19. See 35 U.S.C. § 101.

20. See 35 U.S.C. § 103. In addition, there are two types of subject matter that cannot be patented: mathematical formulas and natural laws, and products of nature. See Gottschalk v. Benson, 409 U.S. 63, 67–68, 175 U.S.P.Q. (BNA) 673, 675–76 (1972); 1 P. Rosenberg, Patent Law Fundamentals § 6.02[2] (1986). Thus, there is, in effect, a fourth requirement: that an invention not fall into one of these categories.

21. The first paragraph of § 112 of the patent statute reads:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains . . . to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

35 U.S.C. § 112.

22. The second paragraph of § 112 of the patent statute reads: "The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention." Id. Although the statute speaks of claims as part of this specification, they are often referred to as a separate part of the application.

premised on an adequate disclosure of the invention—is built deep into the history of patent law.[23] The patent claims serve a different function: Analogous to the metes and bounds of a real property deed, they distinguish the inventor's intellectual property from the surrounding terrain.

Claim breadth is largely a function of two doctrines. The enablement doctrine requires that the specification teach one skilled in the relevant art how to make and use all the embodiments of the invention encompassed by the claims. In appropriate cases, the doctrine of equivalents expands the scope of a patent beyond the literal language of the patent's claims. We consider each in turn.

B. *Doctrines of Disclosure and Enablement*

One important issue in patent law is how broad the knowledge communicated by the disclosure should be. Under section 112, the disclosure must be sufficient to enable someone skilled in the art to make and use all the embodiments of the invention claimed in the patent. This requirement can at times be applied rather loosely: a specification that describes only one working example of an invention but that supplies less guidance on the subject matter at the fringes of a patent's claims is often sufficient.[24]

At first blush it might seem to make sense to limit the rights of a patentee to only those embodiments of the invention she has disclosed in her specification, i.e., those that she has actually created at the time the patent application is filed. But imitators would soon find some minor variation over the disclosed embodiments; with such an ultra-narrow enablement principle, they would then have a nonenablement defense if the patentee tried to enforce the patent. Such a rule would soon render patents useless.

The patent system recoguized this danger long ago. For example, in 1904 King Gillette received a patent for the first disposable blade safety razor.[25] One of the problems Gillette faced was how to keep a very thin, detachable blade rigid during shaving. His solution, as de-

23. See, e.g., Grant v. Raymond, 31 U.S. (6 Pet.) 218, 247 (1832) (An enabling disclosure "is necessary in order to give the public, after the privilege shall expire, the advantage for which the privilege is allowed, and is the foundation of the power to issue the patent.").

24. For an example, see infra notes 82–93 and accompanying text. Note that some cases have held that *no* working examples are required, as long as the specification is nevertheless enabling. See, e.g., In re Strahilevitz, 668 F.2d 1229, 1232–34, 212 U.S.P.Q. (BNA) 561, 563–65 (C.C.P.A. 1982) (upholding a patent where applicant failed to provide working examples). On the Strahilevitz patent and the opportunity it offers biotechnology inventors to file patents before obtaining working examples, see P. Kelly, Prophetic Patents in Biotechnology, 8 Bio/Technology 24, 25 (1990).

25. U.S. Patent 775,134, issued Nov. 15, 1904. See Gillette Safety Razor Co. v. Clark Blade & Razor Co., 187 F. 149, 149 (C.C.D.N.J. 1911), aff'd, 194 F. 421 (3d Cir. 1912).

scribed in his specification, was to " 'secure [the] blade to a holder . . . [so that] it receives a degree of rigidity sufficient to make it practically operative.' "[26] Claim two of the Gillette patent reads " '[I claim as] a new article of manufacture, a detachable razor-blade of such thinness and flexibility as to require external support to give rigidity to its cutting edge.' "[27]

Gillette's success drew imitators, including the Clark Blade and Razor Company. When Gillette sued for patent infringement, Clark claimed that Gillette's patent did not sufficiently describe all the possible embodiments of the blade and that, in particular, Clark's design fell outside the range of what Gillette's patent had described. The Third Circuit rejected this argument, quoting broad langnage from the Supreme Court:

> [C]laim 2 is not invalid . . . for, if such were the law, patentability must have been denied to Elias Howe for "the grooved and eye-pointed needle" which constituted his seventh claim, and of which it was said [by the Supreme Court] in Deering v. Winona:
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> > "The invention of a needle with the eye near the point is the basis of all the sewing machines used, but the methods of operating such a needle are many; and, if Howe had been obliged to make his own method a part of every claim in which the needle was an element, his patent would have been practically worthless."[28]

The *Gillette* case illustrates that a patent's specification need not point out precisely how to make every device[29] that would fall within its claims. Disclosure of an inventive concept or principle, whose precise contours are defined by the claims, is enough.[30]

The infamous Selden patent episode shows the difficulty of cabining a claimed invention.[31] The Selden patent on an automobile design had as its key claim the use of a light, gasoline-powered internal combustion engine.[32] The claim was quite general, failing to specify many

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26. 187 F. at 156.

27. Id. at 149.

28. 194 F. at 423 (citations omitted) (quoting Deering v. Winona Harvester Works, 155 U.S. 286, 302 (1894)).

29. As we use the term in this article, "device" means a product, process or compound.

30. It is important to distinguish our use of the term "principle" here from its use in other contexts. We mean "principle" in the narrow sense of an underlying characteristic that gives a family of devices an identifiable quality. We do not mean a scientific or natural principle, i.e., a broadly applicable law such as gravity or magnetism, which cannot be patented. See supra note 20.

31. For a further discussion of the Selden patent, see infra notes 210–218 and accompanying text.

32. George Selden received a very broad patent in 1895 on the basic elements of the early automobile—"carriage," drive mechanism (transmission) and engine—that gave him a commanding position in the burgeoning automotive field. See U.S. Patent

important details about the engine. The Patent Office allowed that claim, and district courts upheld it twice,[33] despite arguments that the broad idea was obvious, and that the engine referred to in the claim was of a particular kind not encompassing all the engines that were claimed to infringe. Eventually, the Second Circuit drastically narrowed the claim, stating that it covered only the particular kind of gasoline engine used by Selden.[34]

Another example of enablement at work is the recent patent granted to Doctors Phillip Leder and Timothy Stewart of the Harvard Medical School for their successful work involving transgenic mice. They isolated a gene which is associated with cancer in mammals (including humans) and then injected the gene into a fertilized mouse egg, which yielded transgenic mice that are extremely sensitive to carcinogens.[35] This makes the mice excellent animal "models" for studying cancer drugs. Leder and Stewart claimed not only the technique they had used, or the particular transgenic mouse variety they had created, but rather all "non-human transgenic mammals" produced by their technique. It may well turn out that their admittedly important discovery was indeed this broad.[36] On the other hand, significant work may be required to obtain similar results in higher-order mammals. One wonders whether arguments by an accused infringer that she had to do considerable experimenting and problem-solving prior to producing a transgenic dog, or that she created a transgenic cat using a substantially different technique, would be sufficient to take her invention outside the Leder and Stuart claims. In fact, the European Patent Office cited just these concerns when it rejected those claims in the Leder and Stuart patent that went beyond mice and rodents.[37]

No. 549,160, issued Nov. 5, 1895; Columbia Motor Car Co. v. C.A. Duerr & Co., 184 F. 893, 894 (2d Cir. 1911).

33. See Electric Vehicle Co. v. Winton Motor-Carriage Co., 104 F. 814, 814–16 (C.C.S.D.N.Y. 1900); Electric Vehicle Co. v. C.A. Duerr & Co., 172 F. 923 (C.C.S.D.N.Y. 1909), rev'd sub nom. Columbia Motor Car Co. v. C.A. Duerr & Co., 184 F. 893 (2d Cir. 1911).

34. *Columbia Motor Car Co.*, 184 F. at 908–09.

35. See U.S. Patent No. 4,736,866, supra note 8.

36. See Bozicevic, The "Reverse Doctrine of Equivalents" in the World of Reverse Transcriptase, 71 J. Pat. & Trademark Off. Soc'y 353, 358 (1989). This was the first U.S. patent on a recombinant animal and it promises greatly to assist cancer researchers in their efforts to find effective human therapies without subjecting humans to early tests.

37. In re President and Fellows of Harvard College (European Patent Office July 14, 1989), reported in 20 Int'l Rev. Indus. Prop. & Copyright L. 889, 895–96 (1989) ("Onco-Mouse" case) (decision not final):

> The invention as disclosed in its broadest concept . . . relates to *any* oncogene and *any* conceivable mammalian animal. [The European Patent Code] relates to sufficiency [of disclosure] and it is important to note that this article is satisfied only if substantially any embodiment of the invention as defined in its broadest claim is capable of being realised on the basis of the disclosure.
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> It is thus not believable that the skilled man would be able to transfer suc-

It is difficult to resolve issues like these when a patent is filed; at that point, no one knows what future developments will follow or how difficult it will be to achieve them. Thus, there is an argument for granting a broad set of claims for pioneering inventions. Since the inventor may have enabled a broad new range of applications, courts reason, it is unfair to limit her to the precise embodiment through which she discovered the broader principle claimed.[38] As one opinion put it,

> To restrict [a patentee] to the . . . form disclosed . . . would be a poor way to stimulate invention, and particularly to encourage its early disclosure. To demand such restriction is merely to state a policy against broad protection for pioneer inventions, a policy both shortsighted and unsound from the standpoint of promoting progress in the useful arts, the constitutional purpose of the patent laws.[39]

But surely one can go too far. Although as a general rule, a patentee should be able to claim beyond her precise disclosure, current practice seems to permit a range of claims that may stretch beyond the spirit of the enablement doctrine. If the patent examiner can point to something in the prior art that indicates that some embodiments of the claimed invention will be impossible to make without more information than the inventor has disclosed, then the application may be rejected. But if the examiner cannot point to such an indication in the prior art, patent office policy dictates that even very broad claims may be allowed.[40] This means that claims to pioneer inventions often are allowed to cover ground that examiners *believe*, but cannot prove, is well

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cessfully the specific teachings of the present application to all kinds of mammalian animals . . . without applying inventive skill or undue experimentation. Animals which have been used in the prior art are mainly mice and no instructions are to be found in the specification as to how success could be achieved with other mammalian animals.

38. See, e.g., In re Hogan, 559 F.2d 595, 606, 194 U.S.P.Q. (BNA) 527, 537 (C.C.P.A. 1977); In re Goffe, 542 F.2d 564, 567, 191 U.S.P.Q. (BNA) 429, 431 (C.C.P.A. 1976).

39. *Hogan*, 559 F.2d at 606, 194 U.S.P.Q. at 537.

40. Enablement must be established only as of the date the inventor filed for her patent. *Hogan*, 559 F.2d at 607, 194 U.S.P.Q. at 538. An inventor can properly claim subject matter that later turns out to be beyond her actual research, so long as her research enables one skilled in the art to make and use her claimed invention *as that invention was understood as of the filing date*. For example, consider an inventor who claims "crystalline polypropylene," and provides an enabling disclosure to make what everyone in the art would agree was "crystalline polypropylene" as of the filing date. After the filing date, another researcher invents a radically new family of catalysts which for the first time make possible the production of polypropylene of high molecular weight and intrinsic viscosity— two properties that make the fiber commercially useful. It has been held that the inventor's original disclosure is sufficient to sustain a patent since it was enabling as of the filing date. The result is that the inventor's claims cover the later-developed, commercially useful form of the fiber. Phillips Petroleum Co. v. United States Steel Corp., 673 F. Supp. 1278, 1286, 1292, 6 U.S.P.Q.2d (BNA) 1065, 1068, 1074 (D. Del. 1987), aff'd, 865 F.2d 1247, 9 U.S.P.Q.2d (BNA) 1461 (Fed. Cir. 1989).

beyond the area actually explored and disclosed by the inventor.[41] The rule puts the burden of *disproving* enablement on the examiner. The rationale is that any other rule would leave claim scope too much in the hands of individual examiners and their technological forecasting abilities.[42] Narrowing is left to the courts in particular infringement suits.

As we have seen, it is often very difficult to determine whether a patentee has enabled others to make and use all the devices that fall within the claims. One approach that has evolved to help make this determination focuses on the doctrine of "undue experimentation." Under this doctrine, an alleged infringer can argue noninfringement by showing that extensive experimentation beyond what was disclosed in the patentee's specification was required to make the allegedly infringing embodiment. We now turn to some examples of the doctrine at work.

In 1895, Thomas Edison brought a Supreme Court challenge to a very broad patent held by Sawyer and Mann for materials used in light bulb filaments.[43] The patentees had found that carbonized paper worked as an effective light-emitting conductor in light bulbs. Based on this invention, they filed a patent claiming the right to use all carbonized fibrous or textile material as an incandescing conductor.[44] Edison challenged Sawyer and Mann, contending that the claim was too broad: it did not indicate which of the thousands of "fibrous or textile material[s]" would work as conductors in light bulbs, since most do not. Nor did it describe any method for finding out. In effect Edison argued that all Sawyer and Mann had invented was a carbonized paper

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Note that the radically new catalysts here were the famous Ziegler catalysts. See infra notes 288–293 and accompanying text.

In cases where the subsequent modifications are minor, this approach is unobjectionable. But where the subsequent modifications are very substantial, as (arguably) in the case of polypropylene, the enablement doctrine seems to be stretched beyond credibility.

It has been argued by at least one court that the proper place to take account of this concern is at the infringement stage, when the accused infringer can argue that her invention required substantial additional research over that described in the patentee's specification, and therefore is noninfringing under the reverse doctrine of equivalents. See *Hogan*, 559 F.2d at 607, 194 U.S.P.Q. at 538; Texas Instruments v. United States Int'l Trade Comm'n, 846 F.2d 1369, 1372, 6 U.S.P.Q.2d (BNA) 1886, 1889 (Fed. Cir. 1988). However, as described infra at note 113 and accompanying text, this solution has little appeal because the reverse doctrine of equivalents is very rarely used.

41. See In re Armbruster, 512 F.2d 676, 680, 185 U.S.P.Q. (BNA) 152, 155 (C.C.P.A. 1975); In re Geerdes, 491 F.2d 1260, 1265, 180 U.S.P.Q. (BNA) 789, 793 (C.C.P.A. 1974).

42. See Winner, Enablement in Rapidly Developing Arts— Biotechnology, 70 J. Pat. & Trademark Off. Soc'y, 608, 619–23 (1988). The author of this article summarizes the somewhat conflicting cases on the topic, and concludes that "[t]o reject claims for lack of enablement of embodiments that were only imagined hy the examiner does not seem fair." Id. at 622.

43. The Incandescent Lamp Patent, 159 U.S. 465 (1895).

44. Id. at 468.

conductor for use in a light bulb, not a broad class of materials. Edison pointed to his own painstaking experimentation with a wide variety of materials, arguing that his discovery that a particular part of a variety of bamboo plant performed well as a filament was not made any easier by Sawyer & Mann's disclosure. The Court agreed, stating that "[i]f the description be so vague and uncertain that no one can tell, except by independent experiments, how to construct the patented device, the patent is void."[45] The patent would have been upheld, the Court suggested, if it had claimed only what Sawyer and Mann had actually invented (carbonized paper incandescence); it was invalid, however, since it would take a good deal of additional experimentation to determine whether incandescing conductors could be made out of the many materials they claimed.[46]

In an earlier case, *O'Reilly v. Morse*,[47] the Supreme Court considered a similar issue. The case involved a challenge to the scope of a claim in Samuel Morse's famous telegraphy patent. Morse claimed "the use of the motive power of the electric or galvanic current, which I call electro-magnetism, however developed for marking or printing intelligible characters . . . at any distance[]."[48] In essence, Morse declared ownership of all methods of communicating at a distance using electromagnetic waves. But since he had not actually disclosed "all methods" in his specification, much less even imagined them, the Court

45. Id. at 474. Conceptually, this is closely related to another enablement doctrine, which states that patent claims covering a large number of "inoperable species"—i.e., embodiments of the invention that do not work—are invalid unless the specification teaches, or skilled artisans can be presumed to know, how to distinguish the embodiments that work from those that do not. See, e.g., In re Cavallito, 282 F.2d 357, 361, 127 U.S.P.Q. (BNA) 202, 205 (C.C.P.A. 1960) (claims covering generic class of several hundred thousand possible compounds invalid because the applicant had identified only thirty specific operative compounds); see also 2 D. Chisum, Patents § 7.03[7][c] (1990) ("claim will be rejected if it is so broad as to read upon inoperative as well as operative snbject matter").

46. There is some indication that contemporary cases apply a looser standard in upholding the validity of patents over nndue experimentation objections. For example, in In re Wands, 858 F.2d 731, 8 U.S.P.Q.2d 1400 (Fed. Cir. 1988), the court found enablement in a biotechnology case although any potential user of the invention would need to screen many potentially useful monoclonal antibodies for their actual utility. The conrt indicated in dictum that even if the applicants' disclosed screening method had yielded a success rate of only 4 working antibodies out of 143 candidates, it would not necessarily have concluded that undue experimentation was required. Id. at 740, 8 U.S.P.Q.2d at 1406–07; see also Ex parte Jackson, 217 U.S.P.Q. (BNA) 804, 806 (Pat. Off. Bd. App. 1982) (reversing rejection of claim to three specified strains of antibiotic-producing bacterium "and mutations thereof" since "mutations can be intentionally produced [and presumably tested for efficacy] by a variety of known procedures"). A commentator recently suggested that the Board in *Jackson* would only require enabling screening procedures to indicate that "at least *some* such mutants would have the desired characteristic of producing the antibiotic." Lentz, Adequacy of Disclosures of Biotechnology Inventions, 16 Am. Intell. Prop. L.A.Q.J. 314, 324 (1989) (emphasis added).

47. 56 U.S. (15 How.) 62 (1854).

48. Id. at 112.

ruled the claim invalid.[49] As with the light bulb case, the patentee's disclosure was found to be nonenabling.

We turu now to a more specialized scope issue, the patenting of natural products. Although this issue has arisen before in chemical patents,[50] it is of increasing importance because many biotechnology companies are using bacteria and other expression "vehicles" to produce purified versions of naturally-occurring proteins.[51] These patents typically claim purified versions of products that exist in nature. In these cases, it can be argued that it is stretching the concept of inventing greatly to say that the patentee really invented the products. The true invention seems to be a way of producing those products in a desirable form. But because a product claim is typically broader than one simply on a particular way of making that product, patentees seek—and often obtain—product patents.[52] Thus the product versus process patent is-

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49. Id. at 119–20:

> [I]f the eighth claim of the patentee can be maintained, there was no necessity for any specification, further than to say that he had discovered that, by using the motive power of electro-magnetism, he could print intelligible characters at any distance. . . . [T]his claim can derive no aid from the specification filed. It is outside of [the specification], and the patentee claims beyond it.

50. See, e.g., Parke-Davis & Co. v. H.K. Mulford Co., 189 F. 95 (C.C.S.D.N.Y. 1911) (L. Hand, J.) (upholding patent on purified form of adrenalin), aff'd in part and rev'd in part, 196 F. 496 (2d Cir. 1912).

51. See, e.g., Genentech, Inc.'s Patent, [1987] R.P.C. 553, 596 (Pats. Ct.), aff'd, [1989] R.P.C. 613 (Ct. App.) (patent on tissue plasminogen activator (t-PA) protein); see also Mellor, Patents and Genetic Engineering—Is It a New Problem?, 10 Eur. Intell. Prop. Rev. 159 (1988) (describing British t-PA litigation). Further examples include erythropoietin (EPO), see Amgen, Inc. v. Chugai Pharmaceutical Co., 706 F. Supp. 94, 95, 9 U.S.P.Q.2d (BNA) 1833, 1833 (D. Mass. 1989), and the blood clotting protein Factor VIII, see Scripps Clinic & Research Found. v. Genentech, Inc., 666 F. Supp. 1379, 1382, 3 U.S.P.Q.2d (BNA) 1481, 1482 (N.D. Cal. 1987), patent invalidated in Scripps Clinic & Research Found. v. Genentech, Inc., 707 F. Supp. 1547, 11 U.S.P.Q.2d 1187 (N.D. Cal. 1989).

52. In some cases a process patent can be broader than a product patent. For example, a patentee might claim a process for making products A through E; this would be broader, in some sense, than a product patent on product A only. Even here, however, the product patent has advantages, due to the patent principle that a product patent covers a product no matter how it is made. See *Amgen*, 706 F. Supp. at 107, 9 U.S.P.Q.2d at 1844. Perhaps if patent scope were more effectively circumscribed by the enablement doctrine, in many of these cases process patents would be granted rather than product patents. Consider the situation where an inventor comes up with a significantly better process for making a chemical product, but the inventor of the earlier process holds a product patent. One might think that an Edison-like argument that the disclosure of the earlier product patent was no help whatsoever towards the discovery of the new process might carry weight, but in the case of chemical patents it often has not. This doctrine is now taking root in the related field of biotechnology patents, where a product produced by Genentech using recombinant DNA technology was recently found to infringe a patent covering the product, even though the recombinant version of the product was much simpler and cheaper to prepare. See also id. at 110, 9 U.S.P.Q.2d at 1846–47 (product patent on erythropoietin covers recombinantly-produced version of the protein).

sue in chemical and biological technologies is an interesting variation on the patent scope issue.

A related question concerns what is patentable when a new use is discovered for a known, patented product, an event relatively common in chemical products. *Dawson Chemical Co. v. Rohm & Haas Co.*,[53] a Supreme Court case, involved a patent for a new application of propanil, a chemical that had earlier been held to be unpatentable over the prior art.[54] The patentee claimed a process for using the chemical as a fungicide, a use that had not been previously known.[55] The case thus illustrates how process patents can be used to protect a newly discovered use for a known compound. It encourages patent applicants to draft claims in the form "the process of applying Old Product X to New Application Y," and thereby protect their discovery—a new application—in spite of the fact that their application exploits a well-known compound which is not itself patentable.[56]

It is difficult to summarize the content of the disparate doctrines that ensure adequate disclosure. As our brief review illustrates, the factual diversity of cases involving disclosure issues leads to generalized standards that must be applied to a wide array of specific technologies. As a result, courts have a large amount of discretion in applying the doctrines. While one might note with caution certain trends in recent allowed patents,[57] our primary point is not to critique doctrine, but to point out that this discretion exists. After describing the effects of patent breadth on technical advance in Part III, we will suggest ways that courts can use this discretion in certain cases to increase the overall benefits of the patent system.

C. *Infringement Doctrines*

Doctrines relating to enablement have provided a way of determining the appropriate scope of claims. But claims inevitably leave room for interpretation. Even when a claim is not disputed, it is not always clear on its face whether an allegedly infringing device falls within the claim. Further, in many cases an allegedly infringing device may lie

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53. 448 U.S. 176, 206 U.S.P.Q. (BNA) 385 (1980).

54. Monsanto Co. v. Rohm & Haas Co., 312 F. Supp. 778, 164 U.S.P.Q. (BNA) 556 (E.D. Pa. 1970), aff'd, 456 F.2d 592, 172 U.S.P.Q. (BNA) 323 (3d Cir.), cert. denied, 407 U.S. 934, 174 U.S.P.Q. (BNA) 129 (1972).

55. Cf. 1 D. Chisum, supra note 45, § 1.03[8][c] (new use must be nonobvious).

56. Note that even after *Dawson Chem. Co. v. Rohm & Haas*, a "new use" process patent would still infringe a prior product patent if the process employs the patented product. If the holder of the product patent wished to practice the new use, she would also have to take out a license. See infra notes 97—100 and accompanying text.

57. See Lentz, supra note 46, at 318:

> Claims to biotechnology inventions seem uncommonly broad in comparison to typical chemical cases and, therefore, seem especially vulnerable to attack under 35 U.S.C. 112 . . . .

outside the literal scope of the claims, yet a court will find that it falls so close to this scope as to be justly included as an equivalent.

1. *Literal Infringement and the Interpretation of Equivalents.* — Courts analyze infringement in two steps. First, they ask whether the challenger's product falls squarely within the boundaries of the patentee's claims—that is, whether there is "literal infringement" of the patent.[58] If the court determines that there is no literal infringement it moves on to the second question: whether the challenger infringes under the "doctrine of equivalents." The doctrine of equivalents developed because of the frequency of cases where, even though the accused product or process does not literally infringe a claim, it may be considered essentially the same device as was patented. Of the many articulations of the doctrine of equivalents, Judge Learned Hand's captures it the best:

> [A]fter all aids to interpretation have been exhausted, and the scope of the claims has been enlarged as far as the words can be stretched, on proper occasions courts make them cover more than their meaning will bear.[59]

What is such a "proper occasion"? The Supreme Court wrote in 1950, quoting from an earlier case:

> [I]f two devices do the same work in substantially the same way, and accomplish substantially the same result, they are the same, even though they differ in name, form, or shape.[60]

A good application of the doctrine of equivalents is *International Nickel Co. v. Ford Motor Co.*[61] International Nickel obtained a patent that "cover[ed] a cast ferrous alloy" called "nodular iron."[62] The patent taught the addition to molten iron of a " 'small but effective' " quantity of magnesium, fixed by the patent as "about 0.04%" as a minimum.[63] The magnesium caused "the graphite (crystallized form of carbon) to occur in spheroidal rather than flake form thereby producing a product with vastly improved physical properties."[64] International Nickel accused Ford Motor Company of infringement when Ford began making a nodular iron. Even though Ford's iron contained under 0.02% magnesium—less than half the minimum required in International Nickel's

58. See, e.g., United States v. Telectronics, Inc., 857 F.2d 778, 781, 8 U.S.P.Q.2d (BNA) 1217, 1219–20 (Fed. Cir. 1988) (finding literal infringement), cert. denied, 109 S. Ct. 1954 (1989); SRI Int'l v. Matsushita Elec. Corp. of Am., 775 F.2d 1107, 1118, 227 U.S.P.Q. (BNA) 577, 583 (Fed. Cir. 1985) (en banc) (stating that courts will find literal infringement when the accused invention "reads directly, unequivocally, and word-for-word on [the claimed] structure").

59. Royal Typewriter Co. v. Remington Rand, Inc., 168 F.2d 691, 692, 77 U.S.P.Q. (BNA) 517, 518 (2d Cir.), cert. denied, 335 U.S. 825, 79 U.S.P.Q. (BNA) 454 (1948).

60. Graver Tank & Mfg. Co. v. Linde Air Prods. Co., 339 U.S. 605, 608, 85 U.S.P.Q. (BNA) 328, 330 (1950) (quoting Machine Co. v. Murphy, 97 U.S. 120 (1877)).

61. 166 F. Supp. 551, 119 U.S.P.Q. (BNA) 72 (S.D.N.Y. 1958).

62. Id. at 552, 119 U.S.P.Q. at 74.

63. Id. at 555, 119 U.S.P.Q. at 77.

64. Id. at 554, 119 U.S.P.Q. at 75.

patent—it was judged to be an equivalent substance, and thus to infringe the patent.[65]

Courts have determined how broadly they see "equivalents" based on the degree of advance over the art the original patent represents. When the patent is on a "mere improvement" the courts tend not to consider as "equivalent" a product or process that is even a modest distance beyond the literal terms of the claims.[66] On the other hand, a patent representing a "pioneer invention"—which the Supreme Court has defined as "a patent covering a function never before performed, a wholly novel device, or one of such novelty and importance as to mark a distinct step in the progress of the art"[67]—is "entitled to a broad range of equivalents."[68] That is, when a pioneer patent is involved, a court will stretch to find infringement even by a product whose characteristics lie considerably outside the boundaries of the literal claims.[69]

Of course the question of infringement also turns on the precise characteristics of the allegedly infringing device. Following the test laid down by the Supreme Court in *Graver Tank*,[70] courts confronted with a

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65. Id. at 564, 119 U.S.P.Q. at 83. On the other band, Ford might bave been able to obtain a patent on its improvement of the basic International Nickel invention. If Ford could establish that its nodular iron composition met the requirement of patentability—i.e., utility, novelty, and nonobviousness— it would then have the right to control this improvement. Cantrell v. Wallick, 117 U.S. 689, 694 (1886). International Nickel would have had to obtain a license from Ford to use this improvement, even though it held the basic or dominant nodular iron patent. And of course Ford could not use its improvement without a license from International Nickel. This is an example of so-called "blocking patents," a situation often resolved by a cross-licensing agreement. For a discussion of improvement patents, see infra notes 96–98 and accompanying text.

66. See Brill v. Wasbington Ry. & Elec. Co., 215 U.S. 527, 532–33 (1910); Kinzenbaw v. Deere & Co., 741 F.2d 383, 388–89, 222 U.S.P.Q. (BNA) 929, 932–33 (Fed. Cir. 1984), cert. denied, 470 U.S. 1004 (1985).

67. Westinghouse v. Boyden Power Brake Co., 170 U.S. 537, 561–62 (1898). Another test of pioneer status is whether the patent led to a new branch of industry. See, e.g., Ludlum Steel Co. v. Terry, 37 F.2d 153, 160 (N.D.N.Y. 1928).

68. 4 D. Chisum, supra note 45, § 18.04[2]. Inventions falling somewhere between the two extremes are given an intermediate range of equivalents. See Price v. Lake Sales Supply R.M., 510 F.2d 388, 394, 183 U.S.P.Q. (BNA) 519, 524 (10th Cir. 1974). In addition to the broad range of equivalents awarded a pioneer patent, the literal wording of its claims will likely be broad as well, since by definition there is little prior art. See Patent and Trademark Office, U.S. Dept. of Commerce, Manual of Patent Examining Procedure § 706.03(d) (5th ed. 1983 rev. 1989) ("The fact that a claim is broad does not necessarily justify a rejection on the ground that the claim is vague and indefinite or incomplete. In non-chemical cases, a claim may, in general, be drawn as broadly as permitted by the prior art."). The need for a slightly more restrictive rnle in chemical cases is justified on the grounds that the chemical arts are more unpredictable. See id. at §§ 706.03(a), 706.03(2); Levin, Broader than the Disclosure in Chemical Cases, 31 J. Pat. & Trademark Off. Soc'y, 5, 7 (1949).

69. The patent in the *International Nickel* case was in this category. International Nickel Co. v. Ford Motor Co., 166 F. Supp. 551, 564, 119 U.S.P.Q. (BNA) 72, 82–83 (S.D.N.Y. 1958).

70. Graver Tank & Mfg. Co. v. Linde Air Prods. Co., 339 U.S. 605, 85 U.S.P.Q. (BNA) 328 (1950).

device accused of infringing inquire whether it performs the same function and achieves the same result as the invention in the claims, and whether it does so in the same way. Where the accused device shows only minor or "insubstantial"[71] variations in one of these elements—such as the small movement of one part or a minor change in structure—infringement will be found even if the patentee's invention is a "mere improvement."[72] And even a pioneer patent is not infringed by a device that achieves a different result, or achieves it in a different way.[73]

One important set of cases under this doctrine has grappled with the question of whether new technologies, unforeseen at the time the patent was issued, can constitute equivalents. This issue arises when a subsequent device that uses new technology is accused of infringing the original patent. The early cases were split, but the prevailing view now is that new technology can be equivalent.[74] This is true despite the statement in *Graver Tank* that an important determinant in the equivalents inquiry is whether "persons reasonably skilled in the art would have known of the interchangeability of an ingredient not con-

71. This language comes from the *Graver Tank* case itself, see 339 U.S. at 610, 85 U.S.P.Q. at 331, and the Federal Circuit has continued to use it in some cases. See Perkin-Elmer Corp. v. Westinghouse Elec. Corp., 822 F.2d 1528, 1532, 3 U.S.P.Q.2d (BNA) 1321, 1324 (Fed. Cir. 1987) (equivalents cannot be used to encompass more than an "insubstantial change"); Carman Indus. v. Wahl, 724 F.2d 932, 942, 220 U.S.P.Q. (BNA) 481, 488 (Fed. Cir. 1983) (same as to "minor modification").

72. See, e.g., Tigrett Indus. v. Standard Indus., 162 U.S.P.Q. (BNA) 32, 36 (W.D. Tenn. 1967), aff'd, 411 F.2d 1218, 162 U.S.P.Q. (BNA) 13 (6th Cir. 1969), aff'd, 397 U.S. 586 (1970) (by equally divided court) (claim for playpen calling for "a pair of spaced openings" for two converging drawstrings to adjust side webbing infringed by device with only one hole for drawstrings); Weidman Metal Masters Co. v. Glass Master Corp., 623 F.2d 1024, 1030, 207 U.S.P.Q. (BNA) 101, 106 (5th Cir. 1980) ("even the minimum equivalency due to any patent normally forbids the mere reversal of a function of two parts and the small movement of one part to avoid literal infringement by accepting a less efficient job"), cert. denied, 450 U.S. 982, 211 U.S.P.Q. (BNA) 400 (1981).

73. See, e.g., Mead Digital Sys. v. A.B. Dick Co., 723 F.2d 455, 464, 221 U.S.P.Q. (BNA) 1035, 1042 (6th Cir. 1983) (finding that ink-jet printer patent, though a "quantum leap" in the art, was not infringed by device which used elements "in a substantially different way to achieve a substantially different result").

74. Compare Gould v. Rees, 82 U.S. (15 Wall.) 187, 194 (1872) (no infringement where accused infringer "substitutes another [ingredient] in the place of the one omitted, which is new or which performs a substantially different function, or [which] is old, but was not known at the date of the plaintiff's invention as a proper substitute") with Texas Instruments, Inc. v. United States Int'l Trade Comm'n, 805 F.2d 1558, 1563, 231 U.S.P.Q. (BNA) 833, 835 (Fed. Cir. 1986) ("It is not required that those skilled in the art knew, at the time the patent application was filed, of the asserted equivalent means of performing the claimed functions; that equivalence is determined as of the time infringement takes place.") and Pennwalt Corp. v. Durand-Wayland, Inc., 833 F.2d 931, 941–42 n.4, 4 U.S.P.Q.2d (BNA) 1737, 1745 n.4 (Fed. Cir. 1987) (en banc) ("It is clear that an equivalent can be found in technology known at the time of the invention, as well as in subsequently developed technology.") (Bennett, J., dissenting), cert. denied, 485 U.S. 961 (1988) and 485 U.S. 1009 (1988).

tained in the patent with one that was."[75] Despite this language in the leading Supreme Court case on the subject, a device performing the same function and achieving the same result in the same way as a patented invention can be found to infringe even if it uses technology developed after the patent was issued. But this observation is subject to two caveats: 1) new technologies can constitute equivalents only so long as they do not perform a different function[76] or cause the device to operate in a substantially different way;[77] and 2) a truly meritorious improvement can escape even *literal* infringement under the "reverse" doctrine of equivalents discussed below.

That these distinctions may not always be easy to make is demonstrated by the case of *Hughes Aircraft Co. v. United States*.[78] Hughes Aircraft had a patent, developed by an employee named Williams, on a means of controlling the attitude of a communications satellite. The claims called for receiving and directly executing control siguals from a ground station on earth. After the patent was issued, advances in semiconductor technologies permitted satellites to use on-board microprocessors to process and execute control signals without communicating with the ground. "Advanced computers and digital communications techniques developed since [the] Williams [patent]," said the Federal Circuit, "permit doing on-board a *part* of what Williams

75. 339 U.S. at 609, 85 U.S.P.Q. at 331. See Great N. Corp. v. Davis Core & Pad Co., 782 F.2d 159, 165, 228 U.S.P.Q. (BNA) 356, 359 (Fed. Cir. 1986) (examining "the scope and content of the prior art [and] the ordinary level of skill in the art [to determine if] . . . the patentee's product may be treated as an equivalent of what is claimed"); Thomas & Betts Corp. v. Litton Sys., 720 F.2d 1572, 1579, 220 U.S.P.Q. (BNA) 1, 6 (Fed. Cir. 1983) (noting that "the test of equivalency extends beyond what is literally stated in a patentee's specification to be equivalent and encompasses *any* element which one of ordinary skill in the art would perceive as interchangeable with the claimed element"). But see Adelman & Francione, The Doctrine of Equivalents in Patent Law: Questions that *Pennwalt* Did Not Answer, 137 U. Pa. L. Rev. 673, 696 n.103, 697 (1989) (arguing that interchangeability "should be used to reject rather than support the application of the doctrine of equivalents" because it signifies that a patentee could have, but mistakenly or intentionally did not, include this interchangeability in her original claims).

76. See *Pennwalt*, 833 F.2d at 938–39, 4 U.S.P.Q.2d at 1742–43 ("[T]he facts here do not involve later-developed computer technology which should be deemed within the scope of the claims to avoid the pirating of an invention. . . . [T]he memory components of the [accused] sorter were not programmed to perform the same or an equivalent function of physically tracking the items to be sorted . . . as required by the claims.").

77. Cf. *Mead Digital Sys.*, 723 F.2d at 464, 221 U.S.P.Q. at 1042 (finding noninfringement under doctrine of equivalents because accused ink-jet printer used a technique for electrically charging and deflecting ink that differed from the patentee's technique). Perhaps the "different way" element of the conventional equivalents test is simply another way of stating the Supreme Court's "interchangeability" test from *Graver Tank*. See note supra 75 and accompanying text. If so, the "new technology" equivalents cases are not necessarily irreconcilable with *Graver Tank*; they simply couch their inquiry in terms of "same way," rather than "interchangeability."

78. 717 F.2d 1351, 219 U.S.P.Q. (BNA) 473 (Fed. Cir. 1983).

taught as done on the ground."[79] The Court concluded: "[P]artial variation in technique, an embellishment made possible by post-Williams technology, does not allow the accused spacecraft to escape the 'web of infringement.' "[80] Another case found a patented method for laying pipe, calling for a beam of light to align pipe segments, infringed by the use of later-developed laser beam technology.[81]

One should note that these decisions, while we discuss them here under equivalents doctrine, come into conflict with the enablement principles discussed earlier.[82] If one adheres to the doctrine that limits claims to what is enabled by the disclosure, one would think that the doctrine of equivalents would distinguish between allegedly infringing devices that used "new technologies" basically to get around the claims from those that used the technologies to do something significantly better. In some cases, this distinction does not seem to have been made.

A recent case involving Texas Instruments' pioneering patent on the hand-held calculator shows the court applying the doctrine of equivalents in a way more consistent with the principles of enablement.[83] The Federal Circuit held that major improvements in all the essential elements of hand-held calculators rendered the improved de-

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79. Id. at 1365, 219 U.S.P.Q. at 483.

80. Id. at 1365, 219 U.S.P.Q. at 483 (quoting Bendix Corp. v. United States, 600 F.2d 1364, 1382, 204 U.S.P.Q. (BNA) 617, 631 (Ct. Cl. 1979)). One commentator criticized the opinion by Judge Markey in *Hughes*, stating that it was "a curious inversion of the patentee's burden of proving infringement . . . [to say] that the burden was on the infringer to explain why his structure was not an equivalent of the claimed satellite system," and concluding that "the *Hughes* approach would create an unfortunate aura of uncertainty around the scope of claims issued by the [Patent Office]." See Noonan, supra note 2, at 733.

81. Laser Alignment, Inc. v. Woodruff & Sons, 491 F.2d 866, 873–74, 180 U.S.P.Q. (BNA) 609, 613 (7th Cir.), cert. denied, 419 U.S. 874, 183 U.S.P.Q. (BNA) 321 (1974). One older case with a similar holding is Edison Elec. Light Co. v. Boston Incandescent Lamp Co., 62 F. 397 (C.C.D. Mass. 1894). Here the court found that since Edison's patent was for a pioneering invention, it was entitled to a broad construction, which included finding that after-developed technology was equivalent to that specified in the claims. Id. at 398; see also 4 D. Chisum, supra note 45, § 18.04[3] (discussing *Laser Alignment* and other cases involving new or unknown equivalents). Note that in each of these cases the after-developed technology might have been eligible for improvement patent. As mentioned earlier, this does not change the infringement analysis. But it could have given the accused infringer some leverage in bargaining with the holder of the underlying patent. See infra note 99 and accompanying text.

82. See In re Hogan, 559 F.2d 595, 606–07, 194 U.S.P.Q. (BNA) 527, 538–39 (C.C.P.A. 1977) (discussing relationship between enablement and infringement). But cf. Adelman & Francione, supra note 75, at 715–29 (suggesting that the doctrine of equivalents should not be applied when a patentee could have claimed known equivalents but did not, and asserting that the doctrine should be available *only* when a new technology is used to supply an equivalent component of a patented device).

83. Texas Instruments, Inc. v. United States Int'l Trade Comm'n, 805 F.2d 1558, 231 U.S.P.Q. (BNA) 833 (Fed. Cir. 1986).

vices noninfringing.[84] The specification supporting Texas Instruments' pioneer patent, for instance, described the use of integrated circuits containing bipolar transistors.[85] All of the improvements used integrated circuits having metal oxide semiconductor (MOS) transistors.[86]

There were other improvements in the calculators as well. The improved calculators receive input via a device that scans the "matrix" under the keyboard at frequent intervals, whereas the original design had a conductive strip underneath the keypad. This is an example of an improvement that *reduced the number of components* in the invention.[87]

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84. Id. at 1570, 231 U.S.P.Q. at 840:

> It is not appropriate in this case, where all of the claimed functions are performed in the accused devices by subsequently developed or improved means, to view each such change as if it were the only change from the disclosed embodiments of the invention. It is the entirety of the technology embodied in the accused devices that must be compared with the patent disclosure.

This "invention as a whole" standard was repudiated by an en banc decision of the same court the next year calling for an "element-by-element" comparison. Pennwalt Corp. v. Durand-Wayland, Inc., 833 F.2d 931, 936, 4 U.S.P.Q.2d (BNA) 1737, 1741 (Fed. Cir. 1987) (en banc) ("[I]f . . . even a single function required by a claim or an equivalent function is not performed by [an accused device], . . . [a] finding of no infringement must be upheld."), cert. denied, 485 U.S. 961 (1988) and 485 U.S. 1009 (1988). Judge Pauline Newman, who wrote the *Texas Instruments* opinion, dissented along with five of twelve judges and wrote separately: "One-to-one correspondence between every element of a claim and an accused device is the standard formula for inquiry into literal infringement. But this formula is an incorrect application of the doctrine of equivalents . . . ." In fact, she wrote, "the courts have avoided subjecting themselves to rigid rules, for the great variety of technological situations are not amenable to all-encompassing rules." Id. at 957, 963, 4 U.S.P.Q.2d at 1757, 1762 (Newman, J., Commentary). Perhaps this point sunk in; in a later opinion, the Federal Circuit seemed to soften its definition of "element" to allow more flexibility. See Corning Glass Works v. Sumitomo Elec. U.S.A., 868 F.2d 1251, 1259, 9 U.S.P.Q.2d (BNA) 1962, 1968 (Fed. Cir. 1989) ("In the All Elements rule, 'element' is used in the sense of a *limitation* of a claim. . . . [Defendant's] analysis is faulty in that it would require equivalency in components . . . . However, the determination of equivalency is not subject to such a rigid formula.").

85. 805 F.2d at 1566, 231 U.S.P.Q. at 837. The specification referred only to bipolar transistor semiconductors, but did not explicitly limit the invention to use with them.

86. One of the original inventors, Jack Kilby, argued that MOS technology was still unreliable when the patent application was filed and Texas Instruments argued that both types of transistors perform essentially the same function. Id. at 1566–67, 231 U.S.P.Q. at 837–38. The MOS process had been around since 1962, however, when it was discovered by Fairchild Semiconductor, Inc. See J. Tilton, International Diffusion of Technology: The Case of Semiconductors 16 (1971). In any event, very few firms in 1967, the year Texas Instruments filed its patent application, foresaw the rapid rise of MOS technology and its eventual application in industry sectors such as hand-held calculators. These are the very kinds of improvements that should be encouraged, not blocked by an overly broad pioneer patent. Cf. Levin, The Semiconductor Industry, *in* Government and Technical Progress: A Cross-Industry Analysis 9, 13, 46 (R. Nelson ed. 1982) (emphasizing advantages of MOS technology for certain applications).

87. The engineer who made the pioneering invention at issue in the case testified at the trial that "[a]s the cost of logic was reduced, it became economically desirable to reduce the interconnections required for the chip at the expense of increased logic. The

Also, the original Texas Instruments display was shown in its specification as a small thermal printer that printed dots on a tape in response to output signals from the processor. The accused devices all used liquid crystal displays (LCDs), the familiar black-on-gray display that does not produce a paper copy, an example of an improvement that *increases the efficiency of an individual component*.[88] Finally, the internal processing elements of the original calculator were manufactured as discrete components that were electrically interconnected in the final design. The newer calculators, in contrast, had all their logic on one integrated circuit, eliminating the necessity for many electrical interconnections.[89] This is an example of enhanced *overall design*.

The court concluded "that the total of the technological changes beyond what the inventors disclosed transcends . . . equitable limits . . . and propels the accused devices beyond a just scope" for the Texas Instrument patent.[90] Although the mode of analysis used in *Texas Instruments*—described as the "as a whole" test for equivalents—was apparently criticized in a subsequent en banc decision,[91] it has surfaced again in more recent cases, and so apparently still lives.[92] In any event this opinion is instructive for its focus on the merits of the accused device. As we note in the Conclusion, the opinion— especially its emphasis on changes in materials, number and simplicity of components, and increased overall efficiency— should serve as a model for applying the doctrine of equivalents.[93]

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scanning keyboard is one example of this practice . . . ." 805 F.2d at 1565, 231 U.S.P.Q. at 837.

88. Id. at 1567–68, 231 U.S.P.Q. at 838–39. In addition to the fact that the LCD displays do not require paper, they also use less power than the older thermal printer display. Id.

89. Id. at 1566, 231 U.S.P.Q. at 837.

90. Id. at 1571, 231 U.S.P.Q. at 841. Some contend that the "as a whole" test yields unpredictable results and thus creates a great deal of uncertainty. See Bretschneider, How to Craft and Interpret Means Plus Function Claims in Light of the *Pennwalt* and *Texas Instruments* Cases, 6 Am. Intell. Prop. L.A. Selected Legal Papers 68, 73 (1988) ("the degree of uncertainty created by this 'invention as a whole' test is nearly intolerable").

91. See supra note 84.

92. See Sun Studs, Inc. v. ATA Equip. Leasing, 872 F.2d 978, 989, 10 U.S.P.Q.2d (BNA) 1338, 1347 (Fed. Cir. 1989) ("An apparatus claim describing a combination of components does not require that the function of each be performed by a separate structure in the apparatus. The claimed and accused devices must be viewed and evaluated as a whole."); Coruing Glass Works v. Sumitomo Elec. U.S.A., 868 F.2d 1251, 1259, 9 U.S.P.Q.2d (BNA) 1962, 1968 (Fed. Cir. 1989) ("[T]he determination of equivalency is not subject to . . . a rigid formula. An equivalent must be found for every limitation of the claim somewhere in an accused device, but not necessarily in a corresponding component, although that is generally the case."). Compare Wilson Sporting Goods Co. v. David Geoffrey & Assocs., 14 U.S.P.Q.2d 1942 (Fed. Cir. 1990) (holding that accused product should not be held to infringe under doctrine of equivalence if a hypothetical patent claim broad enough to literally cover accused product could not have been obtained from Patent Office).

93. See infra text accompanying note 329.

There are two more limitations on the doctrine of equivalents that should be mentioned: First, just as an applicant cannot claim anything in the prior art when applying for a patent, so are the courts limited by the prior art when "stretching" claim language under the doctrine of equivalents.[94] And second, the doctrine of "prosecution history estoppel" prevents the patentee from recapturing through equivalents claimed subject matter given up during prosecution.[95]

2. *Blocking Patents and Reverse Equivalents.* — The doctrine of equivalents helps the patentee by expanding the scope of her claims beyond their literal boundaries. In a roughly symmetrical way, two similar devices are available to the accused infringer: blocking patents and the reverse doctrine of equivalents.

Two patents are said to block each other when one patentee has a broad patent on an invention and another has a narrower patent on some improved feature of that invention. The broad patent is said to "dominate" the narrower one. In such a situation, the holder of the narrower ("subservient") patent cannot practice her invention without a license from the holder of the dominant patent. At the same time, the holder of the dominant patent cannot practice the particular improved

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94. See Loctite Corp. v. Ultraseal Ltd., 781 F.2d 861, 870, 228 U.S.P.Q. (BNA) 90, 96 (Fed. Cir. 1985) ("[T]he doctrine will not extend to an infringing device within the public domain, *i.e.*, found in the prior art at the time the patent issued . . . .").

95. See Exhibit Supply Co. v. Ace Patents Corp., 315 U.S. 126, 136, 52 U.S.P.Q. (BNA) 275, 279 (1942).

Thus a court recently dismissed an infringement action where the patentee, a biotechnology company, originally claimed a recombinant process for making erythropoietin, a polypeptide that stimulates red cell production. During prosecution of the patent the examiner rejected certain claims as obvious in light of the prior art; in response, the patentee surrendered all process claims. The patentee at trial nevertheless urged the court to interpret its claims to include the rejected material to find infringement by defendant's process for producing the polypeptide. The court declined, refusing to adopt an "interpretation [that] would 'resurrect subject matter surrendered during prosecution . . . .'" Amgen, Inc. v. Chugai Pharmaceutical Co., 706 F. Supp. 94, 110, 9 U.S.P.Q.2d (BNA) 1833, 1846 (D. Mass. 1989) (quoting Thomas & Betts Corp. v. Litton Sys., 720 F.2d 1572, 1579, 220 U.S.P.Q. (BNA) 1, 6 (Fed. Cir. 1983)). The Federal Circuit has provided a useful definition of prosecution history:

> The prosecution history . . . of the patent consists of the entire record of proceedings in the Patent and Trademark Office. This includes all express representations made by or on behalf of the applicant to the examiner to induce a patent grant . . . . Such representations include amendments to the claims and arguments made to convince the examiner that the claimed invention meets the statutory requirements of novelty, utility, and nonobviousness.

Standard Oil Co. v. American Cyanamid Co., 774 F.2d 448, 452, 227 U.S.P.Q. (BNA) 293, 296 (Fed. Cir. 1985). The question of how broadly to define prosecution history is distinct from another question that has engaged the attention of the courts: whether there can be *any* equivalents left for a narrower claim when the prosecution history reveals that broader claims have been rejected. See La Bounty Mfg. v. United States Int'l Trade Comm'n, 867 F.2d 1572, 1576, 9 U.S.P.Q.2d (BNA) 1995, 1999 (Fed. Cir. 1989); Comment, Patent Claims and Prosecution History Estoppel in the Federal Circuit, 53 Mo. L. Rev. 497, 509–13, 517 (1988).

feature claimed in the narrower patent without a license.[96]

It is of course preferable for an inventor to have her own patent free and clear of anyone else's claims. An inventor therefore will not often voluntarily characterize her invention as subservient.[97] But a court may do so in the course of litigation. Where the court upholds the validity of an accused infringer's patent on some enhanced feature, but nevertheless finds that the accused product infringes a prior, broad patent, it is in effect making the accused infringer's patent subservient to the broad patent.[98]

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96. Two aspects of this situation may seem counterintuitive: that the narrower (subservient) patent could ever be issued by the Patent Office, given the existence of the broad patent in the prior art; and that once the subservient patent is issued, the holder of the dominant patent would be prevented from practicing an invention that clearly falls within the scope of her claims. Subservient patents may be issued, however, when they disclose an improved feature which meets the statutory tests of novelty and nonobviousness. See, e.g., Atlas Powder Co. v. E.I. Du Pont de Nemours & Co., 750 F.2d 1569, 1576—77, 224 U.S.P.Q. (BNA) 409, 413–14 (Fed. Cir. 1984). The fact that the subservient patentee has invented a nonobvious variant of a device covered by a broad patent does not mean that the broad patent is invalid for lack of enabling disclosure under 35 U.S.C. § 112. See, e.g., B.G. Corp. v. Walter Kidde & Co., 79 F.2d 20, 22 (2d Cir. 1935) (L. Hand, J.) ("It is true that [the inventor of the spark plug] did not foresee the particular adaptability of his plug to the airplane .... Nevertheless, he did not shoot in the dark; he laid down with perfect certainty what he wished to accomplish and how .... [H]e is not charged with a prophetic understanding of the entire field of its usefulness."); Amerace Corp. v. Ferro Corp., 532 F. Supp. 1188, 1201–02, 213 U.S.P.Q. (BNA) 1099, 1109–10 (N.D. Tex. 1982). And a subservient patent can prevent a dominant patent holder from practicing the particular improved feature claimed in the subservient patent because a patent grant is a right to *exclude*, not an affirmative right to practice an invention. See 35 U.S.C. § 154 (1988). Thus the dominant patentee can exclude the subservient patentee from practicing her invention at all, and the subservient patentee can exclude the dominant patentee from practicing her specific improved feature. See *Atlas Powder*, 750 F.2d at 1580, 224 U.S.P.Q. at 416; Ziegler v. Phillips Petroleum Co., 483 F.2d 858, 871–72, 177 U.S.P.Q. (BNA) 481, 489–90 (5th Cir.), cert. denied, 414 U.S. 1079, 180 U.S.P.Q. (BNA) 1 (1973); cf. Cantrell v. Wallick, 117 U.S. 689, 694 (1886) (Where one patent is an improvement on another patent, "neither of the two patentees can lawfully use the invention of the other without the other's consent."); Cochrane v. Deener, 94 U.S. 780, 787 (1877) ("One invention may include within it many others, and each and all may be valid at the same time.").

97. One example of patents that are so characterized is an improvement patent whose claims are drafted in a special format called "Jepson claims." See, e.g., Pentec, Inc. v. Graphic Controls Corp., 776 F.2d 309, 315, 227 U.S.P.Q. (BNA) 766, 770 (Fed. Cir. 1985); see also R. Ellis, Patent Claims § 197 (1949) (discussing Jepson format as one type of preamble portion of patent claim). Improvement patents are specifically provided for in the patent code. See 35 U.S.C. § 101. A Jepson claim has the same effect as a judicial finding that a patented invention is "dominated" by another invention. Strictly speaking only a patent drafted in Jepson format is an improvement patent. But in this article we use "improvement patent" more loosely, to describe both consciously drafted improvement claims *and* patents later found to be dominated by an earlier patent.

98. See *Ziegler*, 483 F.2d at 871, 177 U.S.P.Q. at 489; Bryan v. Sid W. Richardson, Inc., 254 F.2d 191, 117 U.S.P.Q. (BNA) 157 (5th Cir.), cert. denied, 358 U.S. 815, 119 U.S.P.Q. (BNA) 501 (1958).

Even where a court finds a patent subservient to another—thus creating blocking patents—the holder of the subservient patent is still better off than if she had never filed a patent at all, for two reasons. First, she can exclude the holder of the broad patent from practicing her improvement. Thus, although the improver may infringe the broad patent, she may gain some bargaining leverage by obtaining the subservient patent.[99] Second, because of this, she may be able to reduce the "lost profits" component of the dominant patentee's damages in an infringement action; the dominant patentee would not have replaced all the infringer's sales, presumably, because the infringer's sales were based at least in part on her improved feature.[100]

We turn now to a doctrine that can much more effectively mitigate the impact of literal infringement: the "reverse" doctrine of equivalents. Courts have long recognized that, "[c]arried to an extreme, the doctrine of equivalents could undermine the entire patent system."[101] Scope could be enlarged so far beyond the literal language of claims that patents would take on unlimited power. To check the potentially destructive impact of the doctrine and to preserve symmetry in the rules on infringement, the Supreme Court long ago ruled that

> a charge of infringement is sometimes made out, though the letter of the claims he avoided. The converse is equally true. The patentee may bring the defendant within the letter of his claims, but if the latter has so far changed the principle of the device that the claims of the patent, literally construed, have ceased to represent his actual invention, he is as little subject to be adjudged an infringer as one who has violated the letter of a statute has to be convicted, when he has done nothing in conflict with its spirit and intent.[102]

An example, drawn from the case just quoted, may help to illuminate the doctrine. In 1869 George Westinghouse invented a train

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99. There are limits to the bargaining power an improvement patent confers, however, as described infra notes 115–119 and accompanying text.

100. See Water Technologies Corp. v. Calco, Ltd., 850 F.2d 660, 672–73, 7 U.S.P.Q.2d (BNA) 1097, 1106–07 (Fed. Cir.), cert. denied, 109 S. Ct. 498 (1988); cf. Oil Well Improvements Co. v. Acme Foundry & Mach. Co., 31 F.2d 898, 901 (8th Cir. 1929) (noting that lost profits would not include profits resulting from sales of infringing device to purchasers who selected infringing device because of its "supposed superiority"). Note that the subservient patentee would, however, be liable for damages as measured by the value of royalties to the patentee under a license agreement. See 5 D. Chisum, supra note 45, § 20.03[3], at 20-135 to 20-136 ("In a case of blocking industrial property rights, the reasonable royalty would have to reflect an appropriate apportionment of the expected economic benefits. On the other hand, the patent owner's valid claim may have stood as a sole but complete legal obstacle to the manufacture of the product by the infringer.").

101. Borg-Warner Corp. v. Paragon Gear Works, 355 F.2d 400, 404, 148 U.S.P.Q. (BNA) 1, 5 (1st Cir. 1965), cert. dismissed, 384 U.S. 935, 149 U.S.P.Q. (BNA) 905 (1966).

102. Westinghouse v. Boyden Power Brake Co., 170 U.S. 537, 568 (1898) (citations omitted).

brake that used a central reservoir of compressed air for stopping power. Further advances in his design, primarily the addition of an air reservoir in each brake cylinder, resulted in a brake that was patented in 1887. An improvement on this 1887 brake, invented by George Boyden, added an ingenious mechanism for pushing compressed air, into the brake piston from both the central reservoir *and* a local reservoir in each brake cylinder.[103] With the added stopping power of the Boyden brake, engineers could safely operate the increasingly long trains of the late nineteenth century.

The Westinghouse patent included a claim for "the combination of a main air-pipe, an auxiliary reservoir, a brake-cylinder, a triple valve [the device that coordinated the airflows from the main reservoir and the individual brake reservoir] and an auxiliary valve device, actuated by the piston of the triple-valve . . . for admitting air in the application of the brake."[104] The Court noted that the literal wording of the Westinghouse patent could be read to cover Boyden's brake, since it included what could be described as a "triple valve."[105] But it refused to find infringement on the ground that Boyden's was a significant contribution that took the invention outside the equitable bounds of the Westinghouse patent:

> We are induced to look with more favor upon this device, not only because it is a novel one and a manifest departure from the principle of the Westinghouse patent, but because it solved at once in the simplest manner the problem of quick [braking] action, whereas the Westinghouse patent did not prove to be a success until certain additional members had been incorporated into it.[106]

The *Westinghouse* decision has influenced a number of cases.[107] In

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103. Westinghouse's brake required a complicated series of passageways to supply air from the two sources. Id. at 545, 562–63.

104. Id. at 561.

105. Id. at 568.

106. Id. at 572. On the application of this standard to specific cases, see Pigott, Equivalents in Reverse, 48 J. Pat. Off. Soc'y 291, 295 (1966) (noting that in *Westinghouse* "the claims literally read upon [i.e., cover] the accused structure").

107. See, e.g., Leesona Corp. v. United States, 530 F.2d 896, 905–06, 185 U.S.P.Q. (BNA) 156, 163 (Ct. Cl. 1976); Precision Metal Fabricators v. Jetstream Sys. Co., 693 F. Supp. 814, 819, 6 U.S.P.Q.2d (BNA) 1704, 1708 (N.D. Cal. 1988) (no infringement where defendant's "machines do not operate on the same principle as plaintiff's. . . . This appears to be a case where the defendants are not gaining the benefit of plaintiff's patents, but their equipment could fall within the literal language of the patents."); Mechanical Plastics Corp. v. Unifast Indus., 657 F. Supp. 502, 504, 4 U.S.P.Q.2d (BNA) 1734, 1736 (E.D.N.Y. 1987) ("Where a device serves the same or a similar purpose to the patented invention, but functions in a substantially different way, the fact that it falls within the literal language of the claim does not warrant a finding of infringement."), aff'd, 846 F.2d 78 (1988) (without opinion); Brenner v. Recoguition Equip., 593 F. Supp. 1275, 1278, 225 U.S.P.Q. (BNA) 1068, 1070 (S.D.N.Y. 1984) (alternative holding); see also Pigott, supra note 106 (collecting many cases on two related issues: nar-

SRI International v. Matsushita Electric Corp. of America,[108] the Federal Circuit reaffirmed the availability of the reverse doctrine of equivalents as a defense to literal infringement. The case involved a patent on a filter used to encode color information in a color television camera. The patent claimed a filter with two sets of parallel stripes of equal width "relatively angularly superimposed" over one another.[109] The accused device used a similar design to achieve the same result, but the stripes in its filters must be at forty-five degree angles to one another.[110]

The court unanimously recognized the validity of a reverse equivalents defense:

> The law . . . acknowledges that one may only appear to have appropriated the patented contribution, when a product precisely described in a patent claim is in *fact* 'so *far* changed in principle' that it performs in a '*substantially different* way' and is not therefore an appropriation (reverse doctrine of equivalents).[111]

But the court divided sharply on the issue of whether the defendant's camera filter was "so far changed in principle" that it was excused from infringement without more factual proof.[112] It remanded the case with explicit instructions for the trial court to consider the accused infringer's reverse equivalents defense.

These cases demonstrate the use of the reverse equivalents doctrine by the courts to limit the reach of a patentee's claims in the face of substantial technological improvements. However, use of the doctrine is fairly rare.[113] Issuance of an improvement patent, or a holding that a patent is valid but subservient to another patent, is much more

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rowing claims by reference to the specification to save the claims from invalidity, and "narrowing" claims to excuse infringement under the reverse doctrine of equivalents).

108. 775 F.2d 1107, 227 U.S.P.Q. (BNA) 577 (Fed. Cir. 1985) (en banc).

109. Id. at 1111, 227 U.S.P.Q. at 577.

110. SRI Int'l v. Matsushita Elec. Corp. of Am., 591 F. Supp. 464, 468, 224 U.S.P.Q. (BNA) 70, 73 (N.D. Cal. 1984), rev'd, 775 F.2d 1107, 227 U.S.P.Q. (BNA) 577 (Fed. Cir. 1985) (en banc).

111. 775 F.2d at 1123, 227 U.S.P.Q. at 587 (emphasis in original) (lead opinion, five judges joining). See id. at 1132, 227 U.S.P.Q. at 594 (Davis, J., concurring); id. at 1133, 227 U.S.P.Q. at 595 (Kashiwa, J., dissenting, five judges joining).

112. Compare id. at 1125, 227 U.S.P.Q. at 589 (genuine issues of material fact still unresolved) (lead opinion, five judges joining); with id. at 1132, 227 U.S.P.Q. at 594 (Davis, J., concurring) (reverse equivalents is always a matter of fact, not law) and id. at 1133, 227 U.S.P.Q. at 594–95 (Kashiwa, J., dissenting, five judges joining) (no genuine factual issues left to resolve; one of two alternative legal findings is that reverse equivalents defense is valid here as a matter of law).

113. Ethyl Molded Prods. Co. v. Betts Package, Inc., 9 U.S.P.Q.2d (BNA) 1001, 1026 (E.D. Ky. 1988) ("The reverse doctrine of equivalents, although frequently argued by infringers, bas never been applied by the Federal Circuit."); Phillips Petroleum Co. v. United States Steel Corp., 673 F. Supp. 1278, 1350, 6 U.S.P.Q.2d (BNA) 1065, 1123 (D. Del. 1987) (pointing out that reverse equivalents is rarely successfully asserted), aff'd, 865 F.2d 1247, 9 U.S.P.Q.2d (BNA) 1461 (Fed. Cir. 1989).

common.[114]

At first blush, the technical merits of the allegedly infringing device might seem to be irrelevant where literal infringement is concerned. After all, a patent is the right to exclude; an astoundingly meritorious improvement, while no doubt deserving a patent of its own, ought not escape infringement. The improver can patent the improvement, but this should not affect the original patentee's rights.

This is an appealing argument. An economic rationale for improvement patents would stress their tendency to encourage bargaining between improvers and original patentees. To the extent the improver has a very significant cost-saving technology, it would be in the interest of the original patentee to cross-license with the improver, to gain access to the improved technology.

Unfortunately, the original patentee may use her patent as a "holdup" right, in an attempt to garner as much of the value of the improvement as possible.[115] The chances of this being successful depend on the relative contributions of the original patented invention and the improvement to the "original plus improvement" combination. Where the original invention contributes most of the value,[116] or where the original and improvement inventions contribute roughly equal value, issuing an improvement patent may be a reasonable solution. But where the original patent contributes very little value compared to

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114. See United States Steel Corp. v. Phillips Petroleum Co., 865 F.2d 1247, 1253 n.11, 9 U.S.P.Q.2d (BNA) 1461, 1466 n.11 (Fed. Cir. 1989); Herman v. Youngstown Car Mfg. Co., 191 F. 579, 584–85 (6th Cir. 1911); Bendix Corp. v. United States, 199 U.S.P.Q. (BNA) 203, 222 (Ct. Cl. Trial Div. 1978), aff'd, 600 F.2d 1364, 204 U.S.P.Q. (BNA) 617 (Ct. Cl. 1979).

115. The "holdup" problem was originally applied to situations where one buyer needs to acquire complementary assets from a number of sellers; some of the sellers may raise their prices to capture some of the value the buyer attributes to holding all the assets. See, e.g., Calabresi & Melamed, Property Rules, Liability Rules, and Inalienability: One View of the Cathedral, 85 Harv. L. Rev. 1089, 1106–07 (1972) (example of sale of small parcels of land to buyer who needs all parcels used as illustration of necessity for "liability rule" such as eminent domain). It has been extended to two-party contracts, see Klein, Crawford & Alchian, Vertical Integration, Appropriable Rents, and the Competitive Contracting Process, 21 J.L. & Econ. 297 (1978); Klein, Transaction Cost Determinants of "Unfair" Contractual Arrangements, 70 Am. Econ. Rev. (Papers & Proc.) 356, 356–57 (May 1980), reprinted in Readings in the Economics of Contract Law 139, 139–40 (V. Goldberg ed. 1989). The paper by Klein, Crawford and Alchian presents the best analogy to the improver-original patentee bargaining situation. This paper describes the opportunities for exerting holdup rights where one firm, after investing in an asset with a low salvage value and a rent stream that is highly dependent on an asset owned by another firm, can be held up by the other firm's attempt to capture a large proportion of the rent stream of the combined assets. The owner of an improvement that contributes a very significant part of the value of the "original patent plus improvement" combination— i.e., an improvement that represents a major technical advance— is thus subject to "holdup" by the original patent holder.

116. If the improvement would have been obvious to one skilled in the art, it will not be patentable at all. See 35 U.S.C. § 103 (1988).

the improvement, the holdup problem may be significant. That is, the holder of the original patent may use it to extract much of the value of the "original plus improvement" combination from the improver.[117] The reverse doctrine of equivalents solves the problem by, in effect, excusing the improver from infringement liability—and therefore removing the original patentee's holdup right. Reverse equivalents, of course, did not evolve in explicit recognition of this problem.[118] But

117. To see why this would be bad from society's point of view, consider this example. An original patent has a value of $100; an improvement, also worth $100, is invented, and its inventor wishes to obtain the right to use it by bargaining with the holder of the original patent. Here, the parties may well reach a bargain wbereby the original patentee gains $50 of the value of the improvement and the improver keeps $50 of this gain, yielding a total allocation of $150 for the original patentee and $50 for the improver. (Of course, the gain may be greater if the original patentee is especially "strategic"; or it may be lower if she is exceptionally "fair"; or the parties might not reach any agreement at all, and the improvement will have to wait until the original patent expires; but the fifty-fifty allocation is a good approximation, based on empirical findings. See H. Raiffa, The Art and Science of Negotiation 48 (1982) (empirical research showing the best predictor of final agreement price was the midway point between the opening offers of sellers and buyers).) Depending on the cost of developing the improvement, this may tend to reduce the incentives to invent improvements below the optimal level, since the improver keeps only $50 of the $100 in extra value generated by the improvement. But it is a reasonable result in this case given the strong policy in favor of preserving the reward for the original patentee and, thus, incentives for future original patentees. But where the improvement adds value of $900, compared to the original patent's value of $100, the holdup problem becomes acute. Here, if the parties bargain for an equal allocation of the improvement's value, the improver keeps only $450 of the total value of the improvement. The reduced incentives to invent such substantial improvements are obvious from this example; not even the strong policy favoring incentives for the original patentee to invent can justify such a "windfall" to the original patentee at the expense of the improver. Note also that the social cost in those cases where the parties cannot agree, and where the very significant improvement therefore sits on the shelf for the life of the original patent, is by definition great. Such "deadlocks" do occur, and in fact a certain number of them are predictable where the bargaining parties are acting rationally. See Cooter, Marks & Mnookin, Bargaining in the Shadow of the Law: A Testable Model of Strategic Behavior, 11 J. Legal Stud. 225, 226 (1982).

118. In fact, the most efficient way to deal with the problem would probably be a system of compulsory licensing, whereby the improver would pay a "fair" royalty to the original patentee. This is not part of U.S. patent law, however. See supra notes 6–7 and accompanying text. Current patent law in fact leaves us with two "second-best" alternatives: finding infringement or finding no infringement. Thus the acconnt of the reverse doctrine of equivalents given here is meant to be an explanation of how to work with our admittedly second-best system. A similar problem arises when a firm must use a patented product or process to invent an improved version. Even where the improved version does not incorporate the patented invention, the mere use of it to create the improved version is an infringement. The defense of "experimental use" can be involved by one accused of infringement under these circumstances, but the precise contours of that defense, which is derived solely from case law, are unclear. For an excellent recent article, which calls for a rationalized and expanded experimental use defense for many of the same reasons we advocate favoring a competitive environment for improvement inventions, see Eisenberg, Patents and the Progress of Science: Exclusive Rights and Experimental Use, 56 U. Chi. L. Rev. 1017, 1070–74 (1989). An expanded experimental use exemption would likely have a major impact on biotechnology, where there

the fear of the inefficient use of holdup power[119] does provide a rational account of the doctrine and might even assist courts in applying it. Note too that the same rationale could be applied to analysis of infringement under the doctrine of equivalents; the more significant the technological advance represented by the allegedly infringing device, the less willing the courts should be to find it an equivalent of the patentee's device.[120]

To see when reverse equivalents might make sense, consider the problem we touched on earlier in the section on enablement: broad claims encompassing embodiments that can be made only after significant additional research is performed. The *Westinghouse* case is an ex-

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is much experimentation in an attempt to improve various products. See Eisenberg, Proprietary Rights and the Norms of Science in Biotechnology Research, 97 Yale L.J. 177, 225 n.242 (1987) (describing possible experimental use defense in Scripps Clinic & Research Found. v. Genentech, Inc., 666 F. Supp. 1379, 3 U.S.P.Q.2d (BNA) 1481 (N.D. Cal. 1987), a defense that appeared to be relevant but was not used by Genentech). For a recent proposal to create compulsory licensing when a patented invention must be used to make an improved version, see Feit, Biotechnology Research and the Experimental Use Exception to Patent Infringement, 71 J. Pat. & Trademark Off. Soc'y 819, 840 (1989).

119. Assertion of a holdup right may be inefficient in three ways: first, it may prevent the improvement from being introduced until the original patent expires; second, it may cause a delay shorter than the full patent term, e.g., because of litigation or bargaining time; and third, it may lead to higher cost to the consumer. In this connection, it is worth noting that many studies find that the social returns to particular innovations far exceed the private returns; thus society as a whole may well bear the greatest efficiency loss. See, e.g., Bernstein, The Structure of Canadian Inter-Industry R&D Spillovers, and the Rates of Return to R&D, 37 J. Indus. Econ. 315 (1989) (social rates of return at least twice private rates for industries studied); Bresnahan, Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services, 76 Am. Econ. Rev. 742, 753 (1986) (very large social gain from mainframe computers, 1.5 to 2.0 orders of magnitude above cost of inventing them); Evenson & Kislev, Research and Productivity in Wheat and Maize, 81 J. Pol. Econ. 1309 (1973) (social return up to 300% greater than private return); Griliches, Research Expenditures, Education, and the Aggregate Agricultural Production Function, 54 Am. Econ. Rev. 961, 965–68 (1964) (social rate of return on agricultural research is at least 150% greater than private rate of return to researchers); Mansfield, Rapoport, Romeo, Wagner & Beardsley, Social and Private Rates of Return from Industrial Innovations, 91 Q.J. Econ. 221, 234 (1977) (concluding that median estimated social rate of return on seventeen major product innovations was 26 percentage points greater than the medium pretax private rate of return).

120. Perhaps it is even more useful in that context. Because the doctrine of reverse equivalents applies only where there is *literal* infringement, the improvement at issue has to be very significant to qualify for infringement immunity under the reverse doctrine of equivalents. If literal infringement were often excused, the original patentee would not have much faith in the value of her patent; this might significantly reduce her incentive to invent in the first place. But where the improvement allegedly infringes only under the doctrine of equivalents—a less certain area of the original patentee's scope—there will likely be less of an impact on the original inventor's incentives. So doctrine can be more sensitive to the degree of advance represented by the improvement where it allegedly infringes under the doctrine of equivalents. In terms of the model given in this section, the doctrine of equivalents—as opposed to reverse equivalents—can be used to remedy a greater number of potentially inefficient holdups by original patentees.

ample; Boyden's brake involved a triple-valve, and was therefore within the boundaries of the Westinghouse patent. The court, nevertheless, refused to find infringement, since Boyden's invention was "a manifest departure from the principle of the . . . patent."[121]

II. The Economics of the Patent System Revisited

A. *The Social Benefits and Costs of the Patent System*

In most analyses of the different aspects of the patent system, concern has centered on a simple tradeoff. The analysis has concentrated on how changing patent coverage affects the balance between incentives to the inventor and underuse of the invention due to patent monopolies. Thus, Nordhaus's analysis of optimum patent life is concerned with the tradeoff between increased inventive effort resulting from longer anticipated patent life and greater deadweight costs associated with longer monopoly.[122] Kaplow uses these two variables to analyze the effects of allowing the patent holder greater freedom regarding licensing agreements.[123] Gilbert and Shapiro's recent work on optimal patent length and breadth builds on the tradeoff model, as does Klemperer's.[124]

However, other analyses of the effects of the patent system open

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121. Westinghouse v. Boyden Power Brake Co., 170 U.S. 537, 572 (1898). Judge Newman of the Federal Circuit has acknowledged that the reverse equivalents doctrine "is invoked when claims are written more broadly than the disclosure warrants." Texas Instruments v. United States Int'l Trade Comm'n, 846 F.2d 1369, 1372, 6 U.S.P.Q.2d (BNA) 1886, 1889 (Fed. Cir. 1988).

122. W. Nordhaus, supra note 3.

123. See Kaplow, The Patent-Antitrust Intersection: A Reappraisal, 97 Harv. L. Rev. 1813, 1855–67 (1984). Compared with other economic analyses of restrictive licensing practices, Kaplow's approach differs in that he is careful to emphasize the *net social benefits* of granting a particular patent. Kaplow criticizes Bowman and Baxter for relying on the notion that the individual inventor should be given a patent and allowed to license it using restrictive practices if that inventor's reward is less than or equal to the value of her invention to society. Id. at 1849–54. "Such a view," according to Kaplow, "incorrectly focuses on total social benefits, rather than *net* social benefits (the excess of total benefits over total costs)." Id. at 1828. Kaplow thus structures his analysis of an optimal system so as to take account of the social cost of granting a patent or permitting a restrictive practice.

124. See R. Gilbert & C. Shapiro, supra note 2, at 2.

> Increasing the breadth of the patent typically is increasingly costly, in terms of deadweight loss, as the patentee's market power grows. When increasing the length of the patent, by contrast, there is a constant tradeoff between the additional reward to the patentee and the increment to deadweight loss .... So, the socially cost-effective way to achieve a given reward to innovators is to have infinitely-lived patents with enough breadth to attain the required reward level.

Id.; P. Klemperer, supra note 2, at 2 ("Since any single prize . . . will induce the same r&d activities, we can equivalently think of choosing [patent length and breadth] to minimize the social cost stemming from the resulting monopoly provision rather than the perfectly competitive provision of a new product . . . .").

up a much more complex set of issues. These studies recognize that at any time many actors may be in the invention game, and that the game may have many rounds. This broader orientation brings into view the question of how the lure or presence of a strong patent can influence the multiactor portfolio of inventive efforts.[125] It also alerts the analyst to the possible effects of patents on the ability or desire of different parties to stay in the inventing competition over time, and on the efficiency of the inventive effort over the long run.[126]

We believe that analysis of the effects of varying patent scope needs to recognize this dynamic multiactor context. One problem with the analysis of Gilbert and Shapiro, and Klemperer, is that this is not done. Both papers treat greater scope as roughly similar to greater duration in terms of its incentive effect on initial invention.[127] We have no real trouble with that.[128] Both treat the social costs of greater scope as precluding a wider range of substitutes covered by the patent.[129] Again, no real argnment. However, they treat these substitutes as if they were already in existence or could be made so trivially.[130] It is

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125. For an overview of work in this area, see M. Kamien & N. Schwartz, Market Structure and Innovation 105–12 (1982).

126. See, e.g., Lippman & McCardle, Dropout Behavior in R&D Races with Learning, 18 Rand J. Econ. 287 (1987). See supra notes 12–14 and accompanying text. Note that in his article on restrictive licensing practices Kaplow leaves room for a consideration of some long-term effects:

> The possibility of adverse effects from long-run changes in market structure occurring over the patent life adds another element to aggregate social cost and reinforces [my] conclusion about the relation of private to social benefits [i.e., that private benefits will exceed social benefits due to the presence of social costs not borne by the patentee].

Kaplow, supra note 123, at 1828 n.35.

127. See supra note 124.

128. At least insofar as both length and scope enter into the "tradeoff" analysis. Note, however, that broad claims influence who will he involved in further work in the technology and on what terms. This is different from giving a patent holder a long time to control a particular invention, as Gilbert and Shapiro note. See R. Gilbert & C. Shapiro, supra note 2, at 2 (explaining that their model focusses on patent scope because increases in scope have greater preclusive effect than increases in length).

129. See R. Gilbert & C. Shapiro, supra note 2, at 4–5 (effect of substitutes on price patentee can charge); P. Klemperer, supra note 2, at 3 (modelling cost of precluded suhstitutes by picturing consumers travelling along a product distribution line (Hotelling model)). The article by McFetridge & Rafiquzzaman, supra note 2, raises the same general problem. These authors argue that the greater the degree of postpatent competition, or potential competition, the greater the price discipline on the innovator. The degree of competition is dependent on the scope of protection given to the innovator. In this model competition eats into the percentage of cost savings brought about by the innovator's invention. See id. at 104. This model points generally to the same conclusions reached in the Gilbert and Shapiro paper. But note that it considers only the effect of patents on the development of substitutes for that patented technology and not the effect of the patent on improvements and extensions of the patented technology. It is in this sense still more static than dynamic in its approach and, hence, different from the view taken here.

130. But cf. R. Gilbert & C. Shapiro, supra note 2, at 7–8 (cautioning in conclusion

here that we find their analysis inadequate. Our concern is with the effects of patent scope decisions on whether or not, and if so how efficiently, these substitutes are created. More importantly, these papers for the most part ignore what we consider a critical set of "substitutes": subsequent inventions that not only substitute for the initial invention, but also improve on it in some way. Since some of the follow-on efforts of inventors could result in something not simply slightly different but significantly better than the patented technology, broad patents could discourage much useful research. Thus, these papers are not of much help in rationalizing and reforming those aspects of legal doctrine that apply to the economically significant class of improvement inventions.

The economic models that do try to encompass multiactor dynamics are quite stylized. In some, invention is analogized to fishing from a common pool.[131] There are many competitive inventors, and the first to make an invention gets the patent on it. Each knows that as others catch (invent) there is less in the pool for her. The result is "overfishing": too many people seeking inventions at once.[132] Other economists have modelled technical advance in terms of a multifirm "race to patent," in which many would-be inventors identify a particular goal, and the first to achieve the goal gets the patent.[133] A good deal of variation has been introduced into these models, with different assumptions being made about such variables as the strength of patents and the costs and benefits of innovating versus imitating.[134] Many of the implications of these models are sensitive to particular assumptions, but some are robust. In particular, under a wide range of assumptions, rivalrous inventive efforts generate a great deal of inefficiency.

Despite the drawbacks of these models, the authors of this paper

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that infinitely-lived patents, with reward adjusted solely by variations in scope, could "retard subsequent innovation by establishing monopoly rights to an entire line of research").

131. See, e.g., Barzel, Optimal Timing of Innovations, 50 Rev. Econ. & Statistics 348 (1968); Dasgupta & Stiglitz, Uncertainty, Industrial Structure and the Speed of R & D, 11 Bell J. Econ. 1 (1980); Wright, The Resource Allocation Problem in R & D, *in* The Economics of R & D Policy 41 (G. Tolley ed. 1985).

132. See, e.g., Tandon, Rivalry and the Excessive Allocation of Resources to Research, 14 Bell J. Econ. 152 (1983); Wright, supra note 131.

133. See, e.g., Dasgupta and Stiglitz, supra note 131; Lee & Wilde, Market Structure and Innovation: A Reformulation, 94 Q.J. Econ. 427 (1980); Scherer, Research and Development Resource Allocation Under Rivalry, 81 Q.J. Econ. 359 (1967). For recent treatments of the topic, see Lippman & McCardle, supra note 126; see also Wright, supra note 131, at 41, 49–56 (describing the relationship between the general common pool model and what we call "race" models: "The dissipation of the benefits of research before the socially optimal time . . . is a dynamic intertemporal version of the same type of market failure [described in the common pool models].").

134. See, e.g., Dasgupta, Patents, Priority and Imitation or, The Economics of Races and Waiting Games, 98 Econ. J. 66 (1988) (exploring conditions that make waiting more profitable than entry in races to invent); Katz & Shapiro, R & D Rivalry with Licensing or Imitation, 77 Am. Econ. Rev. 402 (1987) (exploring effects of post-invention dissemination, i.e., licensing or imitation, on two-firm strategic race to invent).

regard that basic conclusion as persuasive. Not only does proprietary control of technology tend to cause "dead weight" costs due to restrictions on use. (We presume here that in general it is not possible to write licensing agreements to completely offset this problem, a matter to which we will return shortly.) Where invention is rivalrous, the process leading to invention is itself inefficient. With exclusive property rights, we pay both kinds of costs in exchange for the benefits of technical advance. But recognition of the costs of rivalrous inventive efforts leads one to speculate about how these costs might be mitigated. This question is the source of Edmund Kitch's prospect theory.

1. *The Prospect Theory.* — Edmund Kitch, in formulating his "prospect theory" of patent rights, moved beyond the static tradeoff model mentioned earlier and incorporated into his analysis some of the insights of the common pool models. Kitch analogized patents to mining claims. Like an exclusive claim to the minerals that may be produced from a plot of land, Kitch emphasized that patents are granted *after* invention but *before* commercialization. According to Kitch, this has two advantages: (1) it allows "breathing room" for the inventor to invest in development without fear that another firm will preempt her or steal her work;[135] and (2) it allows the inventor to coordinate her activities with those of potential imitators to reduce inefficient duplication of inventive effort.[136] This amounts to granting rights over an unexplored pool, with the right-holder being permitted to charge for access to various parts of the pool.[137] Thus the inefficiencies associated with rivalrous uncoordinated invention, as in the fishing or race models, can be avoided.

Kitch goes further in suggesting that the prospect theory "may clarify the process and conditions under which a monopolistic industry will be more efficient than a competitive one."[138] He states that this enhanced efficiency "turns not upon the size of the firm, but its dominance over a fruitful technological prospect."[139]

Reacting to the inefficiencies highlighted by the fishing models, Kitch clearly has a preference for single-firm domination of a techno-

135. Kitch, supra note 12, at 276–77.

In some respects, William Kingston's idea of an "innovation warrant" is similar to the "breathing room" aspect of the prospect theory. Kingston, The Unexploited Potential of Patents, *in* Direct Protection of Innovation 1, 1–34 (W. Kingston ed. 1987). What Kingston has in common with Kitch is a focus on incentives to develop *markets*. But Kingston's proposal is to give patent-like "innovation warrants" to the first firm to commercialize even a minor innovation. This, of course, differs from Kitch, who implicitly assumes the desirability of maintaining the patent system's current focus on technological advance, rather than on mere market innovation.

136. Kitch, supra note 12, at 279.

137. Kitch notes that U.S. mining law performs these two functions as well. Id. at 271–75.

138. Id. at 286.

139. Id.

logical prospect. As Kitch recognizes, this can be achieved by licensing, where a number of firms hold patents on components of a key invention. Alternatively, one firm can hold a single dominant patent. In either case, the advantage seen by Kitch is that development is under the control of a single entity. Rivalry is avoided. Planning is possible.

We have trouble with the view that coordinated development is better than rivalrous. In principle it could be, but in practice it generally is not. Much of our case is empirical. But there are sound theoretical reasons for doubting the advantages of centralization.

For one thing, under rivalrous competition in invention and innovation there is a stick as well as a carrot. Block rivalry and one blocks or greatly diminishes the threatened costs of inaction. Kitch assumes a model of individual or firm behavior where if an action is profitable it will be taken, regardless of whether inaction would still allow the firm to meet its desired (but suboptimal) performance goals. Different models of behavior, like Simon's satisficing hypothesis, predict otherwise.[140] As we shall see, there are many instances when a firm that thought it had control over a broad technology rested on its laurels until jogged to action by an outside threat.[141]

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140. The concept originated with the economist Herb Simon. See Simon, Theories of Decision-Making in Economics and Behavioral Science, 49 Am. Econ. Rev. 253, 262–65 (1959); see also J. March & H. Simon, Organizations 140–41 (1958) (most decision making concerned with discovery and selection of satisfactory, rather than optimal, alternatives). This view is reflected in the work of some analysts of innovation:

> The sluggishness of large firms in certain innovations has been explained by the desire to protect an investment in the then-current technology, satisfaction with the status-quo, underestimation of the potential demand for a new item, neglect of the inventor, and misdirection of research, as well as by incompatibility of bureaucracy and creativity.

M. Kamien & N. Schwartz, supra note 125, at 68. See generally R. Brenner, Rivalry in Business, Science, Among Nations 1–28 (1987). Brenner describes a broad and somewhat iconoclastic view of entrepreneurship as an activity brought on by frustration and adversity—the need to take a gamble. He points out that an increase in rivalry can bring about these conditions, and thus ties increased rivalry and competition to increased innovation.

141. The transition from entrepreneur to established, cautious firm can be breathtakingly fast. An historian who studied the beginning of the electrical lighting industry in the U.S. pointed out that in ten years, Thomas Edison moved from a maverick trying to get incandescent lighting accepted as feasible to a staunch opponent of the "dangerous" innovation of alternating current. H. Passer, The Electrical Manufacturers 1875–1900, at 174 (1953). The same phenomenon has been noted repeatedly. See, e.g., Scherer, Invention and Innovation in the Watt-Boulton Steam-Engine Venture, 6 Tech. & Culture 165, 174 (1965), quoting a letter from James Watt, inventor of the steam engine, to his partner James Boulton:

> On the whole I find it is now full time to cease attempting to invent new things, or to attempt anything which is attended with any risk of not succeeding . . . . Let us go on executing the things we understand, and leave the rest to younger men, who have neither money nor character to lose.

See also M. Kamien & N. Schwartz, supra note 125, at 74–75 (examining alternative explanations of why innovators stop innovating).

More generally, the model of behavior Kitch is employing ignores the limits on cognitive capacity and the tendency to focus on past experience that are characteristics of other models and of organizational behavior as we know it.[142] Once a firm develops and becomes competent in one part of a "prospect," it may be very hard for it to give much attention to other parts, even though in the eyes of others, there may be great promise there.[143] Again, our empirical explorations show many examples of this. Consequently, one might expect that many independent inventors will generate a much wider and diverse set of explorations than when the development is under the control of one mind or organization.

This flags still another limitation of the "pool" or "mining" models. In these models the "fish" or the "minerals" are out there and known (with perhaps some uncertainty) to all parties. But with the technological "prospects," and perhaps even real life mineral prospects, no one knows for sure what possible inventions are in the technological pool.[144] It is not even generally feasible to assign probabilities to possible outcomes on which all knowledgeable people will agree. Indeed different parties are almost certain to see the prospect differently. Because of this uncertainty, development of technology is critically different from other common pool problems. The real problem is not controlling overfishing, but preventing *underfishing* after exclusive rights have been granted. The only way to find out what works and what does not is to let a variety of minds try. If a property right on a basic invention covers a host of potential improvements, the property right holder can be expected to develop the basic invention and some of the improvements. But we would expect a single rightholder to *under*develop—or even ignore totally—many of the po-

142. See R. Nelson & S. Winter, An Evolutionary Theory of Economic Change, passim (1982).

143. See R. Nelson & S. Winter, supra note 142, at 389. To the extent that the holder of a broad patent has market power, it is relevant to note that analysts of monopoly power often remark on the monopolist's reduced incentives to innovate. See K. Arrow, Economic Welfare and the Allocation of Resources for Invention, *in* The Rate and Direction of Inventive Activity 609, 619–22 (R. Nelson ed. 1962) (concluding from model that monopolist's incentive to innovate is lower than inventor in competitive industry); M. Kamien & N. Schwartz, supra note 125, at 29–30:

> The firm presently realizing monopoly profits may be less motivated to seek additional profits than one earning only normal profits. It may, in other words, be less hungry for additional profits than the firm without a monopoly position. Several reasons for this are possible. First, it may begin to regard additional leisure as superior to additional profits . . . . Second, it may become more concerned with protecting its current monopoly position than in acquiring a new one.

144. Invention and innovation are notoriously uncertain activities. C. Freeman, The Economics of Industrial Innovation 148–50 (2d ed. 1982); E. Mansfield, J. Rapoport, J. Schnee, S. Wagner & M. Hamburger, Research and Innovation in the Modern Corporation 9–10 (1971).

tential improvements encompassed by their broad property right.[145]

Of course, Kitch's notions about how a broad patent prospect can be worked out by the patent holder do not preclude involving many minds. However, we regard as fanciful the notion that wider talent can be brought in without real competition through selective licensing practices. A substantial literature documents the steep transaction costs of technology licensing,[146] and there is indirect evidence that these costs increase when major innovations are transferred.[147] Moreover, various studies have indicated that transaction costs tend to be very high if licenses are tailored to particular licensees.[148] It is much

145. As discussed earlier, many improvements are patentable, a fact that demonstrates the independent inventive contribution necessary to make a significant improvement. See supra notes 96–99 and accompanying text. A study of the history of innovations in almost any field will show the key importance of improvement inventions. One good source of such studies is E. von Hippel, The Sources of Innovation 131–207 (1988) (innovation histories of ten industries). See, for example, von Hippel's description of innovations in scientific instruments, several of them patented. He describes the invention of the gas chromatograph, id. at 133–35; then details the improvements in temperature programming, id. at 135; capillary columns, id. at 135; silanization ("[a] major step forward"), id. at 136; argon ionization (patented), id. at 138; electron capture detector, id. at 139; flame ionization detector (patented), id. at 139; mass spectrograph linkage (patented), id. at 140; and process control interface, id. at 141. Likewise, von Hippel describes the invention of nuclear magnetic resonance (NMR) imaging, id. at 143, then describes fourteen major improvements, id. at 145–53. The same pattern holds true for all his innovation histories. Although von Hippel does not directly compare the difficulty—hence cost—of improvement inventions, it is clear from his descriptions that many of the improvements were significant technical achievements. Thus cost and difficulty can be inferred.

146. See, e.g., F. Contractor, International Technology Licensing: Compensation, Costs, and Negotiation 104–05 (1981) (transaction costs averaged over $100,000 for licensing deals studied); D. Teece, The Multinational Corporation and the Resource Cost of International Technology Transfer 44 (1976) (transfer costs constituted over 19% of total project costs in international projects studied); E. von Hippel, supra note 145, at 48 (summarizing empirical studies finding generally low net returns from licensing). More subtle transaction costs, such as possible opportunistic behavior, are described in F. Bidault, Technology Pricing: From Principles to Strategy 126–27 (B. Page & P. Sherwood trans. 1989), and Teece, Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, 15 Res. Pol'y 285, 294 (1986).

147. In addition to the studies by Teece and Contractor cited supra note 146, this point is illustrated by the terms of a broad cross-licensing agreement between DuPont and Imperial Chemical Industries, Ltd., of Great Britain. The agreement provided for blanket licensing of all patents owned by the two companies (one of the reasons it was found to have masked a cartel, see infra note 338), but "there was a clause allowing either party to remove a 'major invention' from the agreement altogether, so that they could make special terms." 2 W. Reader, Imperial Chemical Industries: A History 52–53 (1975).

148. Caves, Crookell & Killing, The Imperfect Market for Technology Licenses, 45 Oxford Bull. Econ. & Statistics 249, 260—62 (1983). A group led by Edwin Mansfield of the University of Pennsylvania reached the same general conclusion after conducting a similar empirical study. See E. Mansfield, A. Romeo, D. Teece, S. Wagner & P. Brach, Technology Transfer, Productivity, and Economic Policy (1982).

simpler to grant roughly identical licenses to all who will pay a standard rate. In our own research, we have not found a single case where the holder of a broad patent used it effectively through tailored licensing to coordinate the R&D of others.

Although the preceding analysis applies specifically to patents, it is interesting that other types of property rights are limited in scope, perhaps for similar reasons. Kitch himself notes, for instance, that in mining law "[t]he mineral claim system restricts the area that can be claimed through rules that specify maximum boundaries in relation to the location of the mineralization,"[149] and that boundaries are required to be clearly marked.[150] While there are no statutory limits on the number of claims an individual can make,[151] the law requires a claimant who has identified a mineral deposit[152] to work a claim actively before property rights will vest.[153] This places practical limits on the number and dimensions of claims. And state law, which establishes limited exclusive rights during the prospecting period prior to the grant of federal rights, similarly requires persistent and diligent work toward discovery on each claim for which protection is sought.[154]

The obvious goal of these requirements—to prevent hoarding and speculation—is analogous to the goal of patent law doctrines designed to limit the breadth of patents. Both sets of rules recognize that although property rights assignments can make development of an asset more efficient, the *scope* of rights is crucial. Property rights that are too narrow will not provide enough incentive to develop the asset, while overly broad rights will preempt too many competitive development efforts. Kitch's prospect theory must be supplemented to take account of this important limitation on the breadth of property rights.[155]

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149. Kitch, supra note 12, at 273 (footnote omitted).

150. Id. See 30 U.S.C. §§ 23, 36 (1988); Hubbard, Drafting Private Agreements Relating to Public Lands, 3 Nat. Resources & Env't 9, 10 (1988).

151. See 30 U.S.C. §§ 23, 35; Comment, The General Mining Law and the Doctrine of *Pedis Possessio*: The Case for Congressional Action, 49 U. Chi. L. Rev. 1026, 1027 n.6 (1982).

152. Before a claim can be filed under federal law, one must identify a mineral deposit. 30 U.S.C. § 23. See Thomas v. Morton, 408 F. Supp. 1361 (D. Ariz. 1976), aff'd sub nom. Thomas v. Andrus, 552 F.2d 871 (9th Cir. 1977) (per curiam).

153. 30 U.S.C. § 28.

154. State law protection is carried out under the doctrine of *pedis possessio*. See Comment, supra note 151, at 1032–46. On the work requirement and the closely related requirement of actual occupancy under this doctrine, see id. at 1033–34. In his study on the evolution of property rights among prospectors during the California Gold Rush, John Umbeck observes that even the earliest contracts establishing such rights included limitations on claim size and minimum working requirements. J. Umbeck, A Theory of Property Rights With Application to the California Gold Rush 91–98 (1981).

155. The literature on common fisheries suggests that a similar consideration influences the design and allocation of fishing rights. This literature details a number of formal and informal limitations on the scope of fishing rights that are either in effect or have been proposed. See Charles, Fishery Socioeconomics: A Survey, 64 Land Econ.

An interesting general point about the economic literature on property rights emerges from this analysis. Economists who theorize about property rights do not appear to have analyzed extensively the issue of how *broad* property rights should be. For the most part this work emphasizes the importance of defining property rights in the first place.[156] The usual assumption is that, with low or nonexistent transaction costs, the parties will bargain to a Pareto superior solution given any initial assignment of entitlements; therefore the "size" of the rights is not important.[157] However, as elaboration of the Coase theorem has made clear, the initial distribution of property rights can make a difference in the equilibrium level of output of the bargaining parties.[158] If one were to look at the patent scope problem from this view, one would conclude that the present authors favor a regime of property rights that limits the scope of a patent in such a way that inventors of significant improvements are in a strong bargaining position with respect to holders of broad patents.[159] This is not a particularly useful way of concep-

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276, 279–80 (1988); see also Clark, Major & Mollett, The Development and Implementation of New Zealand's ITQ Management System, *in* Rights Based Fishing 117, 128 (P. Neher, R. Arnason & N. Mollett eds. 1989) (describing New Zealand fish stock management system, which solves common pool overfishing problem by granting to fishermen "Individual Transferable Quotas" (ITQs), limited in scope by the volume of past catches); Gardner, The Enterprise Allocation System in the Offshore Groundfish Sector in Atlantic Canada, *in* Rights Based Fishing, supra, at 293, 299, 319 (describing similar allocation system based on historical catches in Canadian fishing industry, which made "[t]he race for fish . . . a thing of the past").

156. See, e.g., Coase, The Problem of Social Cost, 3 J.L. & Econ. 1 (1960); H. Demsetz, Toward a Theory of Property Rights, *in* 1 Organization of Economic Activity 104 (1988).

157. See H. Demsetz, supra note 156, at 112–13 (discussion of bargaining using example of patents); see also Anderson, Conceptual Constructs for Practical ITQ Management Policies, *in* Rights Based Fishing, supra note 155, at 191, 196 (concluding that the market for randomly-allocated ITQs would lead to efficient allocation via trading among firms).

158. See R. Cooter & T. Ulen, Law and Economics 105 n.15 (1988).

159. Consider a numerical example. Suppose an inventor has expected profit of $1000 from a pioneering invention. An improver has developed a modification which the improver expects will bring profits of $400. But the improver's entry into the market will reduce the pioneer's profits by $300 because the improvement substitutes for some component in the pioneer's product, reduces the need for replacement parts or the like. If the pioneer's patent covers the improvement, the improver must take out a license. If this is known in advance, the pioneer will demand to be compensated out of the improver's profits for its $300 loss in profits. The improver's expected profit—after paying a royalty to the pioneer under the license—will be only $100. But if the pioneer's rights do not cover the improvement, the improver can market it without a license from the pioneer. Then the improver's expected profit will once again be $400. It is important to note two things about this example: first, it demonstrates the increased incentives for improvements when initial rights are narrow. But second, it also clearly demonstrates the *cost* of narrow scope—a reduced incentive for the pioneer to innovate in the first place. (Note that with narrow rights, the pioneer's expected profits drop from $1000 to $700 after the improver enters without taking out a license.) In fact, taken to its logical conclusion, this is an argument for no patent rights at all, clearly the wrong result. Con-

tualizing the problem, however, since unlike rights that somehow touch tangible property—the usual subject of this analysis—the allocation of property rights between technological pioneers and improvers is not a zero-sum game.[160]

Undoubtedly our position is open to criticism. Rivalry no doubt causes waste. Yet we have little faith in the imagination and willingness of a "prospect" holder to develop that prospect as energetically or creatively as she would when engaged in competition. We are also skeptical about her ability to orchestrate development. Given the way humans and organizations think and behave, we believe we are much better off with considerable rivalry in invention than with too little.[161]

Can we prove it? We can present empirical evidence that the granting of broad patents in many cases has stifled technical advance and that where technical advance has been rapid there almost always has been considerable rivalry. However, we grant that it is possible to see our evidence as not completely persuasive in this regard, or to posit that we have looked at only a few cases and that these might not be representative.

And even if our case is accepted that, up to a point at least, rivalry facilitates technical advance and unified control damps it, one can re-

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sequently it is important to restate one point: We are *not* advocating extremely narrow rights, designed to maximize the incentives to improve; we are arguing that, in close cases where scope doctrines are at issue, decision makers should opt for narrow scope to advance the important interests of society in encouraging improvements.

160. In fact, it is the positive-sum aspects of allowing more competition for improvements that lead us to advocate narrowing the scope of the initial inventor's patent. In addition, of course, are the well-known problems of transaction costs; it seems whimsical to assume that all improvers and potential improvers will be able to bargain with the holders of pioneering patents. Imagine the magnitude of these costs: identifying all the prospective improvers; agreeing on the value of the pioneering invention and the expected value of the improvement; and finding an acceptable division of profits from the "surplus" created when the improvement is combined with the pioneer invention. For some background on the strategic aspects of licensing transactions, see F. Bidault, supra note 146, 83–137; see also Meurer, The Settlement of Patent Litigation, 20 Rand J. Econ. 77, 77 (1989) ("patent validity disputes are not always resolved with licensing agreements because of incentive problems created by private information about validity"). For a heroic effort to imagine a world where these costs are manageable, see Yu, A Contractual Remedy to Premature Innovation: The Vertical Integration of Brand-Name Specific Research, 22 Econ. Inquiry 660 (1984) (arguing that (1) current property rights encourage "rushing" of innovation, and (2) a contractual solution exists whereby manufacturers form pre-invention contracts with prospective inventors). On the effect of multiple bargainers, see generally Cooter, Coase Theorem, *in* 1 The New Palgrave: A Dictionary of Economics 457, 458 (1987) (example of many farmers in Coase's famous farmer-railroad bargaining hypothetical). Without such bargaining the exchange mechanism on which the property rights literature relies so heavily cannot work. It is worth noting in this regard that even in the property rights-based fish harvest schemes described above, the scope of initial entitlements is carefully crafted. See, e.g., Gardner, supra note 155, at 298.

161. For a general discussion, see Nelson, Capitalism as an Engine of Progress, Res. Pol'y (forthcoming).

spond by saying "Yes, but what about the costs and the wastes?" We can rejoin that, in our cases at least, it is not evident that the waste caused by the presence of a broad patent is very considerable.

2. *Clarifying Assumptions.* — Our argument rests on a simple premise: when it comes to invention and innovation, faster is better. What proof do we have that this is true? The answer lies in the work of scholars who have examined intensively the interrelation among research and development expenditures, invention, and productivity growth. Although there are still a great many unanswered questions in this field,[162] the following general points seem to be widely accepted: First, increases in research and development expenditures yield more inventions.[163] Second, the larger numbers of inventions from increased research and development have a positive effect on future productivity growth.[164] And third, productivity growth is important for economic well-being.[165]

These findings support our argument only if there is a link between the *speed* with which innovations are introduced and the overall *number* of innovations. The research just sketched is of no help if the timing of an innovation is unrelated to the number of subsequent innovations. Here we must rely on simple economic reasoning. For the same reasons people prefer to have money in hand now, as compared to the same amount (and more, depending on the interest rate) later, society prefers to have improvements now, rather than later. Again, keeping in mind that at some point increased incentives for improvement will reduce the incentive to create a pioneer invention in the first

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162. See, e.g., Griliches, Introduction, *in* R & D, Patents, and Productivity 1, 17 (Z. Griliches ed. 1984) (listing several problems concerning the ability to detect the major effects of research and development on productivity). One issue that is prior to these—and that to some is still undecided—is whether growth should be the goal of an economic system at all. See generally H. Arendt, The Rise and Fall of Economic Growth (1978) (intellectual history of the economic concepts of progress, growth, and development). For a summary of criticisms of growth, see id. at 84–97.

163. See, e.g., Pakes & Griliches, Patents and R & D at the Firm Level: A First Look, *in* R & D, Patents & Productivity, supra note 162, at 55. Of course, one might argue that narrowing patent scope at the margin will redirect investment away from pioneering inventions and toward improvements on existing products. But two factors mitigate this. First, reducing scope at the margin will not completely eliminate the advantages of a pioneering invention over an improvement. Even without patents, pioneering inventions can lead to much higher returns than mere improvements. Second, narrower scope does *not* mean that pioneering inventions have only the scope of an improvement. There is still a good deal of difference between a narrower-at-the-margins pioneering patent and a mere improvement patent.

164. See, e.g., F. Scherer, Innovation and Growth: Schumpeterian Perspectives 257–59, 270–85 (1984).

165. A. Link & G. Tassey, Strategies for Technology-Based Competition 7 (1987); D. Jorgenson, Microeconomics and Productivity, *in* The Positive Sum Strategy: Harnessing Technology for Economic Growth 57, 57–76 (R. Landau & N. Rosenberg, eds. 1986); cf. H. Arendt, supra note 162, at 142– 51 (describing the strong consensus in favor of economic growth).

place, the sooner improvements can be introduced the sooner the cost-saving (and welfare-enhancing) effects of those improvements will be felt by consumers. And, of course, the early availability of improvements will accelerate the pace with which second- and third-generation improvements—that is, improvements on the improvements—will be introduced.[166]

But it is perhaps not enough to demonstrate the consistency of our thesis with basic economic concepts. Another means of validating our assumptions is by looking for consistency with the goals and purposes of the patent law itself. In its grant of priority to the first to invent;[167] its preference for an early reduction to practice;[168] and its provisions designed to encourage early filing of patent applications,[169] patent law favors not just invention, but *early* invention. Thus our concern that improvements be introduced as quickly as possible simply carries out a basic policy evident throughout the patent system. While there are those who may challenge the propriety of these goals from the standpoint of economic policy, it is both realistic and necessary for courts and the patent office to pursue the goals implicit in both constitutional and statutory provisions. Our assumptions, therefore, while not completely unassailable, are consistent with both economics and policy considerations.

In the remainder of this section we will consider several historical examples of how technical change proceeds in an industry. In the following section we explore industries whose development followed the different models, testing the relative efficacy of a pluralistic rivalrous system versus one in which technical advance is under the control of one or a few organizations. Our goal is to determine whether our theoretical understandings regarding the effect of patent scope in various industry types are consistent with the historical record.

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166. A noted economist who studied technical change made a related point. Machlup, The Optimum Lag of Imitation Behind Innovation, *in* Selected Economic Writings of Fritz Machlup 485, 502 (G. Bitros ed. 1976) (concluding that "*longer* imitation lags are uneconomical . . . , [but] no reliable clue has turned up as to the length of the *optimum lag*"). There has been some debate, however, over the question of the optimal timing of innovations and improvements. See, e.g., F. Scherer, supra note 164, at 67–82; Nelson, Uncertainty, Learning, and the Economics of Parallel Research and Development Efforts, 43 Rev. Econ. & Statistics 351 (1961). But note that this literature studies optimal timing from the point of view of the innovating firm; from society's point of view, there may be additional advantages to sooner rather than later.

167. See 35 U.S.C. § 102(g) (1988).

168. See 3 D. Chisum, supra note 45, § 10.03[1] (describing priority of invention rules, noting that first to reduce to practice is prima facie true inventor, and other inventors who wish to claim priority must prove earlier date of conception).

169. See 35 U.S.C. § 102(b) (person entitled to patent unless, inter alia, invention was published, used or sold more than one year before application was filed).

B. *Differences in Industrial Patterns of Technical Advance*

We have noted earlier that, while most analyses of the effects of the patent system on invention assume implicitly that technical advance proceeds similarly in all industries, this assumption is mistaken: the pattern of technical advance varies significantly from field to field. One of the authors, Nelson, has concluded that at least four different generic models are needed.[170] The first describes discrete invention. A second concerns "cumulative" technologies. Chemical technologies have special characteristics of their own. Finally, there are "science-based" technologies where technical advance is driven by developments in science outside the industry. In each of these models patent scope issues take on a special form. In any industry one or another of these models may be applicable at any given time, or appropriate characterization may require a mix. But the mix differs from industry to industry, and so too, therefore, the salient issues involving patent scope.

What we call the discrete invention model corresponds to much of the standard writing about invention. It assumes that an invention is discrete and well-defined, created through the inventor's insight and hard work. In the standard discussions it may be recognized that the original invention can be improved, or even that improvement or complementary advances may need to be made if the invention is to be of much use. The basic invention may be amenable to tailoring for different uses or customers. But it is implicit that the invention does not point the way to wide ranging subsequent technical advances. It does not define any broad prospect. There are many inventions that fit this model, and these may be of considerable economic and social value. Two examples are King Gillette's safety razor[171] and the ball point pen,[172] and many new pharmaceuticals may also fit this model.[173] And in other industries technical advance appears largely to proceed through inventions of this kind. The consumer goods packaging industry is likely of this sort,[174] as is the toy industry.[175] For inventions and industries like these, while tight and broad control of a particular inven-

170. On cumulative industries, see R. Nelson & S. Winter, supra note 142, at 255–62.

171. See supra notes 25–29 and accompanying text.

172. See J. Jewkes, D. Sawers & R. Stillerman, The Sources of Invention 234–35 (2d ed. 1969).

173. See E. von Hippel, supra note 145, at 53 ("[T]he mechanisms by which pharmaceuticals achieve their medical effects are often not well understood. When this is so, potential imitators cannot gain much helpful insight from examining a competitor's patented product.").

174. See, e.g., Graham v. John Deere Co., 383 U.S. 1, 26, 148 U.S.P.Q. (BNA) 459 (1966) (invalidating patent on spray pump bottle with hold-down cap); K. Brown, Inventors at Work: Interviews with 16 Notable American Inventors 366–68 (1988) (interview with Nat Wyeth, inventor of the plastic soda bottle).

175. See, e.g., Moleculon Research Corp. v. CBS, Inc., 872 F.2d 407, 10

tion may enable a firm to profit handsomely, possession by that firm of a proprietary lock on the invention is not a serious hindrance to inventive work by many other firms. This stems largely from two features of these industries, one having to do with inventive *inputs* and the other with inventive *outputs*. As to inputs, discrete inventions do not typically incorporate a large number of interrelated components; they stand more or less alone.[176] On the output side, the products of discrete technology industries tend not to comprise integral components of some larger product or system; they therefore do not enable the development of a wide array of ancillary products.

However, in a number of technologies, the above characterization is quite inappropriate. In industries like those producing automobiles, aircraft, electric light systems, semiconductors and computers, technical advance is cumulative, in the sense that today's advances build on and interact with many other features of existing technology.[177] This by no means implies that technical advance is slow or inconsequential. Over time dramatic advance occurs in these technologies from improvements to one aspect or another, adding this new feature or that.[178] In many cases the technology in question defines a complex system with many components, subcomponents and parts, and technical advance may proceed on a number of different fronts at once.[179] In these industries inventions may enhance some feature of a prior "domi-

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U.S.P.Q.2d (BNA) 1390 (Fed. Cir. 1989) (finding no infringement of patent on "Rubik's Cube").

176. Ballpoint pens, for instance, involve basically a barrel, the point and ink. Note that even here, however, improvement inventions are possible—just not very many of them, compared to cumulative technologies. See, e.g., J. Jewkes, D. Sawers & R. Stillerman, supra note 172, at 235 (describing invention of quick-drying ink by inventor unaffiliated with ballpoint pen inventors). Thus even ballpoint pens have some of the qualities of a cumulative technology—demonstrating the difficulties of any classification scheme along this dimension. Nevertheless, overall, they must be characterized as a discrete technology.

177. See R. Nelson & S. Winter, supra note 142, at 255–62; see also D. Sahal, Patterns of Technological Innovation 37 (1981) (describing cumulative nature of technical advance in aluminum products, electrical generation, petroleum refining and synthetic fiber production); Levin, Appropriability, R&D Spending, and Technological Performance, 78 Am. Econ. Rev. 424, 427 (1988) (contrasting chemical and drug industries prior to advances in genetic engineering—which the author uses as examples of discrete technologies—with "cumulative industries" such as electronics). It should be noted that at least one analyst of technical change sees *all* technical progress as the process of cumulative change. See D. Sahal, supra, at 112.

178. See, e.g., S. Hollander, The Sources of Increased Efficiency: A Study of Du Pont Rayon Plants 203–04 (1965) (concluding that "minor" improvements "accounted for over two-thirds of the unit-cost reductions attributable to technical change at most of the plants considered"); Enos, A Measure of the Rate of Technological Progress in the Petroleum Refining Industry, 6 J. Indus. Econ. 180, 187 (1958) (emphasizing the cumulative quantitative importance of small improvements in petroleum refining processes).

179. A good description of the nature of invention can be found in the innovation histories of the industries studied by Eric von Hippel that we would classify as cumulative. See E. von Hippel, supra note 145, at 163–82 (semiconductors); id. at 188–95

nant design,"[180] or they may be incorporated into subsequent inventions,[181] or both.

There is much more at stake regarding allowed patent scope in these cumulative technologies than in those where inventions are discrete and stand separately. Particularly when the technology is in its early stages, the grant of a broad-gauged pioneer patent to one party may preclude other inventors from making use of their inventions without infringing the original patent. Two such examples are the Selden patent, which was used to control the development of automobiles, and Edison's successful attack on a broad patent covering light bulb filaments.[182] Thus, a broader pioneer patent may give one party legal control over a large area. Alternatively, in multicomponent products, broad patents on different components held by several inventors may lead to a situation in which no one can or will advance the technology in the absence of a license from someone else. As we shall see, these are not just theoretical possibilities; they describe the development of several important technologies.

Despite the nature of technical advance in cumulative-technology industries, improvement patents (discussed earlier) are no more common in these industries than in others.[183] This is because an improvement patent is undesirable for the reasons discussed above,[184] and because patent lawyers prefer to claim a new or improved component or subcomponent as a distinct product. Accordingly, it is important not to confuse the patent-law concept of an improvement patent with the commercial reality that, in some industries, technical advance proceeds cumulatively, i.e., via a series of improvements.

Technical advance in the chemical industries has some attributes that fit the discrete invention model, some that fit the cumulative technologies model, and some particular characteristics of its own. A new chemical product is in most cases a discrete entity, or it may encompass a particular class of products, like penicillin. But particular chemical product innovations seldom are the keystones to the development of large numbers of other chemicals. Although there are recognizable families of chemical products, the invention of one chemical species seldom gives more than general gnidance in the development of other species. This is primarily a function of the complex and unpredictable

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(tractor shovels). The latter series of innovations are, of course, only one component in the overall composition of farm tractors. See D. Sahal, supra note 177, at 132–36.

180. See, e.g., Dosi, Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change, 11 Res. Pol'y 147 (1982).

181. For example, the semiconductor industry supplies an essential component for electronics, automobiles and many other products. See T. Howell, et al., The Microelectronics Race 4–13 (1988).

182. See infra notes 191–222 and accompanying text.

183. See supra notes 96–121 and accompanying text.

184. See supra note 97 and accompanying text.

relationship between chemical structure and function, most clearly evident in the pharmaceutical industry.[185] Sometimes, however, a new chemical entity turns out to have a wide variety of applications.[186] Because of this, not every chemical product invention shares all the features of a true discrete invention. At the same time, chemical *processes* tend to be improved along the lines of the cumulative technology model, and licensing and cross licensing are well-established practices in these industries. This tradition of licensing mitigates the potential impact of broad patents. As a result of these special features, scope decisions affect the chemical industries differently from others, a point we return to in Part III.

An invention in any of the three regimes described above may be assisted by recent developments in science. But technologies whose advance is predominantly driven by such developments, while rare, warrant special recognition. In these science-based technologies,[187] of which modern biotechnology is a prominent example, research and development efforts attempt to exploit recent scientific developments.[188] These scientific developments tend to narrow and focus perceived technological opportunities in the industry and concentrate the attention of inventors on the same things.

Such science-based technologies warrant analytic distinction for

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185. C. Taylor & Z. Silberston, The Economic Impact of the Patent System: A Study of the British Experience 252 (1973) ("unpredictability [of the behavior of chemicals in the human body] is of a much higher order than that found in non-biological areas of chemical research—and very much higher than that in engineering fields"); 2 D. Chisum, supra note 45, § 5.04[6], at 5-312 ("[A] newly-synthesized compound may be very similar in structure to known and existing compounds and yet exhibit very different properties."). Several of the rules goveruing chemical patents reflect the inability routinely to predict function given a certain chemical structure. See, e.g., In re Papesch, 315 F.2d 381, 386–89, 137 U.S.P.Q. (BNA) 43, 47–50 (C.C.P.A. 1963) (describing chemical obviousness doctrine whereby compound's structural similarity to prior art raises presumption that compound is obvious that can be overcome by evidence that claimed compound exhibits new and unexpected properties); In re Fisher, 427 F.2d 833, 839, 166 U.S.P.Q. (BNA) 18, 24 (C.C.P.A. 1970) ("In cases involving unpredictable factors, such as most chemical reactions and physiological activity, the scope of enablement obviously varies inversely with the degree of unpredictability of the factors involved."). On this latter point, see supra note 68 (discussion of Patent Office rules on enablement in various arts).

186. See, e.g., D. Hounshell & J. Smith, Science and Corporate Strategy: DuPont R&D, 1902–1980, at 480–81 (1988) (describing applications of Du Pont's polyethylene in all segments of the plastics market); id. at 482–86, 708 n.42 (describing wide ranging applications for polytetrafluoroethylene, tradename Teflon).

187. See R. Nelson & S. Winter, supra note 142, at 334–37; Dosi, supra note 180, at 148–49 (description of science-based industries using a different industry taxonomy).

188. Other examples of science-based industries include medical diagnostic equipment (e.g., nuclear magnetic resonance), lasers, and the still nascent superconductor industry. See generally M. Kenney, Biotechnology: The University-Industrial Complex (1986); Kenney, Schumpeterian Innovation and Entrepreneurs in Capitalism: A Case Study of the U.S. Biotechnology Industry, 15 Res. Pol'y 21 (1986) (describing role of scientists, as well as entrepreneurs and capitalists).

several reasons. In the first place, this is a context that engenders inventive races of the sort described earlier, particularly if it is anticipated that the first to apply a scientific finding will get a patent of considerable scope. Many are rushing toward the same objective that all see as feasible and several will get there, but only the first receives a patent. Second, new scientific and technological developments "in the air" open the possibility of a major advance over prior practice, and the contribution made by the individual or firm who first makes these possibilities operational may be relatively small.[189] The invention may diverge from "prior art," in the sense of actual technological accomplishments, and sweep the market, yet still be only a successful application of knowledge that is apparent to the scientifically sophisticated.[190] When this is a possibility, the patent system should be particularly careful in awarding patents of broad scope. Third, and this is where our focus will be, there is a real danger that allowing patent scope to be overbroad may enable the individual or firm who first came up with a particular practical application to control a broad array of improvements and applications.

We now turn to a more detailed discussion of these models of technical advance, with an eye toward what they can teach us about the effects of patent scope.

III. Effects of Patent Scope in Various Industries

Because we are concerned with the effects of patent scope decisions on the subsequent development of technology, we are not interested in the cases of discrete invention. We deal with what we have called cumulative technologies, chemical technologies and science-based technologies, in that order.

A. *Cumulative Technologies*

We have asked two questions about the effects of broad patents on cumulative technologies. One concerns the consequences of "pioneer" patents. We wish to test the validity of the hypothesis that the granting of broad patents is likely to make subsequent invention and development more orderly and productive. The second question is how the presence of broad patents on components of a cumulative technology affects subsequent development.

One must keep in mind, however, what we are *not* testing. We do

189. See, e.g., the description of the commercial development of diagnostic testing kits using monoclonal antibodies, infra notes 307–313 and accompanying text.

190. In theory, the nonobviousness requirement of 35 U.S.C. § 103 (1988) will prevent such obvious inventions from receiving patents. In practice, for a variety of reasons, this requirement does not always function properly. See Merges, Commercial Success and Patent Standards: Economic Perspectives on Innovation, 76 Calif. L. Rev. 803, 857–58 (1988) (discussing invention of monoclonal antibody in critique of nonobviousness doctrine).

not ask whether *any* patent should have been granted in the following cases. We take it as axiomatic that some degree of patent protection is necessary and desirable. And we do not ask whether the scope of the patents discussed should have been limited to the precise embodiments the inventor had developed when the patents were filed. We accept that patents claiming the general inventive principle were justified; and we focus on the impact of broad scope on the environment for subsequent development and improvement.

1. *Electrical Lighting Industry.* — The chain of reasoning in our critique of the prospect theory, and our view of the patent system, is consistent with most of the historical evidence on cumulative technologies. The early electrical illumination industry illustrates this most clearly.

Patents played a very important part in this industry from the beginning. In the field of incandescent lighting, Edison's early patent gave his company, later General Electric, a dominant position. But in certain other sectors, most notably arc lighting and the production of dynamos, efforts to establish dominance via a single broad patent failed. The contrast between these sectors, where entry was easy and competition for improvements was intense, and the incandescent lighting field is noteworthy for our purposes. Most importantly, the history of the early electrical industry supports the notion that broad pioneering patents can play a pivotal role in the evolution of industry structure.

No single patent better illustrates this than Edison's U.S. Patent 223,898, issued in 1880. This was "the basic patent in the early American incandescent-lamp industry," covering the use of a carbon filament as the source of light;[191] it proved to have a profound effect on the industry until it expired.

Although the Edison General Electric Company had some difficulty establishing the validity of its basic patent, once it did the industry changed drastically. In 1891, U.S. Patent No. 223,898 was held valid and infringed by a competing design.[192] General Electric officials then quickly obtained a series of injunctions that shut down a number of competitors.[193] As the aptly-named industry historian Arthur Bright stated, "For twelve years [after the issuance of the 223,898 patent] competition had been possible; it suddenly became impossible."[194] The company's market share grew from 40 to 75 percent; entry into the industry slowed from 26 new firms in 1892 to 8 in 1894, the last year of

191. H. Passer, supra note 141, at 152.

192. Edison Elec. Light Co. v. United States Elec. Lighting Co., 47 F. 454 (C.C.S.D.N.Y. 1891), aff'd, 52 F. 300 (2d Cir. 1892).

193. See A. Bright, The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947, at 89 (1949).

194. Id. at 89. See United States v. General Elec. Co., 82 F. Supp. 753, 771, 80 U.S.P.Q. (BNA) 195, 205 (D.N.J. 1949) (describing Edison patents and their "virtual monopoly of the domestic supply in electric lamps" from 1891 to 1894, in finding defendant liable for various antitrust violations).

the patent's life;[195] and the steady downward trend of lamp prices slowed until the patent expired.[196]

More importantly for our purposes, the validation of Edison's broad patent slowed the pace of improvements considerably.

> Even as the courts were passing on the Edison lamp patent in 1891, the Edison General Electric Company . . . . [recognized that it] gradually had been slipping backward in its commercial position, particularly since 1886 . . . . Its technological contributions were becoming relatively smaller than they had been during the early [eighteen] eighties.[197]

This was especially true in Great Britain, where the Edison Company's patent position was even more commanding, due to its control of a basic patent on a process for producing carbon filaments. A series of court victories over its largest competitors gave the British "Ediswan" company "a practical monopoly of incandescent-lamp production."[198]

Given the lack of competition, it is perhaps not surprising that the pace of technical advance slowed. According to the historian Bright:

> After the introduction of the incandescent lamp and its first rapid changes . . . the Edison Electric Light Company did not introduce many important new developments. Edison himself turned to other problems, and the company's technical leadership in incandescent lighting was not revived until after the merger [that formed General Electric in 1896].[199]

Prior to the enforcement of the patent, Edison's competitors were quickening the pace of technical advance:

> Despite the improvements in the Edison lamp, a number of its competitors had improved their lamps even more rapidly. . . . Efficiency advantages permitted many of the other American concerns to compete very successfully with the Edison lamp after 1885 . . . until the corporate reorganizations and the establishment of patent supremacy regained for the Edison lamp commercial supremacy as well.[200]

The same was true overseas: "In England, filament improvement was almost entirely halted during the period of Edison patent monopoly

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195. A. Bright, supra note 193, at 91, 92 (Table XI). The patent expired in 1894—instead of 1897, seventeen years after issue—because a Canadian counterpart patent expired in 1894, and thus (under then-existing law), so did the U.S. patent. See id. at 91.

196. Id. at 93.

197. Id.

198. Id. at 108.

199. Id. at 122.

200. Id. at 122–23. See M. MacLaren, The Rise of the Electrical Industry During the Nineteenth Century 79 (1943) (describing corporate alliances in early electrical industry resulting from patent blockages); H. Passer, supra note 141, at 324–25 (describing extensive patent blockages leading to merger of Edison General Electric and the Thomson-Houston Company to form General Electric).

from 1886 to 1893."[201] Bright concludes:

> The lengthy and expensive patent struggle in the lamp industry from 1885 to 1894 was a serious damper on progress in lamp design, although process improvement continued. The Edison interests concentrated on eliminating competition rather than outstripping it. . . . After 1894, when it was no longer protected by a basic lamp patent, General Electric devoted more attention to lamp improvement to maintain its market superiority.[202]

Thus the broad Edison patent slowed down progress in the incandescent lighting field. The lesson, however, is not that this patent should not have been granted. It is rather a cautionary lesson: broad patents do have a significant impact on the development of a technology and hence on industry structure, and this should be reflected in those doctrines that collectively determine patent scope.

Two other sectors of the electrical industry—ones where broad patents were invalidated—demonstrate what can happen in the absence of dominant patents. The first was in the production of power generation dynamos, where the Brush Company attempted to establish patent dominance. Brush, together with several other companies, acquired a patent they thought "would give absolute control of all dynamo manufacture in the United States."[203] But the courts thought otherwise; the patent was found to have lapsed when a foreign counterpart patent reached the end of its term.[204] As an historian of the industry describes it:

> The effect of the decision was to free the dynamo from patent control. Anybody could manufacture it. It was only minor details in dynamo design and construction—such as particular coil windings or commutators—which were patentable.[205]

Because there were no broad patents to discourage entry, entry was easy and competition for improvements was intense.[206]

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201. A. Bright, supra note 193, at 138.

202. Id. at 138–39. On General Electric's need to catch up technologically after the Edison patent expired in 1894, see T. Hughes, American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970, at 166–67 (1989). For a description of organizational complacency, and the "shocks" that can break a firm out of a comfortable torpor, see Cyert & March, Organizational Structure and Pricing Behavior in an Oligopolistic Market, 45 Am. Econ. Rev. 129 (1955) (firms with suddenly declining market shares strove more vigorously to increase their sales than firms whose shares were steady or increasing). In another paper, Cyert and March provided an explanation: firms are complacent "until some form of shock (such as failing to meet its goals) forces a kind of search behavior on the organization." Cyert & March, Organizational Factors in the Theory of Oligopoly, 70 Q.J. Econ. 44, 54 (1956).

203. H. Passer, supra note 141, at 41.

204. See Gramme Elec. Co. v. Arnoux & Hochhausen Elec. Co., 17 F. 838 (C.C.S.D.N.Y. 1883).

205. H. Passer, supra note 141, at 41.

206. See A. Bright, supra note 193, at 109; A. Marcus & H. Segal, Technology in America: A Brief History 144 (1989) ("Brush's initial success in manipulating dynamos,

The second failed attempt to establish dominance by way of a broad patent also involved the Brush Company. In 1884 the company brought a test infringement case involving its basic patent on a double-carbon arc light.[207] Unfortunately for the Brush Company, the court found that the defendant's design did not incorporate a key feature of the Brush patent, and thus held that there was no infringement.[208] This ruling had an important effect: "[p]atents were consequently not a handicap to entry into the industry. Firm after firm was organized to manufacture its own arc-lighting system. At one time, nearly fifty different firms were making arc-lighting equipment."[209]

2. *Automobiles and Airplanes.* — We move now to two infamous cases regarding pioneer patents: the Selden patent in the development of automobile technology,[210] and the Wright patent's influence on the growth of aircraft technology. As we have seen, the Selden patent claimed a basic automobile configuration, one using a light-weight internal combustion engine as the power source. The Wright patent was on a broadly defined airplane stabilization and steering system. In both of these cases, the holders of the pioneer patent engaged in extensive litigation against companies that did not recoguize the patent,[211] and

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circuits, and arc lamps . . . engendered competition and yielded improvements" from several competitors).

207. Arc lights work because an electrical current will jump a gap between certain conductors. This is a different principle from the incandescent lamp, which casts light because the current meets resistance in the filament, causing the filament to glow. Arc lights are brighter; this is why they have been extensively used in outdoor lighting, for instance.

208. Brush Elec. Co. v. Western Elec. Co., 69 F. 240, 246 (C.C.N.D. Ill. 1895), aff'd, 76 F. 761 (7th Cir. 1896). Another case previously had held that the Brush patent *had* been infringed by the same device at issue in the *Western Electric* case, but Brush apparently was unwilling to litigate the patent for a third time because the later *Western Electric* decision is the last regarding this patent. See Brush Elec. Co. v. Western Elec. Light & Power Co., 43 F. 533 (C.C.N.D. Ohio 1890).

209. H. Passer, supra note 141, at 42. See M. MacLaren, supra note 200, at 70–71 (describing the many investigators who were attempting to make improvements to the basic arc light design); D. Noble, America By Design: Science, Technology and the Rise of Corporate Capitalism 7 (1977) ("Neither the arc lamp nor the dynamo proved patentable in court tests, however, and, as a result, the manufacture of arc-lighting systems became fiercely competitive.") The Brush Company actually tried to establish patent dominance over another segment of the industry—the market for replacement lamp carbons. This effort failed when, in 1887, its patent on copper-coated carbons was held invalid; once again, the result was an industry that "strongly resembled the economist's conception of pure competition . . . ." Id. at 62.

210. See supra notes 31–34 and accompanying text.

211. See, e.g., Wright Co. v. Herring-Curtiss Co., 204 F. 597 (W.D.N.Y. 1913), aff'd, 211 F. 654 (2d Cir. 1914); Wright Co. v. Paulhan, 177 F. 261 (C.C.S.D.N.Y.) (L. Hand, J.), rev'd, 180 F. 112 (2d Cir. 1910); W. Kaiser & C. Stonier, The Development of the Aerospace Industry on Long Island: Financial and Related Aspects 4–11 (Hofstra Univ. Yearbook of Business, Series 5, vol. 4 1968); supra notes 31–34 and accompanying text.

the Wrights refused to license theirs.[212] Our question is how the presence of these patents affected the evolution of the technologies.

The Selden patent had as its key claim the use of a light gasoline-powered internal combustion engine. This claim was extremely broad and covered a myriad of possible embodiments.[213] Contrary to the prospect theory, however, neither Selden nor his assignee used the patent to orchestrate the efficient improvement of automobile technology; there was no policy of "developing the prospect."[214] They were willing to license anyone who would acknowledge the validity of the patent and pay royalties; to this end they formed the Association of Licensed Automobile Manufacturers.[215] But the Association's purpose was to collect royalties, and perhaps control competition in the industry,[216] rather than to facilitate orderly technological development.

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212. See Dykman, Patent Licensing Within the Manufacturer's Aircraft Association (MAA), 46 J. Pat. Off. Soc'y 646, 647 (1964) (describing formation of industry licensing pool at behest of government because, "[n]o one would license the other under anything like a reasonable basis"). The Curtiss-Wright dispute was the centerpiece of a larger patent logjam in the early aircraft industry. See W. Kaiser & C. Stonier, supra note 211, at 4–11.

213. One can argue that the broad Selden patent should not have been granted in the first place. His critics argued that Selden never built or operated the automobile that was pictured and described in the specification. Of course, this is not a prerequisite to obtaining a patent. See 3 D. Chisum, supra note 45, § 10.05[1] (describing doctrine of constructive reduction to practice whereby filing patent application can constitute sufficient reduction to practice to merit priority of invention). His critics argued further that in any event Selden's claims exceeded what the specifications enabled. Cf. Electric Vehicle Co. v. C.A. Duerr & Co., 172 F. 923, 926 (C.C.S.D.N.Y. 1909), rev'd sub nom. Columbia Motor Car Co. v. C.A. Duerr & Co., 184 F. 893 (2d Cir. 1911); Electric Vehicle Co. v. Winton Motor-Carriage Co., 104 F. 814, 816 (C.C.S.D.N.Y. 1900). See generally J. Flink, America Adopts the Automobile, 1895–1910, at 318–19 (1970) (describing Selden's assignment of patent to the Electric Vehicle Company, whose motive was probably "to hedge against the possibility that the gasoline automobile might prove superior" to the electric vehicle being developed by the company).

214. If they had used the patent for this purpose, we would expect to see a record of licensing agreements whereby firms specializing in various aspects of the automobile were given licenses and in turn were required to contribute or license their improvements back to Selden and his assignee. No such agreements seem to have been made, despite rapid progress in various aspects of automobile design. Cf. D. Hounshell, From the American System to Mass Production, 1800–1932: The Development of Manufacturing Technology in the United States 274 (1984) (describing Ford's improvements in engines, electric starters, flywheels, etc.).

215. In 1903, several years after the Selden patent survived its first challenge, *Winton Motor-Carriage Co.*, 104 F. at 816, the Association of Licensed Automobile Manufacturers (ALAM) was formed. Until it was dissolved in 1911, following the first case finding that the Selden patent had not been infringed, the ALAM exercised some measure of control over the automobile industry through its power to deny licenses to new companies. See J. Flink, supra note 213, at 321.

216. Id. Although controlling competition for improvements might be a part of an orderly development strategy, there is no evidence that the association was doing anything to develop the Selden "prospect." Thus its efforts to control competition look like naked restrictions on entry, not part of a coordinated development scheme.

But did the presence of the Selden patent actually *hinder* technological progress in the industry? That is perhaps a bit more speculative. Law suits based on it surely did absorb considerable time and attention of people like Henry Ford, whose production methods revolutionized the industry.[217] Perhaps more importantly smaller firms may have been put off by the threat of suit. At this early stage in the history of the technology, those that left the industry or chose not to enter may well have taken valuable improvements with them.

An interesting result of this experience with patent litigation was that, even before the Selden patent was pruned back in 1911,[218] the automobile industry, through the Association, developed a procedure for automatic cross licensing of patents. While formal agreements to cross license all new patents no longer exist, the practice of relatively automatic cross licensing has endured to the present.

The Wright brothers patent is different in a number of regards. First of all, the achievement described in the patent—an efficient stabilizing and steering system—was in fact a major one, and it did enable a multiplicity of future flying machines.[219] Second, the Wright brothers were very interested in producing aircraft and in improving their design, and they did so actively. However, there were other important people and companies who wanted to enter the aircraft design and manufacture business. They had their own ideas about how to advance the design of aircraft, and they strongly resisted being blocked by the Wright patent. In this case, and others, it turned out to be extremely difficult to work out a license agreement that satisfied both the holder of a broad patent and an aggressive potential competitor who believed that there was a lot of his own work in his design. The early attempts by the Wright Brothers and Glenn Curtiss, who was the most prominent such potential competitor, came to naught. Litigation followed.[220]

There is good reason to believe that the Wright patent significantly

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217. One historian of the industry states:

> That consumers were in some cases actually intimidated from buying the products of perfectly "good and reliable" but unlicensed manufacturers is . . . quite probable; certainly the advertisements of the A.L.A.M. attempted to accomplish this result. In response to the association's repeated warning "Do Not Buy a Lawsuit with Your Automobile," the Ford Company offered to give each purchaser a bond protecting him against any damages that might arise from this quarter.

R. Epstein, The Automobile Industry 233 (1928). As to Ford, the Selden patent did not stop him, but it did slow him down. See J. Flink, supra note 213, at 323–27 (describing Henry Ford's battle against the Selden patent).

218. See Columbia Motor Car Co. v. C.A. Duerr & Co., 184 F. 893, 908–09 (2d Cir. 1911).

219. See Wright Co. v. Paulhan, 177 F. 261, 271 (C.C.S.D.N.Y.) (L. Hand, J.), rev'd, 180 F. 112 (2d Cir. 1910); Zollmann, Patent Rights in Aircraft, 11 Marq. L. Rev. 216, 218–19 (1927).

220. See Wright Co. v. Herring-Curtiss Co., 204 F. 597, 614 (W.D.N.Y. 1913) (find-

held back the pace of aircraft development in the United States by absorbing the energies and diverting the efforts of people like Curtiss. The aircraft case is similar to that of automobiles in that the problems caused by the initial pioneer patent were compounded as improvements and complementary patents, owned by different companies, came into existence. The situation was so serious that at the insistence of the Secretary of the Navy, during World War I, an arrangement was worked out to enable automatic cross licensing.[221] This arrangement, like the licensing of automobile patents, turned out to be a durable institution. By the end of World War I there were so many patents on different aircraft features that a company had to negotiate a large number of licenses to produce a state-of-the-art plane.[222]

3. *Radio.* — The case of radio in the United States warrants at least a brief recounting, for it is an excellent example of what happens when several companies each hold patents of broad scope. The earliest radio patent was a broad patent granted to the British inventor Marconi in the field of radio transmission.[223] Marconi also invented and acquired rights to the basic technology for tuning,[224] which he controlled until 1914, and the basic Fleming patent on the two element vacuum tube, or diode.[225] These patents helped the Marconi Wireless and Telegraph Company establish an imposing presence in the early radio industry, which was dedicated primarily to large-scale commercial uses such as ship-to-shore communications.

AT&T, as part of its radio operations,[226] acquired rights to two very fundamental patents on the triode vacuum tube, an early radio wave amplification device patented by Lee De Forest.[227] While technic-

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ing that defendants' admittedly different design infringed plaintiff's broad pioneer patent on airplane stabilization), aff'd, 211 F. 654 (2d Cir. 1914).

221. See Bittlingmayer, Property Rights, Progress, and the Aircraft Patent Agreement, 31 J.L. & Econ. 227, 232 (1988).

222. See W. Kaiser & C. Stonier, supra note 211, at 4–11; Bittlingmayer, supra note 221, at 236–40.

223. See S. Sturmey, The Economic Development of Radio 16 (1958); H. Aitken, Syntony and Spark: The Origins of Radio 203–05 (1976).

224. W. MacLaurin, Invention and Innovation in the Radio Industry 45 (1949) (acquisition of basic patent by Lodge on tuning, and issuance of major improvement patent to Marconi, the famous British 7777 patent and American equivalent, filed in 1900).

225. Sturmey cites "a reliable opinion" as describing the Lodge tuning patent, acquired by Marconi, as "a master patent, or something very like it." S. Sturmey, supra note 223, at 17. Marconi's rights in the Fleming "valve" (vacuum tube) patent— said to be basic to the whole art—dated to its invention in 1904. See id. at 32.

226. AT&T entered the radio field when it became concerned that radio could become a possible competitor to its long distance telephone line technology.

227. See L. Reich, The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926 (1985) (triode invented by Lee De Forest). The history of the vitriolic interference between De Forest and Edwin Armstrong, who claimed priority of invention, is summarized in Radio Corp. of Am. v. Radio Eng'g Laboratories, 293 U.S. 1, 2–7 (1934). Many believed then, and still believe, that De Forest was wrongly given priority. See G. Douglas, The Early Days of Radio Broadcasting 12

ally only an improvement on Marconi's diode, the triode was in fact a very significant advance; it was called "the heart and soul of radio."[228]

Several other firms had important patent positions. General Electric entered radio as a natural extension of its expertise in electricity generating systems. It controlled the important Alexanderson patents on the electric alternator, the signal generation invention that made long-range transmission possible.[229] Westinghouse also joined the industry, mostly on the strength of patents on receiving technology, which served as the basis of the firm's successful entrance into the inexpensive home receiver market.[230] Other companies also held American rights of varying breadth over other important radio technologies.[231]

The situation soon became similar to that in the aircraft industry, where different companies could block each other from using key components. A good example is the deadlock between the Marconi Company and the De Forest interests, a classic instance of blocking patents. Marconi's diode patent was held to dominate De Forest's patented triode,[232] yet neither party would license the other.[233] As a consequence, no one used the admittedly revolutionary triode for a time. This is a good example of a case where the reverse doctrine of equivalents might have been invoked to permit De Forest to practice his improvement.[234]

In at least one other area as well—long-range transmission—licensing proved difficult.[235] The upshot was that no one could produce state-of-the-art radio technology without being threatened by litigation.[236] Radio is thus a canonical instance where the presence of a

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(1987); McCormack, The Regenerative Circuit Litigation, 5 Air L. Rev. 282, 293–95 (1934).

228. See G. Douglas, supra note 227, at 8.

229. See W. MacLaurin, supra note 224, at 94.

230. See G. Douglas, supra note 227, at 19–20.

231. See Federal Trade Comm'n, Report of the Federal Trade Commission on the Radio Industry in Response to House Resolution 548, 67th Cong., 4th Sess., Dec. 1, 1923, at 27 (1924) [hereinafter FTC Report].

232. Marconi Wireless Tel. Co. of Am. v. De Forest Radio Tel. & Tel. Co., 236 F. 942, 955 (S.D.N.Y. 1916), aff'd, 243 F. 560, 566–67 (2d Cir. 1917).

233. See FTC Report, supra note 231, at 26.

234. See supra notes 96–127 and accompanying text. De Forest's improvement was considered a major technical advance. Hugh Aitken stated that the invention of the triode "is one of the 'great divides' in the history of radio technology; the whole basis of radio communication begins to shift with the introduction and diffusion of tbis device." H. Aitken, The Continuous Wave: Technology and American Radio, 1900–1932, at 195 (1985) [hereinafter The Continuous Wave].

235. This was the aborted attempt by Marconi to acquire General Electric's alternator technology, as embodied in the Alexanderson patent. This is perhaps anomalous, however, as General Electric might well have agreed to the transaction except for an appeal by the American military to keep this sensitive technology in the hands of domestic interests. See FTC Report, supra note 231, at 14–16. The U.S. Navy ultimately facilitated the formation of RCA, which broke the patent impasse. See infra notes 237–240 and accompanying text.

236. See FTC Report, supra note 231, at 25:

number of broad patents, which were held by different parties and were difficult to invent around, interfered with the development of the technology.[237] The various pioneers formed RCA to break the deadlock; the new company promptly acquired the American rights to the Marconi patents.[238] The companies that owned most major radio patents became RCA shareholders.[239] With all the constituent radio technologies under one roof, RCA established itself as the technical leader in radio and dominated its advance for many years.[240]

As shown by the cases of autos, airplanes, and radios, the many early inventors in cumulative technologies often perform overlapping research. This may lead to blockages unless basic patents are not present, or routine licensing and cross licensing is instituted. We next consider the former possibility by describing important post-World War II technologies that have advanced rapidly because no one held a pioneer patent that was used to restrict access. At the end of this section, we discuss the licensing solution and its impact on our analysis of patent breadth.

4. *Semiconductors and Computers.* — Semiconductors are a good example of a technology that developed without patent blockages. There are two instances in the history of this technology where a broad-gauged patent was issued which could have given its holder control over a large "prospect," but in fact did not. One involved the initial transistor patents held by AT&T. Because of an antitrust consent de-

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> The Navy, in a patent investigation in 1919, had "found that there was not a single company among those making radio sets for the Navy which possessed basic patents sufficient to enable them to supply, without infringement, . . . a complete transmitter or receiver."

(Citation omitted.)

237. See The Continuous Wave, supra note 234, at 249 (impetus behind formation of RCA was that patent rights "threatened to impede further development and commercial exploitation"); S. Sturmey, supra note 223, at 275 (broad patents retarded growth of radio industry).

238. General Electric, "[s]timulated by the Navy," actually formed the Radio Corporation of America (RCA) in 1919. W. MacLaurin, supra note 224, at 103; FTC Report, supra note 231, at 18–21.

239. See FTC Report, supra note 231, at 20–21. RCA also entered into a cross-licensing agreement with General Electric. Id. at 21–22.

240. RCA used package licenses coupled with high royalties to maintain its dominant position. See M. Graham, RCA and the VideoDisc: The Business of Research 41 (1986). Graham describes RCA's use of package licensing to dominate the radio industry from the 1920s until the antitrust enforcement actions of 1958:

> Perhaps the most important enduring consequence of the policy was that it made it uneconomic for most other companies to do radio-related research, because they could not recoup their investment. This left control of the rate and direction of technological change in the radio industry largely in the hands of RCA.

Id.

cree, AT&T was foreclosed from the commercial transistor business.[241] Some have argued that it is not clear whether AT&T would have gone into the merchant transistor business even in the absence of a consent decree.[242] In any case, given that it was not going to do so, AT&T had every incentive to encourage other companies to advance transistor technology because of the value of better transistors to the phone system. AT&T entered into a large number of license agreements at low royalty rates.[243] Many companies ultimately contributed to the advance of transistor technology because the pioneer patents were freely licensed instead of being used to block access.

The second instance involved the parallel inventions of the integrated circuit (by Texas Instruments) and the Planar process for producing them cheaply (by Fairchild Instruments). Both of these companies obtained patents on their own inventions, which meant that each had to license the other to produce integrated circuits effectively.[244] Cross licensing was favored by the government; the Department of Defense, which for some time had provided the lion's share of the market for semiconductors, had a strong interest in seeing these important technologies become broadly available throughout the industry.[245] Again, the absence of a single, broad patent assisted the rapid development of an industry.

The second recent cumulative technology developed without strong, broad patents is electronic computers. Although original computer inventors Eckert and Mauchley did file for and receive a patent on their basic ENIAC design, the patent was ruled invalid because of a judgment that the prior art included much of what they claimed.[246] Since this ruling, patents have played only a very minor role in the computer industry, and where patents are concerned, cross licensing is common.[247] As a result, the pace of technical change has been rapid.[248]

5. *Licensing and Cumulative Technologies.* — In many of the cases we have examined, licensing and industry consolidation emerged as solutions to patent blockages caused by patents. This would appear to have a bearing on our study. Does the consolidation of the radio industry in RCA, for example, support the position that development would have

241. See United States v. Western Elec. Co., 1956 Trade Cas. (CCH) ¶ 68,246, at 71,137–138 (D.N.J. 1956).

242. See Levin, supra note 86.

243. Id. at 76.

244. Id. at 80; J. Tilton, supra note 86, at 77.

245. Levin, supra note 86, at 78.

246. See N. Stern, From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers 2–4 (1981) (citing Honeywell, Inc. v. Sperry-Rand Corp., No. 4-67 Civ. 138 (Minn. Oct. 19, 1973)).

247. See C. Taylor & Z. Silberston, supra note 185, at 294–95.

248. See generally K. Flamm, Targeting the Computer: Government Support and International Competition (1987).

been more efficient had control been in the hands of one party from the beginning, in the form of one super-patent? Or does it imply that patent breadth was irrelevant—consolidation would have happened even with narrow patents?

The first possibility seems remote, and there is indirect evidence that the second is wrong as well. The fact that many inventors and firms made important advances in various components of radio technology indicates that no one firm had the inventive firepower to develop radio on its own. And there is no reason to believe that one firm could have orchestrated the development of the technology, since there was no way to know in advance which inventors would cultivate expertise in each component, or which inventor's approach would work. There were no "proven" experts in transmission or reception that a firm could have granted licenses to, for example; experts emerged only when their inventions turned out to work.[249] And it would have been impossible to identify all the potential experts, since everyone was working on the various components simultaneously.[250] In any event, the inventive scramble that in fact resulted, while by no means optimal, did result in the fairly rapid commercialization of a complex, multicomponent technology. It also resulted in a patent tangle, one that might have been lessened if some of the key patents had been narrower. But it is difficult to see how a *single* broad patent would have led to more rapid commercialization. The ex post consolidation, in other words, simply does not imply that a broad ex ante "prospect" would have been effective in this case.[251]

As to the second objection to our analysis—that the radio industry would have consolidated regardless of patent breadth—two points

249. Cf. H. Aitken, supra note 223, at 308 (describing the development of the American radio industry as "speculative and erratic"); id. at 330 (describing lack of specialization in early days of radio development); id. at 333 (describing the early days of radio when the interactions between scientific, technological, and economic aspects of radio "were only dimly perceived and when institutions to cope with them had barely begun to evolve"). Hugh Aitken describes the progress from the early scientific work of Hertz to Fleming's diode as "highly empirical in nature, very much a matter of trial and error." Id. at 303.

250. For example, the Patent Office interference action concerning the triode originally involved four inventors, two of whom—Edwin H. Armstrong and Irving Langmuir of General Electric—filed patent applications *on the same day*, October 29, 1913. See McCormack, supra note 227, at 282. And in 1915 Alexanderson's alternator became available for the first time. H. Aitken, supra note 223, at 281; W. MacLaurin, supra note 224, at 94. At the same time, AT&T was pioneering research in vacuum tubes. W. MacLaurin, supra note 224, at 95–96.

251. Valuation problems in licensing transactions are difficult enough *after* an invention has been made; they would seem to be inconceivably difficult *prior* to invention. Cf. Meurer, supra note 160, at 80–84 (pointing out that patent validity disputes are not always resolved with licensing agreements because of asymmetric information about validity). It is therefore quite believable that ex ante coordination efforts would quickly break down since prospective inventors would likely value their future improvements more highly than the coordinating firm.

seem relevant. First, narrower patents might have made consolidation unnecessary. If one or more firms could put together a complete radio system without infringing any patents, consolidation would not have been essential, at least for patent-related reasons. One candidate is General Electric: the only essential component for which patent blockage was a problem was the triode;[252] if De Forest's patent had been narrower,[253] or if inventor Edwin H. Armstrong had won his interference with De Forest,[254] General Electric might have put together a noninfringing system.

Second, even if narrower patents would not have prevented the deadlock, they might have helped break it sooner. Perhaps without the value of a "holdup right" on an essential component of radio technology, the firms would have been content to contribute their patents to a pool and compete on the basis of improvements and price competition.[255] Finally, even if *this* industry eventually consolidated into one firm, there is no promise that all industries will do so.[256]

There is also no reason to assume that when blockages arise industries will always turn to the deadlock-breaking solutions we have seen, patent pooling and cross licensing. Though we saw the emergence of cross licensing among aircraft manufacturers, the impetus was war-time government pressure.[257] In the case of the light bulb industry, the government stayed out; when the firms finally pooled technology, it was only to effectuate the operation of a cartel.[258]

There is therefore no guarantee that pooling, cross licensing, or consolidation will always emerge to break an industry impasse. And without these solutions there is nothing to mitigate the effect of broad

252. See The Continuous Wave, supra note 234, at 389 n.5. Westinghouse is perhaps another plausible candidate; by acquiring rights to Armstrong's "regenerative circuit" (triode) patent, see W. MacLaurin, supra note 224, at 106, and an important signal generation patent, they had what appeared to be an infringement-free transmission system, but would have needed some rights to make vacuum tubes. The Continuous Wave, supra note 234, at 476–77.

253. Work by Irving Langmuir of General Electric, an original party to the four-way interference over the triode, might have established some rights in this field. Cf. The Continuous Wave, supra note 234, at 231 (Langmuir's early work on triode amplification produced results superior to De Forest's); id. at 248 (Langmuir part of original interference).

254. GE almost acquired Armstrong's rights during the pendency of the interference, but he eventually sold them to Westinghouse. See W. MacLaurin, supra note 224, at 106.

255. This is analogous to the strategic problem discussed earlier in the context of bargaining between the holder of a basic patent and the inventor of a very major improvement. See supra notes 115–120 and accompanying text.

256. Note too that the savings in transaction costs accompanying consolidation must be weighed against the potential anticompetitive effects of the unified firm. See generally O. Williamson, Markets and Hierarchies: Analysis and Antitrust Implications 155–233 (1975).

257. See supra notes 221–237 and accompanying text.

258. See supra notes 194–196, 199 and accompanying text.

basic patents in cumulative technology industries. Earlier we saw that theory offered a number of reasons to be concerned about these patents. The historical evidence available is consistent with this theory. In most instances this evidence can be read as supportive of our concerns about the effects of broad patents on cumulative technology industries. Chemical industries, which we turn to next, tell a different story.

B. *Chemical Industries*

Chemical industries produce an incredibly diverse range of products, from bulk chemicals like sulfuric acid, to synthetic materials like plastics, to pharmaceuticals.[259] Despite the diversity of products, however, invention in the chemical industries shares several key attributes. To a large extent chemical product invention tends to fit the "discrete invention" model described earlier.[260] Thus product patents tend to define a well delineated class of substances.[261] Valium is valium and, although subject to some variation, sulfuric acid is sulfuric acid. However, research and development on new chemical products is subject to an unusual degree of uncertainty and costly experimentation, both because it is difficult to predict the precise chemical structure needed to achieve a given end and because the effects of using a new chemical substance in a particular way can be startling.[262] Further, once a new product or use is discovered, it is easy for a competitor to replicate.

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259. David Landes, the noted historian of technology, has called the business of chemical manufacture "the most miscellaneous of industries." D. Landes, The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present 269 (1969).

260. See infra notes 171–180 and accompanying text; cf. Levin, supra note 177, at 427 (chemical and drug industries are discrete technology areas "in which innovations . . . stand alone as isolated discoveries").

261. Most chemical claims cover a single compound only in the sense that Gillette's claim covered a single *type* of razor. That is, chemical claims routinely embrace minor variations on the basic structure the inventor discovered. For example, a patentee might claim a compound of structure "Atom 1–Atom 2– Sidegroup," where "Sidegroup" is defined in the claim as including *either* "N-O-O-H" or "N-H2." See Ex parte Markush, 1925 Dec. Comm'r Pats. 126, 128, 340 Off. Gazz. Pat. Off. 839 (1924); 2 D. Chisum, supra note 45, § 8.06[2]. The "family" of variations must share a common principle to be patented using a so-called Markush claim; as stated in In re Schechter, 205 F.2d 185, 189, 98 U.S.P.Q. (BNA) 144, 149 (C.C.P.A. 1953), such a claim will be allowed "where the substances grouped have a community of chemical and physical characteristics which justify their inclusion in a common group, and such inclusion is not repugnant to the principles of scientific classification." Id. (citations omitted).

262. Obviousness and enablement rules for chemical inventions reflect the accepted unpredictability of chemical inventions. See supra notes 194–197 and accompanying text; see also In re Bundy, 642 F.2d 430, 434, 209 U.S.P.Q. (BNA) 48, 51 (C.C.P.A. 1981) (finding sufficient support for patent specification despite absence of precise description of behavior of all analogs of compound); Studiengesellschaft Kohle mbH v. Eastman Kodak Co., 616 F.2d 1315, 1341, 206 U.S.P.Q. (BNA) 577, 600 (5th Cir.) ("[I]n catalytic chemistry, minor changes in components, their ratio, or the external condition of the reaction may produce major changes in the reaction itself."), cert. denied, 449 U.S. 1014, 208 U.S.P.Q. (BNA) 88 (1980).

Thus patent protection on products or novel ways of applying them is vital if the inventor is to reap returns.[263]

In contrast with product technology, most chemical production processes evolve cumulatively in the sense discussed earlier. The first versions of new chemical processes tend to be amenable to a wide range of improvements. Thus one might expect to see the same kinds of problems regarding chemical process patents as we have seen in our examination of other cumulative technologies in the section above.

To analyze the importance of process and product inventions in the chemical industries, it is helpful to disaggregate those industries into three groups: bulk chemicals, synthetics, and pharmaceuticals.

1. *Bulk Chemicals.* — Bulk chemicals consist of products like sulfuric acid, ammonia, ethylene, and other substances that have been known and widely used for some time. Many are natural substances. In any case there are no effective product patents on bulk chemicals.[264]

As a consequence, most research and development is concerned with creating new or improved processes. The development of chemical process technology tends, as noted, to be cumulative; at any time there tends to be one process that is the dominant mode of production. From time to time a dominant process is superseded by a new one. And the early patent or patents on that new process have the characteristics of "pioneer" patents. However, these patents have not generally been used to control subsequent development, which by and large has proceeded with multiple sources of initiative.[265] This is due primarily to the inherently limited power of control conferred by patents in the bulk chemical field.[266] Pervasive cross licensing in chemical industries confirms this.[267]

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263. See C. Taylor & Z. Silberston, supra note 185, at 244–45; see also E. von Hippel, supra note 145, at 66–67 (describing unusual strength of patents in pharmaceutical and chemical industries relative to other industries).

264. C. Taylor & Z. Silberston, supra note 185, at 268:

> The range of [bulk] products has not widened very much over half a century, although naturally their relative importance has greatly changed. Most research efforts are directed towards the reduction of unit costs and improvements in the purity and consistency of standard products. There is relatively little work on new products . . . .

265. See, e.g., infra notes 268–271 and accompanying text (example of alkali process inventions).

266. See, e.g., infra note 272 and accompanying text. This is a function of the unpredictability of chemical inventions. For example, enablement doctrine requires greater support for a broad chemical claim than for a broad mechanical claim. See supra notes 38 and 180–181 and accompanying text. On the other hand, this same feature of chemical inventions makes it easier to establish nonobviousness. See, e.g., In re Papesch, 315 F.2d 381, 391–92, 137 U.S.P.Q. (BNA) 43, 51–52 (C.C.P.A. 1963) (even close structural similarity to the prior art may be overcome by evidence that the claimed componnd exhibits new and unexpected properties). Thus, chemical patents are easier to obtain, but narrower in scope.

267. C. Taylor & Z. Silberston, supra note 185, at 271–72; D. Hounshell & J. Smith,

Thus, until 1861 the Leblanc process dominated the production of alkalis.[268] This process was widely licensed and a number of different companies contributed to its improvement.[269] When, in 1861, the Solvay process was developed and patented, the original patent holder also had a chance to control future development of the process.[270] However, here too the policy of the original patent holder was one of reasonably wide licensing of the basic patent. A number of different companies made improvements; these were also cross-licensed.[271]

Of course there are patent suits and short-term hold ups in the field of bulk chemical process technology, but these problems are usually settled and licensing is a general practice.[272] The recent development of new processes for making acrylamide is a good example. Acrylamide is an organic chemical commonly used to make polymers for "water treatment, pulp and paper processing, textile treatment, food processing and other applications."[273] Until the 1960s it was made in a two-step process using sulfuric acid and ammonia. In the mid 1960s, researchers at several different companies all began investigating ways to improve the traditional process.[274] Both Standard Oil and American Cyanamid came up with processes using copper as the catalytic agent. Dow Chemical also made several patentable inventions in this field.[275]

Lawsuits were filed. Standard Oil sued American Cyanamid arguing that American Cyanamid's process infringed Standard Oil's patent. The court ruled against Standard Oil in this case.[276] On the other

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supra note 186, at 145, 174, 206, 439, 465, 494, 545 (describing widespread licensing of various DuPont patents).

268. See C. Freeman, supra note 144, at 28–29; D. Landes, supra note 259, at 111.

269. C. Freeman, supra note 144, at 28–29.

270. J. Jewkes, D. Sawers & R. Stillerman, supra note 172, at 50.

271. On the improvement patent of 1873, see J. Jewkes, D. Sawers & R. Stillerman, supra note 172, at 50; Solvay Process Co. v. Michigan Alkali Co., 90 F. 818 (6th Cir. 1898). On the American licensee, see D. Noble, supra note 209, at 14.

272. Christopher Freeman has described how the pattern of rather liberal cross licensing in chemical industries led to the development of a separate industry of chemical plant construction firms:

> Technological progress in established basic industrial chemicals is so rapid and so internationalised that more is usually to be gained for both the firm and the country if each national process innovation is exploited by licensing the contracting industry and selling know-how.

Freeman, Chemical Process Plant: Innovation and the World Market, 45 Nat'l Inst. Econ. Rev. 29, 50 (1968).

273. Standard Oil Co. v. American Cyanamid Co., 774 F.2d 448, 450, 227 U.S.P.Q. (BNA) 293, 294 (Fed. Cir. 1985).

274. See id. at 450–51, 227 U.S.P.Q. at 294–95.

275. Id. at 450, 227 U.S.P.Q. at 294 (Standard Oil patent); id. at 451, 227 U.S.P.Q. at 295 (American Cyanamid patent); Dow Chem. Co. v. American Cyanamid Co., 816 F.2d 617, 617, 2 U.S.P.Q.2d (BNA) 1350, 1350 (Fed. Cir.) (Dow patent), cert. denied, 484 U.S. 849 (1987).

276. See *Standard Oil*, 774 F.2d at 453, 227 U.S.P.Q. at 296.

hand, Dow successfully sued American Cyanamid for infringing its patents.[277] However, after this round of legal scuffling, the companies cross licensed each other. No single company tried to hold to itself the right to use the new technology or control its future development.[278]

In short, the pattern of development in bulk chemical process technology is similar to several of the cases of cumulative technologies considered earlier. It is sometimes possible to obtain a fairly broad patent when a new technology is invented.[279] This has the potential to give its holder a measure of control over subsequent development. However, by and large the chemical companies have not used their patents that way, partly under the pressure of competing inventions. These firms choose instead to license or cross license. Thus several companies tend to be involved in the subsequent development of the technology.

2. *Synthetics.* — Product patents are slightly more important in the field of synthetic materials, where they are sometimes connected closely with process inventions; research on a new process for making an established product may yield a distinct and patentable version of the product.[280] But just as in bulk chemicals, reasonably liberal licensing is common in the synthetic chemical industry.[281]

When Du Pont wanted to enter the business of producing Rayon it took out licenses on the product and the key processes from the French firm that held them.[282] Du Pont similarly took out a license on Cellophane technology.[283] Subsequent research and development at Du Pont on both of these products significantly improved them.[284] In turn, Du Pont licensed Nylon to both Imperial Chemical Industries of Great Britain and IG Farben of Germany.[285] Both of these companies

277. See *Dow Chemical*, 816 F.2d at 617, 2 U.S.P.Q.2d at 1350.

278. None of the patents at issue in the various suits appear broad enough to serve the "prospect" function. Under the cases, for example, the Standard Oil process does not appear to infringe Dow's patents. Thus an independent route to the acrylamide-producing process is left open.

279. The original Solvay alkali patent was of this nature; see supra notes 268–271 and accompanying text.

280. Catalytic research led to the invention of polypropylene, for example. See infra note 294 and accompanying text.

281. See, e.g., Standard Oil Co. v. American Cyanamid Co., 774 F.2d 448, 450, 227 U.S.P.Q. 293, 294 (Fed. Cir. 1985) (listing licensees of acrylamide production process patent); id. at 451, 227 U.S.P.Q. at 295 ("[Standard Oil] offered Cyanamid a license . . . [but] Cyanamid took the position that it did not need a license . . . .").

282. See Mueller, The Origins of the Basic Inventions Underlying DuPont's Major Product and Process Inventions, 1920 to 1950, *in* The Rate and Direction of Inventive Activity, supra note 143, at 326.

283. See id. at 328.

284. See C. Freeman, supra note 144, at 61; see also S. Hollander, supra note 178, at 52–120, 199–200 (detailed study of major and minor process improvements at various DuPont rayon plants).

285. 2 W. Reader, supra note 147, at 52–53. Du Pont researchers first synthesized nylon in the late 1930s. The company obtained a series of broad product patents, C. Taylor & Z. Silberston, supra note 185, at 342, culminating with the "Nylon 66" patent

later came up with variants on the original Nylon.

The fact that product patent claims are narrowly bounded keeps the advance of synthetic material technology competitive. Thus Du Pont's Nylon provided a superior alternative in many uses to the earlier Rayon.[286] And newer fibers like Dacron and Orlon subsequently replaced some of Nylon's market.[287]

Another good example of the interdependence of product and process technology in synthetic materials is the effort to develop an improved process for the manufacture of polyethylene. Research teams at several firms worked on this project simultaneously. In the 1950s researchers at the Max Planck Institute, led by a chemist named Karl Ziegler, invented a superior process, based on a new understanding of catalytic compounds.[288] Not only was the new process patentable, but due to the relatively restrictive claims on the older polyethylene patent, the product it produced was outside the scope of Imperial Chemical's basic patents.[289]

In turn, work by an Italian chemist, Giulio Natta, led to significant improvements in the Ziegler process. Natta's group also discovered a way to produce polypropylene, another important polymer.[290] Groups at other companies and research institutes were following the same trail. At least five different companies filed product patents on a version of polypropylene between 1953 and 1955.[291]

Needless to say, the customary round of law suits resulted, and

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covering a commercially valuable form of the fiber. See O'Brien, Patent Protection and Competition in Polyamide and Polyester Fibre Manufacture, 12 J. Indus. Econ. 224, 225 (1964).

286. See D. Hounshell & J. Smith, supra note 186, at 384–86.

287. Id. at 420–22.

288. See J. Jewkes, D. Sawers & R. Stillerman, supra note 172, at 341–42. In the early 1950s, researchers at Phillips Petroleum were working on the same problem. Id. at 342.

289. The original patent contained limitations relating to temperature, pressure and oxygen concentration. In fact one historian of the industry suggests that the search for high-density polyethylene may have been motivated in part by a desire to skirt the Imperial patents. J. Allen, Studies in Innovation in the Steel and Chemical Industries 47 (1967) ("Many of the early would-be Ziegler licensees . . . were, however, probably seeking a route free from the I.C.I. patents, either because they wished to be free, or could not get the know-how as well as the patents."). See Standard Oil Co. v. Montedison, 494 F. Supp. 370, 374–75, 206 U.S.P.Q. (BNA) 676, 685–86, 207 U.S.P.Q. (BNA) 298 (D. Del. 1980), aff'd, 664 F.2d 356, 212 U.S.P.Q. (BNA) 327 (3d Cir. 1981), cert. denied, 456 U.S. 915 (1982).

290. C. Freeman, supra note 144, at 67; *Montedison*, 494 F. Supp. at 374–75, 206 U.S.P.Q. at 685–86. Polypropylene has emerged as a substitute for polyethylene in several key applications. See Smoluk, Polyolefin Foams Take More Performance Jobs, Modern Plastics, Feb. 1988, at 98–100; Mansfield, Nonwovens Report, Textile World, May 1987, at 12.

291. See *Montedison*, 494 F. Supp. at 374, 206 U.S.P.Q. at 685 (patent interference between four firms). The fifth firm apparently bowed out of the competition. See id. at 374 n.4, 206 U.S.P.Q. at 685 n.4.

dragged on for some time.[292] However, the result was not that a single company controlled the basic technology and improvements, but rather a series of cross-licensing agreements which kept the technology open to a number of firms.[293]

3. *Pharmaceuticals.* — We turn now to the two matters regarding the scope of chemical patents which are especially important in the pharmaceutical industry: what to do when someone discovers a new use for an established product, and how to treat a process invention that yields a much purer form of a natural substance than was available earlier.

Earlier we observed that chemical products have a surprising range of uses. Often some of these cannot be foreseen when a product is invented and patented. In a number of cases researchers looking for a

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292. The interference just mentioned, for example, was declared in 1958 and resolved by the District Court only in 1980. See also United States Steel Corp. v. Phillips Petroleum Co., 865 F.2d 1247, 1248, 9 U.S.P.Q.2d (BNA) 1461, 1462 (Fed. Cir. 1989) (upholding Phillips' polypropylene product patent).

293. Polyethylene was discovered in 1935–36 by scientists from Imperial Chemical Industries of Great Britain; Imperial held the early product patents. 2 W. Reader, supra note 147, at 351–54; id. at 357 ("In the USA, the most important market, ICI held a 'composition of matter' patent which protected polythene [i.e., polyethylene] itself, regardless of the process by which it was made."); J. Allen, supra note 289, at 24–25; J. Jewkes, D. Sawers & R. Stillerman, supra note 172, at 280. Du Pont, however, held a patent on a commercially valuable form of the polyethylene. See O'Brien, supra note 285, at 229; C. Taylor & Z. Silberston, supra note 185, at 342. As part of a general cross-licensing and market-sharing arrangement, the two companies licensed these valuable patents to one another for production in their respective home markets. See 2 W. Reader, supra note 147, at 52–53.

This arrangement was challenged by United States antitrust authorities in the late 1940s and early 1950s. Id. at 428–44. The resulting consent decree ordered Du Pont and Imperial to license all patents covered by their agreements, including those remaining on nylon and polyethylene. See United States v. Imperial Chem. Indus., 105 F. Supp. 215, 93 U.S.P.Q. (BNA) 360 (S.D.N.Y. 1952). The compulsory licensing of polyethylene was ordered id. at 223. A follow-up study in Congress concluded that

> the judgment appears to have made it possible for a substantial number of companies to enter this field. There appears to be substantially more competition in the manufacture and sale of polythene products than there was before the judgment was entered.

Staff of the Subcommittee on Patents, Trademarks, and Copyrights of the Senate Comm. on the Judiciary, supra note 7, at 13 (showing that Imperial had issued nine licenses on polyethylene by 1955; Du Pont had issued 17 for polyethylene and 40 for nylon); see also The Polyethylene Gamble, Fortune, Feb. 1954, at 134, 136 (describing eight firms competing in this field under licensing agreements). It is possible that Imperial would have licensed competitors in exchange for new process research, which its competitors pursued partly to gain leverage in licensing negotiations. See 2 W. Reader, supra note 147, at 357 (Imperial was fortunate to have a United States product patent "because in Union Carbide, unknown to ICI, work was going on to develop a process entirely independent of ICI's, and it succeeded."); id. at 433 (describing DuPont's strategy of pursuing process-oriented research to lower the royalty Imperial could charge on polyethylene); see also United States v. Studiengesellschaft Kohle, m.b.H., 670 F.2d 1122, 1124, 212 U.S.P.Q. (BNA) 889, 891–92 (D.C. Cir. 1981) (describing Ziegler's exclusive license to make and sell catalysts to Hercules Incorporated, as well as his licensing of several others to use those catalysts in in-house production).

way to meet a new need will discover that an old product can do the job. In other cases, the discovery of a new use may be accidental—a byproduct of looking for something else. In either case, this is important inventive work that ought to be encouraged and rewarded. How to do this? The Patent Office and the courts have been struggling with this issue for some time.

The general solution has been to award a process patent to the discoverer of a new use. We cited a nonpharmaceutical example earlier, the case of *Rohm & Haas v. Roberts Chemical Co.*.[294] In this case the defendant's patent on use of a well-known product as a fungicide was upheld because this use was not anticipated or claimed in the original patent.[295] This process patent would not enable the patent holder to produce the product in question, but rather only to control its new use. If the use is an important one, such a process patent can provide a substantial reward to the patent holder. This is an important doctrine in the pharmaceutical industry, where new uses are often discovered.[296]

Another special problem that crops up in the chemical patent field involves inventing a synthetic version of a substance found in humans or animals. Typically the discovery involves enhancing purity or lowering cost. Today this issue arises mainly in the field of biotechnology, but the problem has existed for some time. Thus in 1911 Learned Hand upheld a product patent on purified human adrenalin made via a new process.[297] The patent was not simply on the process, but also on the purified natural substance.

The problem with this practice is that it grants patents of unnecessarily wide scope. The adrenalin patent would be infringed by the use of a radically different, and better, process for making the same natural product unless the characteristics of the product were judged substantially different. Yet the argument is not convincing that what the original inventor invented was the product, in addition to her particular process for making it.

The recent case involving Genentech, which we mentioned earlier, illustrates the issue. Genentech had invented a recombinant DNA method for producing the human blood clotting protein factor

294. 245 F.2d 693, 113 U.S.P.Q. (BNA) 423 (4th Cir. 1957); see supra notes 53–55 and accompanying text.

295. Id.; see also 1 D. Chisum, supra note 45, § 1.03[8][c] (collecting other cases on this point).

296. See P. Grubb, Patents for Chemists 158 (1982); Marshall, Penn Charges Retin-A Inventor with Conflict, 247 Sci. 1028 (1990) (dispute between University of Pennsylvania and scientist over scientist's attempt to obtain a "new use" patent for Retin-A as a wrinkle reducer).

297. Hand held that the purified adrenalin, although it existed in the human body, was transformed by the inventor's purification process into a useful drug and therefore constituted "for every practical purpose a new thing commercially and therapeutically." Parke-Davis & Co. v. H.K. Mulford & Co., 189 F. 95, 103 (C.C.S.D.N.Y. 1911) (L. Hand, J.), aff'd in part and rev'd in part, 196 F. 496 (2d Cir. 1912).

VIII:C.[298] That process had major advantages over an earlier, patented technique of purifying the substance drawn from natural blood. Genentech's process was not only better; it was completely different. Yet in the first part of the case, the court upheld the earlier patent, held by the Scripps Institute, on the ground that it was a legitimate product patent and thus Genentech's new method of producing it was an infringement.[299]

In a later ruling, the court invalidated the Scripps patent, saying that it did not adequately disclose the purification method that Scripps itself judged best.[300] But the court did not retract its earlier judgement that a product patent was quite legitimate in this case. We think this is unfortunate social policy. It might well inhibit technical advance in biotechnology, where much invention involves improving ways to produce purified natural products. If the initial patent is granted on the product, rather than the process for making it, subsequent process research by others will be discouraged. This is a good example of a prospect that will likely reduce competition for improvements. While licensing by firms can mitigate this problem, there is no guarantee that this will take place at such an early stage in the industry.[301]

The doctrine of reverse equivalents might be employed to limit the blocking power of product patents in appropriate cases. Under this doctrine a court could rule that an important process invention yielding a more purified form of the product escapes infringement. Although compulsory licensing might be another option, our law does not for the most part permit judicially mandated licensing.[302]

C. *Science-Based Industries*

Earlier, we discussed what makes an industry science-based.[303] Perhaps the most dramatic contemporary example is the biotechnology industry. Scientific advances, especially in molecular biology and biochemistry, created this industry, and continue to feed it ideas, theories, discoveries, and techniques.[304] Other examples include the chemistry

298. See Scripps Clinic & Research Found. v. Genentech, Inc., 666 F. Supp. 1379, 1390, 3 U.S.P.Q.2d (BNA) 1481, 1488 (N.D. Cal. 1987), patent invalidated in Scripps Clinic & Research Found. v. Genentech, Inc., 707 F. Supp. 1547, 11 U.S.P.Q.2d (BNA) 1187 (N.D. Cal. 1989).

299. See id.

300. *Scripps Clinic & Research Found.*, 707 F. Supp. at 1552, 11 U.S.P.Q.2d at 1191.

301. See, e.g., Sit, Biotech, Amgen Remain at Odds, Boston Globe, Apr. 18, 1990, at 41, cols. 3, 3–5 (successful effort of Amgen to stay cross-licensing ordered by district court after both parties were found to infringe each other's patents on erythropoietin (EPO)).

302. See supra note 12 and accompanying text.

303. See supra notes 187–188 and accompanying text.

304. See M. Kenney, supra note 188; Kenney, supra note 188. But cf. Koenig, A Bibliometric Analysis of Pharmaceutical Research, 12 Res. Pol'y 15, 35 (1983) (reviewing data on the number of industrial patents that cite basic scientific research articles in

of catalysis and semiconductors during the 1950s,[305] and the burgeoning new field of superconductivity.[306] Because science-based industries rely so heavily on scientific discoveries, one relevant patent issue is the appropriate scope of patents in the face of the (usually published) science that makes invention in these industries possible.

The modern biotechnology industry is built around two different sets of technologies: recombinant DNA and monoclonal antibodies. Both of these are based on prior, more general advances in molecular biology and both were initially discovered and employed by scientists concerned with pure research. One of these technologies was originally developed in 1975 by Köhler and Milstein, who discovered that individual immune system cells, which generate antibodies to a specific antigen, could be fused with immortal cancer cells, to create a small "factory" for producing antibodies.[307] They did not take out a patent on their discovery. They were awarded a Nobel prize.[308]

The pathbreaking Köhler-Milstein research almost immediately was recognized as opening up a myriad of commercial possibilities.[309] Hybritech was an early entry into the race to develop applications. It was the first to use monoclonal antibodies in diagnostic kits sold to doctors and hospitals to identify the presence of diseases (e.g., AIDS) or heightened hormone levels (e.g. pregnancy tests). It received a patent covering this whole family of diagnostic kits.

Other companies saw exactly the same opportunity, if not so quickly. Monoclonal Antibodies, Inc. was one of these, and it created a similar technique after Hybritech. Monoclonal Antibodies, Inc. made and sold these kits, and Hybritech sued.[310] Monoclonal defended by claiming the Hybritech patent invalid, at least in its broad scope, because given the work of Köhler and Milstein the generic technique was obvious. The trial court recognized the argument, and acknowledged:

[T]he major advance was the invention of Köhler and Milstein

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various pbarmaceutical industry sectors, including biotechnology-derived pharmaceuticals, and concluding that industrial research feeds basic science in this field).

305. At least in its earliest stages. See Nelson, The Link Between Science and Invention: The Case of the Transistor, *in* The Rate and Direction of Inventive Activity: Economic and Social Factors, supra note 143, at 549; Shockley, The Path to the Conception of the Junction Transistor, 23 IEEE Trans. on Electron Devices 597 (1976).

306. Advances in Conductor Materials, N.Y. Times, Sept. 30, 1989, at 32, col. 1; Pool, Superconductor Patents: Four Groups Duke It Out, 245 Sci. 931 (1989).

307. See Köhler & Milstein, Continuous Cultures of Fused Cells Secreting Antibody of Predefined Specificity, 256 Nature 495, 495–97 (1975).

308. Three Immunology Investigators Win Nobel Prize in Medicine, N.Y. Times, Oct. 16, 1984, at A1, col. 4.

309. In fact, the last sentence of the Köhler-Milstein paper itself noted these possibilities. See Köbler & Milstein, supra note 307, at 497; see also Mackenzie, Cambrosio & Keating, The Commercial Application of a Scientific Discovery: The Case of the Hybridoma Technique, 17 Res. Pol'y 155 (1988).

310. This discussion is taken from a longer account of the case in Merges, supra note 190, at 857–58.

> in the making of monoclonal antibodies . . . . Once the scientific community had the monoclonal antibody it was obvious and logical to those expert in the field to use them in known assays as substitutes for . . . polyclonal antibodies . . . of inferior qualities.[311]

However, on appeal, the patent was held valid. Granted, the call was not an easy one: Hybritech clearly invented something. The question was, given that it was building on public science, what was the limit of its contribution? The Patent Office allowed Hybritech a broad prospect and the court concurred.

While a case has not come to court yet, the Patent Office also allowed Genentech a very broad prospect on the second major technology of the new biotechnology industry, expression of recombinant proteins. The basic genetic technique was developed earlier by two scientists, Cohen and Boyer.[312] The two scientists involved saw their basic technique—the insertion of a specific gene into a host cell and subsequent expression of the protein product for which the gene codes—primarily as a contribution to ongoing public science. Their universities urged them to take out a patent, which they did, but the patent is licensed to all comers.[313]

Genentech's patent is an extension of the Cohen-Boyer work.[314] It covers the basic technology of gene expression, where the firm clearly made a major early contribution.[315] Their contribution was to refine existing gene expression techniques to achieve the first successful expression of a human protein in a bacterium.[316]

In their specification, the inventors describe one particular technique for expressing and recovering proteins and apply this technique to the production of two polypeptides.[317] The technique disclosed in the patent no doubt legitimately covers many more specific embodiments than those expressly disclosed. But it can be argued that they simply were the first to bring to practice techniques that persons "skilled in the art" knew could be made to work. It is difficult to tell yet whether the breadth implicit in this patent will hold up, but it has created a good deal of trepidation in the industry.[318] According to the

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311. Hybritech, Inc. v. Monoclonal Antibodies, Inc., 623 F. Supp. 1344, 1353, 227 U.S.P.Q. (BNA) 215, 221 (N.D. Cal. 1985), rev'd, 802 F.2d 1367, 231 U.S.P.Q. (BNA) 81 (Fed. Cir. 1986), cert. denied, 480 U.S. 947 (1987).

312. See Cohen, et al., Construction of Biologically Functional Bacterial Plasmids *In Vitro*, 70 Proc. Nat'l Acad. Sci. 3240 (1973).

313. The prosecution and licensing of this patent are ably described in Ku, Licensing DNA Cloning Technology, 23 LES Nouvelles 112 (June 1983). On the licensing of this patent, see M. Kenney, supra note 188.

314. See U.S. Patent No. 4,704,362, issued Nov. 3, 1987.

315. See S. Hall, Invisible Frontiers: The Race to Synthesize a Human Gene 317 (1987).

316. Id. at 152–53.

317. U.S. Patent No. 4,704,362, supra note 314, at cols. 10–23.

318. See, e.g., infra note 319.

head of a rival biotechnology firm, "If interpreted most narrowly, there are certain bacterial [production] systems that wouldn't even be covered. If interpreted most broadly, it could cover all production systems in bacteria, yeast and cells."[319]

Fortunately for the industry, an even broader patent on gene expression was rejected on obviousness grounds because several of the inventors published results prior to the invention.[320] The investigators had discovered that a gene for a non-operational protein taken from a frog could be inserted into a bacterium and expressed there.[321] On the basis of that research they filed a patent claiming a process for producing proteins comprising "linking a natural or synthetic heterologous gene [i.e., one from a foreign source] . . . to [an] indigenous [bacterium] gene portion."[322] It is worth noting that there is no indication that these claims would have been rejected because of their *breadth*. Thus if the prior publication had not been judged to render the claimed invention obvious, it might have received a patent. Judging from the quoted claim language, this would have been very broad indeed.

The holder of a patent on a broad prospect opened by advances in science need not attempt to control the development of that prospect in any detail. Instead, she could license widely and collect royalties. This has been the case with the Cohen-Boyer patent. This approach is normally more conducive to the development of multiple applications than where the patent holder restricts entry. But if used this way, the grant of a broad prospect cannot be justified on the grounds laid out by Kitch. Holders of broad patents would be operating as tollkeepers, not coordinators, and the subsequent development of prospects would proceed in spite of, or at least in indifference to, the broad patent. While the ability to charge a toll may add to the incentives facing an inventor, it does not ensure more efficient development. Nevertheless, if a broad prospect patent is granted and upheld, widely granting licenses is surely more preferable to the patent holder than developing the entire prospect herself.

Biotechnology is not the only industry where scientific break-

319. See Genentech Receives Broad Patent For Basic Gene-Splicing Techniques, Wall St. J., Nov. 4, 1987, at 8, col. 1 (quoting George B. Rathman, Chairman and Chief Executive Officer of Amgen, Inc.). There are some indications that Genentech is pursuing a strategy of construing the patent claims broadly, but charging a fairly low royalty so as not to create an incentive to challenge the patent. See G-tech to Push for Royalties, BioEngineering News, Nov. 12, 1987, at 1, col. 1.

320. In re O'Farrell, 853 F.2d 894, 7 U.S.P.Q.2d (BNA) 1673 (Fed. Cir. 1988).

321. Id. at 899–901, 7 U.S.P.Q.2d at 1677–78. The frog protein was not truly nonoperational; it formed part of the structure of ribosomes, the cell components where proteins are made. This relatively rare type of ribosomal protein is to be contrasted with the much more common proteins coded for in a cell's DNA—everything from hormones to collagen to antibodies. See id. at 897–98, 7 U.S.P.Q.2d at 1676.

322. Id. at 895, 7 U.S.P.Q.2d at 1674.

throughs sparked a scramble to obtain broad patents. The current rush to obtain patents over superconductors demonstrates that patent positioning often is important at the birth of science-based industries.[323]

As a new science-based technology matures, the issues relating to patent scope change largely because particular technologies become established. Thus the early work on catalysis was science based. But as catalysts were developed, further innovation became more cumulative than science-based. Step-by-step process improvements now dominate the field, succeeding the early advances that came quickly on the heels of the Ziegler and Natta research. As a result, the issues involved in setting appropriate patent scope change as an industry advances.

V. Summary and Conclusions

1. *Cumulative Technologies.* — Our general conclusion is that multiple and competitive sources of invention are socially preferable to a structure where there is only one or a few sources. Public policy, including patent law, ought to encourage inventive rivalry, and not hinder it. As the "race to invent" models show, a rivalrous structure surely has its inefficiencies. But such a structure does tend to generate rapid technical progress and seems a much better social bet than a regime where only one or a few organizations control the development of any given technology.

While there are exceptions, where a few organizations controlled the development of a technology, technical advance appeared sluggish. The company with the inside track has often failed to move aggressively; the Edison light bulb patent is perhaps the best example. At the same time the history of many industries—beginning with the steam engine—show that outsiders with promising approaches have been held back.[324] In what we have called cumulative technologies, particularly when the product in question was a multicomponent system, broad patents on components led to blockages. These were resolved, in some cases, by the development of more or less automatic (if elaborate) cross-licensing schemes. These should not be understood as mechanisms to achieve orderly development of the "prospect" but rather as mechanisms to cancel out the blocking effects of broad patents. There is no evidence, for instance, that firms coordinated the development of a prospect by licensing the cultivation of particular

323. See Pool, supra note 306 (organizations fighting over superconductivity patents).

324. F. Scherer, in his study of the Watt-Boulton enterprise, concluded that "Boulton & Watt's refusal to issue licenses allowing other engine makers to employ the separate-condenser principle clearly retarded the development and introduction of improvements." F. Scherer, supra note 164, at 25. There is much on this point in R. Brenner, supra note 140, at 110–15 (describing resistance to innovations in business and science); id. at 103–04 (many major innovations made by "outside" people and firms).

applications of a broad technology to particular licensees; indeed, patents were often pooled and cross licensed en masse to all firms seeking to enter the field. While sometimes these have come about privately, in other cases patent logjams have been broken only with the powerful force of government intervention. These episodes testify to the blocking power of broad patents as well as social creativity in working around them; they do not argue for the social efficacy of broad patents.

In addition to these general conclusions, we wish to comment on another problem involving patent scope: pioneer patents and the doctrines of enablement and equivalents.

We have seen a number of examples of patents granted on major new discoveries, or pioneer patents. The Wright brothers, for example, received an important and well-deserved pioneer patent on airplane stabilization. This created problems because other inventors such as Glen Curtiss, following close on the heels of the Wrights, were blocked for a time from introducing their advances into the fledgling industry. Our proposal would not mitigate these problems. However, in many cases we have described there was no justification for the broad scope granted and upheld. There was certainly no justification for the broad Selden patent which caused such difficulties. A similar argument could be made with regard to the Genentech "expression" patent. In each of these cases the actual or potential harmful effects of the pioneer patent could have been mitigated had the Patent Office paid closer attention to what the inventor actually disclosed in his specification as an indicator of what the inventor actually achieved, and the broad nature of what was already known and in the public domain, and restricted the allowed scope accordingly. Likewise, the doctrine of equivalents and its reverse can be applied to restrict pioneer patents' scope when necessary.[325] Courts should be encouraged to hew more closely to the substance of the inventor's disclosure when deciding whether an accused device infringes her patent. Because these issues are so important, we make a number of rather detailed recommendations.

In an earlier section of this essay, we suggested an important addition to conventional equivalency analysis. Once a court completes its assessment of the significance of the patented device, it should consider in addition the importance of the advance represented in the *accused* device. This was in essence the approach taken by the court in the *Texas Instruments* case,[326] in which the Federal Circuit denied infringement because the accused calculators showed significant improvements in

325. The *Hughes Satellite* case was an occasion when equivalents might have been applied in this way, see supra notes 78–80 and accompanying text. Reverse equivalents might have been used in a similar fashion in the polypropylene case, see supra notes 288–293 and accompanying text.

326. Texas Instruments, Inc. v. United States Int'l Trade Comm'n, 805 F.2d 1558, 231 U.S.P.Q. (BNA) 833 (Fed. Cir. 1986); see supra notes 83–93 and accompanying text.

many respects over the patentee's design. In light of our comments on the interconnection between enablement and equivalents, we approve of the strict attention the court paid to the *specification* of the pioneer patent in that case.[327] The equivalents inquiry, even for a pioneer patent, should be centered around whether the improved structures of the accused device show major differences from the structures disclosed in the original specification.[328] Specifically, the court should look for differences in the following areas:

- Materials;
- Changes in the number of components;
- Greatly improved efficiency in individual components;
- Increased efficiency in the way components work together, i.e., overall design improvements.

This was the approach followed in the *Texas Instruments* case. In *Texas Instruments*, the accused devices incorporated improvements in all these areas. What makes *Texas Instruments* worthy of emulation is its focus on the degree to which the accused device represents an advance over the patented device. In a way, this simply brings some symmetry to the equivalency issue. Just as a court looks to the degree of advance over the prior art in deciding whether the patented device is a pioneer or only a minor improvement, so too should the courts be encouraged to examine the accused device. If it represents a significant advance, this is a factor that should weigh in its favor when the issue of infringement by equivalency is decided. Analysis along these lines might have reduced the blocking effect of pioneer patents in certain fields we have

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327. See Texas Instruments, Inc. v. United States Int'l Trade Comm'n, 805 F.2d 1558, 1570, 231 U.S.P.Q.2d (BNA) 833, 841 (Fed. Cir. 1986) ("Taken together these accumulated differences [between the invention described in the patent and the accused devices] distinguish the accused calculators from that contemplated in the [Texas Instruments] patent and transcend a fair range of equivalents of [this] invention"), and the opinion of the Federal Circuit denying plaintiff's motion for rehearing, 846 F.2d 1369, 1370–71, 6 U.S.P.Q.2d (BNA) 1886, 1888 (Fed. Cir. 1988) ("[T]hough all of the functions of the claimed elements were performed, none was performed by the structures described in [Texas Instruments' patent] specification or by equivalents of those structures."). The late Judge Davis made this point in his concurrence to the opinion denying plaintiff's motion for rehearing. 846 F.2d at 1372, 6 U.S.P.Q.2d at 1889 (Davis, J., concurring).

328. We do not mean to suggest that the accused device should be found noninfringing if it is nonobvious with respect to the patentee's invention. We recognize that a device can be both patentable and an infringement of an earlier patent—that there can be blocking patents. See Atlas Powder Co. v. E.I. Du Pont de Nemours & Co., 750 F.2d 1569, 1580–81, 224 U.S.P.Q. (BNA) 409, 416–17 (Fed. Cir. 1984). What we mean to suggest is that *at some point* the characteristics of the accused device ought to be considered, and its merits ought to be a factor of importance in the equivalents determination. The *Graver Tank* formulation of the doctrine supports this. See Graver Tank & Mfg. Co. v. Linde Air Prods. Co., 339 U.S. 605, 610, 85 U.S.P.Q. (BNA) 328, 331 (1950) (only "insubstantial" changes are encompassed by the doctrine of equivalents). A recent article points out that this aspect of *Graver Tank* has been ignored. See Adelman & Francione, supra note 75, at 709–10.

studied.[329]

The same point should be borne in mind when a claim covers embodiments that turn out to be well beyond the teaching of the patent's disclosure. This is the case of so-called reverse equivalents. If an improvement represents a very significant advance, it should be held not to infringe—even if it is within the literal bounds of the patentee's claim. This is the lesson of the *Westinghouse* case.[330] As long as compulsory licensing remains anathema, the possibility of a "hold up" by the basic patent holder makes reverse equivalents the best alternative under these circumstances.[331]

A more liberal use of reverse equivalents would be especially valuable when the allegedly infringing improvement embodies new technology not available when the patent was issued. As long as adequacy of disclosure is measured as of the filing date, enablement doctrine will be of no help to the infringing improver.[332] The *Hughes Satellite* case[333] and the polypropylene patent[334] are good examples of the need for a reverse doctrine of equivalents in this situation.

The essential point to grasp is that here, as with regnlar equivalents, courts have their only opportunity to review patent scope in light of later technological developments. They should make good use of the opportunity, with an eye toward preventing the kinds of blockage we have described.

2. *Chemical Industries.* — As we saw in our review of the chemical industries, invention in this field has some of the features of discrete and some of cumulative technologies. For the reasons just described, the latter similarity leads us to counsel caution in the awarding of broad patents in this field. But there are two factors that mitigate our concerns somewhat. First is the relative rarity of very broad patents in the chemical field, primarily because of the unpredictability of chemical research.[335]

Second is the very well established practice of licensing in these industries. Some of the examples we have explored bear this out. Because Ziegler was an academic scientist, he had to license his catalyst

329. Note that this is precisely the type of analysis used by the Court in the original reverse equivalents case involving the Westinghouse air brake. See supra notes 71–90 and accompanying text.

330. See supra notes 73–78, 87 and accompanying text.

331. See supra notes 115–120 and accompanying text.

332. See Phillips Petroleum Co. v. United States Steel Corp., 673 F. Supp. 1278, 1286, 1292, 6 U.S.P.Q.2d (BNA) 1065, 1069, 1074 (D. Del. 1987), aff'd, 865 F.2d 1247, 1253 n.9, 9 U.S.P.Q.2d (BNA) 1461, 1466 n.9 (Fed. Cir. 1989); see also In re Hogan, 559 F.2d 595, 607, 194 U.S.P.Q. (BNA) 527, 538 (C.C.P.A. 1967) (stressing need for reverse equivalents because of this rule).

333. See supra notes 78–80 and accompanying text.

334. See supra note 326.

335. See supra note 262 and accompanying text.

patents to make money on them.[336] And even a huge chemical company like Imperial Chemical found it necessary to license several competing producers of polyethylene before a 1952 antitrust consent decree made licensing mandatory.[337] The reason is probably the same as for bulk chemicals: no one producer could cover all the markets for applications of the products. There was also an incentive to *cross*-license; here as elsewhere competing firms embarked on a series of important process improvements. Even the holder of a basic product patent, such as Imperial Chemical with polyethylene, could probably not afford to ignore an economical improvement, even if that meant licensing the product patent to get it.[338]

As described earlier, licensing by no means renders broad patents harmless.[339] But it may indicate an attitude within these industries that reduces the potential blocking effect of a broad patent.

We turn now to the two special aspects of chemical invention reviewed above: inventions covering new uses of known compounds and purified forms of natural substances.

In the case of new use inventions, we mentioned the fundamental problem, the rule that a product patent covers all uses, and the proposed doctrinal solution of the *Rohm & Haas* case, the abrogation of that rule for newly discovered uses.[340] There are problems with this solution, however. It may be difficult to monitor whether the compound is being used for the new (patented) application or for its old, well-established use. Consider the case of Urbaine Thuau, who filed a patent application containing product claims over a compound he had found useful in the treatment of cervical diseases. However, the compound itself was not new. It had long been used in the leather tanning industry. The Patent Office rejected the patent application, and the Court of Customs and Patent Appeals later affirmed.

> That appellant has made a valuable discovery in the new use of the composition here involved we have no doubt, and it is unfortunate for him if he can not make claims adequate to protect such discovery, but to hold that every new use of an old composition may be the subject of a patent upon the composition would lead to endless confusion and go far to destroy

336. See United States v. Studiengesellschaft Kohle, m.b.H., 670 F.2d 1122, 1124, 212 U.S.P.Q. (BNA) 889, 891–92 (D.C. Cir. 1981).

337. See United States v. Imperial Chem. Indus., Ltd., 105 F. Supp. 215, 223, 93 U.S.P.Q. (BNA) 360, 365 (S.D.N.Y. 1952) (ordering compulsory licensing of polyethylene).

338. Imperial Chemical Industries, Ltd., for example, held a major product patent on polyethylene. Union Carbide had been licensed to make the product during World War II. Although an antitrust action forced Imperial to continue the license, Union Carbide had developed a significant new process, which might well have induced Imperial to continue to license in exchange for the new process. See supra note 293.

339. See supra notes 146–148 and accompanying text.

340. See supra notes 288–296 and accompanying text.

the benefits of our patent laws.[341]

The court expressed particular concern with the "confusion" that might result if purchasers of the product for its newly discovered use bought it from the traditional suppliers. Although these suppliers might have no way of knowing what use the purchaser had in mind, if the new patent were granted, they would be liable nonetheless for patent infringement. While the patent statute includes a detailed provision to deal with this problem,[342] enforcing the rule may be quite difficult.[343]

The Patent Office has been more comfortable about giving a product patent for a new use of an old substance when the patent applicant has modified the substance.[344] There has been recognition, however, that this practice provides incentive for trivial or obvious modifications of an old compound, and results in the granting of a new product patent rather than a new use (or process) patent.[345] In a ruling denying a product patent on an obvious variant of an old compound, the court proposed that the solution might be to eliminate patents on obvious variants of old compounds altogether, instead rewarding each inventor with a process patent on the application she has discovered.

> It is basic to the grant of a patent that the scope of a patent should not exceed the scope of invention. If what makes a structurally obvious chemical substance patentable is the new and unobvious properties or uses discovered by the first person to compound the substance, the discoverer should have protection on what he discovered, i.e. the new properties of the substance, but should not be entitled to a 17-year monopoly on the substance itself. . . . We think that the purposes of the patent law will be adequately served if patents on compounds which are structurally obvious from the prior art are limited to method (i.e. process) patents directed to the new and useful characteristic or property which is the essence of the discovery or invention.[346]

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341. In re Thuau, 135 F.2d 344, 347, 57 U.S.P.Q. (BNA) 324, 326 (1943).

342. See 35 U.S.C. § 271(c) (1988).

343. See 135 F.2d at 347, 57 U.S.P.Q. at 326.

344. See, e.g., Eli Lilly & Co. v. Generix Drug Sales, Inc., 460 F.2d 1096, 1103–04, 174 U.S.P.Q. (BNA) 65, 70–71 (5th Cir. 1972) (patent for Darvon upheld despite close similarity to prior art structures).

345. See Hoxie, A Patent Attorney's View, *in* Seminar on Chemical Invention, 47 J. Pat. Off. Soc'y 630, 638 (1965) ("This . . . has led to inequitable results in that of two discoveries of equal value and 'inventiveness,' one may be patented and the other not depending on whether or not the 'gimmick' novelty [i.e., minor structural variation] can be supplied.").

346. Monsanto Co. v. Rohm & Haas Co., 312 F. Supp. 778, 790–91, 164 U.S.P.Q. (BNA) 556, 566, 165 U.S.P.Q. (BNA) 683 (E.D. Pa. 1970) (Supp. op.), aff'd, 456 F.2d 592, 172 U.S.P.Q. (BNA) 323 (3d Cir.), cert. denied, 407 U.S. 934, 174 U.S.P.Q. (BNA) 129 (1972); see also Comment, Uses, New Uses and Chemical Patents—A Proposal, 1968 Wis. L. Rev. 901, 915 (proposing abolition of product patents on compounds in

This suggestion has so far been ignored. In general, courts have yet to solve the problem of how to reward and thus give incentives to the discovery of new uses. While the problem is not confined to the realm of chemical substances, it crops up mostly here. For reasons which should be clear, we strongly endorse the notion of granting process patents on new uses. We recognize, however, that in some cases enforcement problems may be formidable.[347]

The problem of purified natural product patents also deserves mention. As we have seen, product patents are often granted on purified forms of compounds that occur naturally. Subsequent recombinant versions of the compounds are therefore blocked from effective protection, as in the case of *Scripps Clinic & Research Foundation v. Genentech, Inc.*.[348] While there is reason to believe that the instances of this kind have multiplied in recent years, we have noted that the tradition of granting a product rather than a process patent goes back as far as *Parke-Davis & Co. v. H.K. Mulford & Co.*,[349] when Learned Hand upheld a product patent on purified human adrenalin. In such cases protection consistent with the actual achievement of the inventor would have been provided if the initial patent had been for a *process*, or at most a "product-by-process," rather than for a product. And inventive efforts to come up with a significantly better process to make the product would not be blocked. These concerns seem to have animated a recent British case denying broad claims for Genentech's t-PA drug.[350]

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favor of patents on methods of production and methods of using—two species of process patents).

347. Enforcement may be somewhat more tractable in light of recent legislation making it legal to tie an unpatented product (e.g., the fungicide in *Rohm and Haas*) to the sale of a patented item (e.g., the right to practice the process patent), so long as the patentee does not have market power in the market for the tying (patented) item. See Patent and Trademark Authorization Act, Pub. L. No. 100-703, § 201, 102 Stat. 4676 (1988) (codified at 35 U.S.C. § 271(d)(4) & (5)); see also Merges, Reflections on Current Legislation Affecting Patent Misuse, 70 J. Pat. & Trademark Off. Soc'y 793, 799–801 (1988). This legislation built on an earlier Supreme Court case holding that it is infringement to make, use or sell a product which can only be used in a patented process, in effect extending the coverage of the process patent to include the unpatented product as well. Dawson Chem. Co. v. Rohm & Haas Co., 448 U.S. 176, 201, 206 U.S.P.Q. (BNA) 385, 398 (1980). See Oddi, Contributory Infringement/Patent Misuse: Metaphysics and Metamorphosis, 44 U. Pitt. L. Rev. 73 (1982) (describing implications of this case); see also Kaplow, Extension of Monopoly Power Through Leverage, 85 Colum. L. Rev. 515, 525–32 (1985) (elucidating possibility of anticompetitive effects from tie-ins).

348. See Scripps Clinic & Research Found. v. Genentech, Inc., 666 F. Supp. 1379, 3 U.S.P.Q.2d (BNA) 1481, (N.D. Cal. 1987), patent invalidated, Scripps Clinic & Research Found. v. Genentech, Inc., 707 F. Supp. 1547, 11 U.S.P.Q.2d (BNA) 1187, (N.D. Cal. 1989); supra notes 298–301.

349. 189 F. 95 (C.C.S.D.N.Y. 1911) (L. Hand, J.), aff'd in part and rev'd in part, 196 F. 496 (2d Cir. 1912).

350. Genentech, Inc.'s Patent, [1987] R.P.C. 553, 596, aff'd, [1989] R.P.C. 613 (Ct. App.):

> Had Genentech, as workers in this field may do, developed some totally new product, they would have been entitled to a monopoly on the product,

One (perhaps controversial) way to achieve this would be to recognize a reverse equivalents defense when a recombinant product is accused of infringing a prior purification patent.[351] Also, awarding these more limited patents would be much more consistent with the enablement doctrine; the principle there is to allow the inventor only what she has actually invented as described in the principle spelled out in the specification.

3. *Science-Based Industries.* — The final issue we wish to address concerns the science-based industries. In our discussion we emphasized the dangers of awarding overly broad patents early in the history of an industry founded on recent scientific advances. Hybritech's broad patent on diagnostic assays using monoclonal antibodies provided a useful example. Its breadth seems to exceed the actual contributions of the company's researchers; it includes a good deal of what was previously accomplished by scientists working in the area.

The Hybritech patent raises some of the same problems as a pioneering patent in a cumulative technology. It is too early in the history of the biotechnology industry to tell whether the chemical industries' customary practices of cross-licensing or patent pooling will relieve the pressure of this and other broad patents. Yet the real threat of a patent like this stems from the industry's close ties to science. A science-based industry straddles the public world of science and the private world of intellectual property; an over-broad patent makes private part of the public science such an industry strives to commercialize. This can affect not only the winners and losers in the early days of the industry, and industry structure in general, but also the subtle balance between the private and public spheres. It is a good bet that more and more inventions will be science-based. The Patent Office and courts should not permit the over-privatization of the scientific knowledge that makes the industry possible. Again, scope limitations based on close adherence to the inventor's disclosure and judicious use of the doctrine of equivalents provide the surest way around this danger.

> whatever its process of production. Had they produced some new and valuable variant of t-PA, they might have got [sic] protection on that. What they did by way of invention, however, was to discover a particular route to a known end, and to grant them a monopoly wbich would stop others from attempting to discover alternative, possibly wholly unknown and possibly better routes to that end, would be to stifle research which, in the public interest, it ought to be open to other investigators to pursue and over which other investigators in their turn, if they make valuable contributions, might be able to secure proper protection.

See also Mellor, supra note 51 (describing British t-PA litigation). Recently proposed legislation in the U.S. would achieve much the same result; for an analysis, see Merges, Claiming Genes and Sequences (Background Paper for Sloan Foundation Symposium on Intellectual Property Rights in the Biotechnology Industry, Nov. 2, 1989, on file with the Columbia Law Review).

351. See supra notes 101–114 and accompanying text.

4. *Conclusions.* — Our goal has been to show that scope doctrines can be used to approximate the "tailoring" function proposed by economists who model optimal patent length,[352] with an eye toward retaining incentives for subsequent improvements.

Some readers may interpret the position we have detailed above as a reflection of an antipatent bias on our part. Not so. While it may seem at first blush that any reduction in patent scope—indeed, any lessening of the patentee's potential reward—may severely undercut the incentive to invent, we do not believe this is the case.[353] One must keep in mind that the doctrinal modifications we have suggested will apply only to the broader claims of a small number of patents, primarily those on pioneering breakthroughs. And even where our suggestions come into play, we counsel sensitivity to the nature of technical advance in particular industries. In this connection, we have discussed the limitations of the prospect theory, insofar as it suggests a preference for broad scope across industries.

Ultimately it is important to bear in mind that every potential inventor is also a potential infringer. Thus a "strengthening" of property rights will not always increase incentives to invent; it may do so for some pioneers, but it will also greatly increase an improver's chances of becoming enmeshed in litigation. Indeed this is the very heart of our case. When a broad patent is granted or expanded via the doctrine of equivalents, its scope diminishes incentives for others to stay in the invention game, compared again with a patent whose claims are trimmed more closely to the inventor's actual results. The same is true of a patent granted unduly broad scope by the patent office. This would not be undesirable if the evidence indicated that control of subsequent developments by one party made subsequent inventive effort more effective. But the evidence, we think, points the other way.

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352. See supra notes 132–124 and accompanying text.

353. Some might argue just the opposite—that patent doctrine is irrelevant because economists have come to understand that patents are regarded as essential by firms in only a few industries. See C. Taylor & Z. Silberston, supra note 194, at 334–40, 346–47; Mansfield, Patents and Innovation: An Empirical Study, 32 Mgmt. Sci. 173, 176 (1986) (patents found not essential to protecting innovations in many industries). In this connection, the most recent and complete study of the means for capturing returns from research shows that in most industries advantages associated with a head start, including establishment of production and distribution facilities, and moving rapidly down a learning curve, were judged significantly more effective than patents in enabling a firm to reap returns from innovation. See Levin, Klevorick, Nelson & Winter, Appropriating the Returns from Industrial Research and Development, 1987 Brookings Papers on Econ. Activity 783 (1987) (reporting results of extensive empirical survey of research and development personnel at U.S. corporations). Nevertheless, firms *do* continue to file for, prosecute, obtain, and litigate patents. The rules surrounding them must therefore be of at least some importance, because patents themselves continue to be.