ARTICLE

UNCERTAINTY AND THE STANDARD OF PATENTABILITY

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"I have suggested that, although 'it may be impossible to estimate the total benefits and costs of the patent system, one may attempt to analyze the marginal benefits and costs of particular moderate changes in the duration, scope, or strength of patented protection.' "—Fritz Machlup[1]

I.   INTRODUCTION

To qualify for a patent, an invention must be more than an extension of what was known; it must represent a significant or "nonobvious" step in the art. This Article explains the economic function of the nonobviousness test. It thus extends other recent work on the economics of specific patent doctrines,[2] work which has been spurred in part by the recent explosion of interest in the patent system.[3]

The statutory[4] nonobviousness test serves a gatekeeping function; it seeks to reward inventions that, viewed prospectively, have a low probability of success. As explained below, this Article treats nonobviousness as a legal rule that influences behavior—specifically, the decisions of research and development (R&D) managers to pursue or ignore specific research projects. The nonobviousness standard encourages researchers to pursue projects whose success appears highly uncertain at the outset. The standard insists that only the results from uncertain research should be rewarded with a patent.

This approach has several benefits. First, it transcends particular doctrinal squabbles to clarify the overarching goal of the nonobviousness standard. The second advantage of an uncertainty-based conception of nonobviousness is that it fits nicely with one of several complementary theories often put forth to explain the patent system—the "compensation-for-disclosure" theory. The threshold nonobviousness requirement guarantees that a minimum quantum of information is disclosed in exchange for a patent. Indeed, the view taken here pushes this theory a measure further: it highlights the fact that research which overcomes uncertainty is precisely the sort society values, and hence rewards with a patent. Thus disclosure theory, often seen as embedded in doctrines

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1. FRITZ MACHLUP, THE ECONOMICS OF INFORMATION AND HUMAN CAPITAL 165 (1984).

2. *See, e.g.,* Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope,* 90 COLUM. L. REV. 839 (1990); Robert P. Merges, *Economic Perspectives on Innovation: Commercial Success and Patent Standards,* 76 CAL. L. REV. 803 (1988).

3. *See, e.g.,* Norm Alster, *New Profits from Patents,* FORTUNE, Apr. 25, 1988, at 185; Edmund L. Andrews, *Patents: Courts Called Tougher on Infringement,* N.Y. TIMES, Sept. 16, 1989, at 34. *See generally* ROBERT P. MERGES, PATENT LAW AND POLICY (1992).

4. 35 U.S.C. § 103 (1988):

    A patent may not be obtained [even though the invention is novel under § 102 of the Act], if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains . . . .

requiring a full and adequate description of an invention, also plays a role in the threshold question of patentability.

An uncertainty-based view of nonobviousness also meshes well with other theories of the patent system, including the venerable incentive theory. This theory claims that inventions are socially valuable and that patents are needed to induce inventions that would not otherwise be made, due to the inability of inventors to recoup all the benefits of their inventions.[5] As informed by the incentive theory, the job of nonobviousness is to encourage invention while not over-rewarding it. A clear articulation of this view can be found in an influential 1966 article by Edmund Kitch. According to Kitch, nonobviousness tries to assure that patents will only be given for those inventions that would not have been made without the promise of a patent.[6] That is, society will reward only those who *require* a reward to do their work. This article builds on Kitch's basic insight in an attempt to explain *when* an inventor would need the extra stimulus of a patent, i.e., *which* inventions are likely to be patent-induced.

The uncertainty-based approach taken here helps explain the operation of the current patent system and also suggests some modest reforms. The patent system is shown to have a stronger effect on the incentive to develop inventions as opposed to the incentive to invent. Yet it is also shown that the prospect of a patent does have an important minor influence on decisions to try to invent. Some features of current nonobviousness doctrine are shown to be justified by the incentive role of the nonobviousness standard. For instance, the exclusion of firm-developed information from the prior art is readily explainable in the context of an uncertainty-based view of nonobviousness. The

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5. Studies consistently show that society often gains a very large share of the total value generated by an invention. *See* Jeffrey I. 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); Timothy F. 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); Robert E. Evenson & Yoav Kislev, *Research and Productivity in Wheat and Maize,* 81 J. POL. ECON. 1309 (1973); Zvi Griliches, *Research Expenditures, Education and the Aggregate Agricultural Production Function,* 44 AM. ECON. REV. 961 (1964); Edwin Mansfield et al., *Social and Private Rates of Return from Industrial Innovations,* 91 Q.J. ECON. 221 (1977) (concluding that median social rate of return on 17 major products was more than twice the private rate of return). The problem with this argument is that the social rate of return from non-technical innovations may be just as high. Also, all of the inventions studied were commercialized; thus the studies also support the notion that innovations are what really count.

6. Edmund W. Kitch, Graham v. John Deere: *New Standards for Patents,* 1966 SUP. CT. REV. 293, 301 (stating that "a patent should not be granted for an innovation unless the innovation would have been unlikely to have been developed absent the protection of a patent"); *see also infra* note 53 and accompanying text.

uncertainty-based model also suggests a moderate lowering of patentability standards for very high-cost research.

Part II describes the doctrinal contours of the nonobviousness standard, after a brief consideration of a threshold issue: whether patents matter. Part III presents a simple two-step R&D decisionmaking model. The model assumes that inventors initially decide whether or not to conduct a preliminary experiment, and that the decision to develop a technology is made only after the results of this initial experiment are known. This formalizes the notion that patents augment perceived payoffs from experimentation, hence helping to overcome a rational decision-maker's resistance to high uncertainty research projects. It also reveals that patents offer only a limited incentive to perform research, but may add a significant incentive to *develop* technology—a position held by a small number of commentators. Part III then offers a restatement of the general nonobviousness standard, as well as doctrines touching on serendipitous research results and the treatment of private, firm-specific information, in light of the proposed emphasis on uncertainty. The model is then used to justify a slight lowering of the nonobviousness standard where initial experimentation is very costly. The analysis is then applied to a group of cases involving methodical and costly screening procedures.

Part IV sketches a brief formal model of high-cost research in a multi-firm industry. This model illustrates the need for enhanced appropriability[7] (via a lower patent standard for high-cost research) to achieve socially optimal levels of R&D. Part V reveals the relationship between the economic function of the nonobviousness standard and theories of the patent system. The conclusion sounds a mercifully brief refrain on the themes of uncertainty and the economic function of the patent standard.

II.   THE LEGAL STANDARD

A.   Threshold Issues

1.   *DO PATENTS MATTER?*

This section title might seem a question with a straightforward answer: of course patents matter, firms would not apply for them in such large numbers and litigate them with such tenacity if they were irrelevant. I touch on the subject here only because a medium-sized (but growing) literature puts this straightforward answer in doubt.

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7. Appropriability can be briefly defined here as means for capturing the value created by R&D expenditures.

While there have always been some critics who questioned the need for patents,[8] the recent critique carries extra weight because it is both current and based on substantial empirical research. These researchers find that patents are regarded by firms in only a very few industries as important means of capturing returns from research.[9] The most recent and complete study along these lines shows that in most industries head start advantages, including establishment of production and distribution facilities, and rapid progress down a learning curve, were judged significantly more effective than patents in enabling a firm to reap returns from innovation.[10]

Of course these studies and earlier sources contain some counter-indications. There certainly are inventors who swear by the patent system,[11] and a historian recently proclaimed the positive effects of the patent system on technical advance during the "first" industrial revolution in Britain.[12] Likewise, some recent empirical work finds that in

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8. *See, e.g.,* KEVIN BROWN, INVENTORS AT WORK 44, 189, 325 (1988) (quoting from interviews with inventors describing the importance of technical challenges and the unimportance of monetary gains to their pursuit of inventions); FRANK W. TAUSSIG, INVENTORS AND MONEY-MAKERS 17-54 (1915) (discussing what he calls "the instinct of contrivance" in all inventors, an instinct they would probably follow even without monetary gain); *cf.* S.C. GILFILLAN, THE SOCIOLOGY OF INVENTION (1935); Jack Hirshleifer, *The Private and Social Value of Information and the Reward to Inventive Activity,* 61 AM. ECON. REV. 561, 571-72 (1971) (since inventors have "inside information" about their inventions, they can reap gains by investing in assets that their inventions will make more valuable and selling short assets that their inventions will make less valuable; because of this, inventors might be overcompensated for their inventions if they are given special rewards such as patents).

9. *See* C.T. TAYLOR & Z.A. SILBERSTON, THE ECONOMIC IMPACT OF THE PATENT SYSTEM (1973); Edwin Mansfield, *Patents and Innovation: An Empirical Study,* 32 MGMT. SCI. 173, 176 (1986) (patents found not essential to protecting innovations in many industries); *cf.* ERIC VON HIPPEL, THE SOURCES OF INNOVATION 46-53 (1988) (patent licensing does not permit firms to reap rents from inventions).

10. Richard C. Levin et al., *Appropriating the Returns from Industrial Research and Development,* 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783 (reporting results of extensive empirical survey of research and development personnel at U.S. corporations).

11. *E.g.,* Richard Halstead, *Silence Golden for SF-Based Dolby,* S.F. BUS. J., June 23, 1986, at 1 (interview with Ray Dolby, inventor of audio engineering devices: " 'I have a general principle that I follow,' Dolby says. 'I don't go into any area that I can't get a patent on.' If you don't stick to that approach, 'you quickly find yourself manufacturing commodities.' ").

12. HAROLD I. DUTTON, THE PATENT SYSTEM AND INVENTIVE ACTIVITY DURING THE INDUSTRIAL REVOLUTION 1750-1852 (1984) (arguing that patents were instrumental in the introduction of all the major technical improvements of the industrial revolution). Dutton also notes that the patent system's inefficiencies actually made it close to an ideal system, since it encouraged invention but did not protect new technology too much from those who would try to improve it. *Id.* at 204-05; *cf.* Joel Mokyr, *The Industrial Revolution and the New Economic History, in* THE ECONOMICS OF THE INDUSTRIAL REVOLUTION 1 (Joel Mokyr ed., 1989).

> Property rights in new techniques were protected, albeit imperfectly by British patent law. Some inventors who failed to capture any of the social benefits of their work were rewarded directly by society.... The cumulative

a handful of industries patents are essential.[13] But it is safe to say there is a consensus among economists that in the aggregate patents offer only a very limited incentive to invent.[14]

This recent scholarship does not contend that firms seeking patents are irrational. Those writing in this vein ascribe the continued vitality of the patent system to a number of motivations. For the most part these are negative; they center around using the patent system defensively, to insure that one is not excluded from a profitable product line.[15] This literature views patents as bargaining chips used to counter those of competitors as ulterior instruments in a broader game of competitive intrigue. These commentators imply that no firm would obtain patents if its competitors did not. A variant of this scholarship stresses how cheap patents are, and implies that the occasional defensive benefit is worth the relatively low cost of patenting.[16]

A similar but less critical view concedes that most patents are not worth the cost. It stresses the *exceptional* case of a highly lucrative invention covered by a strong patent. The idea here is that no one knows

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effect of small improvements made by mostly anonymous workers and technicians was often more important than most of the great inventions.

Id. at 28 (footnote omitted).

13. *See, e.g.,* DAVID SCHWARTZMANN, INNOVATION IN THE PHARMACEUTICAL INDUSTRY (1976).

14. A nice summary of the consensus has been given by the economist Paul Stoneman: "[D]espite a long-standing concern over the nature and impact of the patent system, the importance of the system, in practical terms, may not be particularly great." PAUL STONEMAN, THE ECONOMIC ANALYSIS OF TECHNOLOGY POLICY 115 (1987).

15. *See* VON HIPPEL, *supra* note 9, at 51-53; Edwin Mansfield, *Intellectual Property, Technology and Economic Growth, in* INTELLECTUAL PROPERTY RIGHTS IN SCIENCE, TECHNOLOGY AND ECONOMIC PERFORMANCE 26 (Francis W. Rushing & Carole G. Brown eds., 1990) (patents taken out in some industries because "the prospective benefits of patent protection, including (besides royalties) whatever delay is caused prospective imitators and the use of patents as bargaining chips, are judged to exceed costs").

16. *See, e.g.,* VON HIPPEL, *supra* note 9, at 51-53. A completely different perspective on the continuing use of patents is given in GEORGE BASALLA, THE EVOLUTION OF TECHNOLOGY 124 (1988) (arguing that patents serve largely to perpetuate the culture of invention):

> The significance of patents is not that they offer strong and indisputable incentives for invention. . . . In fact, the effectiveness of the patent system is less important than the fact that every industrialized country in the West has made patenting a national institution, complete with supporting bureaucracy, legislation, and state funding. When combined with the zealous pursuit of patents by industry, the existence of professional careers in patent law practice, the transformation of the patent in Communist countries, the popular enthusiasm for the idea of the patent, and the economist's and historian's interest in probing the meaning of patents, the result is an obsession with technological novelty that is without precedent. No other cultures have been as preoccupied with the cultivation, production, diffusion, and legal control of new machines, tools, devices, and processes as Western culture has been since the eighteenth century.

at the time the patent must be filed whether an invention is exceptional. Because of the relatively low cost, it makes sense to file. The few exceptional inventions—estimated by one observer to be no more than one thousand per year—justify the many worthless patents, as well as the social cost they carry with them.[17]

Yet another critique of patents starts from the premise that they were originally quite successful in promoting innovation—the actual introduction of inventions into commerce—but have become almost useless in furthering this goal under current conditions.[18] This critique is

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17. F.M. SCHERER, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 440 (2d ed. 1980) ("[I]n any given year there are likely to be a thousand or so moderately to extremely important inventions patented."); *see also* JOEL MOKYR, THE LEVER OF RICHES: TECHNOLOGICAL CREATIVITY AND ECONOMIC PROGRESS 252 (1990) (patent system justified by high-value, low probability innovations—when "a crackpot hits the jackpot"). For an interesting and valuable proposal to extend special patent-like protection to these rare "revolutionary" inventions, see A. Samuel Oddi, *Beyond Obviousness: Invention Protection in the Twenty-First Century*, 38 AM. U. L. REV. 1097 (1989).

18. *See* DIRECT PROTECTION OF INNOVATION 1-34 (William Kingston ed., 1987). (proposing a system of property rights to come into effect only when a new product is actually introduced on the market). These proposals contain some useful suggestions, as indicated by the commentators assembled to critique them. *See* Gordon Tullock, *Intellectual Property, in* DIRECT PROTECTION OF INNOVATION, *supra*, at 171; Brian D. Wright, *On the Design of a System to Improve the Production of Innovations, in* DIRECT PROTECTION OF INNOVATION, *supra*, at 227. This premise was well stated in the concurrence of Judge Frank in Picard v. United Aircraft Corp., 128 F.2d 632, 642-43 (2d Cir.), *cert. denied*, 317 U.S. 651 (1942).

> But if we never needed, or do not now need, patents as bait for inventors, we may still need them, in some instances, as a lure to investors. It is sometimes said that there is no need thus to coax investors, because our giant corporations, with their research laboratories, will, without such bait, do the needful. The answer perhaps is that industrial history discloses that those corporations, at times and to some extent, have been prodded into undertaking such research and into developing improvements because of the threat of competition from occasional "outsiders," armed with patent monopolies, and supplied with funds by a few private enterprisers. Thus, paradoxically, monopoly may evoke competition: The threat from patent monopolies in the hands of such "outsiders" may create a sort of competition—a David versus Goliath competition—which reduces the inertia of some huge industrial aggregations that might otherwise be sluggish.

Id. (footnotes omitted); *see also* SUBCOMM. ON PATENTS, TRADEMARKS & COPYRIGHTS OF THE SENATE COMM. ON THE JUDICIARY, 85TH CONG., 2D SESS., AN ECONOMIC REVIEW OF THE PATENT SYSTEM (Comm. Print 1958) (written by the economist Fritz Machlup).

> And it is after all the "difficulty" of inventing which determines the relative scarcity of invention and, consequently, provides the rationale for the policy of creating an extra stimulus for inventive effort. This presupposes, however, as do most other problems under discussion, that it is invention rather than enterprising innovation which the patent system is supposed to encourage. If society aims at stimulating innovation and at attracting venture capital into pioneering investment, then the controversies about the nature of "inventions" are beside the point. After all, the innovators' risks are not proportional to the costs and results of the inventive efforts.

merely a prelude to the proposal to protect innovations directly, rather than indirectly through the protection of inventions.[19]

Taking all these critiques together, two arguments may be made in defense of the patent system: first, that the criticisms are not true; and second, that they are irrelevant, even if true. I believe the latter. But I will run through both arguments.

The main problem with the data on which the criticisms are based is that it may be out of date. It predates an important discontinuity in the patent system: the creation of the Court of Appeals for the Federal Circuit in 1982.[20] It appears that the Federal Circuit has strengthened patents considerably since 1982.[21] A student recently found a marked increase in published patent damage awards after 1982, compared to the 1970-1981 period.[22] All this indicates that the value of a patent may have increased in recent years. If so, the criticisms of a patent's worth may be out of date.

The second, and more powerful, retort is that the critics' arguments are irrelevant. Even if the *average* patent is not particularly valuable, this does not mean that the lure of patents will not act as a powerful stimulus to invention, at least in some cases. In fact, there are several good reasons to believe it will. The first is the well-known optimism of inventors—the "socially wholesome illusion" championed by the economist Fritz Machlup.[23] Many inventions that turn out to be average are backed by inventors who believe they are special; the power of patents in special cases thus induces inventors to perfect many an average invention.[24]

Id. at 9 (footnotes omitted).

19. *See, e.g.,* DIRECT PROTECTION OF INNOVATION, *supra* note 18, at 59 (discussing notion of an "innovation warrant" to protect the first commercialized embodiment of a new invention or idea).

20. *See* Federal Courts Improvement Act of 1982, Pub. L. No. 97-164, 96 Stat. 25 (codified at scattered sections of 28 U.S.C.).

21. Between 1982 and 1985, the Federal Circuit found that only 46% of the patents it adjudicated were invalid, a marked contrast to the old invalidity rate of approximately 66%. This 1982-1985 figure is derived from data presented in Donald R. Dunner, *The Court of Appeals for the Federal Circuit—The First Three Years: Introduction,* 13 AM. INTELL. PROP. L. ASS'N Q.J. 185, 187-88 (1985) (Tables 1-3). The data cover cases decided through October 1985. The older data are presented in Lawrence Baum, *The Federal Courts and Patent Validity: An Analysis of the Record,* 56 J. PAT. OFF. SOC'Y 758, 760 (1974). Baum found that in some circuits, patents were practically never upheld. *See id.* at 762 (between 1961 and 1973, the Eighth Circuit invalidated 89% of adjudicated patents). There is some evidence that the *unpublished* opinions of the Federal Circuit are even less likely to find a patent invalid. *See* Erica U. Bodwell, *Published and Unpublished Federal Circuit Patent Decisions: A Comparison,* 29 IDEA 233 (1989).

22. *See* SEREBOFF, A STUDY OF AWARDS IN PATENT SUITS AND SETTLEMENTS FOR THE PERIOD 1970 TO 1989 (1990).

23. *See* MACHLUP, *supra* note 1, at 166-67.

24. Do not read "worthless" for average here. Most technical progress is made up of small, incremental improvements to existing products and processes. *See, e.g.,* SAMUEL HOLLANDER, THE SOURCES OF INCREASED EFFICIENCY: A STUDY OF DUPONT RAYON PLANTS

Another way of stating this argument is that the patent system should *only* be concerned with the marginal inventor, the one who without the patent system is equally likely to pursue an invention as not. To this hypothetical inventor in equipoise, patents may be the deciding factor. If so, the fact that many other inventors and inventive entities consider patents inconsequential is unimportant. It is this "inventor at the margin" we are concerned with, at least from the incentive point of view.[25]

The approach taken in this article builds on this assumption. It assumes that inventors who consider patents insignificant will invent regardless of the patent system. These inventors thus make no difference to a defender of the patent system. Society will obtain useful devices from these inventors whether or not they get patents; it is the other, perhaps smaller, group of "patent-dependent" inventors whose behavior society is trying to influence with the patent system. As long as there are some inventors to whom patents make a difference, it is worth having a patent system and it is worth trying to influence their behavior. Thus the critique of the patent system built around the average inventor is irrelevant to the incentive side of the ledger.[26] From an economic policy standpoint it is interesting to note that small firms may be more likely to be marginal inventors.[27] Patents thus may be particularly important to

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(1965) (detailed study of major and minor process improvements at various DuPont rayon plants); *cf.* ALFRED MARSHALL, PRINCIPLES OF ECONOMICS 281 n.1 (8th ed. 1948) ("In many businesses only a small percentage of improvements are patented. They consist of many smaller steps, which it would not be worthwhile to patent one at a time.").

25. Of course, if many inventions that are patented would have been made if patents did not exist, it can be argued that there is a net loss: we may have encouraged some inventors—the "marginal" ones referred to above—to invent, but at the cost of awarding costly monopoly rights to all those inventors who would have invented anyway. While it is not a complete answer to this objection, I would point out that this is another justification for the nonobviousness requirement. Although society may wind up granting monopoly rights over inventions that would have been made even in the absence of a patent system, at least it will not do so where the inventions are completely trivial. That is, a somewhat stringent "gatekeeper" will cut down on the number of patents issued to all inventors, including those for whom patents are an easy way to restrict competition, rather than a major incentive in producing their inventions.

26. Of course, this assumes that the availability of a patent system won't act as a *disincentive* to those who are otherwise indifferent to patents. I have yet to see a persuasive argument why this might be so; certainly such inventors are not disparately affected by the availability of patents to those who care about them. On the myriad non-economic motives to invent, see TERESA M. AMABILE, THE SOCIAL PSYCHOLOGY OF CREATIVITY (1983); S. Colum Gilfillan, *Fundamental Inventions—Nobody's Baby, in* JOINT ECON. COMM., 88TH CONG., 2D SESS., INVENTION AND THE PATENT SYSTEM (Comm. Print 1964); Ron Westrum, Motives for Inventing (paper presented at the Society for the History of Technology Annual Meeting, Cleveland, Ohio, Oct. 1990) (on file with author).

27. *See, e.g., Biotechnology Patent Backlog: Hearings Before the Subcomm. on Regulation and Business Opportunities of the House Comm. on Small Business,* 100th Cong., 2d Sess. 25 (1988)

the firms which are reputedly superior innovators and job-creators.[28]

Of course, opponents of the patent system would point out that motivating the marginal inventor might still result in a net social loss, depending on the social costs that result from her patent monopoly. Yet surely this critique would be better directed at the standard of patentability or some other feature of the patent system, rather than at the existence of the system in toto. In at least some cases, patents contribute to social welfare. Perhaps it can be shown that patent standards are too low, or patent scopes are too wide, or the seventeen year term is too long; but there is no reason to suppose that the whole system is wrong. As long as every inventor who receives a patent is required to contribute something of value to society, the potential for welfare loss attending the patent monopoly must be weighed against this contribution. Indeed, as long as patent doctrines require such a contribution and as long as there is competition in the markets where inventions are introduced, the burden would seem to be on those who would show that the current balance is too favorable to inventors.

2.   DOES THE PATENT STANDARD INFLUENCE THE AMOUNT OF RESEARCH?

The discussion above shows why there is good reason to believe that patents are important. There is also good reason to believe that the criteria for granting patents (the patent standard) are important. The analysis used in this article presumes that today's decisions regarding the patentability of one firm's research influences the amount and direction of other firms' research. The standard of patentability is assumed to have behavioral effects and thus merits careful review. Firms will say, "Look, Firm A got a patent for doing that risky research; let's do some risky research ourselves." There are several reasons to believe the patent standard has such effects. Detailed case studies show that almost every firm at least tries to evaluate the cost effectiveness of proposed research

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(statement of Robert P. Merges) (reciting instances of small business reliance on individual patents).

28. *Cf.* Zoltan J. Achs & David B. Audretsch, *Innovation in Large and Small Firms: An Empirical Analysis*, 78 AM. ECON. REV. 678 (1989) (small firms were 43% more innovative than their larger counterparts for the entire sample of manufacturing industries); DOUGLAS K. SMITH & ROBERT C. ALEXANDER, FUMBLING THE FUTURE: HOW XEROX INVENTED, THEN IGNORED, THE FIRST PERSONAL COMPUTER 119 (1988) (after Federal Trade Commission investigation suggesting that compulsory licensing of Xerox's basic document copying patents to competitors might be part of antitrust remedy, Xerox officials stated that patents were no longer as important as they had been when the company was small). *But cf.* American Patent System: Hearings on S. Res. 92 Before the House Subcomm. on Patents, Trademarks, and Copyrights of the House Comm. on the Judiciary, 84th Cong., 1st Sess. 221 (1956) (statement of Walton Hamilton) ("A strong patent in weak hands is not worth anything.").

and development projects.[29] R&D managers also consider "patentability" or "patent strength" prior to investing in R&D projects.[30] Thus the prospect of getting a patent may enter into the *initial* project investment or selection choice.[31] If so, the standard of patentability enters at this stage.[32] Even for firms whose research proceeds further before making a

29. *See* Edwin Mansfield & Samuel Wagner, *Organizational and Strategic Factors Associated with Probabilities of Success in Industrial R&D*, 48 J. BUS. 179, 190 (1975); NUALA SWORDS-ISHERWOOD, PROCESS OF INNOVATION 93, 103, 107, 110, 121, 131, 134, 142 (1984) (project evaluation by firms in the paper, oil, medical imaging, and semiconductor industries); *but see id.* at 103 (company that "no longer attempts to quantify returns from R&D investment," but still monitors progress); NEIL H. WASSERMAN, FROM INVENTION TO INNOVATION 120, 121 (1985) (importance of economics in the development of almost every phase of telephone cable technology, for example, decision whether to pursue line-loading technology, where "uncertainty as to benefits and costs and the large anticipated outlays for the development of the invention made it imperative to construct a detailed, accurate theory of the economics of the innovation"). For an interesting case study on the way R&D project decisions, decisions regarding individual experiments, and the prospect of patent protection interact, see Akzo, N.V. v. E.I. du Pont de Nemours, Inc., 810 F.2d 1148, 1149-50 (Fed. Cir. 1987) (description of parallel research efforts to produce Kevlar, a synthetic fiber).

30. Jackson, *Decision Methods for Evaluating R&D Projects*, RES. MGMT., July-Aug. 1983, at 16, 17 (illustrating a "scoring model" decision technique where one of seven factors to consider is "Patent and License Situation"); William E. Souder, *A System for Using R&D Project Evaluation Methods*, 21 RES. MGMT. 29, 32 (1978) (using patentability as one of five criteria on which projects are ranked in a side-by-side comparison); EDWARD B. ROBERTS, GENERATING TECHNOLOGICAL INNOVATION, 170, 175 (1987) (noting that a chemical company studied by author uses patentability as a criteria when assessing research project viability, and that two firms—Fetterlof and Merck—said they "would not touch unpatentable products"); J.J. Hutter, *The Development of Fluorescent Lamps at Philips up to 1940, in* PHYSICS IN THE MAKING 273, 288 (A. Sarlemijn & M.J. Sparnaay eds., 1989) (describing how Philips's patent position influenced the development of the fluorescent lamp); *cf.* Karl Heinrich Oppenländer, *Patentschutz und Wettbewerb im Innovationsprozeß, in* PATENTWESEN, TECHNISCHER FORTSCHRITT UND WETTBEWERB 47, 60-62 (Karl Heinrich Oppenländer ed., 1984) (No. 113 in the series Schriftenreihe des Ifo-Institutes für Wirtschaftsforschung) [hereinafter PATENTWESEN] (a survey of West German firms by the Ifo-Institut showed that without patent protection an average of 21% of all the inventions surveyed would not have been made; for large companies, this figure was 39%); L. Uhlman, *The Innovation Process in Industrialized Countries, in* INNOVATION, ECONOMIC CHANGE AND TECHNOLOGY POLICIES 21, 32 (Karl A. Stroetman ed., 1977) (study of 218 innovations from 126 companies finding that "[l]aws relating to competition, taxation, patents, etc." influenced the decision to commercialize inventions in 13% of the cases studied); WASSERMAN, *supra* note 29, at 91 (Alexander Graham Bell's patents on the telephone were crucial to getting financiers to back him).

31. *See, e.g.*, Halstead, *supra* note 11; BROWN, *supra* note 8, at 115 (quoting Bob Gundlach of Xerox: "[T]he patent umbrella was crucial [in development of xerography]. The fact that Xerox could invest in new processes with some assurance that it could get a return on that investment later was essential when it came to developing xerography."). *See generally* Westrum, *supra* note 26, at 13 ("The monopoly granted by a patent may very much increase the expected returns from commercialization of an invention, and for this reason it may be a powerful motivation to bring the invention to fruition or actually to put products derived from it on the market.").

32. Firms also look to the potential that their research will infringe other firms' patents; in this sense, patents enter into research selection as a negative influence as well. *See, e.g.*, Michael E. Gorman & W. Bernard Carlson, *Interpreting Invention as a Cognitive Process: The*

detailed cost/benefit analysis, patentability might enter in the very rough (and sometimes implicit) economic feasibility decisions made by the R&D department at the outset of the research project.

The discussion here is not meant to imply that patentability is the sole or even a major influence on firm R&D decisions. Yet as the literature reviewed above suggests, patents do have an effect on firms' R&D investment decisions. This is not surprising; as long as patents are worth something—and the volume of patent applications and litigation suggest they are—they will have some effect at the margin. A firm whose decisionmakers are closely divided as between pursuing an R&D project and investing elsewhere can be expected to be influenced by the enhanced returns a patent may bring. And so long as the prospect of patents has any influence on R&D decisions, it is worthwhile examining the standard of patentability.[33] Indeed, because the standard will influence these decisions, courts charged with interpreting the nonobviousness standard ought to be cognizant of its impact on the behavior of firms, and ought to modify it where necessary to carry out the underlying goals of the patent system.

B.   Doctrine

The patent code says an invention must be "novel," "useful," and "nonobvious" to be patentable.[34] These criteria applied together determines the patentability of inventions. A novel invention is one whose combination of features is not found in any single preexisting invention, technical article, or other piece of "prior art." The logic behind this is fairly straightforward; surely it would be improper to permit someone to claim property rights in something that has been well-known

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Case of Alexander Graham Bell, Thomas Edison, and the Telephone, 15 SCI. TECH. & HUM. VALUES 131, 145 (1990) ("[T]he leaders of Western Union decided that there was no need to buy Bell's patent because the telephone could be easily duplicated and improved by inventors already associated with the company."). For a suggestion about the magnitude of the costs of "inventing around," see Edwin Mansfield et al., *Imitation Costs and Patents: An Empirical Study*, 91 ECON. J. 907, 913 (1981) (survey of R&D personnel in random sample of companies produced result that patents caused a "median estimated increase in [the cost of imitation] of 11%").

33. As a fallback, I would argue that even assuming the patent standard has little or no effect on firm behavior, there are reasons we would desire a non-trivial standard of patentability. Regardless of the motives firms have in pursuing research, the grant of a patent can involve fairly significant social costs. Thus we would want to make sure society does not incur such costs without receiving some benefit. This is a more conventional "static tradeoff" view of the matter than the prospective, behavioral impact view taken in the text. *See, e.g.*, WILLIAM D. NORDHAUS, INVENTION, GROWTH AND WELFARE 86-88 (1969).

34. 35 U.S.C. § 103 (1988). This is in addition to the other requirements in 35 U.S.C. §§ 101 (utility) and 102 (novelty). Novelty means "literal newness"; nothing exactly like the invention sought to be patented has been invented previously.

for a long time—say, in the practice of cutting cheese by using a cutting board and knife. This information is already in the public domain when the "inventor" seeks to patent it; society has no need to grant a patent to get this information. It is not novel, either in the everyday sense or the patent law sense.

Now imagine an inventor who seeks to patent a method of cutting cheese using a knife as a cutting tool and a sheet of *titanium steel as a cutting board.* Our inventor searches diligently and finds no evidence of prior patents or periodical articles describing her method; there also seems to be no record of people actually using her method. Because the *prior art* contains no mention of it, it is novel, in the patent sense.

The invention must still satisfy § 103 of the patent code. This bars the granting of a patent, although the test of novelty has been passed, when the invention is obvious. Nonobviousness, it has been said, is "the ultimate condition of patentability."[35] In our example, the invention would be found obvious. It merely combines two well-known components—a knife and a sheet of hard material—to achieve a well-known objective, cutting things. Thus in our example, the Patent Office would likely reject the titanium steel cutting board patent application. Alternatively, because accused infringers normally raise the invalidity of the patent as a defense, a court might well invalidate the patent for obviousness if it were somehow granted in the first place.[36]

The rationale for obviousness is evident from the cutting board example. Without it, anything differing only slightly from the prior art would be patentable. Even if the award of a patent to this particular patentee did not reduce social welfare much, surely such a patent would

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35. NONOBVIOUSNESS—THE ULTIMATE CONDITION OF PATENTABILITY (John F. Witherspoon ed., 1980). Thomas Jefferson, who oversaw the first American patent act, recognized early on that the patent system must concern itself with the difficult task "of drawing a line between the things which are worth to the public the embarrassment of an exclusive patent, and those which are not." 13 WRITINGS OF THOMAS JEFFERSON 335 (memorial ed. 1904).

36. Thus nonobviousness must in effect be established twice by the patentee, at least if she ever litigates her patent. However, an issued patent which is litigated comes with a presumption of validity under the patent code which makes it less likely—though by no means impossible—that a court will declare the patent invalid. *See* 35 U.S.C. § 282 (1988) (presumption of validity); *see also* Dunner, *supra* note 21, at 187-88 (Table 1) (data show that for cases decided under § 103 by the Court of Appeals for the Federal Circuit—the unified, national court of appeals for all patent cases—the court affirmed 86% of district court decisions finding patents nonobvious and therefore valid, and 60% of district court decisions finding patents invalid for obviousness). It is interesting to contrast this figure with older data; between 1921 and 1973 the circuit courts found nearly two-thirds of adjudicated patents invalid. Baum, *supra*, note 21. In some circuits, patent validity was practically never upheld. *See id.* at 762 (between 1961 and 1973, the Eighth Circuit invalidated 89% of adjudicated patents). Note that certain evidence not normally available to the Patent Office may assist the patentee in establishing the nonobviousness of her invention; some forms of this "objective" evidence of nonobviousness have been criticized. *See* Merges, *supra* note 2.

deplete the stock of publicly-available resources available to the next inventor.[37] From this perspective, nonobviousness is designed to maintain a penumbra around the stock of known devices, techniques, etc., insuring that trivial extensions from what is known will not be granted property rights.

The legal standard of nonobviousness is built on this rationale. As it is often stated, the test of nonobviousness views the inventor's situation just prior to making the invention and asks how "nonobvious" it was that the invention would work.

At the outset, notice that there is something of a temporal paradox built into the standard. *Given* that the invention does work—there will be no patent application if it doesn't—how uncertain was it that it would work just prior to the time it was invented?

The cases hold that no patent will issue if, just prior to the invention, there was a "reasonable probability of success"[38] that the invention would work, as judged by someone "skilled in the art." If there was *no* reasonable probability of success, the resulting invention deserves a patent.[39] That is, an invention must be downright improbable for it to be patentable.[40]

The probability of the invention is viewed from the perspective of an ordinary skilled artisan,[41] *not* from the perspective of the actual inventor. There are good reasons why an objective standard is favored here. A subjective standard would be quite difficult to apply, and applicants would have an incentive to downplay their technical knowledge. Also, the objective standard guarantees that an inventor will contribute truly valuable information to the technical community.

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37. *See, e.g.,* Jessica Litman, *The Public Domain,* 39 EMORY L.J. 965 (1990).

38. *See, e.g., In re* Merck & Co., 800 F.2d 1091, 1097 (Fed. Cir. 1986) (the standard for obviousness is not "absolute predictability, [but] only a reasonable expectation that the beneficial result will be achieved"); Loctite Corp. v. Ultraseal, 781 F.2d 861, 874 (Fed. Cir. 1985) (obviousness is an objective standard, and it is only material what a person of ordinary skill would have thought); *In re* Longi, 759 F.2d 887, 897 (Fed. Cir. 1985); *In re* Lamberti, 545 F.2d 747, 751 (C.C.P.A. 1976).

39. *See, e.g.,* W.L. Gore & Assocs., Inc. v. Garlock, Inc., 721 F.2d 1520 (Fed. Cir. 1983) (upholding nonobviousness of invention, since "there was no testimony and no finding that one skilled in the art would transfer conventional thermoplastic processes to those for unsintered PTFE [polytetrafluoroethylene, i.e., "Gore-tex"], *or would have been able to predict what would happen if they did"*) (emphasis added); *Ex parte* Old, 229 U.S.P.Q. (BNA) 196, 200 (Bd. Pat. App. & Int. 1985) (reversing final rejection by patent examiner for obviousness, because "he himself does not urge that the character of [the invention] . . . could be predicted").

40. *See, e.g.,* Continental Oil Co. v. Witco Chem. Corp., 484 F.2d 777, 784 (7th Cir. 1973) (invalidating patent for invention that was "[a]t most . . . somewhat doubtful until after an experiment had been made").

41. Under the statute, a "person having ordinary skill in the art," 35 U.S.C. § 103 (1988)—thus the acronym "PHOSITA." *See* John O. Tresansky, *PHOSITA—The Ubiquitous and Enigmatic Person in Patent Law,* 73 J. PAT. & TRADEMARK OFF. SOC'Y 37 (1991).

Finally, since the objective standard judges the obviousness of the invention on the basis of publicly-available information,[42] it does not punish inventors who produce "private" information not available to the ordinary skilled artisan.[43] Thus the standard indirectly encourages inventors to generate valuable private information, secure in the knowledge this will not be held against them when they apply for a patent.[44]

Again, what is important is not the chance of success measured with the aid of hindsight, but what someone skilled in the art would have predicted that chance of success to be before the invention was made.[45] For purposes of applying this test, it is useful to imagine not one omniscient skilled artisan, but rather a "roomful of engineers." The relevant probability of success is the *consensus* probability these engineers would estimate with all relevant knowledge in mind just prior to the actual key experiment.

C. The Patent Standard and Races to Invent

We have seen that the patent standard insures that each invention will contribute a minimal quantum of information to the technical arts. Implicit in this view is the notion that inventors must be kept from patenting *too soon;* that technological advance should be rewarded when it is "ripe." An important rationale behind requiring a minimal contribution of information is to distinguish patent races from so-called "common pool" situations such as overfishing.

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42. The hypothetical "skilled artisan" is endowed with all relevant knowledge in the prior art. *See In re* Winslow, 365 F.2d 1017 (C.C.P.A. 1966). But the skilled artisan may also be misled by all this prior art; a long line of cases hold that if the prior art "teaches away" from the solution found by a patent applicant, this is strong evidence of the nonobviousness of that solution. *See, e.g., In re* Diminski, 796 F.2d 436 (Fed. Cir. 1986); *In re* Gordon, 733 F.2d 900 (Fed. Cir. 1984); Robert W. Harris, *Apparent Federal Circuit Standards for Weighing Nonobviousness Argument that Prior Art Reference Teaches Away from Present Invention*, 70 J. PAT. & TRADEMARK OFF. SOC'Y 79 (1988).

43. That is, even if an inventor's own research shows that the critical experiment is quite likely to succeed, this will not render the invention obvious. Only publicly available information, for the most part, is used to determine whether the invention is likely to succeed, and therefore obvious. Consequently, an inventor's own private information will not render her invention obvious, despite the fact that, had the "reasonably skilled artisan" known this information, this artisan would have predicted success for the critical experiment.

44. I argue later that even if an inventor *in fact* knew for certain that a particular experiment would work, because she invested time and effort in a series of experiments leading up to the critical successful experiment, the patent should be granted if a person of ordinary skill in the art would have predicted that there was no reasonable chance of success for that experiment. This arguments turns on the non-availability of "private prior art" in the general prior art from which obviousness is judged; the argument explains a feature of nonobviousness that has been of interest in recent years.

45. *See In re* Adams, 356 F.2d 998, 1002 (C.C.P.A. 1966).

Using economic modeling, many analysts have concluded that multi-firm R&D races indeed resemble common pool situations such as overfishing.[46] Most of these models utilize game theory techniques where firms make investment decisions sequentially, using varying amounts of information about their rivals' moves and responses. The basic assumption is that inventions can be planned and rationally pursued; the primary variable is the *speed* at which a firm pursues a particular invention. Under the basic form of these models,[47] the incentives (which often include a patent) to "win" the race cause firms to invest in R&D "too fast" (and sometimes "too much") compared to the socially optimal rate.[48] In this way these race models resemble the basic common pool model for assets such as fish.[49] Under the common pool model, multiple fishermen inefficiently rush to exploit a commonly-owned (i.e., public) resource. The fish are available to the fisherman who first appropriates them. Similarly, patent rights are available to the firm which first does

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46. *See, e.g.,* Partha Dasgupta & Joseph Stiglitz, *Uncertainty, Industrial Structure and the Speed of R&D,* 11 BELL J. ECON. 1 (1980); Glenn C. Loury, *Market Structure and Innovation: A Reformulation,* 94 Q.J. ECON. 395 (1979); F.M. Scherer, *Research and Development Resource Allocation Under Rivalry,* 81 Q.J. ECON. 359 (1967). For recent treatments of the topic, see Steven A. Lippman & Kevin F. McCardle, *Dropout Behavior in R&D Races with Learning,* 18 RAND J. ECON. 287 (1987).

47. Other attempts to model interfirm R&D competition include refinements such as the possibility that information generated by one firm's research may benefit competitors (the so-called "spillover" effect). *See, e.g.,* Benjamin Bental & Dennis Fixler, *Firm Behavior and the Externalities of Technological Leadership,* 32 EUR. ECON. REV. 1731, 1744 (1988) (externality created by ability of trailing firm to learn from leading firm's technology makes it a viable strategy to "lag behind" in some circumstances, thus changing the dynamic of the "race"); *cf.* Richard C. Levin & Peter C. Reiss, *Cost-reducing and Demand-creating R&D with Spillovers,* 19 RAND J. ECON. 538 (1988) (summarizing empirical data on industries where each firm's research has industry-wide benefits). For other refinements and extensions, see JEAN TIROLE, THE THEORY OF INDUSTRIAL ORGANIZATION 396-99 (1990) (describing embellishments on basic race models); Partha 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); Michael L. Katz & Carl 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).

48. For an explanation, see Pankaj Tandon, *Rivalry and the Excessive Allocation of Resources to Research,* 14 BELL J. ECON. 152 (1983) (excessive duplication of research results when competitors race for "common" result that will be covered by a strong property right). *See also* Partha Dasgupta & Paul Stoneman, *The Economic Theory of Technology Policy: An Introduction, in* ECONOMIC POLICY AND TECHNOLOGICAL PERFORMANCE 18-21 (Partha Dasgupta & Paul Stoneman eds., 1987) ("[T]he winner-takes-all form of compensation to research units ... encourages excessive R&D investment and excessive risk-taking on the part of R&D units competing for the prize.").

49. *See generally* Brian D. Wright, *The Resource Allocation Problem in R&D, in* THE ECONOMICS OF R&D POLICY 41, 49-56 (George S. Tolley ed., 1985) (describing the relationship between the general common pool model and "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].").

the necessary research. The problem in both situations is that too much is spent too quickly on the "capture" of valuable assets.

A significant criticism of the common pool models as applied to R&D is that new technology, unlike things such as fish, is *not* "already out there." It must be invented—i.e., conceptualized, synthesized, constructed—and so differs fundamentally from fixed assets like fish, which need only be found and harvested. With technology, unlike fish, there is independent value in the "search" for the asset. Consequently, the question of what search costs are optimal is more difficult for technology; expenditures on search can, in effect, make new fish, or even (sometimes) entirely new beasts altogether.

Implicit in this critique of common pool models as applied to R&D is the notion that patentable technology is not "already out there." It must be made, not found. And this suggests a further defense of the nonobviousness standard of patentability. For it is this standard which guarantees that the search for a patentable invention will not be like the search for fish—it will be for something not only new, but beyond the penumbra of the already-known. In short, having a standard of patentability is what makes the search for patentable technology different from the search for a fixed asset that is already out there.

The gatekeeping function of the patent standard makes a great deal of sense from this point of view. Without it, firms would be making patentable inventions all the time. If every one were patented, a great deal of technology would be locked up. In fact, because it was so predictable—so "easy to find," to extend the fishing metaphor—patentable technology would closely resemble the fixed assets that are the subject of the common pool models. Under these circumstances, with no viable patent standard to prevent firms from taking out numerous patents, the predictions of the pool models might well be borne out: overfishing (i.e., too much patenting) compared to the socially optimal level would ensue. Thus there is another justification for the patent standard—to prevent wasteful expenditure on the capture of trivial pieces of technology.[50]

D.   Relationship Between Patent Standards and Patent Scope

As shown above, the nonobviousness standard is clearly a *threshold* standard. It determines which inventions deserve the reward of a patent.

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50. Note that this point corresponds to one part of Mark Grady's thesis that the patent system is designed to minimize rent dissipation. *See* Mark F. Grady & Jay I. Alexander, *Patent Law and Rent Dissipation*, 78 VA. L. REV. 305 (1991). On that thesis in general, see Robert P. Merges, *Rent Control in the Patent District: A Comment on the Grady-Alexander Thesis*, 78 VA. L. REV. 359 (1991).

Yet this standard of patentability is incomplete without a legal definition of the breadth of the invention.

Nonobviousness is determined with reference to the claimed invention. That is, the Patent Office or court asks whether the invention *as claimed* is obvious or not.[51] Thus inventors often amend or modify their patent applications by reducing the scope of their claims, to overcome a nonobviousness rejection from the Patent Office. For example, consider an inventor who perfects a chemical process that uses a certain chemical compound in concentrations ranging from 15% to 80%. In her patent application, she claims the process using that compound in the full range of concentrations she has found effective—from 15% to 80%. Next, assume the patent examiner turns up a prior art reference (a scientific article, for instance) that describes the use of a similar compound in a similar process in concentrations from 1% to 20%. The examiner may assert that this reference makes the applicant's invention obvious, at least in the lower ranges of compound concentration. In response, the applicant may modify her claims to include the process using the compound only in some higher range, say from 40% to 80%. This modified claim, the examiner may rule, meets the test of § 103 (i.e., is not obvious), and hence is patentable.

Yet the conclusion on nonobviousness does not determine another issue of importance to the applicant—the upper boundary of her claim. Perhaps she wishes to extend the upper boundary to 100%, so she would be claiming a process using all concentrations of the compound from 40% to 100%. Clearly if an 80% concentration is nonobvious, so is a 100% concentration. Thus the nonobviousness test cannot be used to determine if this new, expanded claim, is patentable.

In this situation the enablement test set forth in § 112 applies. In general, enablement seeks to determine whether the inventor's claims adequately reflect her research—whether, in effect, she is claiming more than she taught her fellow artisans. If she has claimed more than she has taught, the legal conclusion is that she has not adequately "enabled" one skilled in the art to make or use all embodiments of her invention. Those claims that are not enabled are rejected by the Patent Office or invalidated by a court.

From an economic point of view, the purpose of enablement doctrine is to insure that the property right granted to an applicant is of an appropriate scope, in light of the contribution her research makes to the relevant field. Enablement insures that the scope of the right accurately reflects the value of the invention. Contrast this to the function of nonobviousness as previously discussed. Nonobviousness insures that

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51. *See, e.g.,* Windsurfing Int'l, Inc. v. AMF, Inc., 782 F.2d 995 (Fed. Cir.), *cert. denied sub nom.* BIC Leisure Products, Inc. v. Windsurfing Int'l, Inc., 477 U.S. 905 (1986).

the information inherent in the invention claimed has some minimum threshold quantum of value. As long as the claimed invention had a low enough probability of success before it was made, it is deemed to be valuable enough, and is therefore patentable. But beyond this, nonobviousness does not seek to determine exactly how large the inventor's contribution is to the art, and hence how expansively she may define her invention in her claims.[52] This is the domain of enablement, and the other doctrines that collectively determine patent scope.

E.   The Proposed Patent Standard

The conventional ideal standard of patentability is that patents should only be awarded to those inventions that would not have been made without the availability of the patent.[53] That is, patents should only be given out when they make a difference. They should never be "icing on the cake" for an otherwise motivated inventor.

It would be impossible in most cases to apply this standard. If asked, firms would always say they need patents. Also, as the preceding discussion indicates, very few patents would be granted today under this standard, since so few industries consider patents essential.

The *patentability* standard I propose aims to influence the marginal firms and marginal inventors referred to above. It should influence at least these marginal inventors to pursue riskier research than they otherwise would. My preferred standard rewards one who successfully invents when *the uncertainty facing her prior to the invention makes it more likely than not that the invention won't succeed.* Uncertainty under this

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52. Even so, certain aspects of the enablement doctrine have a probabilistic twist, viz.: did the patentee make it probable that someone skilled in the art could produce the subject matter she claims in her patent? This is especially true in relatively empirical arts such as biotechnology, where there are limits to the guidance a patentee can provide in her specification. *See, e.g., In re* Wands, 858 F.2d 731 (Fed. Cir. 1988); Patrick Kelly, *Patenting EPO Analogs: Screening vs. Predictability,* BIO/TECHNOLOGY, Feb. 1990, at 112; *see also* Pierserafino Marsico, *The Chemical-Pharmaceutical Product Patent: Absolute Protection, General Formulas and Sufficiency of Description,* 11 EUR. INTELL. PROP. REV. 397, 405 (1990) (citing decision of Rome Tribunal, stating that a "patent must be held invalid where the description does not completely indicate a given solution for the implementation of the invention, but imposes on the technician all the experimentation and randomness of success that characterise the studies and research of the patentee"). This same concept is reflected in the "undue experimentation" doctrine in U.S. law. For a description of this and other scope-related concepts, see Merges & Nelson, *supra* note 2.

53. *See* S.C. Gilfillan, *The Root of Patents, or Squaring Patents by their Roots,* 31 J. PAT. OFF. SOC'Y 611, 611 (1949) ("A patent is helpful and proper when it rewards sufficiently useful creative work which *might not have been done without* that prospective reward. . . . This principle has always been the basis for granting patents for inventions won by genius or luck, and denying them for inventions that could have been made by anyone skilled in the art, or inventions that follow logically from already known principles."); Kitch, *supra* note 6.

standard is measured from the perspective of the average skilled inventor in the field.

One possible objection to this approach is that it might work too well; under this standard firms might undertake more high-risk research than is otherwise warranted because the results of high-risk research are more readily patentable. This is bound to be true to a certain extent; assuming the amount of potential R&D investment is fixed, when patents are introduced there will be some displacement from the low-risk research that would have been pursued absent patents. On the other hand, if the social rate of return from the higher-risk projects is greater— and there is reason to believe it will be—this displacement is warranted. Again, the evidence is empirical; I refer to the studies of returns from major technological advances discussed previously.[54] Many of these advances were achieved in the face of significant uncertainty, suggesting a correlation between this uncertainty and the eventual rate of return.

Yet the risk of a very serious degree of displacement appears low. At some point even for the marginal inventor the risk of failure will be so high that the admitted lure of a patent will not induce her to attempt the invention. There is no real danger, in other words, that a standard based on technical uncertainty will shift all research toward the high-risk category.

III. MODELING THE STANDARD: PATENTS AS INCENTIVES TO INVENT

The incentive theory of patents is the most widely accepted theory; references to it are everywhere. As with any incentive, patents are thought of as a "sweetener" to influence a particular decision. The decision in the case of patents is usually taken to be the decision to invent. The disclosure theory of patents is also important in understanding our patent system. An attempt to integrate these two theories appears in Part V below. But for present purposes, it is best to focus on the incentive theory.

A. A Formal Model of the Invention Process

There is a model of the invention process, and of the patent system's role in this process, implicit in the incentive theory as it is usually presented in the patent literature. This model is of the inventor deciding whether to attempt an invention. The decision can be thought of as an investment decision like any other. The inventor faces the choice of attempting to invent, or of investing her money elsewhere. In this

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54. *See* sources cited *supra* note 5.

conception, patents are held out as a potential reward to induce the inventor to decide to proceed with research.

This section explores the incentive theory by presenting a simple formal model of this decision process. The first stage of the model consists of an inventor facing the choice of whether to attempt preliminary experimentation on the invention.[55] The next stage of the model presents another decision: whether to develop the nascent invention. By separating the invention process into two steps, the model tries to "unpack" some features of the conventional (implicit) model of invention, and thus capture more of the complexity of the invention process.

In this two-step decision model, the inventor makes an *initial* estimate of the potential returns from the inventive process, prior to beginning any experimentation.[56] This is equivalent to the common

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55. This corresponds roughly to a common stage in research and development (R&D) projects: the preliminary screening of candidate technologies, or preliminary investigation of a technology for a suspected or hoped for quality. *See, e.g.,* Steven N. Wiggins, *The Pharmaceutical Research and Development Decision Process, in* DRUGS AND HEALTH 55, 58 (Robert B. Helms ed., 1981) ("The screening procedure is a low-cost method of separating compounds that warrant more careful testing from toxic substances and from substances that have no observable pharmacological action."). On the use of formal decision-making techniques in research and development management, see WILLIAM E. SOUDER, PROJECT SELECTION AND ECONOMIC APPRAISAL (1984); Uhlman, *supra* note 30, at 32 (study of 218 innovations from 126 companies finding that, at least at the stage of deciding whether to develop an invention, "[t]he formal procedure adopted in [this] decisionmaking process has, therefore, to a considerable extent been standardized in industrial enterprises"); *cf.* Edwin Mansfield, *How Economists See R&D*, HARV. BUS. REV., Nov.-Dec. 1981, at 98 (reporting results of empirical research indicating that although economic evaluations based on quantitative techniques increase a project's chances of commercial success, some managers are reluctant to adopt project selection methods).

> The precise extent to which quantitative models of this sort are being used in the United States is unknown. Some surveys indicate that many of the laboratories—particularly the bigger laboratories—in the chemical, drug, and electronics industries have used them. But the surveys cannot tell how significant these techniques really are in the decision-making process. In some laboratories, they are taken quite seriously indeed; in others, they are little more than window dressing for professional hunches and intracompany politics.

Id. at 102.

56. Aficionados of the literature on uncertainty may note that a discussion of rational investment decisions in a paper ostensibly concerned with uncertainty requires some explanation. This is so because, ever since Frank Knight's pioneering work in 1921, this literature has recognized a fundamental distinction between risk and uncertainty. Risk is generally defined as an assessment of likelihood based on repeated instances of an event. *See* FRANK H. KNIGHT, RISK, UNCERTAINTY AND PROFIT 19-20, 233 (1921). Uncertainty, by contrast, usually describes a unique situation not susceptible to measurement by repeat instances over time. *Id.* at 20, 233. Decisions regarding invention are clearly attended by uncertainty, not risk, as Knight himself recognizes. *See id.* at 318 ("The most fundamentally and irretrievably uncertain phases or factors of progress are those which amount essentially to an increase of knowledge as such. This description evidently holds for the improvement of technological processes and the forms of business organization

situation of the R&D manager deciding whether it is even worthwhile to begin to explore a research area.[57] If she decides the preliminary experimentation is worthwhile, she is faced with a second choice when that experimentation is successfully completed: to develop the invention, or to abandon it.[58] Figure 1 shows a simple "decision tree" describing the

and for the discovery of new natural resources."). Yet this does not mean that inventors facing an investment decision cannot make probability judgments about the chances of success, nor does it imply that such judgments are meaningless. Knight recognizes that

> [t]hough we cannot describe a new invention in advance without making it ... yet it is possible in a large degree to offset ignorance with knowledge and behave intelligently with regard to the future. These changes [i.e., advances] are in large part the result of deliberate application of resources to bring them about, and in the large if not in a particular instance, the results of such activity can be so far foreseen that it is even possible to hire men and borrow capital at fixed remunerations for the purpose of carrying it on.

Id. at 318. This is simply a particular instance of Knight's general observation about decisions made under uncertainty: "that a judgment of probability is actually made in such cases." *Id.* at 226. Note in this connection Kenneth Arrow's treatment of research as overcoming uncertainty: "The outcome of any research project is necessarily uncertain, and the most important results are likely to come from projects whose degree of uncertainty to begin with was greatest." Kenneth J. Arrow, *Insurance, Risk, and Resource Allocation, in* ESSAYS IN THE THEORY OF RISK-BEARING 135, 138 (1974); *see also* JON ELSTER, RATIONAL CHOICE 19 (1986) (describing uncertainty as a situation where the decisionmaker does not know the value of gathering more information, and so must make *"some* decision"). Knight identifies such judgments as "subjective," KNIGHT, *supra,* at 233, which is in full keeping with the model that follows, in the sense that the "Bayesian" features I use are often characterized as reflecting a subjective outlook. *See, e.g.,* THEODORE M. PORTER, THE RISE OF STATISTICAL THINKING 78-80 (1986) (describing eighteenth century reactions to Bayes' Theorem which charged that it was "illusory" and "arbitrary"); COLIN HOWSON & PETER URBACH, SCIENTIFIC REASONING: THE BAYESIAN APPROACH (1989) (responding to charge that Bayesian approach is too subjective). Note, however, that the test for nonobviousness is an *objective* test in that is asks whether "one skilled in the art"— a "reasonable person"-like construct that is essentially objective—would have predicted success for the key experiment faced by the inventor. As a consequence, the nonobviousness test as I see it employs an interesting duality: it measures the *subjective* judgment of the *objective* "skilled artisan" to assess likelihood of experimental success, and hence patentability.

57. *See, e.g.,* Wiggins, *supra* note 55, at 63 ("[A]t some point the [researcher] who has the [research] idea goes to the head of his or her research unit and suggests that the idea be pursued in a formal project. This is the *primary* source of all new research projects undertaken by pharmaceutical companies.").

58. The use of project "hurdles" or decision points in the pharmaceutical industry is described in Wiggins, *supra* note 55, at 70. One researcher finds that for a majority of inventors, patents act primarily as an incentive to commercialize, rather than invent. *See* Giorgio Sirilli, *Patents and Inventors: An Empirical Study,* 16 RES. POL'Y 157, 164 (1987). But unless this is true of all inventors, it does not undercut the model in the text, since, again, the patent standard is designed to influence only those marginal inventors whose initial decisions to invent *are* affected by profitability and patentability. For case studies where patents have primarily influenced the decision to commercialize, see SCOTT LANDIS, THE WORKBENCH BOOK 210-20 (1987) (inventor of collapsible workbench would not have commercialized invention without promise of a patent because it was so easy to copy) and Westrum, *supra* note 26, at 15 (describing Pilkington Company's decision to commercialize "float glass" glass production technology only with patent protection).

two-step investment process. In the figure, squares represent decisions which must be made and circles represent chance events over which the decisionmaker has no control.

An important feature of this model is that the researcher does not know at the time of the initial experiment whether it will be a success. She may have some idea, or even a strong belief; but until the experiment is actually performed, there is no way of definitely knowing whether it will work. This matters because of a key assumption in the model: that a patent is much more valuable if it covers a product which is successful in the marketplace.[59] This is equivalent to assuming that a patent has little or no value in and of itself; its value stems solely from its ability to prevent competitors from appropriating the intrinsic benefits of the invention which the patent protects.

As a result of this assumption, and in light of some reasonable values for the probabilities of each event in the model, increasing the payoff associated with a patent strengthens the reward to successful innovation, but not as directly as one might think. The researcher knows that neither a promising experimental result nor a commercially successful product based on the invention[60] are certain at the outset. Thus the added financial return that accompanies a patent has only a *contingent* value; it is not certain.

This may seem obvious. But when some realistic numbers are plugged into the basic model, it quickly becomes apparent just how limited the incentive effect of a patent is. To take a reasonable case, suppose the probability[61] of obtaining a promising experimental result is

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59. Or, what amounts to the same thing, if it covers some *aspect* of a product which is successful in the marketplace. Note here that I have previously described my misgivings about a standard of patentability that relies on evidence of "commercial success" to *prove* that an invention ought to be patented. *See* Merges, *supra* note 2.

60. I.e., a successful innovation.

61. Throughout this article, I use probability in the *subjective* sense: a person's best estimate, based on past experience, of the likelihood of some event occurring. This must be contrasted with "objective" probabilities, such as those involving dice and coin flips.

> There are two fundamentally different ways of arriving at [a] probability judgment . . . . The first method is by *a priori* calculation, and is applicable to and used in games of chance. . . . It must be strongly contrasted with the very different type of problem in which calculation is impossible and the result is reached by the empirical method of applying statistics to actual instances. . . . [T]he first, mathematical or *a priori*, type of probability is practically never met with in business, while the second is extremely common.

See KNIGHT, *supra* note 56, at 214-15. Knight goes on to explain a third type of probability judgment, with no empirical backing, made in a unique situation, which he terms an *estimate. Id.* at 225. He says that these estimates or judgments under uncertainty form the real basis of profit in a capitalist economy, since the other types of risk can be planned for and thus minimized. *Id.* at 232, 310-11. From the passage quoted, it is fairly clear that Knight would see invention as a highly uncertain activity, and thus one that is not capable of "statistical" characterization. Nevertheless, he recognizes the need to form judgments,

50%, and the probability of a commercially successful project is 40%. Suppose further that past experience indicates that for projects that are ultimately successful, the initial experiment produces promising results 70% of the time. Assume that the chance of obtaining a patent for a product that is a commercial success is 50%.[62] Finally, assume that the award of a patent increases the financial payoff of a successful invention by 20%; we can say that without a patent, the payoff for a successful invention is $1000, but with a patent it would be $1200.[63] (There is a net return of zero if the initial experiment does not produce promising results, or if the experiment is promising but turns out to yield a commercially unsuccessful product.[64])

With these numbers, the extra incentive offered by a patent can be analyzed. If we allow the decisionmaker to decide whether to continue with the project after the initial experiment,[65] the incentive effect of a

albeit subjective, about the likelihood of uncertain events. *See, e.g., id.* at 282 ("The judgment [under uncertainty] . . . is a judgment of the probability of a certain outcome, of the proportion of successes that would be achieved if the venture could be repeated a large number of times."). Thus the probabilities discussed in this article can be seen in Knightian terms as either empirical-statistical probabilities or probability estimates under uncertainty. The only catch is that the standard of patentability asks whether an invention would have been obvious to one skilled in the art to which it pertains. 35 U.S.C. § 103 (1988). Since this implies an "objective" standard—the "reasonably skilled inventor"—it might be seen as incompatible with Knight's classification of uncertainty estimates as inherently subjective. The standard may, however, be stated in a way that squares with Knight's category of true uncertainty: it might be thought of as a consensus of the actual judgments of actual artisans of reasonable skill in the field. This is in effect what is done, because the prior art that is consulted to determine patentability is written by actual practitioners in the field.

62. Others have modeled the issuance of a patent as a random variable. *See, e.g.,* Ben-Zion, *The R&D and Investment Decision and Its Relationship to the Firm's Market Value: Some Preliminary Results, in* R&D, PATENTS AND PRODUCTIVITY 209, 302 (Zvi Griliches ed., 1984).

63. This is a conservative estimate of the average value of a patent to the average patentee, since it has been found that the average patent increases the imitation cost only modestly. *See supra* note 32.

64. This is a plausible assumption under either of two scenarios. First, an unpromising experimental result eliminates the chance of a successful project. This would make the probability of a successful project zero. Alternatively, there might be a small chance that the unpromising experimental result could still lead to a successful project. Even so, the high probability of an unsuccessful project, together with a plausible estimate of the net loss that would attend such a project, could produce a zero or negative *net* expected value after an promising experiment. Note, however, that if the probability of a successful project after an unpromising experiment is some number greater than zero, the probability of a successful project after a promising experiment would have to be reduced accordingly; the sum of both these must equal the overall probability of a successful project. This would simply lower somewhat the expected value of a project undertaken after a promising experiment.

65. This corresponds with how R&D decisions are actually made in many instances. *See* Mansfield & Wagner, *supra* note 29 (reporting survey of R&D decisionmaking in 20 large corporations, where three identifiable stages are common: technical completion, commercialization, and evaluation or profitability). Mansfield and Wagner add that "[i]n

patent becomes clear. Given the figures discussed above, the inventor will be facing one of two situations after the initial experiment. If the experiment produced promising results, the inventor will increase her estimate of the chances of commercial success because of the additional information that the experiment was successful. Her initial estimate was that the chance of a successful project was 40%; she will *raise* this estimate in light of the promising experimental results. Specifically, as shown in Figure 2, the probability of a successful project increases to 56%—up from the original estimate of 40% before the experimental results were known.[66] Likewise, if the experiment had produced *unpromising* results, the probability of a successful project would drop to 24%.

In such a two-step decision model, the expected value of a project, as viewed before the experiment, with a patent that increases the payoff of a successful project by 20% (to $1200) is $308 (see Figure 3), and the expected value without the possibility of a patent is $280 (see Figure 4). By contrast, when estimated at the time of a decision to develop, the expected value of the project is $560 without patents (see Figure 3) and is $616 with patents (see Figure 4). The marginal effect of the patent on the incentive to develop is thus twice as large as on the incentive to experiment.

In any event the main point is the same: under plausible assumptions the incentive effect of a patent is relatively modest. The availability of a patent would only change the behavior of a rational decisionmaker in cases where the expected value of the project without the possibility of a patent is slightly below the cost of undertaking the project. While this of course depends on the magnitude of the patent's contribution to expected payoff, under plausible assumptions of this magnitude the incentive effect will be quite small. This finding conforms to the views of some research and development managers, who consider

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recent years, there has been a tendency for firms to utilize formal, quantitative project selection techniques based on estimated rates of return, payment periods, and other such criteria." *Id.* at 190.

66. Although it is intuitive that the chance of success would increase given a promising result, a precise figure for the increase can be arrived at using Bayes' Theorem. This allows us to calculate the probability of commercial success given a promising experiment, when we have available the data stated in the text. Specifically, the probability of success given a promising experiment (written $P(\text{Suc} | \text{Prom})$) is calculated by the following formula, where $P(\text{Suc})$ is the probability of success, $P(\text{Prom})$ is the probability of a promising result, and $P(\text{Prom} | \text{Suc})$ is the probability that a successful project will begin with a promising experiment.

$P(\text{Suc} | \text{Prom}) = P(\text{Prom} | \text{Suc}) \cdot P(\text{Suc})/P(\text{Prom})$

In the example in the text, this produces the following result: $(0.7 \cdot 0.4)/0.5 = 0.56$.

See generally HOWARD RAIFFA, DECISION ANALYSIS: INTRODUCTORY LECTURES ON CHOICES UNDER UNCERTAINTY 14-20 (1968).

patentability as a factor—albeit only one of many—in selecting research projects.[67]

Of course, while the extra payoff from a patent does not translate directly into an identical extra incentive, it still has some effect. Presumably, the difference might matter in some cases. Consider for example the case where the expected cost of the research project is $300. Then the extra incentive of the patent would add the extra stimulus needed to lead the researcher to do the project. (Recall that without the possibility of a patent, the expected value of the project is $280, which the rational decision maker would not pursue it because of the expected net loss; with the patent, however, there would be an expected net gain of $8.)

But what if public policy demanded an increase in the expected value of the research project? Assuming for the moment that the only policy instrument for affecting this decision is the payoff from a patent, how much would we have to increase this payoff to cause, say, a 50% rise in the decisionmaker's initial expected value?

For the sake of simplicity, and to mirror real world practice, let's stay with the two-step decision model. That is, the inventor can do an initial experiment, and then decide whether to develop the experimental result or not. Under this scenario, the increase in the patent payoff needed to raise the initial expected value 50% (to $462) would be a whopping $2300, or a 130% increase over the non-patent payoff! Although patents may have this effect in some industries, especially pharmaceuticals, the analysis strongly suggests that in most cases where a *major* incentive is needed patents will not be the most effective policy instrument. To encourage basic research with patent incentives, for example, would take the promise of "super-patents" of extremely broad scope or long length. These would presumably carry high social costs. Thus the current system of outright public funding for basic research seems sensible by comparison.

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67. *See supra* notes 29-30. Note that some commentators believe it is anomalous to talk of "rational choices" to invent, since invention, which is suffused with creativity, is primarily the subject of inspiration. *See, e.g.*, ANDREW HARRISON, MAKING AND THINKING: A STUDY OF INTELLIGENT ACTIVITIES 67-68 (1978) (noting the difficulty of a rational account of invention, since it is usually thought of as a creative undertaking). *But see id.* at 70 (noting distinction between invention, where one knows one's goal and is searching for an end, and creativity, where neither is really known). Suffice it to say that I believe there is at least some rational component to invention. And note that, as argued elsewhere, the patent standard is irrelevant as an inducement where an inventor would attempt her invention regardless of the magnitude of potential reward. *See supra* notes 25-28 and accompanying text.
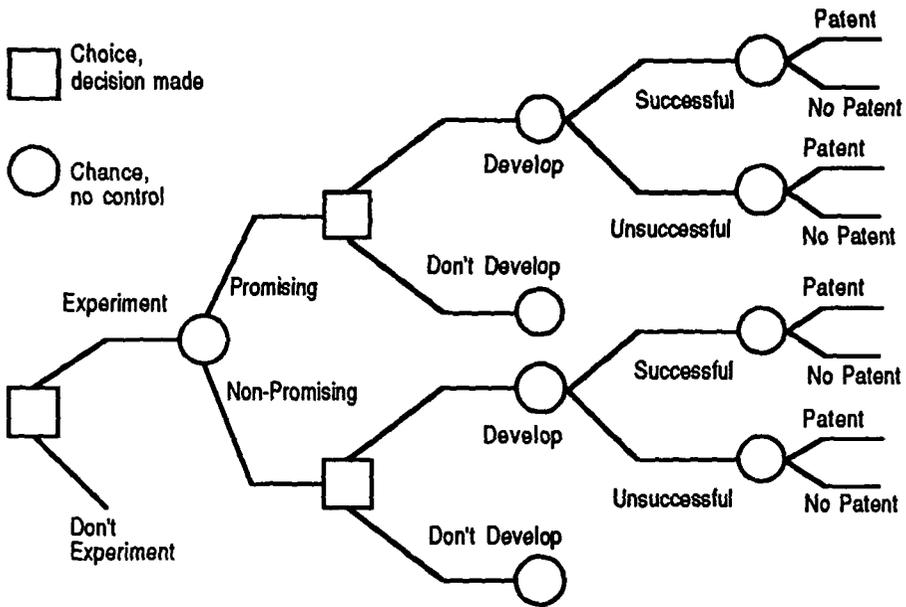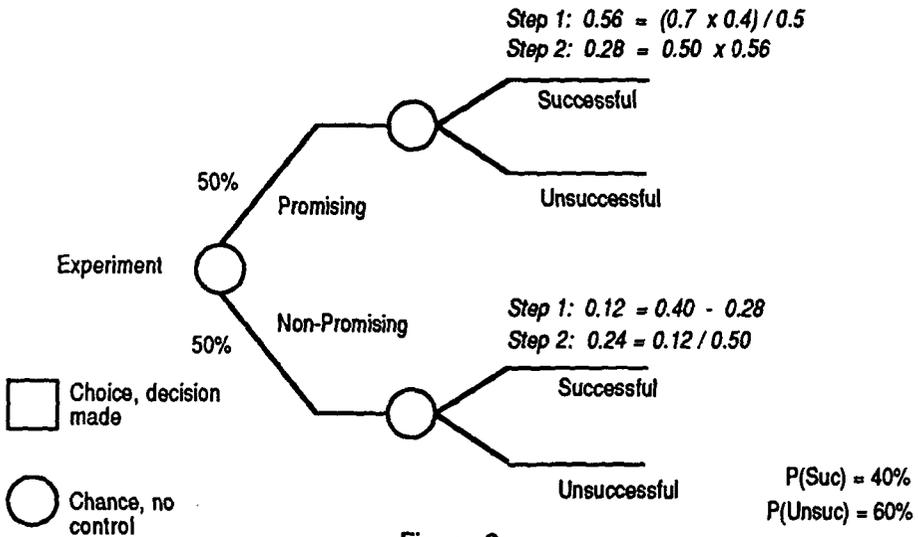
Figure 1

Figure 2

Payoffs

Patent = $1200

Expected Value [$1100]   50%
Successful

Expected Value = [$616]   56%
Promising

Expected Value = [$308]   50%   50%
Experiment

No Patent = $1000

Unsuccessful = $0

Non-Promising = $0

Expected value in a world in which patents
are possible and add 20% to the payoff of a
successful invention.

Don't
Experiment

Figure 3

Payoffs

Expected Value = [$560]   Successful = $1000
Promising   56%

Expected Value = [$280]   50%
Experiment

Unsuccessful = $0

Non-Promising = $0

Expected value in a world without patents
and the additional value added
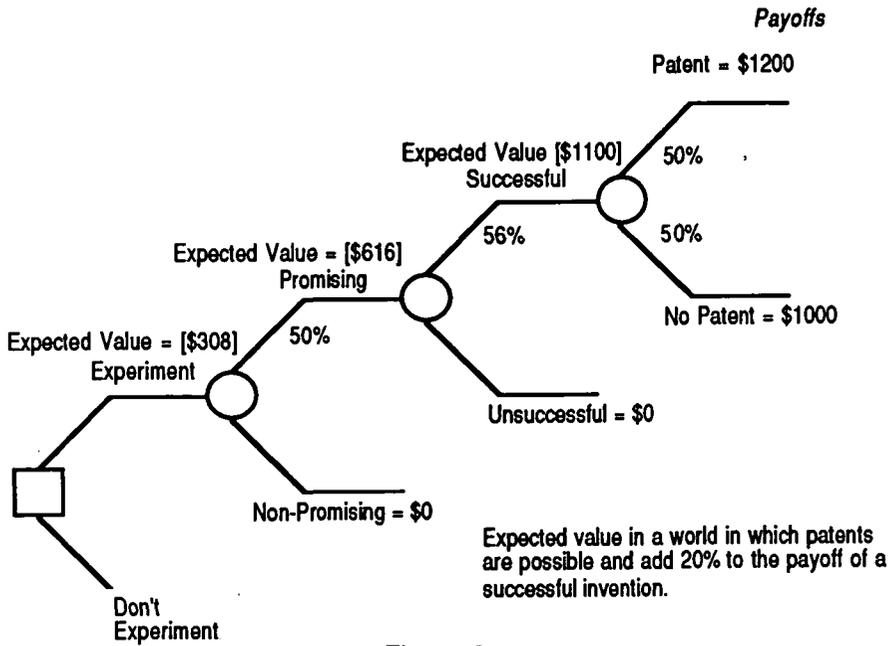to the payoff of a successful invention.
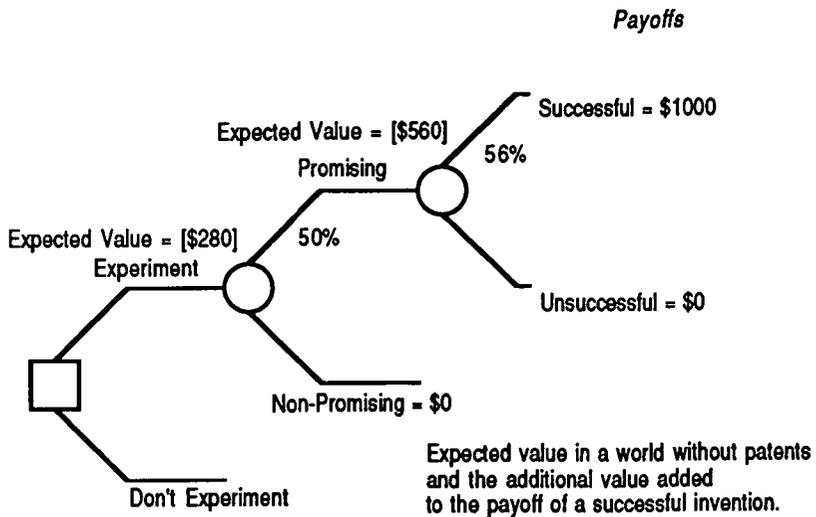
Don't Experiment

Figure 4

B. Low Uncertainty Research and the Model

The model provides justification for denying patents on research with a high probability of promising results. Where there is both a low payoff and a good chance of initial experimental success, making a patent easier to obtain—increasing *P*(Pat) in the example above—would amount to increasing the payoff from doing a research project whose outcome is quite predictable. This would be tantamount to rewarding success in rather obvious projects. What would be the cost to society of allowing patents on the results of projects with predictable outcomes?

To get an idea, picture the same decision tree without a branch for patents; that is, imagine the payoff from success did not include the possibility of getting a patent. Given a high probability of a promising experimental result, high correlation between commercial success and promising results, and a reasonable payoff from success, the absence of patents would not make much of a difference. The rational inventor might well go ahead with the project anyway.[68]

If she did, society would benefit from the research without the cost of granting the patent. The key point is that, *regardless of the social cost of granting a patent*,[69] it is better for society to have an invention for free. *Any* patent-related cost for an invention that could have been obtained without a patent is too high.

In 1966 Edmund Kitch explained the nonobviousness standard in terms quite consonant with the point just made,[70] although S.C. Gilfillan, a sociologist who wrote on the patent system, said much the same in 1949.[71] These commentators both believed that the standard of patentability should be used, in the words of Kitch, "to sort out those innovations that would not be developed absent a patent system."[72]

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68. Assume for example the same probabilities outlined above, an expected payoff from success of $1000, and project expenses totaling $250. Since the expected value of the project is $280, the rational inventor would go ahead with it since she stands to gain $30 (expected value of $280 minus cost of $250).

69. As long as this cost is not zero. Empirical evidence indicates that whatever the total social cost of a patent, it is not, on average, zero. *See* Merges & Nelson, *supra* note 2, at 908-09 (case studies of the anticompetitive effects of various key patents).

70. Kitch, *supra* note 6, at 301 (stating that "a patent should not be granted for an innovation unless the innovation would have been unlikely to have been developed absent the protection of a patent").

71. Gilfillan, *supra* note 53, at 611 ("A patent is helpful and proper when it rewards sufficiently useful creative work *which might not have been done without* that prospective reward. . . .") (emphasis in original). *See also* SCHERER, *supra* note 17, at 442-43 (patents were granted only to those inventions that the patent system actually induced, society would receive a net benefit); Oddi, *supra* note 17, at 1101 (citing SCHERER, *supra*, note 47, and dubbing as "patent-induced" those inventions produced only because of the patent system).

72. Kitch, *supra* note 6, at 301. From one perspective, the Kitch thesis is uncontroversial, since it merely highlights the "gatekeeping" function of the nonobviousness test. But from another perspective, it presents an interesting logical

In an ideal patent system, the social benefit of the invention would be weighed against the cost of creating it and the social costs accompanying exclusive rights to it.[73] If the "net" was positive, the patent would be granted and the project would be undertaken. But this is nonsense; it is virtually impossible to arrive at reasonable values for these figures *ex ante*, and even *ex post* such valuations will prove difficult. The model's assumptions regarding private firm valuation of expected costs and benefits are unrealistic enough. The social welfare calculations would take it outside the realm of credibility!

Given that these cost/benefit calculations are difficult, there are two possibilities. One choice is to grant patents even though the experiments on which the projects depend are fairly certain to prove promising; the other choice is to deny patents, even though in some cases this will mean that projects that might have been undertaken had patent protection been available will be foregone. Which is preferable?

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problem. If it is taken literally, then each inventor must be questioned about her motives, and if she avers that the promise of a patent is the only reason she pursued her invention, a patent must issue. Even if we take the test less literally, it presents problems. For if we restate it as requiring patents only when the "reasonable inventor" would not have pursued an invention unless it were patentable, we are still left with the difficult question of applying the test to particular cases. *When* would the reasonable inventor need this extra stimulus; what kinds of research projects would be left undone without patents? In the end, questions like these indicate that Kitch's original insight is only a starting point. This article fleshes out the insight by explicitly tying the gatekeeping test to a measure of uncertainty.

73. It might be thought that in such a situation *any* loss in welfare accompanying exclusive rights is worth the cost, since without those rights (in the example I have given) the technology under consideration would never have been invented. In other words, it must be efficient to permit *any* restrictive practice on the part of a patentee who has created something that did not exist before; from society's point of view, it is preferable to have a new thing with restrictions, no matter how onerous, than to not have it at all. This is implicit in much of the "property" view of patents. However, a good deal is missing from this description. For example, it assumes that an invention is a distinct and identifiable thing, and that the patent which covers it protects only that thing. This is not necessarily true; for example, a patent may protect one feature of a larger machine or process. If so, the patentee may use the "leverage" of the patented item to raise prices for the entire machine or process. *See* Louis Kaplow, *Extension of Monopoly Power Through Leverage*, 85 COLUM. L. REV. 515, 525-32 (1985) (there is evidence that market power may in some circumstances permit a licensor to "extend" his monopoly over the tying product into the market for a tied product); *cf.* Louis Kaplow, *The Patent-Antitrust Interface: A Reassessment*, 97 HARV. L. REV. 1813 (1984). In this case, the effect on the market for the tied product—the overall process or machine—can be seen as an externality generated by the creation of the property right in the tying product. While it is true that the tying product may have some intrinsic value, it is not true that this justifies the level of social cost—the negative externalities—that may be attendant upon the grant of an unrestricted property right in that product.

This comes down to an empirical judgment. Kitch, in a judgment I agree with, says that denying patents is preferable.[74] There are more projects with a high probability of promising results that would still be undertaken without a patent system than there are such projects that need the extra incentive of a patent.

There is support for this view both in my model and in some recent empirical research. In my model the initial decision to undertake a project is much more sensitive to changes in the probability of experimental success than it is to changes in the payoff structure, resulting from changes in the probability of getting a patent.[75] This is simply a function of the fact that the model has several stages, and the payoff from obtaining a patent comes at the end of a series of actions and decisions. The probability of experimental success, on the other hand, has a much more direct impact on the initial decision.

Empirical research bolsters this conclusion. In a recent study of a large number of companies, a team of economists found 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.[76] In another recent study of 100 U.S. manufacturing firms, Edwin Mansfield found that in only 2 of 12 industry groups would firms have decided not to develop products they had in fact developed if no patents had been available.[77] These studies show clearly that a relatively small number of projects depend critically on the availability of patent protection. Since there is no reason to believe that projects with a chance of initial experimental success differ from the average project in this respect, there

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74. Kitch puts it in terms of cost, saying that "it is the implied judgment of the [nonobviousness] test that the cost of innovation of [a low] . . . order of difficulty can probably be recouped in a competitive situation while the costs of innovations of a greater difficulty cannot." Kitch, *supra* note 6, at 302.

75. That is, in the decision model outlined above, the initial decision of whether to invest in the experiment and thus begin the project depends more heavily on the probability of a promising result than the payoff if the project is a success. An increase in the payoff for a successful project is an easy way to model an increase in the probability of receiving a patent, since the payoff for a successful project is the probability of getting a patent times the payoff with a patent plus the probability of not getting a patent times the payoff of a successful project without a patent.

76. Levin et al., *supra* note 10; *see also* NANCY S. DORFMAN, INNOVATION AND MARKET STRUCTURE: LESSONS FROM THE COMPUTER AND SEMICONDUCTOR INDUSTRIES (1986) ("first-mover" advantages are the main reason firms innovate in these industries, with patents a secondary consideration).

77. Mansfield, *supra* note 9, at 175 (Table I). The two industry groups where patents have a significant impact are pharmaceuticals, where firms that were surveyed said 65% of recent innovations would not have been developed in the absence of patents, and chemicals, where the figure was 38%. *Id.* The average of the other 10 industry groups was 6.7%. *Id.*

is no reason to believe that patents are necessary to induce very many of these projects. Consequently, society should not be concerned if the standard of patentability denies protection for high-probability-of-success projects: they are likely to be pursued anyway.[78]

To be sure, there may be cases where the expected value of a project is below zero, given a certain cost and without the added payoff from a patent. One such case might be where there is a fairly certain experiment, leading to a product likely to succeed in the market, but involving very high experimentation costs and/or costs of commercial failure. Should patents be granted in these cases? Although the conventional doctrine says no, section F below presents an argument for granting patents in such circumstances.

C.   Incentives to Develop

The model provides an interesting insight into the patent incentive structure. Despite the fact that one of the most common rationales for the patent system is the incentive theory, the truth is that on average patents provide only a modest incentive at the outset of the research process.[79] And another point emerges as well: we should not try to tamper with

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78. There will be cases where the expected payoff is too low without proprietary rights for firms to pursue high-probability-of-success projects. In most of these cases, it will be worth the cost of the forgone projects to have a patent system that does not protect inventions which are clearly achievable *ex ante*. Yet there may be some cases where the loss is great. An example might be so-called "orphan drugs," drugs for diseases with so few sufferers that pharmaceutical firms do not foresee enough of a market to make drug development worthwhile. Certainly this is one rational account of why Congress passed the Orphan Drug Act in 1982. Orphan Drug Act, Pub. L. No. 97-414, 96 Stat. 2049 (1982) (codified as amended at 21 U.S.C. §§ 360aa-ee). This Act provides "market exclusivity"—patent-like protection—for orphan drugs, many of which fall short of the requirements for patentable inventions. *See* 21 U.S.C. § 360cc(a) (1988). For a case indicating that a chemical firm would have preferred patent protection, but settled for a first-mover advantage, see Continental Oil Co. v. Witco Chem. Corp., 484 F.2d 777, 782 n.14 (7th Cir. 1973) (internal memo indicated that firm "has no unique or patentable features" so "the only possible advantage we can hope for is to be first or early in the market").

79. The approach taken here is consistent with that of F.M. Scherer, *Time-Cost Tradeoffs in Uncertain Empirical Research Projects, in* INNOVATION AND GROWTH: SCHUMPETERIAN PERSPECTIVES 67-82 (1984). Scherer models the tradeoff between time and cost by constructing a decision function that allows the researcher to invest in sequential research approaches until the marginal value of taking the next approach equals the expected benefit of the project, minus the cost of all the research approaches. In the version of his model that assumes unequal probabilities of success for the different approaches, he notes that "it will ... be advantageous to schedule the approach with the highest success probability first, and so on." *Id.* at 74. This model could easily be extended to support the conclusions reached here since as it becomes more and more expensive to pursue low-probability approaches, the extra incentive of a patent might be necessary in some cases to encourage the researcher to try these approaches. Note also that as in my model, assuming that a patent adds only modestly to the payoff of a successful project, this would have only a modest effect; in terms of this model, researchers would try a few more approaches, but not many more.

this, at least in the average case. It would cost too much to significantly augment the potential payoffs from obtaining a patent.

The model also shows that patents may have a greater impact on incentives to *develop* than incentives to invent. Once a promising result is in hand, the heightened payoff from a patent more directly affects the expected value of developing the product. This is because the incentive is much less "diluted." If the researcher knows from past experience that a promising experimental result is more likely to be successful, she can revise her estimate of the chance of success *given* a promising result. Because the researcher's estimate of the probability of receiving the payoff from a successful invention rises after the experiment, her expected value rises as well. *This* is the point at which the patent has the most direct effect: providing an incentive to develop. It is because the experimental results are promising that the researcher revises her estimate of the probability of a successful innovation; hence the enhanced payoff from a patent enters into her expected value assessment with less "dilution" and a higher probability.[80] Note that while this appears also to support the notion of awarding "innovation patents," there are independent reasons to doubt the efficacy of such a policy.[81]

D.   Why Not Use Commercial Certainty as the Patentability Standard?

The preceding section argued that patents have only a modest effect on the decision whether to initiate an R&D project. As a consequence, high social costs attend a decision to raise the value of a patent, or the probability of obtaining one, in every case. This section will return to the theme introduced earlier: that in determining when it *is* appropriate to award a patent, the key factor is the level of uncertainty facing the inventor just prior to the crucial experiment leading up to the patent.

As a preliminary matter, recall that in the two-step model presented above, the probability of a promising experiment greatly affects the expected value of the project as a whole. When an experiment is highly unlikely to be promising, ultimate commercial success is quite unlikely indeed. In just these situations, the enhanced payoff that comes with a patent will be welcomed. As noted above, there are scenarios under which high-risk research will not be performed if patents are not available.

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80. Interestingly, this premise was well stated in the celebrated concurrence of Judge Frank in Picard v. United Aircraft Corp., 128 F.2d 632, 642-43 (2d Cir. 1942) ("But if we never needed, or do not now need, patents as bait for inventors, we may still need them, in some instances, as a lure to investors."). *See also* Fritz Machlup, *Patents, in* 2 ENCYCLOPAEDIA OF THE SOCIAL SCIENCES 461, 467 (1968) (stating that one theory of the patent system is that it gives incentives to develop technology).

81. *See supra* note 18 and accompanying text.

But the structure of the model indicates that the probability of commercial success also affects the inventor's prospects. The thought might well occur: why not augment the payoffs where the chance of commercial success is low? Why focus on uncertainty at the initial experimental stage, when uncertainty at the second, or commercialization stage, can also drive expected returns below the break-even point, hence discouraging perhaps useful research?

There are two primary reasons for excluding commercial uncertainty from the patentability standard. First is the intrinsic social value of producing information in the face of highly uncertain technical challenges. As discussed in Part II above, every promising experimental result contributes valuable technical information to the relevant technical community. But unlike technical information, information about what the market desires would seem to produce relatively few positive externalities. Although a few firms may benefit from it, this information is difficult to extrapolate, and it quickly loses its value in any case as market conditions change. Only if the incentive to market a product encourages a reluctant firm to introduce a product that comes to be valued highly by consumers will it have produced much of consequence. Even in this case, the legal system will be asked to assess commercial or market uncertainty. This would seem to be even more difficult than assessing technical uncertainty, as in the current patent system.

The second reason for excluding commercial uncertainty from the patentability standard is that in the model outlined above, a promising experiment produces valuable information *even if it never leads to a viable commercial product*. Contrast this with the prospect of encouraging an entrepreneur to market a product in the face of high commercial or market uncertainty: the only immediate payback for the incentive given is the availability of the new product on the market. If the product is ultimately unsuccessful, the incentive will not have achieved much. In the current system, humbling commercial failure does not deprive a patent of all social value. But in a system of rewards for overcoming commercial uncertainty, failure would be total.

E.   Nonobviousness Doctrine and the Uncertainty-Based Model

So we see that patents provide only a modest incentive to undertake research. And we have addressed the reasons why patents are not granted for the results of all research projects. In addition we have touched on the rationale for a standard of patentability, namely the need to sort out those inventions that would probably have been forthcoming without patents. Now we will explore the precise mechanism by which this sorting out takes place under current doctrine.

As implied above, the ideal patent system would weight the benefit to the inventor of the prospect of a patent against the cost to society of issuing that patent. If the resulting figure were a net positive, the patent would issue; otherwise, no patent would be granted.

How does the current system compare to this ideal? In general, not too badly. Specifically, the current system has the following features:

• It uses technical difficulty as a proxy for the likelihood that an invention would have been made without the promise of a patent; and

• It presumes that there is a high social cost to granting patents that cover inventions that could have been made by any researcher with ordinary skill.

The wisdom of this approach lies in its use of technical difficulty as a measure of social value. The more difficult an invention is to make, the more likely a patent will issue. Conversely, the easier an invention is to make, the greater the social cost involved in granting a patent to cover it.

And the current system is administratively tractable. One major flaw in the ideal patent system mentioned earlier is the high cost of administering it. Difficult estimates would have to be made for elusive quantities: social benefit, social cost, etc. Even if it were possible to make these estimates, it would be expensive.

The test of nonobviousness in patent law attempts to make the analysis more tractable by focusing on technical difficulty. While at first blush it might seem just as troublesome to estimate technical difficulty as "social cost," the patent system has developed a procedure that make this estimation possible, albeit never easy.

The first part of this approach is a set of clearly defined rules that help define the relevant universe of technical expertise. Detailed provisions of the patent code define precisely what material falls within the "prior art."[82] It is this prior art which serves as the backdrop for the nonobviousness analysis; it is this information which helps the Patent Office and the courts ask, "nonobvious compared to *what?*" The second part is a less clear cut, but still useful, set of guidelines for determining the knowledge, skills and characteristics of the person "skilled in the art," the mythical "reasonable" inventor against whom the efforts of the actual inventor are measured.[83] The patent code requires the courts to presume

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82. The precise content of the prior art is defined by 35 U.S.C. § 102. *See* 35 U.S.C. §§ 102(a), 102(c) (1988); 2 DONALD S. CHISUM, PATENTS § 5.03[1][a] (1986). Although these provisions setting forth prior art appear in the section of the patent code defining the novelty requirement, they also apply to the nonobviousness inquiry. *See In re* Bass, 474 F.2d 1276, 1289 (C.C.P.A. 1973); Paul M. Janicke, *What is "Prior Art" Under Section 103? The Need For Policy Thought, in* NONOBVIOUSNESS—THE ULTIMATE CONDITION OF PATENTABILITY 5:101-5:111 (John F. Witherspoon ed., 1980).

83. Cases have held that the "skilled person in the art" means those responsible for most of the technical advances in an industry. *See, e.g.,* Orthopedic Equip. Co. v. United States, 702 F.2d 1005 (Fed. Cir. 1983); Jacobsen Bros. v. United States, 512 F.2d 1065 (Ct. Cl.

that this reasonably skilled inventor knows *everything* in the prior art. This has been criticized as unrealistic.[84] But like so much in this area of patent law, it is defensible on the grounds of administrative feasibility. In other words, a test based on "reasonably accessible" prior art or the like would require difficult decisions, while the current practice of assuming knowledge of all prior art, no matter how obscure, is easy to administer.

The third part of this approach incorporates the case law which has grown up around the test of nonobviousness, and contains a set of loosely-applied rules of thumb that help determine whether a patent should be issued. One such rule, examine below, restates the test of obviousness by asking whether the skilled inventor would have estimated that there was a "reasonable chance of success" for the experiment that led to the invention. If so, no patent is issued; if not, the result is deemed nonobvious.

The case law has long recognized the importance of certain "objective" factors in determining nonobviousness: the commercial success of the invention (which I have criticized),[85] the failure of competitors to make the invention (which I have suggested ought to be *the* major objective factor), a long-felt need in the industry for an invention, and recognition in the industry of a notable achievement.[86] A principal advantage of these factors is that, unlike the technical merit of an invention, they are relatively easy to ascertain. Since most finders of fact in patent cases are not technically trained, it has been argued that the use of these factors makes patent law more manageable for the courts and more predictable for the parties.[87]

The basic doctrine thus appears to mesh well with the emphasis on uncertainty presented in the preceding text and model. The uncertainty approach can now be applied to specific doctrinal features.

1975); *see also* Environmental Designs, Ltd. v. Union Oil Co., 713 F.2d 693, 696 (Fed. Cir. 1983), *cert. denied*, 464 U.S. 1043 (1984), where the court provided a list of factors relevant to a determination of the level of skill in the art:

    (1) educational level of the inventor;

    (2) type of problems encountered in the art;

    (3) prior art solutions to the problems;

    (4) rapidity with which innovations are made;

    (5) sophistication of the technology; and

    (6) educational level of active workers in the field.

    84. *See* Michael Ebert, *Superperson and the Prior Art*, 67 J. PAT. OFF. SOC'Y 657 (1985) (proposing that courts' presumption that skilled artisan knows everything in a field should be restricted by taking account of cognitive limitations of real people).

    85. Merges, *supra* note 2.

    86. *Id.*

    87. *See, e.g.*, Rochelle C. Dreyfuss, *The Federal Circuit: A Case Study in Specialized Courts*, 64 N.Y.U. L. REV. 1, 25-26 (1989).

1. INCENTIVES FOR PRIVATE INFORMATION

An important question that one might ask at this point is how the standard is applied if an inventor knows more than the reasonably skilled person in the art. Does this reduce her chances of obtaining a patent?

Clearly the answer is "no" because all manner of mischief would accompany a system that refused a patent simply because an inventor had been certain of her experiment: it would encourage early experimentation with little background work, it would lead to lying on patent applications, and the like. Instead, patent law measures the chances of success not against the inventor's subjective evaluation, but against the objective standard of the reasonably skilled worker in the field. Because this hypothetical reasonably skilled artisan is endowed with only *publicly* available technical knowledge—the prior art—the proprietary knowledge of the actual inventor is immaterial to the obviousness inquiry. This encourages firms to invest in proprietary knowledge prior to the commencement of a particular invention project.[88] Of course, investment in such information might well affect the inventor's cost calculus. She will need to justify the expense by a reduction in costs or an increase in expected payoff. For example, if the preliminary research indicates that the project will not be a success, the inventor can avoid the expense of a failed project. On the other hand preliminary research might lead to a larger expected payoff, e.g., by focusing the project on a more promising or profitable technology.[89] In either case the

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88. In fact, since private knowledge is not held against the inventor when patentability is determined, the inventor can be expected to invest in such knowledge up to the point where its money value is just equal to the cost of obtaining more of it. *See* George J. Stigler, *The Economics of Information*, 69 J. POL. ECON. 213 (1961). If this were part of the prior art, the implicit cost of obtaining such knowledge would rise and less would be produced. This would naturally affect the firm's decision to invest in such preliminary research. But it would also affect society at large, since much of this preliminary knowledge takes the form of basic research, which is often publicly disclosed, even when undertaken by private firms. The analysis of this problem in terms of incentives to invest in private information is very similar to the argument made by Anthony Kronman regarding the appropriateness of contract rules permitting parties to keep certain information confidential during negotiations. *See* Anthony T. Kronman, *Mistake, Disclosure, Information and the Law of Contracts, in* THE ECONOMICS OF CONTRACT LAW 114 (1979).

89. To some extent the simple model above reflects this. In that model, recall that the cost of performing the initial experiment is weighed against the expected value of the project. To be more complete in this respect, however, the model would have to have at least one round of preliminary research *before* the "initial experiment" stage. There would then be a preliminary decision: pursue the pre-experimental research or not? While it is possible to model this in the framework presented earlier, it would detract from the simplicity of the model. For an important treatment of the "focussing" effect such iterative decisionmaking can have on research and development, see Richard R. Nelson, *The Role of Knowledge in R&D Efficiency*, 97 Q.J. ECON. 453, 459 (1982) (constructing a "search" model showing how firms refine their approach to R&D with experience). *See generally* RICHARD R. NELSON & SIDNEY G. WINTER, AN EVOLUTIONARY THEORY OF ECONOMIC

inventor who performs preliminary research has in effect bought information. The patent system should not—and does not—discourage this by including private information in the prior art against which the ultimate invention is judged.[90]

2.   SERENDIPITOUS DISCOVERIES

One objection to the foregoing might be that many discoveries are accidental; by centering the analysis on a rational decisionmaker, the model presented here omits an important class of inventions—those made unintentionally.[91] The first response to this is to reiterate a point made at the outset: for the purpose of this paper, inventors who will perform research regardless of the incentives facing them are irrelevant. Just as society need not worry about adding to their financial rewards if they are motivated by non-financial considerations, we need not worry about the incentive effects of the patent system on serendipitous inventors.

CHANGE (1982) (making extensive use of models and simulations where firms modify their search for new products and processes over time based on past experience).

90. The notion of private information might help explain a phenomenon long associated with the patent system, the practice of filing a long series of improvement patents to build on a basic invention. Many observers have complained of this as a major flaw in the patent system, since it permits firms to "lock up" entire fields of technology for extended periods of time. *See, e.g.*, DAVID F. NOBLE, AMERICA BY DESIGN: SCIENCE, TECHNOLOGY, AND THE RISE OF CORPORATE CAPITALISM 93 (1977) (outlining techniques for "prolonging monopolies" used by General Electric and AT&T, including extensive acquisition of "auxiliary patents"); United States v. General Elec. Co., 82 F. Supp. 753, 815 (D.N.J. 1949) (accusing General Electric of this practice with regard to the incandescent light bulb). What needs to be recognized in such situations, however, is that it may be easier for the firm that pioneered a technology to compete for improvements because of their informational advantages. If they are rewarded for their achievements as anyone else who made them would be, they have earned them and are acting rationally to invest in them. *See* JACOB RABINOW, INVENTING FOR FUN AND PROFIT 245 (1990) ("After the birth of the idea comes . . . the process of 'inventing around yourself.' If you don't invent a picket fence of systems to compete with your own, some other son of a bitch will. . . . You end up with not one invention but with a dozen. You end up with a portfolio of patents. Your first brilliant idea was just a beginning."); *cf.* HERBERT A. SIMON, *Theories of Bounded Rationality, in* 2 MODELS OF BOUNDED RATIONALITY: BEHAVIORAL ECONOMICS AND BUSINESS ORGANIZATION 408, 410 (1982) (describing class of models of decisions under uncertainty where decisionmaker's task "is to find the alternative [choice of action] that maximizes his expected profit net of search cost"; by extension, these models suggest rationality of searching for improvements on one's own prior inventions, given that search costs for these will be lower than for others because of pre-existing knowledge).

91. *See, e.g.*, ROYSTON M. ROBERT, SERENDIPITY: ACCIDENTAL DISCOVERIES IN SCIENCE (1989); *cf.* JAMES H. AUSTIN, CHASE, CHANCE, AND CREATIVITY: THE LUCKY ART OF NOVELTY (1978).

But it might be argued that granting patents to such inventors is socially wasteful.[92] The ideal test of patentability described earlier holds that a patent should only be granted where it is necessary to call forth an invention. Since accidental discoveries are not motivated by financial incentives, it might be argued that issuing a patent in such cases violates this ideal test.

There are two responses to this. First, while serendipitous research is not *directly* motivated by financial rewards, in many cases a serendipitous discovery is made in the course of a research project aimed at another goal. Without the possibility of a patent covering the *intended* result, perhaps the inventor would never reach the unintended result. An example may be the discovery of drugs to treat very rare diseases; these are often made in the course of research on more widespread diseases.[93]

Second, allowing an exception to the rules on patentability might further complicate and lengthen the process of obtaining a patent or defending it in infringement litigation. If the Patent Office or an accused infringer could argue that an invention did not deserve a patent because it was discovered through serendipity, an extra layer of elaborate fact-finding would be added to the patentability inquiry. It is simpler, and thus more administratively feasible, to apply the same *ex ante* nonobviousness standard as is applied in other cases. Section 103 of the patent code even contains a sentence that reflects this view, although it was inserted into the code for other reasons.[94]

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92. This position is hinted at in Oddi, *supra* note 17, at 1116 (defending proposition that high cost-low benefit inventions are some of the few where patents are truly justified, and arguing that alternative appropriability techniques and lack of self-interest in suppressing inventions make it less necessary to protect low cost-high benefit inventions such as those made serendipitously).

93. "Orphan drugs are discovered more often by accident than by design. A survey of orphan drugs conducted by the Subcommittee on Health and the Environment of the House Energy and Commerce Committee found that about one-fifth of known orphan drugs were discovered solely as a response to an orphan disease, while two-thirds were discovered serendipitously. Chance discovery often occurs during research or clinical testing of drugs for nonorphan diseases." Donna B. Grossman, *The Orphan Drug Act: Adoption or Foster Care,* 39 FOOD, DRUG & COSMETIC L.J. 128, 130 (1984) (citing SUBCOMM. ON HEALTH AND THE ENVIRONMENT OF THE HOUSE COMM. ON ENERGY AND COMMERCE, 97TH CONG., 2D SESS., PRELIMINARY REPORT ON THE SURVEY ON DRUGS FOR RARE DISEASE 9 (Comm. Print 1982)).

94. "Patentability shall not be negatived by the manner in which the invention was made." 35 U.S.C. § 103 (1988). This was made a part of the statutory standard to limit the effect of Supreme Court cases implying that a patentable invention required a "flash of genius." *See* Giles S. Rich, *Congressional Intent—Or, Who Wrote the Patent Act of 1952?, in* NONOBVIOUSNESS—THE ULTIMATE CONDITION OF PATENTABILITY 1:1, 1:7-1:8 (John F. Witherspoon ed., 1980). *See generally* HANNS ULLRICH, STANDARDS OF PATENTABILITY FOR EUROPEAN INVENTIONS 85-86, 89-91 (IIC Studies in Industrial Property and Copyright Law No. 1, 1977).

3. METHODICAL SCREENING: A SPECIAL CASE OF RISKY RESEARCH

Since the early 1960's[95] the courts have been ruling consistently that "obvious to try" is not the standard of patentability.[96] One court said:[97]

> [A]pplication of the "obvious to try" test would often deny patent protection to inventions growing out of well-planned research which is, of course, guided into those areas in which success is deemed most likely. These are, perhaps, the obvious areas to try. But resulting inventions are not necessarily obvious. Serendipity is not a prerequisite to patentability. Our view is that "obvious to try" is not a sufficiently discriminatory test.

One group of "obvious to try" cases involves prior art which suggests that a certain area should be investigated, and yet the resulting invention is either not suggested in the prior art, or has unexpected properties.[98] For example, in *Novo Industri A/S v. Travenol Laboratories*,

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95. At one time "obvious to try" was an accepted standard of obviousness, and even a showing by the applicant that unexpected results were reached or success was unlikely would not defeat a finding of lack of invention. Mandel Bros. v. Wallace, 335 U.S. 291, 295 (1948) (patent for an improved anti-perspirant declared invalid due to lack of invention). The Court rejected the patentee's argument that, in the process of trying a number of compounds, he was surprised by the compound which was ultimately successful. A reasonable chemist would have expected it to fail. The Court held, however, that the prior art demonstrated that the solution lay in a limited number of permutations, making the success of any of them obvious: "we think that the state of the prior art was plainly sufficient to demonstrate to any skilled chemist searching for an anticorrosive agent that he should make the simple experiment that was made here. . . . It is not surprising therefore that after experimenting with various standard alkalies in an effort to find a corrosion inhibitor that would not greatly reduce acidic astringency, the patentees promptly turned to urea." *See also In re* Sejournet, 285 F.2d 823, 825 (C.C.P.A. 1961) (claims for patent for method of extruding a composite steel billet was not patentable for lack of invention because the method would have been obvious to try in light of the prior art).

96. *See, e.g., In re* Fine, 837 F.2d 1071, 1075 (Fed. Cir. 1988) (claims of application for patent for system for detecting and measuring small quantities of nitrogen compounds held not obvious because none of prior art, alone or in combination suggested the claimed invention—at most they made it obvious to try); *In re* Dow Chemical, 837 F.2d 469, 473 (Fed. Cir. 1988) (patent for impact resistant rubber-based resin having improved resistance to heat distortion held nonobvious). The court ruled that the PTO used the impermissible "obvious to try" standard because the prior art did not provide a reason for selecting the procedure used.

97. *In re* Lindell, 385 F.2d 453, 455 (C.C.P.A. 1967) (patent application for circuit interrupter construction was invalid as obvious; while the lower court used the impermissible "obvious to try" standard in its analysis, a reexamination of the record indicated that the invention was obvious, nonetheless) (citing *In re* Tomlinson, 363 F.2d 928 (C.C.P.A. 1966)).

98. *In re* Goodwin, 576 F.2d 375, 377 (C.C.P.A. 1978) (application relating to an improved mold lubricant used in glass manufacture was not obvious, merely obvious to try, because the results were unexpected); *In re* Mercier, 515 F.2d 1161, 1167 (C.C.P.A. 1975) (claims of patent application for process for splitting acetals and hemi-acetals held not obvious; even though prior art disclosed a known relationship between compounds, this differs from a disclosure of equivalent compounds; a known relationship merely

Inc.,[99] the court upheld the patentability of a species of fungus that produced an enzyme used for making cheese, holding that while it was obvious to examine this species along with others, the results obtained were unexpectedly good. Again, courts do not ask for certainty of success; an invention is held obvious if the resulting invention does not differ significantly from what was suggested in the prior art or if the inventor was reasonably certain that she would succeed.[100]

The law is more complicated when the prior art suggests that the inventor either try a number of choices or vary a number of parameters.[101]

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indicates obviousness to try because many compounds have a known relationship but are not substitutes in different reactions); *In re* Tomlinson, 363 F.2d 928, 931 (C.C.P.A. 1966) (some claims in application for product and process patents relating to stabilized polypropylene held invalid for obviousness, and other found to be valid; the examiner incorrectly based his finding on the fact that it would have been obvious to combine two of the elements); *In re* Eisenhut, 245 F.2d 481, 486 (C.C.P.A. 1957) (patent application for process for manufacture of washable, cloth-like material from cellulose fibers without spinning or weaving rejected for lack of invention because a result which flows naturally from the prior art is not an invention unless an unexpected result is obtained); Merck & Co. v. Danbury Pharmacal, 694 F. Supp. 1, 29, 32 (D. Del. 1988) (patent for cyclobenzaprine held nonobvious, citing *In re* Merck, 800 F.2d 1091 (Fed. Cir. 1986), in holding that the standard is not whether an invention would be obvious to try, but whether such an experiment would have been expected to succeed), *aff'd*, 873 F.2d 1418 (Fed. Cir. 1989); *Ex Parte* Old, 229 U.S.P.Q. (BNA) 196, 200 (Bd. Pat. App. & Int. 1985) (claims in patent for monoclonal antibodies recognizing human renal cell antigenic systems upheld as nonobvious; while the experiment was obvious to try, the results were clearly unpredictable).

99. 677 F.2d 1202, 1208 (7th Cir. 1982) (patent involving the identification of a fungus species which produces a milk-coagulating enzyme needed for the production of cheese held not obvious because, although it was obvious to try the particular fungus species, the results were totally unexpected).

100. *In re* Dow Chemical, 837 F.2d 469 (Fed. Cir. 1988).

101. *See, e.g.*, Uniroyal v. Rudkin-Wiley Corp., 837 F.2d 1044, 1053 (Fed. Cir. 1988) (patent infringement suit concerning an air-deflecting device for reducing wind resistance encountered by tractor-trailer trucks is remanded because district court incorrectly applied obvious standard by using "obvious to try" reasoning; the lower court rejected the patent as obvious even after finding that beyond the prior art, "experimentation [would be needed] to extract the exact parameters that would make the device work," and after holding that "even an expert would be unable to predict the result an aerodynamic device would have on a tractor-trailer vehicle"); *In re* Geiger, 815 F.2d 686, 688 (Fed. Cir. 1987) (holding that prima face case of obviousness was not established in Patent Office rejection of claims in application relating to method of inhibiting scale formation and corrosion of metallic parts in cooling water systems; the prior art merely made it obvious to try various combinations of known corrosion prevention agents); *In re* Yates, 663 F.2d 1054, 1057 (C.C.P.A. 1981) (prima facie case of obviousness was not established by the PTO on patent concerning a process for oxidizing an olefin to an unsaturated aldehyde, since examiner merely suggested a reason why it might have been obvious to try varying a number of parameters); *In re* Antonie, 559 F.2d 618, 620 (C.C.P.A. 1977) (patent application for rotating biological contactor apparatus held not obvious, merely obvious to try, because inventor varied every parameter of a system in order to optimize the effectiveness of the system without guidance from the prior art as to which parameters to vary or how to vary them); Polaroid Corp. v. Eastman Kodak Co., 641 F. Supp. 828, 853 (D. Mass. 1985) (Polaroid's patents for film and camera were held valid because "[t]he fact that one skilled

In *In re O'Farrell*, the court stated that an invention is merely obvious to try when the prior art "gave either no indication of which parameters were critical or no direction as to which of many possible choices is likely to be successful."[102] The courts are not clear as to how many parameters need to be varied, or how many permutations are necessary to render an invention nonobvious.[103] One case has held, however, that "routine optimization" is not tantamount to nonobviousness.[104] Instead, the court has focused on the amount of guidance the prior art gives, which steers the inquiry back to the reasonable certainty of success standard.[105] If the worker expects to succeed by working through many permutations, then the invention should be obvious.[106]

In *Merck & Co. v. Biocraft Laboratories*[107] the prior art suggested 1200 combinations, but the invention was found to be obvious because each of the combinations was expected to be effective, thus rendering any of the 1200 obvious.

Based on the recent "obvious to try" cases, it appears that the standard is a subset of the reasonable expectation of success standard. If an inventor is faced with a large number of variables, and the prior art does not provide enough guidance to narrow those down to a manageable level, then an inventive step is needed to proceed. Consequently, the skilled worker could not be reasonably certain of success. On the other hand, if the number of possible permutations has been limited by the prior art, then a mechanic could plod through them one at a time and be reasonably certain of success.[108]

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in the art would consider as possible candidates in an extensive search the mordants disclosed in these references does not meet the standard of obviousness under 35 U.S.C. § 103"), *aff'd*, 789 F.2d 1556 (Fed. Cir.), *cert. denied*, 479 U.S. 850 (1986).

102. 853 F.2d 894, 903 (Fed. Cir. 1988).

103. *See, e.g., id.*

104. *In re* Kulling, 897 F.2d 1147 (Fed. Cir. 1990); *see also Ex parte* Sugimoto, 14 U.S.P.Q.2d (BNA) 1312 (Bd. Pat. App. & Int. 1990) (invention involving routine substitution would have been obvious).

105. Merck & Co. v. Biocraft Lab., 874 F.2d 804, 807 (Fed. Cir.) (patent for pharmaceutical combination of amiloride and hydrochlorothiazide held invalid due to obviousness), *cert. denied*, 493 U.S. 975 (1989). "[A]n invention is 'obvious to try' 'where the prior art [gives] either no indication of which parameters [are] critical or no direction as to which of many possible choices is likely to be successful." *Id.* (quoting *In re* O'Farrell, 853 F.2d 894, 903 (Fed. Cir. 1988)). In this case, the invention was not only obvious to try, but also obvious because although the prior art did not single out the applicant's combination, it did suggest 1200 effective combinations, making all of them obvious. "That the [prior art] discloses a multitude of effective combinations does not render any particular formulation less obvious." *Id.*

106. *Ex parte* Erlish, 3 U.S.P.Q.2d (BNA) 1011 (Bd. Pat. App. & Int. 1987); *Ex parte* Allen, 2 U.S.P.Q.2d (BNA) 1425, 1429 (Bd. Pat. App & Int. 1987), *aff'd in unpublished opinion*, 846 F.2d 77 (Fed. Cir. 1988). *But cf. In re* O'Farrell, 853 F.2d 894 (Fed. Cir. 1988).

107. 874 F.2d 804 (Fed. Cir. 1989).

108. *See infra* note 130 and accompanying text.

F.   Risk Aversion and High-Cost Research

In the model presented so far, the focus has been on the "expected monetary value" ("EMV") of the research project. This is calculated simply by using the researcher's best estimate of payoffs, probabilities, and costs. The resulting EMV is the value the "rational" decisionmaker would give to the entire project, viewed prospectively.

But of course there is no single definition of "rational."[109] Some inventors may quite rationally prefer projects with a certain range of probabilities, or they may prefer one type of payoff structure, or they may be especially wary of projects with certain features. While it is very difficult to capture all the precise variations in preferences that might exist, it is possible to model at least one preference that deviates from straight EMV: the case of risk aversion. As will be shown below, positing a risk-averse inventor has interesting implications for the model.

Risk aversion is a simple idea: some people prefer a safer but lower expected payoff to a riskier but higher payoff. Put another way, the risk-averse investor would demand a higher expected return for a project as compensation for an increase in risk.

There are a number of ways to formalize the notion of risk, but one common one, suitable here, is to say that the riskiness of a project increases as the variance in potential outcomes increases. A simple case will demonstrate. Picture a lottery where one has a 50% chance of winning $20 and a 50% chance of losing $10. The EMV for this lottery is $5. Now picture a lottery with a 1% chance of winning $1000, a 1% chance of winning $100, a 1% chance of losing 100, a 1% chance of losing $500, and a 96% chance of neither winning nor losing anything; again the expected value is $5. Many investors, however, would likely prefer the first lottery to the second. The risk-neutral investor, of course, would be indifferent since the expected return is $5 in both cases.

It is possible to use a mathematical measure of this phenomenon—variance—to model risk aversion. The variance in the first lottery would be 225, while that of the second lottery would be 12,675. The standard deviation—a familiar statistical measure, defined as the square root of the variance—is 15 for the first lottery and roughly 113 for the second. Putting the issue in these terms makes it clear why someone might prefer lottery one over lottery two.

We can use the variance-based account of risk aversion to describe how a risk-averse inventor would approach the decision described above. A common way to demonstrate the effects of risk aversion is to find the

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109. *See* NELSON & WINTER, *supra* note 89, at 8-9, 58; ELSTER, *supra* note 56; Henk Bodewitz et al., *Towards a Cognitive Model for Technology-Oriented R&D Processes*, 17 RES. POL'Y 213, 223 (1988) (discussing social as well as economic determinants of R&D decisionmaking on several projects studied).

amount of money a risk-averse person would take in place of the risky
decision. This amount is called the "certainty money equivalent," or
CME; by comparing the CME to the straight (risk-neutral) expected value
of the decision, we get an idea of how much the risk-averse
decisionmaker is willing to give up to avoid taking the risk. This is
sometimes called the "risk premium," although it might better be termed
the "risk avoidance" premium, since it measures how much one is willing
to give up in expected value to avoid risk.

To analyze the effect of risk aversion on our decision, we must begin
with an assumption about the degree of risk aversion.[110] This will take
the form of a mathematical function. The function will take as its
argument (or "input") a payoff, i.e., a number representing a straight risk-
neutral assessment of the money value of a particular event. In the
example above, the payoff for a successful project where no patent was
obtained was set at $1000. This function will produce (as "output") the
risk-averse decisionmaker's *personal utility* for that payoff. It will, in a
sense, map real-world payoffs onto the decisionmaker's personal
valuation system, thus taking account of her risk aversion.

The shape of the function must correspond to the intuitive notion
that as payoff value increases, so will personal utility; everyone, risk-
averse or not, values more money over less. So the function must be
sloped upward. But as payoff value increases, the risk-averse
decisionmaker's personal utility would be expected to increase less
rapidly. That is, the personal utility valuation of the first dollar will be
higher than the valuation of the million-and-first dollar. In economic
parlance, we would expect "diminishing returns," or a concave function.
On the other hand, for the risk-neutral decision maker, we would expect a
linear utility function. The relationship between risk-averse and risk-
neutral utility functions is captured in Figure 5, where the curved line

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110. In a sense, the entire analysis implicitly makes another assumption: that a firm
cannot select a portfolio of R&D projects in a way that diversifies away the risk (or a large
portion of the risk) of failing. This is assumed because it is impossible to tell much about a
research project before it is complete, and therefore one cannot separate out risk factors
that are specific to particular project from those that run through an entire portfolio. It is a
simply impossible, or at least very expensive, to discover along what dimensions the
projects vary, and therefore to diversify one's portfolio of research projects in a way akin
to an investor diversifying away "specific" or "unsystematic" risk in her portfolio of
stocks, bonds, and the like. *See, e.g.*, STEPHEN A. ROSS & RANDOLPH W. WESTERFIELD,
CORPORATE FINANCE 159-73 (1988) (describing models of diversified investment portfolios).
For an interesting model of how firms in the petroleum industry select investments with
an eye toward minimizing the overall risk of their project portfolio, see CONSTANCE E.
HELFAT, INVESTMENT CHOICES IN INDUSTRY (1988) (using a covariance model to predict
optimal risk-adjusted portfolio choices). Note that where the firms Helfat studied made
investments in new technologies, "the cost estimates for these projects [were] likely to be
understated," suggesting that these were the most difficult projects to accommodate to the
firm's overall risk-level goals. *Id.* at 93.

represents the risk-averse utility function and the straight line the risk-neutral utility function.

Using this function, personal utilities can be calculated given payoffs. The first quantity to be determined is the risk-averse decisionmaker's personal valuation of the $1000 payoff, the amount that will accompany a successful project where there is no possibility of obtaining a patent. Using a common concave function,[111] we would get 900.[112] This means that a decisionmaker with the risk aversion described in the function would value the $1000 payoff at only 900 "personal utility units."[113] The personal utility of the alternative payoff, the one accompanying an unsuccessful project, is similarly computed. Since the payoff in this case is by definition zero, the personal utility is also zero. Now, by multiplying both 900 and 0 by their respective probabilities, we can get an *expected* utility figure for the entire decision; using the figures derived earlier, this would be 504.[114]

This number tells us what the decision is worth to the risk-averse decisionmaker. Unfortunately, it gives us the answer in personal utility units. The question of what certainty money equivalent (CME) corresponds to this personal utility valuation still remains; this will give us a sense of the risk avoidance premium—in *dollars*—of this decisionmaker. Now that the value of the decision has been "translated" into terms that have meaning for the individual decisionmaker, this figure must be "translated back" from this figure into dollars. A formula that gives us the appropriate CME for any expected utility valuation by the decisionmaker is needed. The CME of the decisionmaker needs to be evaluated in *dollars*, not utility units.

CME in dollars can be found through the use of a formula which relates expected utility to expected payoff and payoff variance.[115] By

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111. We will use the general form $U = P - (k \cdot P^2)$, where k is some constant which determines exactly how concave the function is over a restricted domain of P. We will use a small value for k—0.0001—and therefore employ a function with only a minor degree of concavity. This corresponds to the assumption that our decisionmaker is not *highly* risk averse.

112. $U = P - (0.0001)(P^2) = 1000 - (0.0001)(1000)^2 = 900$.

113. It is important to remember that personal utility is *not* measured in dollars. A dollar is worth a dollar to everyone, but a payoff of $1000, assuming some degree of risk aversion, or diminishing value of money, may be translated into 900 personal utility units. These units can *only* be used to compare one personal valuation to another, not a personal value to a dollar amount.

114. That is, the probability of success given a promising result, times the personal utility valuation of a successful project, plus the probability of no success times the personal utility valuation of an unsuccessful project, or (0.56)(900) + (0.24)(0), which equals 504.

115. The formula is as follows:
$$E(U) = E(P) - k(E^2(P) + V)$$
where $E(U)$ equals expected utility, $E(P)$ equals expected payoff, k equals some constant (0.0001 in our example above) and V equals the population variance of the range of

plugging in the appropriate expected utility value, we can solve for a straight, risk-free expected value figure that represents how much in dollars the risky decision is worth to the decisionmaker. In doing so, we will set the variance term in this formula equal to zero, since this corresponds to a risk-free CME for a given expected utility. Using this formula in the example above, we would get $532.[116] This means that the risk-averse person described by our function would be indifferent as between the project we have described and a cash payment of $532. Compare this with the straight expected value of the research project, $560.[117] Since the risk-neutral decisionmaker would not take anything less than this $560 in place of the opportunity to pursue the project, this means that the risk-averse decisionmaker values the project some 5% less than the risk-neutral decisionmaker.

One realistic feature of this risk-aversion function is that as the difference between the payoff for a successful and unsuccessful project—the variance—increases, the ratio of CME to expected value goes down. As the payoff structure indicates a riskier and riskier project, the risk-averse and risk-neutral valuations of the project diverge more and more. At some point, the divergence is so great that, given reasonable estimates of the cost of experimentation and development, many decisionmakers

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payoffs. Population variance for a range x_1 through x_n equals $((x_1 - m)^2 + (x_2 - m)^2 + \ldots + (x_n - m)^2)/n$, where m is the mean (or average) of the range x_1 through x_n. This formula for $E(U)$ is derived for the formula for U given above in the following manner. The variance V equals

$$
\begin{aligned}
V \quad &= E((P - E(P))^2) \\
&= E(P^2 - 2E(P)P + E^2(P)) \\
&= E(P^2) - 2E^2(P) + E^2(P) \\
&= E(P^2) - E^2(P).
\end{aligned}
$$

Also,

$$U = P - kP^2$$

so that

$$
\begin{aligned}
E(U) \quad &= E(P - kP^2) \\
&= E(P) - kE(P^2) \\
&= E(P) - kE^2(P) + kE^2(P) - kE(P^2) \\
&= E(P) - kE^2(P) - k(E(P^2) - E^2(P)) \\
&= E(P) - kE^2(P) - kV \\
&= E(P) - k(E^2(P) + V),
\end{aligned}
$$

as desired.

116. From above, $E(U) = E(P) - k(E^2(P) + V)$. In our example, we know $E(U)$, k, and V: the expected utility is 504 personal utility units, see *supra* notes 113-14 and accompanying text; k equals 0.0001, as above; and we will set variance equal to zero because we are looking for a certainty money equivalent. Solving the formula above for $E(P)$ will produce the CME our risk-averse decisionmaker would accept in place of the opportunity to make the decision. Putting the above formula in quadratic form and solving for $E(P)$ yields:

$$E(P) = (1 - (1 - 0.0004E(U))^{1/2})/0.0002$$

With $E(U)$ equal to 504, $E(P)$ equals $532.

117. This is the expected value *given* a promising experimental result.

would opt out of the project, even though it still has a net positive expected value.

For example, compare the CME of two projects. Project one gives an equal chance of earning $2000 and $0, as in our example. The expected payoff ($E(P)$) is therefore $1000; the variance is 1,000,000.[118] Project two gives an equal chance of making $4000 and $0. The expected payoff of project two is $2000, but the variance is higher—4,000,000. The CME for project one is $876; when compared to the expected payoff of $1000, this gives a CME/$E(P)$ ratio of 0.876. The CME for project two is $1394; the CME/$E(P)$ ratio is 0.697. Thus it is easy to see that as the variance increases, the CME/$E(P)$ ratio decreases. According to the risk aversion function, the decisionmaker becomes more risk-averse.

This means that for a high-variance project, inventors trying to decide whether to pursue the project will be more risk-averse. When deciding on these projects the benefits will be heavily "diluted" by the extra risk. Assuming that society values inventions in a risk-neutral way, the result will be fewer such invention projects than the preferred number.

The policy solution is easy to envision: create some extra incentive to offset the inventor's lower perceived utility. This might take a number of forms. For example, the initial experimentation stage of the high-risk project could be subsidized by the government. Government funding of basic research is one instance of this; basic research projects often involve high costs and potentially high but quite uncertain rewards.[119]

In addition, a patent-related policy solution is possible. This could be accomplished by creating an extra-high payoff for those successful projects whose inventors faced a high-variance project. Because perceived payoff is a combination of dollar payoffs and probabilities, this could be achieved by either augmenting the potential profit from a patent or by increasing the probability of obtaining one. Naturally, this paper focuses on the latter alternative. Although as mentioned above, the effects of any patent-related incentive on initial decisions to invent are quite limited, some marginal inventors might be swayed by the extra reward. Thus it is at least worth attempting.

One practical way to assess whether a project involved a high degree of risk is to look at the cost.[120] If the project was very costly

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118. Recall that population variance for a range x_1 through x_n equals $((x_1 - m)^2 + (x_2 - m)^2 + \ldots + (x_n - m)^2)/n$, where m is the mean (or average) of the range. Here this yields $((2000 - 1000)^2 + (0 - 1000)^2)/2$ or 1,000,000.

119. *See* Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 67 J. POL. ECON. 297 (1959).

120. The relationship between cost and variance can be seen from a simple qualitative example. Assume a game of chance where you are asked to pick balls from an urn; each pick costs some money. Even if the number of winning balls is fixed, i.e., does not vary with the number of picks, the possible loss from playing the game increases as you pick

relative to others in the industry, it is a good candidate for the extra "risk bonus" discussed here.[121] As previously discussed, the cases seem to indicate that patents on high-cost inventions do meet with extra success in the courts.[122] The discussion here confirms the wisdom of this practice. Moreover, I have attempted to furnish another rationale for the practice. Once again, I would merely add that it would be better for inventors if the courts made this practice explicit in the patentability jurisprudence.[123]

I am not suggesting that Congress should change the statutory standard.[124] I am suggesting an *interpretation* of the current standard that would recognize the central place of uncertainty. I see nonobviousness as a test of whether an invention entailed a high degree of technical uncertainty at its outset. In the case of an inexpensive or moderately

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more balls. Because your possible loss increases with more picks, more picks entails greater variance.

121. This bears a close relationship to a point made by the economist F.M. Scherer: patents are especially defensible where they award inventions whose costs are high relative to their benefits. *See* SCHERER, *supra* note 17, at 448 (innovations with low potential benefits relative to costs need promise of a patent to hasten development). The proposal outlined here merely stresses that what is important is *perceived* costs—which may be a function of risk aversion when variance is high—as compared to benefits. Note also that this is in line with Kitch's analysis of nonobviousness. *See* Kitch, *supra* note 6, at 302.

122. Panduit Corp. v. Dennison Mfg., 774 F.2d 1082, 1099 (Fed. Cir. 1985) (fact that patent holder took seven years and spent millions of dollars is evidence that prior art did not render invention obvious), *vacated on other grounds*, 475 U.S. 809 (1986); Hardinge Bros. v. Marr Oil Heat Mach. Corp., 27 F.2d 779, 781 (7th Cir. 1928) (fact that patentee and infringer both made long and expensive experiments in an effort to make an oil burner with a cover on it is evidence that invention was not obvious); Bethlehem Steel Co. v. Nelies-Bement-Pond Co., 166 F. 880, 896 (C.C.D.N.J. 1909) (patentee showed that he spent between $50,000 and $125,000 "perfecting" his invention; the court, in invalidating the patent, found that the actual experimentation was extremely limited, the large amounts of money were spent after the invention was made, and were merely to fine tune it; decision implies that had the money been expended for the original research, it would have been relevant); Edoco Technical Products, Inc. v. Peter Kiewit Sons' Co., 313 F. Supp. 1081, 1086 (C.D. Cal. 1970) (the fact that a long and expensive period of experimentation was required to solve the problem was important evidence of nonobviousness), *aff'd*, 177 U.S.P.Q. (BNA) 481 (9th Cir. 1973); *cf.* Eli Lilly & Co. v. Generix Drug Sales, 460 F.2d 1096, 1103 (5th Cir. 1972) (inventor who undertook costly and painstaking research in developing propoxyphene hydrochloride should be rewarded with a product patent; a use or process patent would be insufficient incentive and would discourage the inspiration process); United States v. Ciba-Geigy Corp., 508 F. Supp. 1157, 1168 (D.N.J. 1981) (for patent relating to hydrochlorothiazide, the costly research undertaken should be rewarded with a product patent).

123. *Cf.* Oddi, *supra* note 17, at 1127 (suggesting that courts ought to consider "qualitative and quantitative investment in research and development" as an additional objective factor in determining nonobviousness).

124. I will note, however, that from an economic point of view the statute's concern with "pure obviousness" is besides the point. As suggested here, the inquiry should be "how obvious *given a reasonable budget constraint*"? However, for purposes of this paper at least, I concede the administrative difficulty of evaluating technical uncertainty in light of industry and firm R&D *in every case*. Thus the emphasis on a discrete and more easily identifiable class of cases—*very* high cost projects.

expensive research project, the inquiry need go no further than technical uncertainty.[125] But for a high-cost research project, one whose cost is much higher than the average project in the industry, we must also take account of the fact that a reduction in *perceived payoffs* makes the project look less attractive to the reasonably skilled inventor.

The notion of including cost as a component of technical uncertainty may be disquieting. After all, it might be thought that if the end result of a certain experiment is obvious, it is no less obvious simply because it may be very expensive to verify. The high cost, it will be argued, does not make the result any less likely. But a little reflection reveals that there is a relationship between predictability and cost, especially when cost is very high. The reason, once again, involves risk aversion.

As previously shown, the greater the divergence between potential outcomes, the more a risk-averse person's preference for choice diverges from expected value. So far this has been modeled as a reduction in the perceived payoffs from the risky activity. It would be easy, however, to treat the payoff as constant and say instead that the risk aversion lowers the anticipated *probability* of the positive payoff.

For example, using our risk aversion function, we calculated earlier that a risk-averse person would be indifferent as between a project with expected value of $560 and a cash payment of $532.[126] The risk-averse person implicitly discounts the expected value of the risky project. The same general conclusion is reached by keeping the payoff constant and changing the probability. With a payoff of $1000, the risk-averse person *in effect* assesses the probability of a successful project at only 0.532, since 0.532 times $1000 equals $532. From this perspective, the risk-averse person implicitly subtracts 0.028 (0.56 − 0.532) from the probability of successfully completing the project.[127]

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125. The cases for the most part agree with this. *See, e.g., In re* Farrenkopf, 713 F.2d 714, 718 (Fed. Cir. 1983); Orthopedic Equip. Co. v. United States, 702 F.2d 1005, 1013 (Fed. Cir. 1983). At least one case, however, seems to question whether technical achievement is required, by implying that *commercial* uncertainty might satisfy the nonobviousness requirement. *See* Leinoff v. Louis Milona & Sons, 726 F.2d 734, 740 (Fed. Cir. 1984), *overruled by* A.C. Auckerman Co. v. Chaides, 960 F.2d 1020 (Fed. Cir. 1992) (upholding patent for inserting leather strips between strips of fur to make pelts, even though prior art made clear this technique was possible; court held, in face of defendant's objection that patentee had merely "discovered" market demand for furs made with this technique, that an invention "may create a new want and be nonobvious"). Except in the case of very high-cost research projects, commercial uncertainty ought not to support a claim of nonobviousness, for the reasons stated above in the discussion of disclosure theory.

126. That is, (0.56)($1000) + (0.24)($0). *See supra* notes 116-17 and accompanying text.

127. The example in the text uses probabilities and payoffs of success *given* promising experimental results. This is irrelevant to a discussion of patent standards, of course, since it is the probability of experimental success—technical uncertainty—that is at the heart of the patentability test. The analysis yields the same general conclusion, however, when applied to implicit reductions in the probability of a promising experiment caused by

Assuming once again that high project costs are a good proxy for high variance, and thus risk, one result is that the cost of doing research does in effect impact prospective assessments of technical uncertainty. Thus it is entirely defensible to take these costs into account in assessing the perceived *ex ante* probability of project success.

Yet it is feasible to do so only under when the invention whose patentability is at issue came as part of a very high cost research project. Although the foregoing might suggest the desirability of taking cost into account in all cases, it would not have much of an impact in low to moderate cost research projects, which by assumption involve only low to intermediate levels of variance. Moreover, cost data adds a layer of complexity to patentability decisions that would not often be worth the gains.
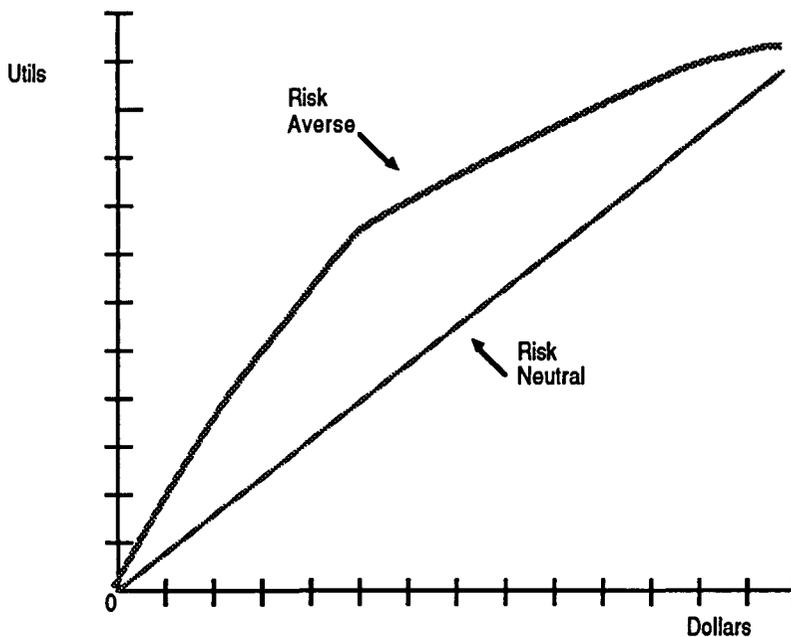

Figure 5

1.   *BUT AREN'T INVENTORS RISK-SEEKERS?*

A plausible objection to my treatment of risk aversion begins from the premise that inventors are not risk-averse, they are risk-takers.[128] My

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devaluation of high-risk payoffs. I simply choose to use the same numbers as in earlier examples.

128. Many people seem to believe this. Support can be found in FRANK W. TAUSSIG, INVENTORS AND MONEY-MAKERS (1915) (describing the psychological differences between

response is that while in the main this may be true,[129] for the subclass of inventions we are concerned with here—high cost projects with a roughly even chance of success—this objection is irrelevant. My argument turns on two points: (1) a precise characterization of the kind of research that would be affected by a "risk adjustment" to the standard of patentability; and (2) empirical research elucidating the differences between R&D in large and small firms.

Allowing high research costs as a "plus factor" in determining patentability would affect a small number of cases. First, of course, only those patents sought in connection with high-cost projects would be affected. To keep this number small, "high-cost" should be defined as 50% or more above the average research project in the *industry* (not the

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inventors and financiers, including attitudes toward money and risk); and JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM, AND DEMOCRACY 73-74 (1950):

> Spectacular prizes much greater than would have been necessary to call forth the particular effort are thrown to a small minority of winners, thus propelling much more efficaciously than a more equal and more 'just' distribution would, the activity of that large majority of businessmen who receive in return very modest compensation or nothing or less than nothing, and yet do their utmost because they have the big prizes before their eyes and overrate their chances of doing equally well.

Id. See also BROWN, *supra* note 8, at 44, 189, 325 (quoting from interviews with inventors describing the importance of challenges and the unimportance of monetary gains to their pursuit of inventions).

129. And society should be glad if risk-seeking inventors pursue ambitious research, whether it succeeds or not. There are many social benefits when an inventor *overestimates* a project's chances of success, or the efficacy of patent protection, or even the chances of patentability. MACHLUP, *supra* note 1, at 166-67:

> It will be best from the point of view of society if innovators optimistically overestimate th[e] lag [between innovation and imitation]. If they expect the lag to be longer than it actually is, innovation will be enhanced and imitation will not be delayed. That it may create this socially wholesome illusion on the part of innovators is the strongest justification for a well-designed patent system.

Id. Assuming the project is not successful but the patent is granted, society will benefit from the knowledge of a technology that works but cannot be successfully developed— i.e., a path that others should *not* try. There are even some benefits without public disclosure, since there is a market for "negative know-how," or knowledge of what will not work. *See, e.g.,* Metallurgical Indus. v. Fourtek, Inc., 790 F.2d 1195, 1203 (5th Cir. 1986) (characterizing the value of negative know-how as integral to improvement, and thus in most cases the equivalent of "positive knowledge"); Continental Group, Inc. v. Kinsley, 422 F. Supp. 838, 845 (D. Conn. 1976); Gillette Co. v. Williams, 360 F. Supp. 1171, 1173 (D. Conn. 1973). But see dictum to the contrary in Materials Dev. Corp. v. Atlantic Advanced Metals, Inc., 172 U.S.P.Q. (BNA) 595, 606, 610 (Mass. Super. Ct. 1973). *Cf.* Mansfield, *supra* note 55, at 98:

> Many . . . [formal project selection] models fail to recognize that R&D is essentially a process of buying information, that *unsuccessful projects can provide valuable information*, and as a result that the real task is to facilitate sequential decision making under conditions of uncertainty.

Id. (emphasis added).

firm). Moreover, the patentee should have the burden of establishing these high costs. Second, although the risk adjustment would be available for all high-cost projects resulting in patents, in many of these it would make no practical difference. If the pre-adjustment probability of success were low, a patent would issue even without the risk adjustment. If the pre-adjustment probability of success were high, the minor "plus factor" would not be enough to overcome the nonobviousness test. Risk adjustment would matter only in those high-cost cases where the probability of success was close to the line of patentability; in these cases, it would give a helping hand to the inventor.

Now that I have made clear which research projects would be affected by the risk adjustment mechanism I have described, it remains to be shown that risk aversion is a real concern for these projects. To begin with, many high-cost research projects are done by large firms,[130] whose R&D managers are presumably at least somewhat risk-averse.[131] While

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130. *See* Keith Pavitt, *R&D, Patenting and Innovative Activities*, 11 RES. POL'Y 33, 38 (1982). Pavitt, in an attempt to refute the hypotheses that large firms do more non-patentable R&D, or that they are less inefficient than small firms, states:

> I correlated the proportion of individuals [i.e., small inventors not associated with a company] in total patenting in each [industry] sector (a measure of ease of patenting) . . . against average plant sales in the sector (a measure of level of resources required). . . . [T]he correlation was -0.49 and significant at the 2% level: scale of resources required may influence to some extent the degree to which individuals contribute to sectoral patenting activity. This suggests [an] explanation of the inverse relationship between size of firm and R&D intensity, on the one hand, and the patent to R&D ratio on the other. *Smaller firms gravitate to sectors, and within sectors to products, where the costs of making innovations are somewhat lower than those of big firms.*

Id. (emphasis added). *See also* CHRISTOPHER FREEMAN, THE ECONOMICS OF INDUSTRIAL INNOVATION 137 (2d ed. 1980) (reviewing data which seems to show that smaller firms are more efficient R&D spenders, based on the fact they obtain more patents per dollar of R&D than large firms).

> [T]here are significant differences between *industries* in the relative performance of small and large firms. In the *chemical* industry, where both research and development work are often very expensive, large firms predominate in both invention and innovation. In the mechanical engineering industry, inexpensive ingenuity can play a greater part and small firms or private inventors make a larger contribution.

Id. For a review of the data on large vs. small firm "research efficiency"—largely a matter of number of patents per R&D dollar—see F.M. Scherer, *Corporate Size, Diversification and Innovative Activity, in* INNOVATION AND GROWTH: SCHUMPETERIAN PERSPECTIVES 222, 228-29 (1984) ("The patents of larger [lines of businesses] tend more frequently to cover more complex systems and subsystems entailing high R&D outlays per invention. [But] [t]he relationship is a weak one."). *See also* MORTON I. KAMIEN & NANCY L. SCHWARTZ, MARKET STRUCTURE AND INNOVATION 67 (1982) (review of research tending to show that inventive efficiency increases with size up to a point, then begins to decrease).

131. Most large firm executives are risk averse. *See* KENNETH R. MACCRIMMON & DONALD A. WEHRUNG, TAKING RISKS: THE MANAGEMENT OF UNCERTAINTY 260 (1986) (study of 500 senior business executives which found that "managers in large firms were more averse to risk than other managers"). There is no reason to believe that R&D managers would have different "risk profiles" than the cross-section of executives surveyed for this

small risk-neutral or risk-seeking firms also undertake a good number of high-cost research projects,[132] these projects often involve higher technical risk on average than those undertaken by large firms.[133] Since the chance

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study. For example, the study found that senior executives from the chemical, pharmaceutical and manufacturing industries—which traditionally rely heavily on research—had risk preferences which did not diverge from the from the average. *Id.* at 262. One study of investments in oil industry projects—including several that involved the development of new technology—showed that managers behaved in a risk-averse fashion; specifically, they chose projects as if they were diversifying the "portfolio" of firm projects with respect to risk. HELFAT, *supra* note 110, at 5, 127; *see also* Mansfield & Wagner, *supra* note 29, at 181 (reporting results of interviews with R&D personnel from 16 large corporations; average probability of technical completion of attempted projects was 0.57); *cf.* ROBERTS, *supra* note 30, at 157 (Texas Instruments tries to overcome risk aversion of R&D decisionmakers by supporting three internal funding sources, which encourages R&D managers to take more risks). *But cf.* Dasgupta & Stoneman, *supra* note 48, at 18-21 (theoretical model of race for a patent shows that competition among firms may actually cause too much high-risk research); Tor Klette & David de Meza, *Is the Market Biased Against Risky R&D?*, 17 RAND J. ECON. 133 (1986) (same).

132. Biotechnology, an industry where small firms predominate, is a good example. *See, e.g., Biotechnology Financing: Stocks Face Mixed Outlook*, BIOTECHNOLOGY NEWSWATCH, Oct. 2, 1989, at 1 (reporting on presentation by accountant stating that "[o]n average, smaller [biotechnology] firms are spending $100,000 a month on R&D, the larger ones $7 million to $8 million"; and reporting estimate by venture capitalist that since 1976, $5 billion has been raised to fund biotechnology companies); *Biotechnology's New Strain of R&D Cash*, BUS. WK., Apr. 18, 1983, at 104 ("Developing a new therapeutic drug can cost a company from $3 million to $100 million, and rigorous Food & Drug Administration tests can take more than five years. . . . For genetic-engineering companies, many with no marketable products to generate cash flow, the investment burden is tough to bear."); Ann Hagedorn, *Suits Sprout Over Rights to Seeds*, WALL ST. J., Mar. 5, 1990, at B1 (describing suit over genetically advanced celery variety: "With companies spending millions of dollars yearly on biotechnology to create novel seed varieties, the costs of losing the seeds to competitors are greater than ever."). *But see* SCHWARTZMANN, *supra* note 13, at 85 (noting that small firms in the pharmaceutical industry usually perform relatively inexpensive, low-cost research such as finding new dosage forms for old, well-known drugs). *See generally* KEITH PAVITT & S. WALD, THE CONDITIONS FOR SUCCESS IN TECHNOLOGICAL INNOVATION 34-52 (1971) (describing interaction between large and small firms in R&D).

133. For example, Edwin Mansfield studied the research and development projects of primarily large firms in the chemical and petroleum industries in the 1960's. He found that his "findings seem to support the hypothesis . . . that the bulk of the research and development carried out by large corporations . . . is relatively safe from a technical viewpoint." MANSFIELD ET AL., *supra* note 69, at 20; *see also id.* at 25 ("With regard to the median estimated probability of technical success . . . the regressions suggest that [it] is higher (not lower) . . . in the largest [chemical] firm in the sample than in a firm that is one-half its size.") (footnote omitted); J.Y. Kamin, I. Bijaoui & R. Horesh, *Some Determinants of Cost Distributions in the Process of Technical Innovations*, 11 RES. POL'Y 83, 89 (1982) (in study of 33 innovations in Israeli chemical and electronics industries, authors "found that the small firms [i.e., under 500 employees] undertake a significantly higher proportion of complex [technological innovation] processes than are undertaken by the larger firms"); D. Hamberg, *Invention in the Industrial Research Laboratory*, 71 J. POL. ECON. 95, 99-103 (1963) (summarizing empirical research from the 1950's tending to show that large firms pursued relatively safe research; discusses why medium to small firms might pursue riskier projects). *But cf.* MANSFIELD ET AL., *supra*, at 25 (noting the limitations of the data and some counter-indications). It also appears that firms which spend a higher

of obtaining patent coverage increases with the degree of technical uncertainty at the outset of the project, many projects undertaken by these small firms are likely to result in patentable inventions anyway (assuming the projects are successful). The added incentive of a higher probability of obtaining a patent in high-cost cases will simply not matter where small firms conduct high-cost research; the plus factor will not change the outcome in most cases. As a consequence, the fact that small firms are often risk-neutral or risk-seeking does not weaken the case for an upward adjustment in the standard of patentability for high-risk research.[134]

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percentage of their revenue on R&D use a formal decision-making process more often than other firms. *See* Uhlman, *supra* note 30, at 30-31 (study of 218 innovations from 126 companies finding that "[t]he higher the share of [revenue] spent on research and development . . ., the more frequently a detailed target is set for the time, funds and solution possibilities . . . available for solving a specific problem"). Assuming firms that spend more on R&D undertake more high-cost projects, and further assuming that a formalized process leads to more risk-aversion, this might indicate another rationale for the plus factor. For a spirited argument that small inventors contribute most of the major breakthroughs in many industries, see JOHN JEWKES ET AL., THE SOURCES OF INVENTION (2d ed. 1969), especially at 205-09. *See also* Robert E. Berney & Ed Owens, *Small Business Policy: Subsidization, Neutrality, or Discrimination*, 22 J. SMALL BUS. MGMT. 49 (1984):

> The tendency for small business to develop a larger number of important advances in technology is often attributed to less separation of ownership and management. In large firms, managers tend to have shorter time horizons than owners. Consequently, managers tend to push projects with short-term payoffs even when other projects have higher present value to the stockholders. However, both small and large businesses innovate to secure monopoly profits from innovation.

Id. at 54.

134. It might be argued that the growing emphasis on large firm-small firm joint ventures may mitigate the differences between the two types of firms' R&D efforts. *See, e.g.,* John Case, *Sources of Innovation,* INC. MAGAZINE, June 1989, at 29 ("Big companies frequently enable a small company's inventions to become marketable innovations. Pharmaceutical and chemical giants . . . have helped create the biotech industry—by distributing grants to university researchers, by investing in fledgling companies, by contracting to do production or marketing for small firms. . . . Today . . . there's more and more of this joint venturing."). Note, however, that the transaction costs associated with such arrangements are considerable, making them less than an ideal solution. Note too that many of the transaction costs involved have yet to occur for the joint ventures being formed today. Perhaps when disputes over ownership and control of joint venture technology increase, firms will realize they are less than a panacea. And in the meantime, large firms continue to be accused of harboring more risk aversion than is good for the economy. *See, e.g.,* NATIONAL ADVISORY COMM. ON SEMICONDUCTORS, A STRATEGIC INDUSTRY AT RISK: A REPORT TO THE PRESIDENT AND THE CONGRESS 25 (1989) (calling for pools of "risk-tolerant" capital to encourage more high-risk research); Susan Dentzer, *The Maypo Culture,* BUS. MONTH, Nov. 1989, at 26, 29 (low rate of investment by U.S. corporations in part attributable to unwillingness to take risks); Robert H. Hayes & William J. Abernathy, *Managing Our Way to Decline,* HARV. BUS. REV., July-Aug. 1980, at 67, 68-69 (accusing U.S. companies of losing their taste for the high-risk investment needed to keep innovations flowing).

Lowering the standard of patentability in high-cost research projects will likely affect only those firms that need the extra incentive. For the most part the perverse effects associated with a risk adjustment "plus factor" will therefore be small. And even in those few cases where risk adjustment tips the scale and a patent is granted to a small, non-risk-averse firm, the public will at least have the benefit of the disclosure of valuable (because costly to obtain) information.[135]

2. CASES ON HIGH-COST RESEARCH

Although the cost of research has never been part of the formal analysis of nonobviousness, some decisions have noted that the expenditure of a large amount of money tends to show that an invention is not obvious.[136] For example, in *Edoco Technical Products, Inc. v. Peter Kiewet Sons' Co.*,[137] the district court upheld a patent on a device used in pouring concrete. In rejecting the infringer's objection that the invention was obvious, the court noted that "a long and expensive period of experimentation was required by the patentees to solve the problem."[138] But expensive research, in and of itself, has never been seen as an important indicator of patentability. It is proposed here that courts do so in a limited class of cases.

G. Administrative Feasibility and Perverse Incentives

Proving relatively high research cost will not be difficult or burdensome. Patent applicants and patentees collect this information anyway for a variety of reasons, including: (1) tax benefits (e.g., the R&D tax credit), (2) internal cost accounting, (3) use in project evaluation, (4) use in licensing negotiations and the like. Patentees appear to have no trouble showing research expenditures at the damages stage of a patent infringement suit, and as noted above such information has been introduced in some cases to show the nonobviousness of the invention involved. Simply adding one more reason to collect data on the cost of a research project does not appear to pose a major problem.

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135. Although the disclosure function of patents is secondary to the incentive function, firms do rely on patents as one source of technical information. *See, e.g.,* SCHWARTZMANN, *supra* note 13, at 306 ("Scientists in the research laboratories of pharmaceutical companies follow the patents filed by other manufacturers in order to keep abreast of critical developments."). *But see* Michael J. Meurer, *The Settlement of Patent Litigation*, 20 RAND J. ECON. 77, 80-81 (1989) ("Asymmetric information about innovations persists despite the disclosure requirement in 35 U.S.C. § 112 ... because 'the disclosure regulations of the patent system are often evaded...' Even when disclosure is complete, it might not provide crucial information about the content of prior art ...." (quoting NORDHAUS, *supra* note 33)).

136. *See supra* note 122.

137. 313 F. Supp. 1081 (C.D. Cal. 1970), *aff'd*, 177 U.S.P.Q. (BNA) 481 (9th Cir. 1973).

138. *Id.* at 1086.

Likewise, the fact that one would need *comparative* data to qualify for the boost in patentability would not pose too great a problem. Currently, evidence of the research approaches and results of industry competitors—including third party competitors not involved in a patent infringement suit—is introduced to show such nonobviousness factors as long felt need in the industry and failure of others to invent. Comparative data is also sometimes used to establish "reasonable royalty" rates in determining a patentee's damages from infringement. It is a short step to determine competitors' research costs. The burden of applying the new test will lessen once enough data is collected to establish basic comparative criteria. This is especially true of the test as it will be applied in the Patent Office, given the volume of patent applications and the specialization of examiners. For instance, after a short time, examiners in the chemical sections of the Office will have some experience applying the test and will therefore have some rules of thumb regarding the normal range of research expenditures for their areas of specialization.

Another objection to the proposed "risk adjustment" for high-cost projects is that it might skew investment decisions. That is, an inventor might decide at the margin to spend extra money on a project to insure that it falls into the high-cost category and therefore qualifies for the beneficial patent standard proposed above. To some extent, this would not be bad; after all, the basic idea behind the patent system is to encourage investment in research and development. And some of this extra research might prove very useful, despite the motivation for undertaking it. As discussed above, however, the patent system is equally concerned not to over-reward routine (low uncertainty) research. Thus the skewing of investment is a real worry.

But not too great a worry. For one thing, the extra incentive of a patent, and therefore *a fortiori* of the extra boost of easier patents for high-cost projects, is modest. A firm would be foolish to lavishly spend its way to a modest benefit. Another reason not to worry too much about skewing is that the qualifying test to receive the extra boost to patentability is quite high. It would be difficult, not to mention unprofitable in many cases, to artificially inflate a research project budget so as to bring it to a level 50% higher than that of the average project in the industry. And finally, of course, where the Patent Office or a litigation opponent discovers the applicant's cost-padding strategy, the doctrine of inequitable conduct can be invoked to render the patent completely unenforceable.

IV. ADJUSTING THE STANDARD FOR EXPENSIVE RESEARCH: A MULTI-FIRM MODEL

This section uses the example of multi-firm competitive research to bolster the argument that patents ought to be slightly easier to obtain for the results of high-cost research projects. Here the single-firm "decision theory" model introduced above is modified to include the presence of other firms.

When more than one firm is capable of undertaking a research project, the decision to invest in the project is more complicated than in the preceding models. The reason is that the decisions of other firms whether to undertake the project affects the possible payoff from the project. This is based on a simple premise: the more firms researching a problem, the more likely that at least one firm will solve it, i.e., come up with the invention. Thus for any particular firm, the number of other firms who have chosen to research a project will affect its decision whether to enter the project "sweepstakes." Of course, if an individual firm always had the right to use the results of its own research, this would not be true. In this case, the simple decision theory model presented in the preceding section would completely describe the choice faced by the firm. But what this model omits, and what the model in the following section tries to capture, is the impact of the patent system's basic rule that even independent discovery is not a defense to patent infringement. Put in terms of the single firm's decision in the multi-firm context, there is some chance that even a success will be a failure—i.e., that even if *this firm's* research project is successful, a successful outcome for another firm which leads to a patent will block this firm's ability to use the research results. This is *not* to say that the activity (or inactivity) of the other firms affects a particular firm's probability of successfully completing the project; only that these other firms, in the aggregate, affect the probability of obtaining the sole patent to cover that success. In this way, the number of competing firms affects a firm's expected payoff.

The other factor affecting a firm's decision to enter the research sweepstakes is the cost of pursuing the research project. If entry were free, every firm that had the capacity would enter, since expected value would always be positive. (There is always some chance that an individual firm would be both successful and first, and therefore obtain the patent; and with zero cost, it would always pay to try.) But once research costs something, this is no longer true. For then a firm will have to balance its expected value—again, determined in light of the number of other competitors—against the cost of the project. Only if entry were cost-effective, i.e., expected benefit minus cost were positive or at least zero, would a firm in fact enter.

This analysis clearly indicates that a rise in the cost of the project will reduce the number of firms that would decide to enter. Viewed from the perspective of a single firm's decision, a rise in cost lowers the expected value of the project. Herein lies the intuitive point developed in the model below. Higher research cost will lead in some cases to a below-optimal number of entrants.

For any given project, a limited number of firms will compete to reach the goal (success) first. Since the rewards are generally larger for the first to complete a patented invention, the model assumes that only the first firm to succeed gets the patent, and thus all the rewards.

As a consequence, each firm views the problem of deciding whether or not to play the research game as one where the expected benefits of winning do not have to be divided among several winners; only *one* winner "takes all."[139] The probability of winning is related to the probability that *at least one* firm will get the research result; but firms do not look at the possibility of dividing the prize among multiple winners. Again, only one will take the prize. Thus the probability term takes into account that more than one firm might play and win: it is calculated as:

Probability of at least 1 success = 1 – (Prob. no one succeeds).

On the other hand, since the cost of research for each firm, i.e., the "price" of entering the research competition, is not divided, there is no need to divide expected benefits by the number of firms playing—no expected value times number of firms or "$E(v)/n$" type of calculation.

This analysis of cost will demonstrate that there is an interesting relationship between the cost of research and some of the other variables interest. Thus, the cost of doing research, c, must be considered.

Assume that the cost c of doing a research project is the same for all firms that decide to pursue the research. Furthermore, assume—perhaps unrealistically—that as the number of firms competing for the research result increases, cost stays the same.

Recall that the probability of success, P, is the same for all firms. Then the probability that no one succeeds will be equal to $(1 - P)^n$, where P = the probability of success and n = the number of firms trying to perform the research.[140] For example, where only one firm is researching, and the probability of success is 0.4, the probability that "no one" (i.e.,

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139. This is consistent with much of the economic literature on races to invent, which uses game theory to model the optimal commitment of resources to inventions pursued by a group of competitors. *See, e.g.*, Jennifer F. Reinganum, *A Dynamic Game of R and D: Patent Protection and Competitive Behavior*, 50 ECONOMETRICA 671 (1982).

140. In a sense, this step is not technically correct since the outcomes of research at each firms are not truly independent. True independence would require an *ex ante* estimate of P so good that information about the success or failure of other firms would not affect it. This is not the case here since such information would affect an *ex ante* estimate of the tractability of the research problem thereby affecting P.

this firm) does succeed is $(1 - 0.4)$ or 0.6. Likewise when two firms are doing the research, the chance that neither will succeed is $(1 - P)^2 = (0.6)^2 = 0.36$, and so on.

This should establish that $(1 - P)^n$ is the proper measure of the probability that no one succeeds. But what is the probability that at least one firm will succeed? It is $1 - (1 - P)^n$. To verify, consider the example of one firm, i.e., where $n = 1$. Then the chance of success will be $(1 - (1 - P))$; if $P = 0.4$, this will be 0.4, which certainly makes sense. What about when $n = 2$? For $P = 0.4$, the probability that at least one of the firms succeeds will be $1 - (1 - 0.4)^2$, or $1 - 0.36$ or 0.64. This makes intuitive sense, since two firms with a 40% chance of success should have, one would think, a better than even chance of succeeding.

Anyhow, from society's point of view, the expected value of a research project should equal its anticipated monetary benefits multiplied by its probability of success; that is:

$$\text{Expected benefit} = (\text{Benefit}) \cdot (\text{Probability}) \qquad (1)$$

As discussed above the probability should be equal to $1 - (1 - P)^n$. Thus, (1) should be written:

$$\text{Expected Benefit} = \text{Benefit} \cdot (1 - (1 - P)^n) \qquad (2)$$

Just for convenience, set the benefit of a given project equal to 1. Now this term can be disregarded for purposes of the model. But keep in mind that the real value this term takes on will be some number much higher than $1.00. (If it helps, think of it as "one research payoff unit," and set it equal to $1 million or $10 million in your mind.)

We have discussed two elements of the research problem so far, the expected benefit (benefit times probability of success) and the number of firms researching the problem. It is reasonable to ask at this point, "How are they related?" The answer lies in Figure 6.

This tells us that as the number of firms rises, the expected benefit increases, but at a decreasing rate. (The curve is "concave.") This makes some sense—at some point, there will be so many firms that an additional one does not increase the probability of success much, and thus it adds little to expected benefit.

What about the cost of research? That would seem to be important too. Recalling our assumption above that cost is a constant multiple of the number of firms undertaking research projects, we can add a cost curve to Figure 6; this has been done in Figure 7.

Since cost is constant, total cost will always be the straight line described by the equation c times n.

Now we can begin to analyze the situation from society's point of view. What is the optimal number of firms, n, we would want

conducting this research project? The answer is that number that maximizes the *net* social benefit of the research—that is, the number of firms where the difference between benefits and cost is the greatest. In terms of our model, then, the problem is to maximize the difference between $1 - (1 - P)^n$ and $c \cdot n$.

The maximum difference will be where the slope of the $c \cdot n$ line is equal to the slope of our concave benefit function, $1 - (1 - P)^n$. This is indicated by "n^*" on Figure 8.

So from an optimal social planner's point of view, the best this society can do to efficiently pursue this research project is to put n^* firms to work on it. But even if the firm that was successful, or that was both successful and first, if more than one were successful, could appropriate all the social benefits of the research, the outcome would be different. Even if the potential researching firms knew how many other firms had decided to pursue the project, they would run though the calculations themselves and decide to pursue the project so long as their own investment was likely to pay off—that is, in terms of the model, so long as the number of firms was such that the addition of this firm would not cause the $1 - (1 - P)^n$ curve to cross the $c \cdot n$ line. That is, in terms of Figure 8, so long as the number of firms, n, would still be less than or equal to n_o.

But is it reasonable to assume that the successful firm with its patent gets all the social benefits? Quite clearly, the answer is no. Empirical research has mounted in the last few years, showing that firms do not capture all or even a large part of the social benefits their research generates. This is known in the literature as the appropriability problem.[141]

Thus another variable must be introduced into the model to signify that a firm can only hope to capture a fraction of the social benefits its research generates. This variable is fraction *A*, the appropriability factor. In terms of our graph, *A* is a constant; the degree of appropriability does not change with the number of firms pursuing the research. Thus, since *A* is some fraction of the total social benefits, which we have defined as 1, a curve drawn to signify a *firm's* view of the expected benefits of research will look like the *A* curve in Figure 9.

Focusing on the *A* curve for a moment, let's consider how it affects the number of firms that would engage in the research project. Recall that what a firm cares about are the benefits of the project, the probability that it will be successfully concluded by at least one firm, and its cost. The middle concern is important here. It means that firms deciding whether to enter the research competition will keep an eye on their competitors. Any one firm will decide to invest so long as its contribution to the probability of success increases the expected benefit more than the

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141. *See, e.g.*, Levin et al., *supra* note 10.

contribution costs. If a large number of firms have already decided to work on the project, a firm will not want to invest in research, since its investment will add less to the expected payoff than it costs.

One way to see this is to view participation in the project, i.e., a decision by a single firm to try the research project itself, as the purchase of a lottery ticket. The question the firm asks is, is it worth it to play? The answer will be determined by comparing the expected benefits of playing against the cost of doing so. The benefits, of course, depend on how many other firms have decided to play; this is because in the model expected benefit equals probability of success times payoff, with payoff fixed at 1. Thus expected benefit depends on the probability of success, which is evaluated according to the formula $1 - (1 - P)^n$. As n rises, the value of this formula falls. Thus a firm trying to decide whether to enter will look at how many other firms have entered the research project or "game."

When will it decide to play? When the benefits are greater than or, at the very least, equal to the cost of playing. When will this be? This happens when c is equal to the firm's expected benefit. What is the firm's expected benefit in relationship to the number of participating firms? Recall that the probability of winning is defined as the probability *that at least one* firm will succeed. This means that, from the entering firm's point of view, it is the total number of participating firms that counts. In other words, it is unconcerned with its *marginal* contribution to expected benefits. So long as the total number of firms, after it joins, is expected to produce benefits that outweigh total cost, it makes sense to join.[142] In other words, so long as after joining the average benefit (expected benefit divided by the number of firms) is greater than or equal to the average cost, the firm will join.[143] On the graph, this is shown as the point where the $A(1 - (1 - P)^n)$ curve intersects the $c \cdot n$ line, shown as n_e in Figure 10.

This is the equilibrium entry point in our model—the point that represents how many firms would elect to attempt the research for a given probability (P) and level of appropriability (A).

One interesting result from this is that for given (and probably realistic) levels of appropriability, the equilibrium number of firms (n_e) will be less than the socially optimal number (n^*). Society is losing at these values of n_e—fewer than the optimal number of firms will try the research project. On the other hand for some levels of appropriability,

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142. *See* Wright, *supra* note 49, at 49-56.

143. In terms of the model, we would set $A(1 - (1 - p)^2)/n$, average benefit, equal to average cost, which is $c \cdot n/n$ or c. Thus, after multiplying though by n, we would have: keep investing until $A(1 - (1 - p)^2) = c \cdot n$. Remember that the model assumes that each firm has an equal chance of successfully completing the research and obtaining the patent, thus the division by n.

i.e., values of A, n_e will be greater than n^*—and we will get too many firms trying their hand at the project.

Next we shall examine the optimal level of appropriability, A. Recall that A is a constant which, when multiplied by each value on the Benefit Curve $1 - (1 - P)^n$, produces what we have called the A curve. There is an optimal level of appropriability, A^*—some value of the appropriability factor—that makes the A curve cross the cost curve ($c \cdot n$) at the value of n^*. This is the socially optimal level of appropriation—the level that makes firms join the research until the total number of firms equals n^*. This is shown in Figure 11.

Now we will analyze the effects of a rise in the cost of doing research, c. Consider the rise from c_1 to c_2 in Figure 12. Note that such a rise in cost changes n^*, since higher c increases the slope of the $c \cdot n$ curve and hence changes the point at which the distance between the cost and benefit curves is greatest—n^*. Note further that a new n^* requires a re-calculation of A^*, the optimal appropriability factor, so as to arrive at a new A curve to cross the $c \cdot n$ curve at the new n^*. This is shown in Figure 12.

The important point to note about this diagram is that the rise in cost, leading to a rise in the $c \cdot n$ line, forced a rise in A^*, to bring the A curve up high enough to cross the new $c \cdot n$ at the new n^*, n^*_2.

This is the point of the whole exercise: a rise in cost, especially a steep one, will of necessity require a rise in appropriability, A, to keep the optimal number of firms in the research project. We have previously noted that A has two components—the probability of receiving the benefit of success times the magnitude of the benefit. Assuming the magnitude of the benefit is fixed, we must raise the probability of receiving it. Since this is the factor we have modeled as the probability of getting a patent, the implication is clear: the probability of getting a patent must be raised in order to offset the higher cost of research. This translates quite simply into a straightforward policy recommendation: *lower* the standard of patentability—i.e., increase the probability of getting a patent—when the cost of performing research is high.
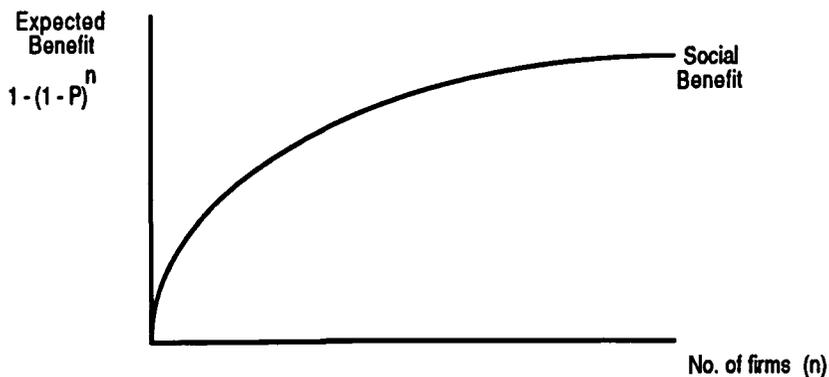
Expected
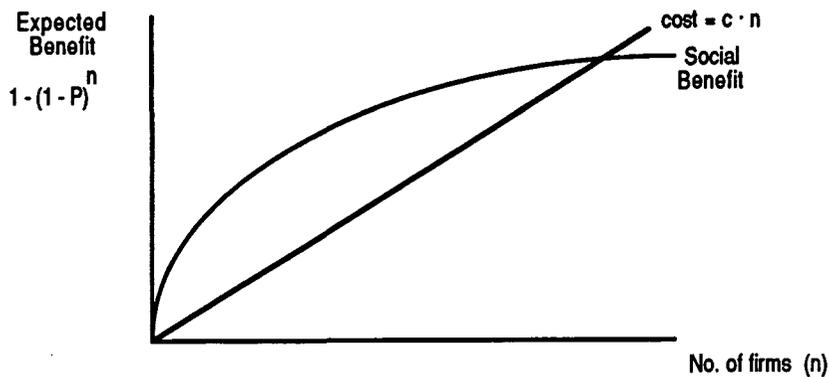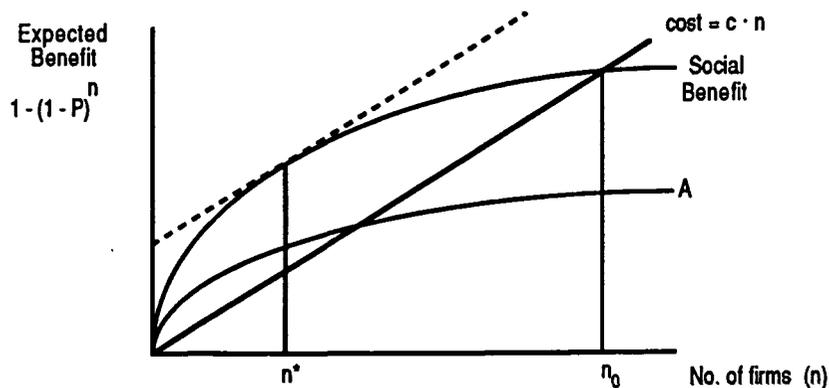Benefit

$1 - (1 - P)^n$

Social
Benefit

No. of firms (n)

Figure 6

Expected
Benefit

$1 - (1 - P)^n$

cost = c · n

Social
Benefit

No. of firms (n)

Figure 7

Expected
Benefit

$1 - (1 - P)^n$

cost = c · n

Social
Benefit

A

n^* n_0 No. of firms (n)

Figure 8

Expected
Benefit

$1 - (1 - P)^n$

Social
Benefit

A

No. of firms (n)

Figure 9

Expected
Benefit

$1 - (1 - P)^n$

cost = c · n

Social
Benefit

A

n^* n_e n_0 No. of firms (n)

Figure 10

Expected
Benefit

$1 - (1 - P)^n$

cost = c · n

Social
Benefit

A^*
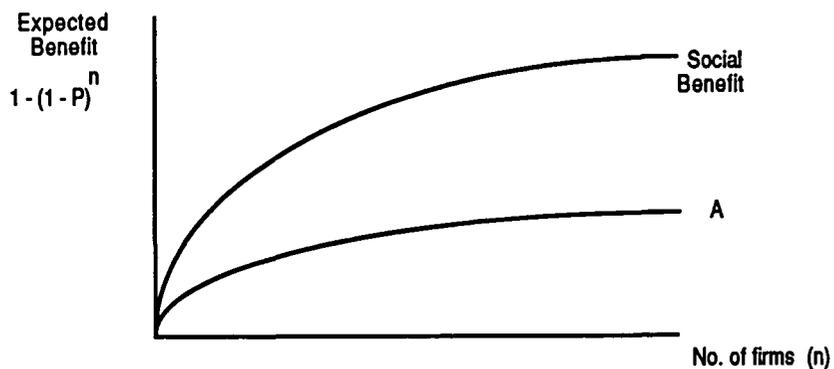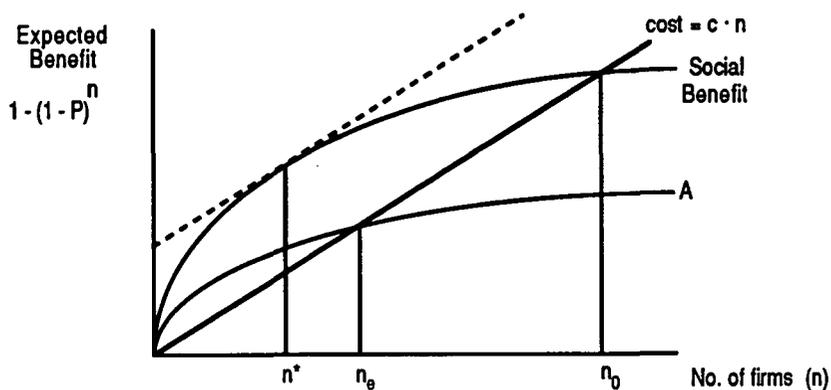
n^* n_0 No. of firms (n)
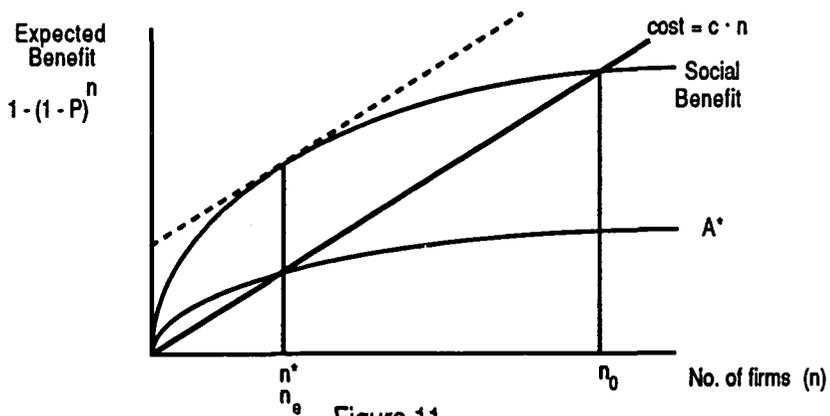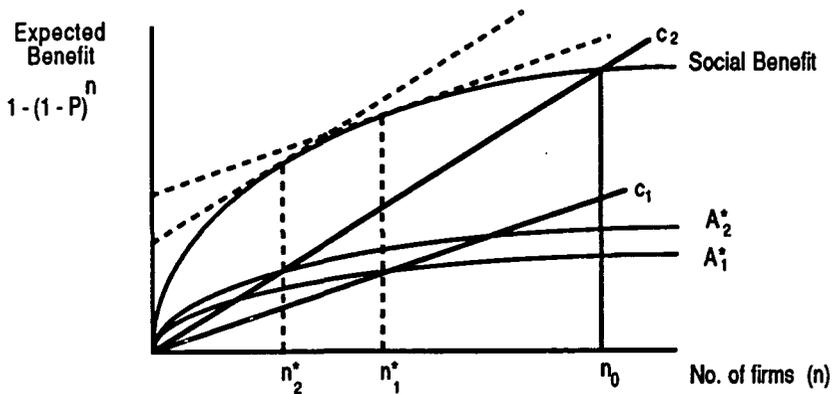n_e
           Figure 11

Figure 12

V. THE STANDARD OF PATENTABILITY AND THEORIES OF THE PATENT SYSTEM

Earlier we saw that there are several competing theories of the patent system, and that two—the incentive theory and the disclosure theory—are most prominent. While these two are not inconsistent, they do emphasize different benefits from patents. For the incentive theory, the important function of the patent system is to encourage those who would otherwise not invent to put the effort into an invention. Under this theory the public benefits two ways: by having the inventor's product or process enter into the economy, and by having access to the information the inventor produced, in the form of the patent specification.

This latter benefit is really at the heart of the disclosure-for-monopoly theory. Under this view the chief benefit of a patent is that it adds to the stock of public technical information. The incentive theory, then, tends to emphasize the economic importance of the patentee's invention, with the informational content of the patent a second-order benefit. Disclosure-for-monopoly theory emphasizes the information embodied in the invention as the inventor's primary contribution to economic activity.

Fortunately for purposes of this discussion, a choice between them need not be made. For whether patents encourage the introduction of new devices or simply the disclosure of new information, the nonobviousness test serves a vital gatekeeping function.[144] It may be to

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144. One view, moreover, would eliminate the distinction between "product" and "information" altogether. *See* HAROLD DEMSETZ, *The Theory of the Firm Revisited, in* OWNERSHIP, CONTROL AND THE FIRM 144, 159-60 (1988):

> Because it is uneconomical to educate persons in one industry in the detailed knowledge used in another, recourse is had to developing or encapsulating

deny rewards to truly insignificant devices. It may be to weed out truly
unimportant information. Either way, its function is to distinguish the
patentable from the unpatentable, and hence insure that whatever is
patented serves some minimally useful function—either invention as
useful device, or invention as information.

Even so, the disclosure theory provides a perhaps more convincing
rationale for the nonobviousness standard. For the most part, a patent
application is filed long before the invention it describes goes into use.
While most patent applications take an average of two years to reach a
final decision in the Patent Office, they are still likely to be issued before
the invention is used. However, as soon as the patent issues, it is
available to the public. Thus even if the invention never goes into
widespread use, the information in the patent specification is in the
public domain, ready to serve as a source of information to anyone in the
relevant technical community who is interested.

Because every patent is available for its information content
regardless of whether it is ever embodied in a commercial product, a
better defense of the patent system is to emphasize this informational
role. This way, the system is not solely justified on the basis of the
relatively small number of patented inventions that achieve widespread
success, and hence directly contribute to economic activity. Although the
informational value of the average patent may be quite modest compared
to the commercial significance of this handful of important patents, every
patent can at least claim to contribute something to the economy via its
information content.

Importantly, patents result in the production of *public* (as opposed
to secret or private) information. When a patent is issued, it is published;
it becomes available to anyone interested in the relevant technology. The
disclosure theory emphasizes the importance of technical information to
technical advance, and is consistent with empirical and anecdotal
evidence highlighting the importance of patents as a source of technical
information.[145] Moreover, disclosure theory recognizes that inventors

this knowledge into products or services that can be transferred between
firms cheaply because the instructions needed to use them do not require in-
depth knowledge about how they are produced .... Roughly speaking ...
the vertical boundaries of a firm are determined by the economics of
conservation of expenditures on knowledge.

145. Although the value of technical information in patents is often questioned, *see, e.g.*,
Susan Scotchmer & Jerry Green, *Novelty and Disclosure in Patent Law*, 21 RAND J. ECON. 131
(1990), actual researchers, at least in some fields, do appear to refer to patents as a source
of useful information. *See, e.g.*, Gerald M. Murphy, Jr. & Leonard R. Svensson, *What
Patents Teach*, 20 CHEMTECH 146 (1990); J.B. van Benthem, Book Review, 16 INT'L REV.
INDUS. PROP. & COPYRIGHT L. 123, 124 (1985) (emphasizing "the significance of
comprehensive patent documentation as a source of technical knowledge, which is of
value at all stages of the innovative process, and particularly in avoiding ill-advised

have the option of keeping their information secret. Although for many industries, trade secrecy has certain disadvantages compared to obtaining patents, even in these industries it is often a second-best form of intellectual property protection. Disclosure theory recognizes this, and underscores the fact that inventors must be enticed to make their knowledge public. And finally, disclosure theory is in keeping with a general trend in economic theory to appreciate the importance of information in organizing economic activity.[146]

Certainly an emphasis on information content is consistent with the compensation-for-disclosure theory. Stressing the technical information in a patent, moreover, is specifically useful in the context of a discussion of the standard of patentability. This is primarily because, at least during the prosecution of the patent application, the ultimate commercial value of the invention is rarely known with any degree of certainty. Thus it makes sense to view the Patent Office's job not as an assessment of the possible value of the invention in action, but instead as an evaluation of

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investment when research and development projects are being prepared") (citing Erich Häußer, *Mehr Innovation durch Bessere Information, in* PATENTWESEN, *supra* note 30, at 133); *Gleaning Corporate "Secrets" from Patents,* 8 CHEMTECH 532 (1978); Harry M. Allcock & John W. Lotz, *Patent Intelligence and Technology—Gleaning Pseudoproprietary Information from Publicly Available Data,* 18 J. CHEM. INF. & COMPUTER SCI. 65 (1978); *cf.* Lothar Scholz & Heinz Schmalholz, *Patentschutz und Innovation, in* PATENTWESEN, *supra* note 30, at 204 (stating that 10% of project innovators surveyed stated that the immediate impetus for a particular research project had come from information in patent specifications). Second, some scholars studying the interdependencies between technological fields, and the basic research-commercial product linkage, present data showing that patents are often cited in scientific articles—an indication that they contain technically useful information. *See, e.g.,* Mark P. Carpenter et al., *Citation Rates to Technologically Important Patents,* 3 WORLD PAT. INFO. 160 (1981); Mark P. Carpenter et al., *Linkage Between Basic Research Literature and Patents,* RES. MGMT., Mar. 1980, at 30. (For a good review article on the whole field of "patent bibliometrics," see Bjørn L. Basberg, *Patents and the Measurement of Technological Change: A Survey of the Literature,* 16 RES. POL'Y 131 (1987).) Third, detailed case studies of particular industries demonstrate that patents played an important disclosure role in the development of many technologies. *See, e.g.,* Michael E.D. Koenig, *A Bibliometric Analysis of Pharmaceutical Research,* 12 RES. POL'Y 15, 28-29 (1983). And finally, some commentators have even suggested that the line between science and technology is becomingly increasingly blurred. One of the arguments made in support of this thesis is the cross-citation betweeen patents and scientific articles. F. Narin & E. Noma, *Is Technology Becoming Science?,* 7 SCIENTOMETRICS 369 (1985).

146. *See* KENNETH ARROW, THE LIMITS OF ORGANIZATION (1974) (the firm is a rational response to the limited information-processing capabilities of individuals); 2 HERBERT A. SIMON, MODELS OF BOUNDED RATIONALITY: BEHAVIORAL ECONOMICS AND BUSINESS ORGANIZATION 71-73 (1982) (introduction to series of papers on "The Economics of Information Processing"); OLIVER E. WILLIAMSON, THE ECONOMIC INSTITUTIONS OF CAPITALISM 51, 82-83 (1985) (discussion of importance of "informational asymmetry," where one party to a contract has more information than another; this is a key feature of transaction-cost economics); *see also* ALFRED D. CHANDLER, STRATEGY AND STRUCTURE (1962) and ALFRED D. CHANDLER, SCALE AND SCOPE (1990) (detailed historical/empirical evidence for the proposition that the organization of a firm is a rational response to the physical and informational demands of its particular business).

the significance of the inventor's contribution to technical knowledge.[147] And, importantly, those familiar with patents have long cited the disclosure theory as the fundamental rationale of the system.[148]

Under disclosure theory, the role of the Patent Office is to police the "contract" between society and the inventor. In fact, older cases often referred to patents as contracts in this sense.[149] Recall that the terms of this contract are that the inventor gains a monopoly good against society, in exchange for disclosure of the inventor's information. The Patent Office is then in a sense acting to insure the adequacy of the inventor's contribution—guaranteeing that the inventor is providing sufficient

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147. The disclosure requirement in § 112 of the patent code can be seen in this connection as a requirement that the patentee submit information in a form that is transferable to other experts in the relevant field. *See infra* part VI. It should be noted, however, that empirical studies show that the value of pure technical information, unembodied in particular products or (especially) people, is lower than many economists once assumed. This is evident from a series of studies of the market for licensed technology, where returns to the licensor are usually quite low. The explanation is that the transfer of pure information—what the authors sometimes call the "blueprint" view of technology—is subject to a variety of problems, including difficulties of transmission and possibilities of intentional obfuscation and misleading disclosure. *See, e.g.,* DAVID J. TEECE, THE MULTINATIONAL CORPORATION AND THE RESOURCE COST OF INTERNATIONAL TECHNOLOGY TRANSFER 44 (1976) (transfer costs constituted 19% of total project costs in international projects studied); FAROK J. CONTRACTOR, INTERNATIONAL TECHNOLOGY LICENSING: COMPENSATION, COSTS, AND NEGOTIATION 105 (1981) (transaction costs averaged over $100,000 for licensing deals studied); FRANCIS BIDAULT, TECHNOLOGY PRICING: FROM PRINCIPLES TO STRATEGY 126, 127 (Brian Page & Peter Sherwood trans., 1989) (possibility of opportunism); David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy,* 15 RES. POL'Y 285, 294 (1986) (transaction costs affect ability to license efficiently); *see also* Robert P. Merges, Patents and Transaction Costs (Sept. 1992) (unpublished draft, on file with author).

148. *See, e.g.,* 11 WILLIAM HOLDSWORTH, A HISTORY OF ENGLISH LAW 424, 427 (1938) ("Under the old practice [before the eighteenth century] the consideration for the [patent] grant was the introduction into, and working of, a manufacture which was new to Great Britain. Under the new practice the new consideration is the written disclosure of the invention contained in the specification."); 1 WILLIAM C. ROBINSON, THE LAW OF PATENTS FOR USEFUL INVENTIONS § 41, at 61 (Boston, Little, Brown & Co. 1890) (stating that one of the "fundamental grounds" on which the patent grant rests is "[t]hat the inventor, having made such an invention as is entitled to the patent privilege, must communicate it to the public by publishing an accurate description of its character and uses"); 1 *id.* § 43, at 66 (speaking of the inventor's "reward for his disclosure" as the patent monopoly). Although the jury instructions by Lord Mansfield in *Liardet v. Johnson* (K.B. July 18, 1778), which stipulated that a patentee must file a full and detailed specification to qualify for a patent, are often said to have enshrined the disclosure theory in patent doctrine, recent scholarship suggests that the growing reliance on specifications reflected the need to distinguish one patent from another. *See* CHRISTINE MACLEOD, INVENTING THE INDUSTRIAL REVOLUTION: THE ENGLISH PATENT SYSTEM, 1660-1800, at 49-53 (1988); John N. Adams & Gwen Averley, *The Patent Specification: The Role of* Liardet v. Johnson, 7 J. LEG. HIST. 156 (1986).

149. *See, e.g.,* Century Elec. Co. v. Westinghouse, 191 F. 350 (8th Cir. 1911). *See also* 1 ROBINSON, *supra* note 148, § 40, at 58-59 ("[A patent] is a true contract, to the stipulations in which each party is bound with the same strictness as in any other contract, and which is to be interpreted in the same manner as other legal obligations." (footnote omitted)).

consideration for the contract. The Patent Office thus acts as society's agent in negotiating a disclosure agreement with an inventor. And nonobviousness is the standard society has given the Patent Office in evaluating which "deals" it considers worth making.[150]

Ultimately, then, the nonobviousness test determines the quantum of information an inventor must supply. To state the test in the terms developed above, it assures society that the information produced by the patentee is sufficient to overcome a good deal of uncertainty in some technical area. Stating the test this way directly links two important concepts in my analysis: the value of the information and the degree to which it clears up uncertainty. And it is consistent with contemporary thinking about information, which many economists have defined as that which overcomes uncertainty.[151]

VI. CONCLUSION

This article has explained the economic function of the nonobviousness standard of patentability: to encourage research that is highly uncertain. Various doctrinal features—including the "obvious-to-try" (non)standard, the irrelevance of in-house research to the obviousness of a firm's inventions, and the rationale for protecting both methodical and serendipitous inventions—have been organized and explained under the rubric of uncertainty. And a modest lowering of the standard has been proposed for research which is very expensive in the early stages.

This article has also highlighted several underappreciated facets of the patent system, which are made clear by an emphasis on the nonobviousness standard. First is the importance of the technological information contained in each patent specification, a feature which most clearly manifests the disclosure theory of the patent system. Second is the fact that patents may spur development more than invention per se.

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150. This way of examining the problem bears some resemblance to Vic Goldberg's reconceptualization of regulatory agencies. *See* Victor P. Goldberg, *Regulation and Administered Contracts*, 7 BELL J. ECON. 426 (1976); *cf.* Seymour v. Osborne, 78 U.S. (11 Wall.) 516, 533 (1871) (referring to patent as a governmentally-granted "franchise").

151. *See, e.g.,* MACHLUP, *supra* note 1, at 25-26 ("Economic decisionmakers as a rule seek more knowledge when they think that the cost of acquiring it will be less than the disadvantages due to their ignorance and uncertainty."); Stigler, *supra* note 88, at 224; J. Hirshleifer & John G. Riley, *The Analytics of Uncertainty and Information—An Expository Survey*, 17 J. ECON. LIT. 1377 (1979). There is a well-developed literature on jobseekers' investments in information to reduce uncertainty about possible openings and wages; see MACHLUP, *supra* note 1, at 78-99; J.J. McCall, *Economics of Information and Job Search*, 84 Q.J. ECON. 113 (1970).

Interestingly, this may in fact be such an important function that it more than outweighs the contribution patents make to incentives to invent.[152]

Throughout, the article has assumed that firms care what the standard of patentability is, and that minor changes in the standard can exert subtle marginal influences on the rate and direction of firm-level R&D. As the literature on the economics of particular patent doctrines expands, it is hoped the analysis presented here and in related works can serve as a rudimentary model for considering the economic consequences of specific patent rules.

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152. The incentive-to-develop concept may show other benefits of the patent system, especially vis-à-vis alternative mechanisms for rewarding research such as the R&D tax credit. One advantage of patents over the R&D tax credit is that the latter benefit accrues as soon as research is begun, and therefore cannot be used to selectively reward more promising R&D. Patents are different. Especially when viewed as incentives to develop technology, patents have the advantage of not rewarding all research indiscriminately; they only reward potentially promising research (thanks to the nonobviousness standard). It is interesting to note in this connection that firms try to characterize as many expenses as possible as R&D-related for purposes of the R&D tax credit, and that the regulations on this matter are complex and difficult to administer. *See* J. CORDES, *A Survey of Research Findings on the R&D Tax Credit, in* THE R&D TAX CREDIT: ISSUES IN TAX POLICY AND INDUSTRIAL INNOVATION 5, 11 (1984). The nonobviousness standard in patent law eliminates the need to justify R&D expenses—the input to R&D—by measuring the technical merits of inventions—the output of R&D. While it is not irrational to advocate an indiscriminate tool such as the R&D tax credit, the details of this instrument, as well as the debate on it merits, might be enhanced by recognizing the complementary and in some ways superior features of patents.