

# Washington University Journal of Law & Policy

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Volume 2 *Re-Engineering Patent Law: The Challenge of New Technologies*

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January 2000

## Patents as Incomplete Contracts: Aligning Incentives for R&D Investment with Incentives to Disclose Prior Art

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### Recommended Citation

Jay P. Kesan and Marc Banik, *Patents as Incomplete Contracts: Aligning Incentives for R&D Investment with Incentives to Disclose Prior Art*, 2 WASH. U. J. L. & POL'Y 023 (2000), [https://openscholarship.wustl.edu/law\\_journal\\_law\\_policy/vol2/iss1/3](https://openscholarship.wustl.edu/law_journal_law_policy/vol2/iss1/3)

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## Part I: Administrative Law Issues

### Patents as Incomplete Contracts: Aligning Incentives for R&D Investment with Incentives to Disclose Prior Art

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#### I. INTRODUCTION

##### *A. Patents as Contracts: Incentives for Investment in R&D*

Biotechnology inventions synthesized through recombinant DNA technology, such as genetically-modified crops and hormones, are the products of large investments in research and development (R&D).<sup>1</sup> By conferring rights to the inventor to exclude others from making, using, or selling a patented invention without a license, patents provide incentives for inventors to invest in costly and risky R&D.<sup>2</sup> Patents also encourage the dissemination of information about new inventions, thus permitting competitors to build upon or develop improved versions of patented inventions. While patents create

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1. For a good review of the science and business of biotechnology and its relationship to the patent system, see Dan L. Burk, *Biotechnology and Patent Law: Fitting Innovation to the Procrustean Bed*, 17 RUTGERS COMPUTER & TECH. L.J. 1, 5-24 (1991).

2. For discussions on the various economic incentive-based theories of patent protection, see Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017 (1989); Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265 (1977); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990).

incentives for investment in R&D, they also impose social costs such as reduced levels of competition or wasteful design-around efforts by competitors. Thus, efficient patent systems aim to induce investment in R&D while limiting losses due to market power.

The fact that market power can be mitigated by limiting the scope of patent protection influences patent enforcement policy. This mitigation is accomplished by granting narrowly defined patents as opposed to broad ones and by maintaining post-issuance opportunities to invalidate patents that fail to meet the statutory requirements of patentability—including novelty, utility, nonobviousness, and enablement. While these strategies increase public welfare by creating more competitive markets, they also create uncertain property rights that make it more difficult for patent holders to appropriate the surplus of their inventions. Weak or uncertain intellectual property rights may thus reduce incentives for investment in high technology R&D.<sup>3</sup>

Patent policy makers must consider not only the elements that distort perfect competition, but also the ways in which a policy distorts investment incentives for R&D. In this Article we propose that viewing patents as *incomplete* contracts is a useful means to analyze the relationship between legal institutions of patent enforcement and investment in R&D. It is helpful for one to consider first why many view a patent as a contract: in exchange for disclosure of the invention, the public's agent, the U.S. Patent & Trademark Office (PTO), grants the patentee a limited right to exclude others from making selling or using the invention. Thus, the quid pro quo of the patent system provides the patentee with a limited property right in exchange for adequate disclosure about the invention. Describing patents as contracts also suggests that policy makers should apply the Coase theorem to propose an optimal patent policy.<sup>4</sup> Patent policy that creates well-defined property rights leads to efficient use of social resources, such that new innovations will be introduced to

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3. See JEAN O. LANJOUW & MARK SCHANKERMAN, PATENT SUITS: DO THEY DISTORT RESEARCH INCENTIVES? (1998) (noting that patent infringement suits in our legal system dilute and distort R&D incentives).

4. R.H. Coase, *The Problem of Social Cost*, 2 J. L. & ECON. 1, 25 (1959) (outlining the importance of rules for fixing initial allocations of resources with which parties can bargain for exchanges to increase joint profits).

meet society's demand for new technology. While analyzing patent policy in the same way as other property rights is an attractive proposition, several differences between patents and other property rights are crucial.

Patents, unlike many other property rights, may be rescinded after they have been granted. Patents may be rescinded either because the patent may be invalidated or the scope of patent protection may be modified in post-issuance litigation. Thus, a patent may be viewed as a contingent property right. Investors in R&D projects will view the patent in terms of a probabilistic property right, where the probability of invalidation reduces the expected return of an R&D investment project.<sup>5</sup> Another important distinction has to do with the R&D process itself: an investor must commit to R&D expenditure without knowing whether the benefits of the project will accrue to the patentee because the patent still runs the risk of invalidation. Such information may be costly to obtain prior to investing, because the investor does not know enough about the invention until it is made. Therefore, the public cannot "contract" with the inventor to create a new invention but instead must establish patent enforcement rules by which a patent may be invalidated. As Coase envisioned, such rules may be difficult to specify in sufficient detail so as to work in the same manner as a property right.

We propose that patents are incomplete contracts because they create contingent property rights, which in turn reduce incentives for investment in R&D. Reduced levels of R&D investment retard the rate at which new technologies are delivered to the public.<sup>6</sup> The literature on this slowed rate (hold-up) explains reductions in investment of specific capital in terms of opportunistic behavior or informational asymmetry.<sup>7</sup> We wish to distinguish these losses from the losses that occur as a result of the gap-filling of incomplete contracts between the patentee and the PTO. The gap-filling or

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5. See LANJOUW & SCHANKERMAN, *supra* note 3.

6. See *id.* (noting that incentives for R&D and entry are weakened by patent enforcement systems).

7. See, e.g., Benjamin Klein et al., *Vertical Integration, Appropriable Rents, and the Competitive Contracting Process*, 21 J.L. & ECON. 297 (1978); Oliver E. Williamson, *Transaction-Cost Economics: The Governance of Contractual Relations*, 22 J.L. & ECON. 233 (1979).

default rules correspond to the substantive rules in patent law that allow opportunities for invalidating a patent.<sup>8</sup> In other words, these default rules confer broad *residual rights* to the public to invalidate a patent through post-issuance litigation.

The theoretical model developed here applies to and builds on Grossman and Hart's model of incomplete contracts in the patent system and the process of technology commercialization.<sup>9</sup> We view the inventor and the PTO as vertical partners in a technology commercialization process that ranges from R&D investment to patent issuance. The decision variables in this process are the amount of prior art disclosed during patent prosecution and the presumption of validity accorded to the prior art disclosed by the patentee.

We begin by defining incomplete contracts and then introduce the technology commercialization process in Section II. In Section III we develop the model, and in Section IV we apply it to analyze the impact of different patent policies in high and low (or well-established) technology fields of invention.

Our core insight in this Article is the following: in the case of high technology patents where the PTO is poorly informed about the relevant prior art, it may be optimal for the PTO to provide incentives to the patentee to produce a complete prior art disclosure. Such incentives could accord a specific, high presumption of validity<sup>10</sup> to the disclosed prior art, thereby limiting the use of the disclosed prior art for invalidation purposes in subsequent (*i.e.*, post-issuance) litigation. We show that a regime that trades a reduction in post-issuance litigation uncertainty for a complete prior art disclosure maximizes social welfare because it benefits both the patentee and the PTO. The patentee favorably views the reduction in litigation uncertainty and greater control over the possibility of patent invalidation, which induces higher levels of *ex ante* investment in

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8. See, e.g., 35 U.S.C. § 102 (1994).

9. Sanford J. Grossman & Oliver D. Hart, *The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration*, 94 J. POL. ECON. 691 (1986).

10. The presumption of validity that we are proposing is different from the general presumption of validity associated with every granted patent in 35 U.S.C. § 282 (1994). Under our proposed presumption of validity to be specifically accorded to disclosed prior art, a court will not invalidate a patent based on disclosed prior art unless it is convinced that no reasonable examiner would have allowed the patent in light of the disclosed prior art.

R&D. From the public's perspective a fuller prior art disclosure may allow the PTO to grant patent rights commensurate with innovation and to avoid the detrimental consequences of an overbroad patent grant.<sup>11</sup> In sum, this proposal is an incentive-compatible trade that maximizes joint social surplus.

### *B. Incomplete Contracts Defined*

Economists and legal scholars have used the term “incomplete contract” differently. The legal appreciation for incomplete contracts has been in understanding how the rights and obligations of each party remain unspecified as a result of gaps in the literal language of a contract. A contract is “obligationally” or literally incomplete if some of the details of the contract, such as price, delivery time, or technical specifications remain unspecified for a set of circumstances in which the contract is to apply.<sup>12</sup> In this regard, much of the legal focus on incomplete contracts is in determining the gap-filling role courts should play in specifying the default rules (such as good faith) that apply to contracts.

Default rules eliminate literal incompleteness by specifying the terms of a contract when the parties fail to do so. Any contract is thus made literally complete as a result of default rules that attach to an incomplete contract. Default rules may take the form of general terms that specify price, delivery date, or other details *outside* specific terms of the contract.

On the other hand, the economist's definition of incomplete contracts refers to the ex post efficiency of contractual outcomes. Does the contract allow the joint surplus of the parties to be maximized by taking into consideration the buyer's marginal valuation of the good and the seller's cost? A contract is economically incomplete if it fails to induce Pareto-improving trade in all of the relevant contractual contingencies. Such contracts are

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11. Here we are assuming that the PTO is able to appreciate the import of the prior art disclosed to it by the patentee.

12. Ian Ayres & Robert Gertner, *Strategic Contractual Inefficiency and the Optimal Choice of Legal Rules*, 101 YALE L.J. 729 (1992). See also Ian Ayres & Robert Gertner, *Filling Gaps in Incomplete Contracts: An Economic Theory of Default Rules*, 99 YALE L.J. 87 (1989) [hereinafter Ayres & Gertner, *Filling Gaps*].

thus “state contingent” incomplete because the immutable terms of the contract prevent parties from engaging in mutually beneficial trade.<sup>13</sup> Economic incompleteness is viewed with reference to “states of the world” because these factors determine a buyer’s willingness to pay and a seller’s costs. For instance, the value of a gallon of water will be higher to the buyer during a drought than during a flood. Yet, if a contract fixes the price of water (either through literal specification or by default rules) at a price that does not vary with the weather, the market will not clear, leaving some buyers unserved or creating a glut in all but a small range of prices. These outcomes are not ex post efficient because both parties could benefit (buyer could get water, seller could get a better price) if the contract terms were renegotiated. The contract is therefore economically incomplete because it does not lead to an ex post efficient outcome.

Only relatively recently did legal audiences consider this form of incompleteness, that is the efficiency considerations of trading rules, in deciding the role the courts should play in gap-filling or in the interpretation of default rules. For example, Hadfield analyzes the roles efficiency-minded courts should play in determining the damages for breach when they are limitedly competent.<sup>14</sup> She proposes that even a limitedly informed court can enhance welfare by enforcing a liability standard, as opposed to a bright line rule, because the former induces changes in the contracting partner’s ex ante behavior, while the latter does not.<sup>15</sup> In a similar vein, Ayres and Gertner have argued against the conventional wisdom that courts should enforce terms that maximize the joint surplus of the parties.<sup>16</sup> They contend that courts should maintain penalty defaults against the more informed party to a contract, so as to induce the parties to reveal

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13. See Ayres & Gertner, *Filling Gaps*, *supra* note 12. See also Benjamin E. Hermalin & Michael L. Katz, *Judicial Modification of Contracts Between Sophisticated Parties: A More Complete View of Incomplete Contracts and Their Breach*, 9 J.L. ECON. & ORG. 230 (1993).

14. Gillian K. Hadfield, *Judicial Competence and the Interpretation of Incomplete Contracts*, 23 J. LEGAL STUD. 159 (1994).

15. *Id.*

16. In this case the surplus refers to the profits of the parties to the contract, given that investments have already been made. In this model, we consider the case where joint surplus is increased as a result of incentives to invest in surplus-enhancing activities, such as R&D. See Ayres & Gertner, *supra* note 12. See also Charles J. Goetz & Robert E. Scott, *The Mitigation Principle: Toward a General Theory of Contractual Obligation*, 69 VA. L. REV. 967 (1983).

information that would lead to ex post efficient contracts.<sup>17</sup> These studies emphasize foremost that the terms of the contract itself can have important effects on ex post efficiency, as a result of the parties' means of dealing with literal incompleteness.

The relationship between literal incompleteness and economic incompleteness, therefore, depends on the role default rules play in filling the gaps of incomplete contracts. Contracts that avail themselves of many forms of literal incompleteness leave many gaps to be filled by default rules. To the extent that default rules create inefficient outcomes (because thin markets are created), literal incompleteness results in economic incompleteness. However, economic incompleteness may result from the court's inability to verify whether certain actions have been performed as desired by the contracting parties (for example, whether all relevant prior art known to the patentee has been disclosed during the course of patent prosecution to the PTO).

The premise of Grossman and Hart's incomplete contracts theory of ownership is non-verifiability.<sup>18</sup> In this model, a literally incomplete contract results because some activities of the contract may be observable to the person undertaking them yet are non-verifiable to the courts. These activities are what they term "non contractibles."<sup>19</sup> Gaps of literal incompleteness are filled not by default rules but rather by "residual rights" that enable one party to essentially specify the default rules that apply in contingencies outside the literal terms of the contract. Problems of verifiability are typically observed in the case of a two-stage production process, where optimal production decisions of the second stage are contingent upon the outcome of the first stage. A contract between the upstream and the downstream partner may be economically incomplete if it fails to induce the upstream (stage-one) partner from making investments that maximize the joint surplus of the parties. If the contributions of the upstream partner are observable but not verifiable to the courts, as when the technology is not separable, or the task to be performed is not programmable, the upstream partner

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17. See Ayres & Gertner, *Filling Gaps*, *supra* note 12.

18. See Grossman & Hart, *supra* note 9.

19. *Id.*

will not have any basis to appropriate the benefits from the diligent performance of his duties. The principal-agent model views this result as incentive incompatible. However, the important distinction is that the upstream partner, anticipating that the benefits will be appropriated by the downstream partner, will be reluctant to make surplus-enhancing investments in the first place.

Grossman and Hart suggest that an allocation of residual rights to the upstream partner would reduce this economic incompleteness.<sup>20</sup> In the following section, we build on this approach of optimal ownership by proposing that the R&D and patenting process can also be viewed as a vertical relationship between the patentee (inventor) and the PTO (public).

### *C. Patents as Incomplete Contracts*

The R&D and patenting process includes many of the sources of economic incompleteness described above. A patent may be viewed as a literally incomplete contract whose gaps are filled by rules of patent enforcement. These rules apply to prosecution, infringement, and invalidation. Patents can be economically incomplete contracts because the patent prosecution process may not make full use of the patentee's information about, for example, the novelty of the invention, and because the process does not provide adequate incentives for the patentee to reveal such information.

The R&D and patenting process also may be considered a joint production problem, where the patentee's investment in R&D and resulting claims of novelty are non-verifiable. One important distinction, however, is that the R&D investments that a patentee makes do not necessarily improve the surplus (as in the case of the relationship-specific capital assumed in the models of hold-up) to be shared by the patentee and the public. Such investments merely increase the chances of producing that surplus because the outcomes of R&D projects are not deterministic. Although the formal model we develop in this Article relies substantially on this latter view of R&D and the patenting process as a joint production problem, the notions of default rules and asymmetric information have clear applications

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20. *Id.*

to the patenting process.<sup>21</sup>

A patent is literally incomplete because invalidating prior art under the statutory standards is subject to judicial discretion.<sup>22</sup> Section 102 of Title 35 of the United States Code requires that an invention be new in order for it to be patentable.<sup>23</sup> If the invention has been described in a printed publication anywhere in the world more than twelve months prior to the filing date of a patent, the patent may be rendered invalid in post-issuance litigation.<sup>24</sup> Courts have ruled that a printed publication must be accessible to the public in order to invalidate prior art under section 102. However, the meaning of a “printed publication accessible to the public” is subject to judicial discretion. For example, in *In re Hall* the courts ruled that a doctoral dissertation catalogued in library archives constituted a printed publication within the grasp of the public’s knowledge, even though it may not have been actually accessible to an inventor or scientist.<sup>25</sup>

A patent may be viewed as an incomplete contract because the courts can attach a different legal significance to the claims of a patent *after* it has been issued. In *Amgen, Inc. v. Chugai Pharmaceutical Co.*, the court invalidated Amgen’s claim over any DNA segment that would encode for a hormone that stimulates red blood cell production, on the ground that the specification did not enable the broad scope of patent protection sought by Amgen.<sup>26</sup> In *Enzo Biochem, Inc. v. Calgene, Inc.*, the plaintiff asserted that Calgene’s FLAVR SAVR brand tomatoes incorporated genetic antisense technology that was covered in Enzo’s patents.<sup>27</sup> However, the court held that Enzo’s claims of infringement were not substantiated because the actual use of the Enzo patent was limited to antisense technology in *E. coli*, because the patent did not provide enabling information for use in plants and animals.<sup>28</sup>

One can view outcomes such as these as cases where institutions

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21. See *infra* Parts II and III.

22. 35 U.S.C. § 102 (1994).

23. *Id.*

24. *Id.* § 102(b).

25. 781 F.2d 897 (Fed. Cir. 1986).

26. 927 F.2d 1200 (Fed. Cir. 1991).

27. 14 F. Supp.2d 536, 541 (D. Del. 1998).

28. *Id.* at 541-70.

of patent enforcement create economically incomplete contracts, because literal incompleteness compels the court to resort to default rules. These rules allow a patent to be invalidated by several different contingencies not anticipated during patent prosecution. In the hypothetical situation of complete contracting, there would have been no uncertainty as to whether a prior art reference would render a patent invalid. Thus, reducing the extent of incompleteness in the patent contract would allow greater investment in R&D projects without incurring risks of being unable to appropriate the benefits of the project. In contrast, greater incompleteness in the patent contract creates opportunities for this type of ex post hold up, reducing the ex ante incentives for investment in R&D.<sup>29</sup>

A patent may be invalidated or the scope of a claim reduced as a result of incomplete or imperfect information about the state of the art. In this model, we suppose that in the case of high technology fields of invention, the patentee and the PTO are asymmetrically informed about the relevant prior art. Lack of knowledge about the prior art results in inefficient contracting between the patentee and the PTO, because the PTO, not being aware of such prior art (especially non-patent art), may grant overbroad claims for inventions already within the grasp of the public.<sup>30</sup> This information asymmetry thus allows the patentee to collect an information rent in the form of a license fee for a claim in a patent that may not be valid. In addition, competitors and improvers may expend resources to design around potentially invalid claims. When patent claims are granted for inventions already known to the public, they create disincentives for follow-on innovation. These disincentives ought not to exist as an initial matter because the public already knows the subject matter of the invention.

Litigation costs to invalidate such unwarranted patents also

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29. See LANJOUW & SCHANKERMAN, *supra* note 3.

30. See Robert P. Merges, *As Many As Six Impossible Patents Before Breakfast: Property Rights for Business Concepts and Patent System Reform*, 14 BERKELEY TECH. L.J. 577 (1999) (noting that there is a vast amount of non-patent prior art in the software-implemented business concept field that is unknown to the PTO); see also Andrew M. Riddles & Brenda Pomerance, *Software Patentee Must Conduct Own Search: Prior-Art Searches Made by the Patent Office Often Are Not Thorough Enough To Be Trusted*, NAT'L L.J., Jan. 26, 1998, at C19 (stating that the PTO is just a "registration process" for some types of software patents).

exacerbate welfare losses due to imperfect or asymmetric information. A patentee, holding a patent that could be invalidated in post-issuance litigation, may decide to set a license fee that is lower than the cost of litigation (*i.e.*, a sub-litigation cost license fee).<sup>31</sup> A potential infringer, not wishing to bear the risk and costs of litigation, may pay the license fee for an unenforceable patent.<sup>32</sup> As long as the costs of litigation and information acquisition for other infringers are significant, a patentee may continue to collect several small license fees. Indeed, as Lanjouw and Schankerman have shown, one of the determinants of the probability that a patent will be challenged is the size of the stakes, which corresponds to the license fee.<sup>33</sup> High license fees will make the costs of litigation and prior art retrieval worthwhile for potential infringers. Low license fees, in contrast, allow the patentee to escape invalidation by discouraging attempts to invalidate a patent.

Considerations like these inform firms' decisions whether to invest in R&D. Models of expected utility maximization, however, do not capture the important effects of public policies, such as rules of patent enforcement. Investing in an R&D project is different from an optimal lottery strategy, because institutions of patent policy could allow the inventor to have control over the probability of exploiting a valid patent (in other words, the probability of post-issuance patent invalidation). The control referred to here may manifest itself in terms of the prior art information the patentee can disclose to the PTO during prosecution. Thus, we are concerned with how patent policies that permit such tradeoffs might effect the initial decision to invest in R&D. We describe this in the context of the overall R&D and patenting process, which we refer to as the technology commercialization process.

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31. J. Beckwith Burr, *Competition Policy and Intellectual Property in the Information Age*, 41 VILL. L. REV. 193, 204 (1996) (stating that with the high cost of defending patent infringement lawsuits, "many improvidently granted patents are likely to go unchallenged").

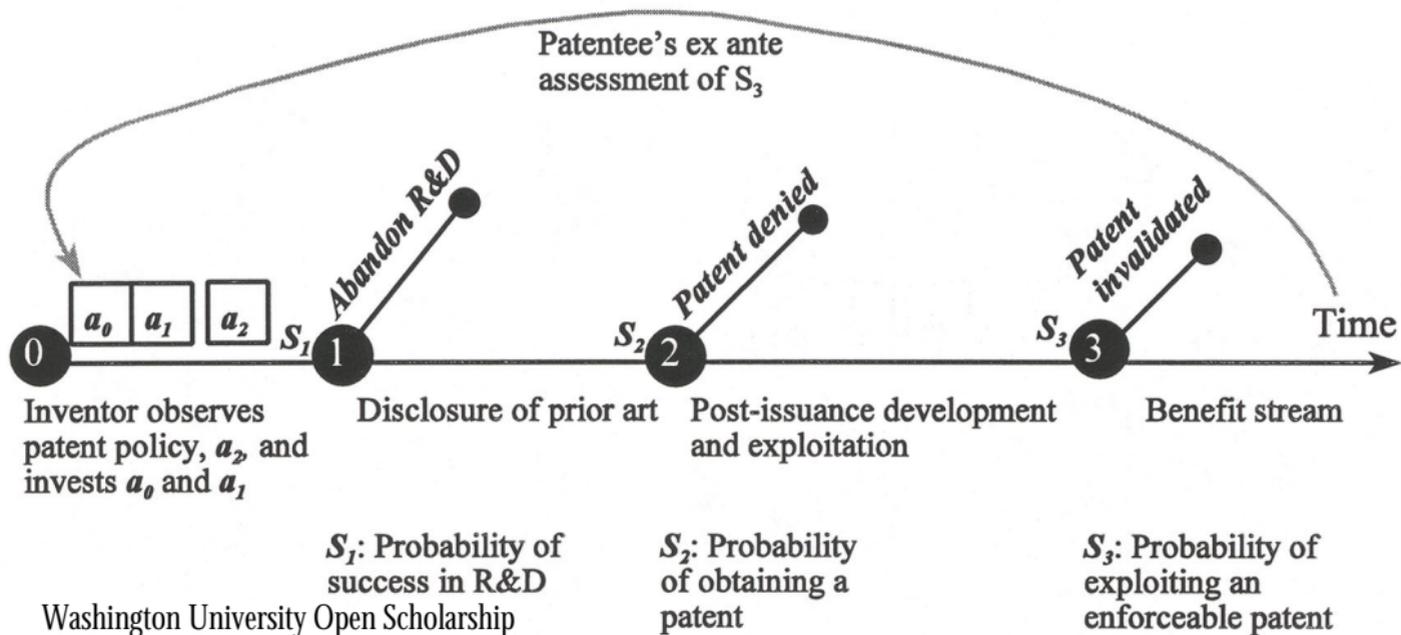
32. *Id.*

33. See LANJOUW & SCHANKERMAN, *supra* note 3.

## II. PATENTS AND THE TECHNOLOGY COMMERCIALIZATION PROCESS

A new invention begins as an investment project. The expected value of the invention depends on the outcome of initial R&D efforts, the probability of obtaining valuable property rights protecting the invention (a patent), and the probability of successfully exploiting that property right (market success). This sequence is described in Figure 1. At time 0, the inventor evaluates the alternatives for investment in R&D projects based on their expected net profits, given the public's specification of the terms of the patent regime ( $a_2$ ) (*e.g.*, duration, eligible subject matter for patent protection) and makes an R&D investment ( $a_1$ ). If the results of R&D are successful (probability  $S_1$ ), the inventor applies for a patent and obtains one with a probability  $S_2$  at time 2. Once a patent is obtained, the invention creates an expected revenue stream of monopoly rents or licensing fees for the duration of the patent. However, the validity, enforceability, and scope of protection of a patent may be challenged in court (with probability  $(1-S_3)$ ) after it has been issued on a variety of grounds (*e.g.*, inability to meet the requirements for patentability), if such evidence is presented to the court in post-issuance litigation. The disclosure of prior art during patent prosecution and the presumption of validity accorded to the disclosed prior art are two factors that effect a patent's validity and thus its ability to generate benefit streams. Each of these may be considered decision variables in the technology commercialization process illustrated below.

Figure 1: Schematic Representation of the Technology Commercialization Process



### A. Disclosure of Prior Art During Prosecution

The prior art is the basis for determining whether the invention sought to be patented meets statutory requirements of novelty and nonobviousness. For example, if a prior art reference, such as a scientific publication or a printed document, demonstrates that the invention has been used anywhere in the world twelve months prior to the patentee's filing date, the invention is statutorily barred from being patented.<sup>34</sup> Prior art disclosure provides benefits for both the public and the PTO, albeit for different reasons. A complete prior art disclosure reduces the probability ( $S_3$ ) that a patent will be invalidated in post-issuance litigation, since it allows the PTO to evaluate a larger set of prior art references that could be used to later invalidate the patent. A patent granted based on a more complete disclosure of prior art is less likely to be invalidated, because it reduces the number of references that will have not been previously considered by the PTO, thus benefiting the patentee.<sup>35</sup>

The public benefits from a complete prior art disclosure because it allows the PTO to grant claims of proper scope that are commensurate with the extent of innovation due to better information regarding the state of the art. Complete disclosure can be particularly important in high technology sectors where the PTO may not have access to all of the prior art that is available to the inventor.<sup>36</sup> The PTO, not being an expert in the field and having limited resources, may not be able to access all the relevant prior art compared to the inventor, who is typically an expert in the field.<sup>37</sup> This is especially true where the relevant prior art is non-patent art such as scientific publications, or the relevant prior art information is already in the public domain, as in the case of computer software. In the context of

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34. 35 U.S.C. § 102(b) (1994).

35. John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 AIPLA L.Q. 185, 194, 234 (1998) (studying 299 patents over an eight-year period from 1989 to 1996 and finding that the percentage of invalidation based on uncited prior art was 40.8%, but the probability of invalidation based on cited prior art was 29.6%).

36. In this respect, the PTO held public hearings in June of 1999 on the subject of identifying sources of information for prior art references and preferable methods for gaining access to prior art in emerging fields, such as computer software and biotechnology.

37. Very few patentees cite any non-patent prior art during the course of prosecution. See Allison & Lemley, *supra* note 35, at 231-34.

the patent quid pro quo, one may view this as creating information asymmetry between the trading parties, with the PTO as the lesser-informed party. In contrast, in the case of inventions in low technology or established technology areas,<sup>38</sup> such as the mechanical arts, the PTO can better ascertain the state of the art. Thus, we assume that the PTO and the patentee are symmetrically informed in the case of low technology or established technology inventions. These assumptions have implications on the nature of the exchange between the PTO and the patentee. This is clearer when we consider according a high presumption of validity for prior art disclosed to the PTO by the patentee.<sup>39</sup>

### *B. Presumption of Validity Accorded to Disclosed Prior Art*

If an extensive prior art disclosure is made by the patentee at the time of patent prosecution, a patent will be difficult to invalidate because that prior art cannot be the basis for invalidation by the courts in post-issuance litigation.<sup>40</sup> While a more complete prior art disclosure decreases the probability of invalidation, a high presumption of validity also reduces the probability of invalidation. This presumption restricts the opportunities for the courts in post-issuance litigation to attach a different legal significance to the prior art. For the patentee a high presumption of validity accorded to

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38. By low technology inventions, we have in mind simple mechanical inventions such as a new type of corkscrew. The social benefits conferred by such devices is likely to be smaller than those produced by a high technology invention such as a new cure for cancer or AIDS.

39. See *supra* note 11.

40. There is a presumption of validity for every granted patent. See 35 U.S.C. § 282 (1994) ("A patent shall be presumed valid."). The presumption of validity granted to issued patents is a check on the judiciary in patent cases. See John R. Thomas, *On Preparatory Texts and Proprietary Technologies: The Place of Prosecution Histories in Patent Claim Interpretation*, 47 UCLA L. REV. 183, 219 (1999). The presumption of validity has not been uniformly applied by the courts, however. See also Mark D. Janis, *Rethinking Reexamination: Toward a Viable Administrative Revocation System for U.S. Patent Law*, 11 HARV. J.L. & TECH. 1, 9-11 (1997). 35 U.S.C. § 282 does not grant a strong or weak presumption of validity with respect to disclosed or undisclosed prior art. As a practical matter, prior art disclosed to the PTO during prosecution is less likely to be used successfully against the patentee in post-issuance litigation compared to uncited prior art. See Allison & Lemley, *supra* note 35, at 231-34. Nevertheless, cited prior art is used to invalidate a patent a significant percentage of the time. See *id.* at 234 (noting that about 30% of the prior art-based patent invalidations rely on cited prior art).

disclosed prior art reduces the chance that a patent will be invalidated as a result of the disclosed prior art taking on different legal significance. In contrast, under a regime with a low (or non-existent) presumption of validity for disclosed prior art, prior art disclosed during prosecution can be reexamined by the courts in a post-issuance lawsuit (*e.g.*, invalidation or infringement suit) in order to render the patent invalid. Because this proposal removes the possibility of reducing market power through post-issuance patent invalidation, the public may wish to accord a high presumption of validity only in circumstances where the resulting benefits outweigh distortions to competition and reductions in incentives for R&D investment. One such benefit is the creation of a more certain property right. This right allows investors to undertake more risky R&D projects, because the expected value of the project is not reduced further by uncertainty over patent rights.<sup>41</sup> The increase in investment in R&D in high technology projects can outweigh the social losses in market power, because high technology inventions often create significant positive externalities that spill over into other markets. In addition, under a regime that accords a high presumption of validity for disclosed prior art, the PTO may capitalize on a complete prior art disclosure and grant patent rights that are commensurate with the new information in the patent disclosure. Thus, the PTO would avoid the negative consequences brought about by an overbroad grant of patent rights.

### *C. Characterizing Optimal Patent Policies*

Optimal patent policy must weigh, among other things, the inducements provided for investment in R&D against the social costs imposed by patents. One social cost is the diminished ability to develop new inventions as a result of a policy that discourages investment in R&D. Improperly issued patents create difficulties for inventors that add social costs, including wasteful design-around

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41. See Rochelle Cooper Dreyfuss, *Information Products: A Challenge to Intellectual Property Theory*, 20 N.Y.U. J. INT'L L. & POL. 897, 900 (1988) (noting that a strong presumption of intellectual property protection is necessary to avoid distortions in R&D investment patterns).

activities of inventors who try to avoid infringement. The cost of developing new inventions that incorporate patented inventions increases if downstream inventors must pay upstream inventors license fees.<sup>42</sup> Existing patents may also raise the financing costs for R&D projects, because they increase the possibility that the new invention will infringe upon existing patents. Financiers view this as raising the risk (or lowering the expected return) of the investment project and thus command a higher risk premium on loans to inventors.

In sum, these are the costs of economically incomplete contracting: A patentee may have access to information relevant to patentability that the PTO could benefit from. However, the patentee may decline to reveal the information to the PTO without adequate incentives.

The doctrine of inequitable conduct<sup>43</sup> and the duty to disclose information material to patentability<sup>44</sup> encourage patentees to produce material prior art to the PTO. Inequitable conduct arises when information material to patentability is not disclosed to the PTO or false material information is disclosed to the PTO with an intent to deceive the PTO.<sup>45</sup> However, the level of proof required to establish a claim of inequitable conduct has been set so high by the Federal Circuit that it has reduced the incentive to disclose prior art to the PTO. The Federal Circuit has held that even gross negligence in failing to disclose prior art is not in itself sufficient to prove an intent to deceive the PTO.<sup>46</sup> Since 1988, the PTO has indicated that it will neither investigate nor reject patent applications based on violations of the duty to disclose material prior art, since it is not well-equipped to make such a determination.<sup>47</sup> The Federal Circuit has frowned on

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42. Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698 (1998).

43. See *Molins PLC v. Textron, Inc.*, 48 F.3d 1172 (Fed. Cir. 1995); *Kingsdown Med. Consultants, Ltd. v. Hollister, Inc.*, 863 F.2d 867 (Fed. Cir. 1988).

44. 37 C.F.R. § 1.56 (1999) ("Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section.")

45. See *Kingsdown*, 863 F.2d at 876.

46. *Id.*

47. MARTIN J. ADELMAN ET AL., *CASES AND MATERIALS ON PATENT LAW* 746 (West

assertions of inequitable conduct as a defense in patent lawsuits and charged that the habit of claiming inequitable conduct has “become an absolute plague.”<sup>48</sup> The net result is that there is little incentive to provide a complete disclosure of the prior art to the PTO. Indeed, Allison and Lemley report that non-patent prior art was not disclosed to the PTO in the vast majority of cases they studied over an eight year period from 1989 to 1996.<sup>49</sup> These results indicate that private information regarding the relevant prior art is not adequately disclosed to the PTO, because there is no significant incentive for the patentee to disclose relevant prior art. As a result, in certain technical areas with significant non-patent prior art, the PTO is not equipped to determine the scope of the non-obvious contribution made by the patentee.<sup>50</sup>

One means of correcting this inadequacy is through a policy that accords a high presumption of validity to disclosed prior art. This policy would allow the PTO to exploit the patentee’s private information by granting claims of proper scope. In high technology fields of invention, such as biotechnology and computer software, the problem of asymmetric information is particularly acute, perhaps as a consequence of imperfect or asymmetric information between the patentee and the PTO.<sup>51</sup>

To the extent that increased information allows patents of proper scope to be granted and reduces the probability of invalidation for the patentee, it reduces economic incompleteness. This is because both the public and the patentee are made better off through a “contract” that allows a high presumption of validity to attach to disclosed prior art. This is a case where the objectives of the PTO and the patentee are congruent, and we model this disclosure and patenting process as a joint production process or a vertical relationship.<sup>52</sup>

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1998).

48. *Burlington Indus. v. Dayco Corp.*, 849 F.2d 1418, 1422 (Fed. Cir. 1988) (stating that “the habit of charging inequitable conduct in almost every major patent case has become an absolute plague”).

49. *See Allison & Lemley*, *supra* note 35.

50. *See Merges*, *supra* note 30.

51. *See infra* Part II.A.

52. *See Merges*, *supra* note 30 (proposing patent policies such as a patent opposition system that will efficiently coordinate the efforts of the PTO and private parties to achieve a socially desirable result). *See also* Craig Allen Nard, *Certainty, Fence Building and the Useful*

However, such an analysis does not account for the option value of being able to retain full rights to invalidate a patent in post-issuance litigation. Because it may be difficult to ascertain what a properly defined high technology patent should encompass, the option of being able to easily invalidate a wrongly-issued patent may not be negligible. If the PTO finds that a basic patent, on a gene sequence for example, should never have been issued, the value of being able to invalidate the patent is removing what could be a development obstacle for future inventions. In the case of high technology inventions, if wrongly-issued patents are significant obstacles to the development of important inventions, this option value can be high. The public welfare benefits of such an option value are difficult to determine and most likely vary considerably across different fields of invention. Accounting for this option value in a model of incomplete contracts with asymmetric information is a complex issue since it requires introducing additional assumptions about the information levels of each party and the value of the information over time. This model does not attempt to do this. As a result, we assume that in according a particular presumption of validity to disclosed prior art, the PTO is conscious of the option value it gives up in exchange for information from the patentee, and is capable of appreciating the import of the prior art disclosed by the patentee. Indeed, a fundamental assumption in our analysis is that the PTO is capable of appreciating the import of the information disclosed to it by the patentee. If adequate resources are provided to the PTO,<sup>53</sup> it is reasonable to assume that the PTO will be able to review prior art that is disclosed to it during prosecution.

### III. MODELING PATENTS AS INCOMPLETE CONTRACTS

Consider the three-period model described in Fig. 1, in which the inventor (patentee) invests  $a_0$  in R&D at time 0. The patentee also invests  $a_1$  prior to observing the outcome of R&D, in order to assess

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*Arts*, 74 IND. L.J. 759, 765 (1999) (proposing a patent opposition system to achieve greater ex ante proprietary and competitive certainty).

53. See Merges, *supra* note 30 (sketching the functions and goals of an ideal patent office).

the intellectual property situation in the relevant field. Investment  $a_1$  allows the patentee to conduct a complete search of prior art in order to determine if the R&D project could lead to an infringing product but also to be able to support claims of novelty and nonobviousness in a patent application. Since the decision to invest in R&D depends on the expected profits,  $a_0$  is a function of a prior belief about  $S_3$ , the probability of holding a valid patent in the post-issuance stage. This depends on the regimes of patent enforcement employed by the courts. Hence, we can write  $a_0 = a_0(S_3)$ . In addition, at time 0, the PTO invests  $a_2$  in bureaucratic infrastructure and commits to particular institutions and practices of patent examination.

The results of investment  $a_0$  in R&D initiated at time 0 are contingent upon the success rate ( $S_1$ ). If R&D is successful the patentee applies for a patent at time 1. In the course of applying for a patent, the patentee discloses prior art  $q_1$  and makes a claim on territory not within the prior art. If the patent is issued then the patentee may exploit the patent by producing the invention and selling it (presumably at monopoly prices) or licensing it. If a patent does not issue (probability  $(1-S_2)$ ), the patentee may choose to either reapply with modifications, appeal the PTO's decision, or abandon the project. During the patent application process, the claims may be negotiated in light of information made available to the PTO either from the patentee or through its own search. However, obtaining a patent, does not ensure that the property right is fixed; it may be invalidated in post-issuance litigation, depending in part on the presumption of validity ( $q_2$ ) that the public (PTO) has accorded to the cited prior art.

The process in Figure 1 can be thought of as a two-period production model in which each party (the patentee and the PTO) supplies appropriate levels of  $q_1$  and  $q_2$  in order to bring a new invention to the market. The disclosed prior art ( $q_1$ ) is non-contractible in the sense that the public cannot determine whether the complete prior art known to the public has been disclosed to the PTO. The presumption of validity accorded to the cited prior art by a court in post-issuance litigation is a patent policy choice that is known at time 0. The non-contractibility of  $q_1$  creates an opportunity to allocate residual rights of control over the variables  $q_1$  and  $q_2$ . Hence, one can ask whether a joint surplus could be increased by allowing one party

to control  $q_1$  and  $q_2$  through the choice of patent policy specified at time 0. With this question, we define the benefit functions of each party.

Rents from successful patenting accrue to the inventor for the duration of the patent with probability  $S_3$ . The net benefits of knowledge disseminated to the public (which includes users, improvers, and competitors) as a result of the patent disclosure are captured with certainty. The benefit accruing to each party can be expressed as  $B_i[a_0, a_i, \mathbf{j}_i(q_1, q_2)]$ , where  $i=1$  for the inventor and  $i=2$  for the public. We assume that  $B_i$  is increasing in  $\mathbf{j}_i$  for each party. In the case of the patentee,  $\mathbf{j}_1$  corresponds to the probability ( $S_3$ ) of having an enforceable patent.  $B_1$  is thus a realization of expected benefits, given  $S_3$ . The PTO similarly wishes to maximize  $\mathbf{j}_2$ , which are the social benefits of patents issued with properly defined scope and adequate specification (*e.g.*, providing enabling disclosure to improvers and competitors in addition to maintaining incentives for R&D).

The problem for the policy maker is, therefore, to decide how to accord the rights to control  $q_1$  and  $q_2$  in order to maximize joint surplus ( $B_1 + B_2$ ). To reiterate the problem being modeled, we have defined the following function representing the joint surplus:

$$(1) B_1[a_0, a_1, \mathbf{j}_1(q_1, q_2)] + B_2[a_0, a_2, \mathbf{j}_2(q_1, q_2)]$$

where the variables are defined as:

$a_0$ : ex ante investment in R&D by patentee

$a_1$ : ex ante investment in prior art search by patentee

$a_2$ : ex ante investment in patent system (salaries and work-load of patent examiners)

$q_1$ : disclosure of known prior art

$q_2$ : presumption of validity for cited prior art

$B_1$ : patentee benefits (monopoly prices, licensing fees)

$B_2$ : public benefits (knowledge disseminated, consumer benefits)

$S_1$ : probability of success in R&D

$S_2$ : probability of obtaining a patent

$S_3$ : probability of holding an enforceable patent

$\mathbf{j}_1$ : patentee benefits as a result of disclosure ( $q_1$ ) and presumption of validity ( $q_2$ )

$\mathbf{j}_2$ : public benefits from disclosure ( $q_1$ ) and presumption of validity ( $q_2$ )

For simplicity we assume that  $S_3 = \mathbf{j}_1$ , implying that patentee benefits of control over  $q_1$  and  $q_2$  are increased with the probability of capturing rent streams. Since the present analysis is concerned only with cases where the patentee patents the product of a successful R&D project, we assume that  $S_1$  and  $S_2$  are independent of control over  $q_1$  and  $q_2$ .

*A. Specification of the Model Under High and Low Technology Environments*

The respective benefit functions of the patentee and the PTO will be different for the case of high technology (*e.g.*, biotechnology or computer software) and low technology or established technology inventions, since the costs and the benefits of operating in these environments differ. These differences are captured in the respective  $\phi_i$  functions that we define as linear combinations of  $q_1$  and  $q_2$  as expressed below:

$$(2) \quad \mathbf{j}_1 = \mathbf{a}_1 q_1 + \mathbf{b}_1 q_2 + \mathbf{e}_1 C \text{ (patentee)}$$

$$(3) \quad \mathbf{j}_2 = \mathbf{a}_2 q_1 + \mathbf{b}_2 q_2 + \mathbf{e}_2 C \text{ (PTO)}$$

The functions are distinguished by the values for the coefficients  $\mathbf{a}_n$ ,  $\mathbf{b}_n$ , and  $\mathbf{e}_n$ , which are weights on the relative importance of non-contractibles ( $q_1$ ) and contractibles ( $C$ ).<sup>54</sup> The magnitude of the coefficient indicates the relative importance of the factor (hence the degree to which control will matter), while the sign of the coefficient indicates whether increases in the value of the variable ( $q_1$  or  $q_2$ ) result in an increase or decrease in benefits. A negative coefficient indicates that control of the variable by party  $j$  adversely affects the benefit function ( $\mathbf{j}_j$ ). This is the case of incongruent objectives. The differences in the coefficients for the high and low technology sectors are due to information asymmetries and are explained below.

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54. We define contractibles as those elements of patentee or public (PTO) benefits that are independent of  $q_1$  and  $q_2$ . These include profits resulting from brand names or other sources of market power.

### 1. High Technology Sectors

In high technology sectors, R&D techniques evolve rapidly, such that an inventor, being an expert in the field, has better knowledge of the state of the art than the PTO. Therefore, in equation (3), asymmetric information between the patentee and PTO is assumed. The benefits for the PTO in obtaining a more complete disclosure is that it will be able to grant claims of proper scope. Thus, the coefficient  $a_2$  will be large and positive. Since overly broad claims may prevent other inventors from creating improved products or applying the knowledge disclosed in the patent in new areas, the public values information about the prior art relatively more than its right to invalidate a patent. Therefore, the coefficient  $b_1$ , on the presumption of validity ( $q_2$ ) accorded to the patent, will be small and positive.

Because the costs and risks of R&D in high technology are high, a patent must be stable in order to reduce the post-issuance chances for invalidation. This stability will offset the high costs of R&D with high expected profits. Thus, the weight on  $q_2$  and  $b_1$ , will be positive and large. As the patentee discloses more prior art information, she increases her chance of obtaining a stable patent. Thus, the weight on  $q_1$  will depend on the degree to which a complete prior art disclosure can reduce the probability of invalidation. If there is a strong relationship, as a result of an incentive provided by the PTO,  $a_1$  will be large and positive.<sup>55</sup>

### 2. Low Technology or Well-Established Technology Sectors

In low technology sectors, we assume symmetric information between the patentee and the PTO. Since the PTO can easily identify the relevant prior art, it will be concerned most with not giving up its right to invalidate the patent in exchange for information it could obtain from sources other than the patentee. Thus, for parties with symmetric information, disclosure of prior art will be relatively unimportant for both the PTO and the patentee. This is particularly so

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55. See *infra* Section IV.

because the patentee does not receive any incentives to conduct a thorough prior art search and disclose it to the PTO. Thus, the coefficients  $\mathbf{a}_1$  and  $\mathbf{a}_2$  will be small and positive indicating that either party should be indifferent to disclosure by the PTO or the patentee. Since low technology inventions involve less cost and risk for the inventor, the PTO would prefer to accord a higher presumption of validity only when it would induce investment in risky high technology R&D, creating large social benefits. Therefore, for the case of low technology inventions, granting a high presumption of validity reduces  $\mathbf{j}_2$  by relatively large amounts. Thus,  $\mathbf{b}_2$  is large and negative.

Because the probability of success  $S_1$  is generally higher in the low technology case, the expected profits from an R&D project may be higher for a low technology project. Thus, the low technology inventor can afford to bear a higher probability of invalidation that would result from a low presumption of validity. Therefore, the coefficient  $\mathbf{b}_1$  is small and positive. Given that both  $\mathbf{a}_1$  and  $\beta_1$  are small, most of the weight will be on the contractibles (C) or factors such as brand names or marketing channel agreements—conditions not relying on patents or R&D. In this case,  $\mathbf{e}_1$  will be large. The assumptions we make on the parameters of each of the  $\mathbf{j}_i$  functions are summarized in Table 1.

In high technology sectors, a more complete disclosure of prior art would be Pareto-improving since both coefficients  $\mathbf{a}_1$  and  $\mathbf{a}_2$  are positive and large. Since  $\mathbf{b}_2$  is small, both parties could benefit from a policy in which presumption of validity is “traded” for a more complete disclosure of prior art supplied by the relatively better informed patentee. Thus, the objectives of the patentee and the PTO are congruent. For low technology inventions, the objectives will be incongruent because  $\mathbf{b}_2$  is a large negative coefficient, indicating that granting stable property rights on low risk R&D would penalize the public’s benefit function.

Table 1

Coefficient	Description	High Technology		Low Technology	
		Magnitude	Sign of Coeff.	Magnitude	Sign of Coeff.
$\alpha_1$	Relative importance of prior art for patentee ( $i=1$ ) and PTO ( $i=2$ )	Large	+	Small	+
$\alpha_2$		Large	+	Small	+
$\beta_1$	Relative importance of presumption of validity	Large	+	Small	+
$\beta_2$		Small	-	Large	-
$\epsilon_1$	Relative importance of contractibles	Insignificant	+/-	Large	+/-
$\epsilon_1$		Insignificant	+/-	Large	+/-

The tradeoff that the PTO must consider is how increases in the presumption of validity decrease public benefits ( $B_2$ ) by reducing the opportunities for invalidation and simultaneously increase the incentives for investment in R&D. These effects are described in equation (4) below. For low technology inventions, we have the following relationship:

$$(4) \quad \frac{\partial B_2}{\partial j_2} > \frac{\partial B_2}{\partial a_0} \text{ LowTech}$$

This is because the productivity benefits of low technology R&D are small in relation to the welfare benefits of reducing market power. Since low technology R&D produces only small shifts of production frontiers, the welfare benefits of reducing market power by maintaining a low presumption of validity and preserving post-issuance invalidation rights offset any benefits that would result from increased investment in low technology R&D.<sup>56</sup> In contrast, for high technology R&D, we have the following relationship:

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56. Recall that  $j_2$  is maximized by minimizing  $q_2$ , since  $b_2 < 0$ .

$$(5) \quad \frac{\partial B_2}{\partial j_2} < \frac{\partial B_2}{\partial a_0} \text{ HighTech}$$

The effect of increases in R&D thereby outweighs the social losses due to market power that occur as a result of a high presumption of validity granted to disclosed prior art. This is because high technology patents may disclose revolutionary teachings or methods that the public may build upon or use. The public welfare losses from having to pay license fees in this case are relatively small in comparison to the benefits the new technology provides. It should be clear that equations (4) and (5) are assumptions and not results of this model. These are consistent with the parameter values of Table 1, in which it is assumed that each agent maximizes their respective  $j_i$  functions. Based on these assumptions, we propose optimal patent enforcement policies for both high and low technologies.

#### IV. ANALYZING ALTERNATIVE PATENT POLICIES

We consider two policies, which are distinguished by the incentives provided by the PTO to the patentee to disclose all relevant prior art. Policy 1 “trades” a high presumption of validity for information on prior art that may not be available to the PTO. Under this policy, prior art disclosed at the time of patent prosecution cannot be used in subsequent litigation to invalidate the patent, except in very limited circumstances.<sup>57</sup> Thus, the patentee can effectively reduce the opportunities for invalidation by citing all relevant prior art to the PTO. Since a high presumption of validity attaches only to the prior art disclosed by the patentee, we can write  $q_2=q_2(q_1)$ . Thus, the benefit functions under Policy 1 are:

$$(6) \quad j_1 = a_1q_1 + b_1q_2(q_1) + e_1C$$

$$(7) \quad j_2 = a_2q_2 + b_2q_2(q_1) + e_2C$$

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57. A threshold test for invoking disclosed prior art might be the following: A court will not invalidate a patent based on disclosed prior art unless it is convinced that no reasonable examiner would have allowed the patent in light of the disclosed prior art. In other words, disagreement about what the disclosed prior art teaches would not suffice to invalidate the patent.

Under Policy 1, the patentee discloses the relevant prior art in relation to the desired presumption of validity, which we assume to be high. We denote  $q_1$  and  $q_2$  under this policy as  $(q_1, q_2) = (q^{\mathfrak{C}}, q^{\mathfrak{D}})$ . Under Policy 2, there is no such exchange between the patentee and the PTO. In this case the PTO conducts its own prior art search, and information known only to the patentee is not accorded any special legal significance. In other words, the PTO maintains no presumption of validity with respect to the disclosed prior art. The forms of the  $\mathbf{j}_i$  functions are exactly as initially specified and are reproduced below as:

$$(8) \mathbf{j}_1 = \mathbf{a}_1 q_1 + \mathbf{b} q_2 + \mathbf{e}_1 C$$

$$(9) \mathbf{j}_2 = \mathbf{a}_2 q_1 + \mathbf{b}_2 q_2 + \mathbf{e}_2 C$$

We denote the disclosure of prior art and presumption of validity as  $(q_1, q_2) = (q^{\mathfrak{2}_1}, q^{\mathfrak{2}_2})$ . The effects of each policy in both high and low technology scenarios are examined in the next section.

#### A. Policy 1: High Technology

Given the relative importance of the high presumption of validity ( $\mathbf{b}$  is large), the patentee maximizes  $\mathbf{j}_1$  by disclosing as much as information as possible in order to capitalize on the high presumption of validity. The patentee's disclosure and the high presumption of validity ( $q^{\mathfrak{C}}, q^{\mathfrak{D}}$ ) maximize  $\mathbf{j}_1$ , but will also approximately maximize  $\mathbf{j}_2$ , because both  $\mathbf{b}$  and  $\mathbf{j}_2$  are small. This result occurs because the patentee is made better off by a policy in which a presumption of validity attaches to all relevant prior art disclosed to the PTO. The PTO is also able to accord patent claims of proper scope, in light of the additional information it receives from the patentee. Policy 1 applied to the case of high technology thus leads to higher joint surplus, due to coordination between the PTO and the patentee. Since  $\mathbf{j}_1$  is increasing in  $q^{\mathfrak{C}}$  and  $q^{\mathfrak{D}}$ , such coordination will lead to higher levels of ex ante investment in R&D by the patentee, which increases both  $B_1$  and  $B_2$ . Since  $S_3 = S_3(\mathbf{j}_1)$ , increasing the value of the  $\mathbf{j}_1$  function corresponds to increasing the expected value of the investment project.

*B. Policy 1: Low or Well-Established Technology*

Policy 1 applied to the case of low technology does not maximize public benefits ( $B_2$ ) because the incentives provided by the PTO are “wasted” and do not increase the information available to the PTO, and, therefore, do not offset the losses in  $j_2$  caused by a high presumption of validity. The patentee discloses all prior art, yet the PTO is symmetrically informed (assumption of low technology), which implies that  $q'_1 \approx q''_1$ . Thus,  $j_2$  is not maximized but instead approximately minimized since  $b_2$  is large and negative in equation (7). The increase in  $j_1$  is brought about by a high presumption of validity (note that  $a_1$  and  $b_1$  are small under this policy). However, the sum of the public and patentee benefits is small due to the reduction in public benefits brought about by the high presumption of validity that is improperly granted in this scenerio.

*C. Policy 2: High Technology*

By setting a low presumption of validity for prior art, Policy 2 removes the incentive for the patentee to disclose prior art. Since the PTO conducts its own prior art search,  $j_2$  is not maximized because the PTO is necessarily less informed than the patentee. Thus,  $q_2 < q^2_1$ . Hence, the  $j_1$  function is not maximized by  $q^2_1$ . Furthermore, given  $q_2 < q^2_2$  and a small negative coefficient ( $b_2$ ),  $j_2$  is not maximized. Because the PTO (or policy maker) “controls” the presumption of validity ( $j^2_1 < j^2_2$ ), there will be less investment in  $a_0$  under Policy 2 than under Policy 1. This is because, in this model, the lower level of  $j_1$  corresponds to a lower probability of having a valid patent ( $S_3$ ). Under a policy which accords a low presumption of validity, the investor’s ex ante assessment of the probability of being invalidated causes him to assign a lower expected return to the investment project. This makes investment in high risk (high technology) projects less attractive than investment in other projects that have higher private returns but lower social returns (e.g., low technology projects). Benefits ( $B_1 + B_2$ ) are thus not maximized when the PTO relies on its own prior art search in the case of high technology inventions.

*D. Policy 2: Low or Well-Established Technology*

With no information asymmetry, a policy that maintains a low presumption of validity will approximately maximize  $j_2$  since the coefficient  $b_j$  is small. Since  $a_j$  and  $b_j$  are both small, any policy affecting these variables directly or indirectly will have a small effect on  $j_1$ . In this case, Policy 2 is efficient in the sense that it does not waste the privilege of according a high presumption of validity in order to induce R&D into low technology inventions. Even though this maintains a higher probability of invalidation for the patentee, its effect in reducing incentives for R&D investment is less acute than in the case of high technology because a higher probability of technical success ( $S_1$ ) compensates for a lower probability of owning a valid patent ( $S_3$ ). Policy 2 applied to the case of low technology, therefore, approximately maximizes  $B_1 + B_2$  because of the public welfare benefits it maintains through a low presumption of validity.

## V. CONCLUSION

We began with the familiar concept that a patent can be a quid pro quo between the patentee and the public, trading a limited right to exclude for an adequate disclosure of the invention. Because of the legal regimes governing post-issuance patent litigation that allow a patent to be invalidated by the courts after it has been issued, a patent may be considered an economically incomplete contract between the patentee and the public. Describing patents as incomplete contracts allows us to consider the efficiency effects of alternative patent policies that allocate control over two variables (prior art and presumption of validity) to one party.

Our approach in developing a model of patents as incomplete contracts is to ask whether one can increase the joint surplus of a partnership if there is coordination achieved by one party taking partial control of the other's rights. The answer to this question is not obvious, because control of rights or assets reduces the bargaining power over ex post surplus, while it can increase joint benefits if the objectives of both parties are aligned. We apply this model to the technology commercialization process where the patentee and the public (acting through its agent, the PTO) are seen as vertical

partners. Thus, this model adopts a systems approach by incorporating R&D decision making and public policy from the perspective of each party.

We use the incomplete contracts framework to understand the welfare tradeoffs of market power and the timely development of new technologies. We consider two specific patent policies. Under Policy 1, prior art disclosed by the patentee to the PTO during patent prosecution is accorded a strong presumption of validity in post-issuance litigation, limiting the use of cited prior art to invalidate the patent. Under Policy 2, there is no presumption of validity accorded to prior art cited by the patentee.

These two policies are considered in the context of low and high technology environments, which are distinguished by the costs of invention and the level of information asymmetry between the patentee and the PTO. In high technology sectors, such as computer software or biotechnology, the patentee is better informed about the relevant prior art with respect to an invention, as compared to the PTO. The high technology sector is further distinguished by the benefits R&D procure to society, as well as the increased risks associated with high-tech R&D projects. Given the costs and benefits of innovation in each scenario, we consider which patent policy could best maximize joint social surplus.

For the case of high technology inventions, Policy 1 induces higher levels of ex ante investment in R&D. The public efficiently trades a strong presumption of validity for information about the prior art. Since prior art is valued by both parties, Policy 1's transfer of residual rights encourages disclosure thereby enhancing welfare. When the objectives of the patentee and the PTO are not aligned, as in the case of low or well-established technologies, Policy 1 would not maximize the public welfare since the costs of reduced opportunities for the public to invalidate the patent outweigh the benefits of increases in investment.

For the case of low technology inventions, Policy 2 is optimal, since it allows the public to curtail losses due to market power by maintaining opportunities for invalidating a patent. In low technology inventions, the increased bargaining only slightly reduces incentives for investment since R&D projects of this type are less expensive and undertaken with limited regard to patent protection. The main reason

these policy prescriptions apply is an accounting for the positive externalities that different technologies create, while assuming that the benefits from high technology are a result of public policy incentives. The incomplete contracting framework allows us to view the patent policy of choosing appropriate incentive schemes as a function of informational and technical (productivity) considerations.

The optimal policy for high technology inventions, such as in biotechnology (characterized by asymmetric information and high productivity effects), provides incentives for well-informed patentees to reveal information regarding the relevant prior art to the PTO during patent prosecution. This is consonant with a body of contracting literature that proposes that when parties are asymmetrically informed, default rules that penalize the more informed party will be welfare enhancing by inducing that party to reveal information.<sup>58</sup> However, in our case, we do not impose a penalty on the better informed party, the patentee. Rather, we permit a transfer of ex post bargaining rights (*i.e.*, reduce the public's residual right to invalidate the patent) in order to induce the better informed party to reduce the informational asymmetry between the patentee and the PTO. In this regard, the objectives of the patentee and the public are mutually aligned since the reduction in ex post bargaining also creates ex ante incentives for higher R&D investment.

This simple model assumes that the costs and benefits of information and different technologies are exogenously determined. In practice, they are part of a larger problem in which the policy environment and private strategies evolve together. As new policies are implemented, decision-makers "update" their R&D investment decision criteria. Therefore, developing dynamic models for this process would be a worthy research endeavor but by no means uncomplicated—investment planning in high technology increasingly incorporates complex models of resource management. New models must view R&D organizations not only as rational decision-makers but also as sources of new capabilities, because the inventive process in itself disseminates new knowledge through enabling disclosures in

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58. See Ayres & Gertner, *Filling Gaps*, *supra* note 12.

patents. These are important factors in high technology R&D, as is the trade-off between market power and incentives to invest considered in our model of the technology commercialization process.