Cost-Plus Patent Damages

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This Article assesses recent proposals to use risk-adjusted costs of producing an invention as a basis for either setting patent damages or valuing patents taken by eminent domain. In theory, cost-plus damages can address one of the central challenges of patent law: ensuring that a patentee does not obtain excessive rents for an invention. But cost-plus damages have three principal problems. First, risk may be difficult to estimate, and estimates may be infected by hindsight. Second, if the permitted rate of return is too low, there may be insufficient incentives to invent. Indeed, even a rate of return that seems generous for existing companies may

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discourage entry into the industry. Third, inventors may spend much more on invention, anticipating that these greater expenses will not only increase the chance of success, but also increase the amount that they can charge. This Article assesses recent literature proposing cost-plus patent damages, and it offers a simulation model to assess the magnitude of these problems. It concludes that while these problems are serious, social welfare still might be increased by considering cost-plus damages as a factor in the patent damages calculus.

I. Introduction

Governmental mechanisms for rewarding innovation generally do not require direct assessments of the cost of the research and development (R&D) undertaken. The exceptions prove the principle that the government is wary of making individualized assessments of whether research spending is wasteful. Research-and-development tax credits effectively allow partial reimbursement of research costs,[1] but these are available to all inventors, requiring no analysis of whether private firms have spent their money well.[2] The government must police for fraud,[3] but within broad contours even inefficient research spending is subsidized. Because such tax credits will not cover anywhere near the entire cost of R&D, private actors have strong incentives to spend their money wisely. Meanwhile, government research grantors may consider the expected cost of future research activities as part of their analysis of the overall promise of research plans,[4] but this is but one factor in an open-ended inquiry.[5] And once grants are issued, recipients enjoy some flexibility in reworking budgets.[6] Grantees are often constrained less by the detailed research plan than by the desire to produce strong results and earn future research grants.

The cost of conducting research plays even less of a role in the patent system. An inventor can receive a patent even if the invention required little work, so long as the general requirements of patentability are met. Indeed, the section of the United States patent statute requiring that inventions be nonobvious explicitly requires that "[p]atentability shall not be negated by the manner in which the invention was made,"[7] whether through diligent effort or through serendipitous

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1 I.R.C. § 41(a) (2012).

2 *See, e.g.*, Daniel Hemel & Lisa Larrimore Ouellette, *Beyond the Patents-Prizes Debate*, 92 TEX. L. REV. 303, 311–12 (2013) (discussing the effect of tax credits on inventor incentives).

3 *See, e.g.*, United States v. Kilpatrick, 821 F.2d 1456, 1461 (10th Cir. 1987) (prosecuting defendants for creating false tax deductions on non-existent R&D payments).

4 *See, e.g.*, NATIONAL SCIENCE FOUNDATION, PROPOSAL AND AWARD POLICIES AND PROCEDURES GUIDE 67 (2017) (requiring financial and administrative reviews as a condition to funding).

5 Government research grantors consider many factors, including the qualifications of the research team, the strength of the rationale underlying the research proposal, and the social value of a successful outcome. *See id.* at 63–64.

6 *See, e.g.*, Joshua Sarnoff, *Government Choices in Innovation Funding (With Reference to Climate Change)*, 62 EMORY L.J. 1087, 1094 (2013) (noting that outputs of R&D are not measured with respect to specific spending inputs).

7 35 U.S.C. § 103 (2012).

discovery.[8] Indeed, the provision was added to the patent statute to overrule case law requiring a "flash of genius" as a condition for receiving a patent.[9] Our historical system was antipathetic to the inventor who incurred great costs to produce an invention, and even today the inventor receives no special consideration for making large investments. The theory is not that costs are irrelevant, but that the government should monitor outputs rather than inputs.[10] Private parties will have incentives to invest in research activities that are likely to produce new inventions. If the government is capable of determining what is sufficiently new but not so good at measuring the cost of producing innovation, this theory is sensible. A patent system, the theory continues, need not even require the government to assess invention value, because inventors will naturally steer their efforts to producing the most valuable inventions as cheaply as possible.

Yet in two critical doctrinal areas, patent law necessarily requires more governmental attention. First, while the law of nonobviousness does not consider cost explicitly,[11] it is a doctrine that filters out easy (and thus cheap) inventions.[12] An invention that "would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains" cannot receive a patent.[13] Even if the courts approach this as an epistemic inquiry, resisting direct tallying of costs,[14] obvious inventions will generally be cheap inventions. The Federal Circuit, exploring whether an invention should be considered "obvious to try,"[15] has stressed the relevance of the "ease and predictability" of the techniques for accomplishing the invention.[16] Thus, the nonobviousness doctrine can be viewed at least in part as an inquiry into how much one would expect it to cost to complete an invention.

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8 *See* Graham v. John Deere Co., 383 U.S. 1, 16 n.8 (1966) ("[I]t is immaterial whether [the invention] resulted from long toil and experimentation or from a flash of genius."); General Tire & Rubber Co. v. Firestone Tire & Rubber Co., 489 F.2d 1105, 1118 (6th Cir. 1973) ("The present statute emphasizes the proposition that it makes no difference as to patentability by what manner an invention is made."); Sbicca-Del Mac, Inc. v. Milius Shoe Co., 145 F.2d 389, 394 (8th Cir. 1944) ("It is of no consequence, whether the thing 'be discovered by accident, or by long, laborious thought, or by an instantaneous flash of mind.'").

9 The patent statute overturned a "flash of creative genius" requirement set forth in *Cuno Eng'g Corp. v. Automatic Devices Corp.*, 314 U.S. 84, 91 (1941). *See also* DONALD S. CHISUM, CHISUM ON PATENTS § 5.02 (providing a history of § 103).

10 For a model that gives special consideration to costly inventions, *see* Matthew Erramouspe, *Staking Patent Claims on the Human Blueprint: Rewards and Rent-Dissipating Races*, 43 UCLA L. REV. 961, 975 (1996).

11 For a proposal that nonobviousness doctrine should take into account cost, *see* Glynn Lunney, *E-Obviousness*, 7 MICH. TELECOMM. TECH. L. REV. 363, 413 (2001).

12 Michael Abramowicz & John F. Duffy, *The Inducement Standard of Patentability*, 120 YALE L.J. 1590, 1613 (2011).

13 35 U.S.C. § 103 (2012).

14 For an argument that the nonobviousness doctrine should adopt an explicitly economic foundation, see Abramowicz & Duffy, *supra* note 12, at 1590.

15 *See generally* KSR Int'l Co. v. Teleflex Inc., 127 S. Ct. 1727, 1742 (2007) (suggesting that the "obvious to try" test is appropriate when the field is sufficiently limited to present a finite number of potential solutions).

16 *See In re* Kubin, 561 F.3d 1351, 1360 (Fed. Cir. 2009).

Second, the patent system may not care about the value of the invention when assessing obviousness, but it does care when assessing patent damages.[17] In many cases, this is not necessary. A patentee can receive injunctive relief for infringement,[18] and then the government need not make an assessment of the invention's value. But patentees will also seek monetary relief for past infringement.[19] Moreover, since the Supreme Court's decision in *eBay Inc. v. MercExchange, L.L.C.*,[20] courts are hesitant to grant injunctions, especially when an invention may represent a small component of a large product.[21] When a potential user of a patent knows of a patent, can confirm its validity, and negotiates in advance, the possibility of an injunction should yield a price that allows the inventor and user of the invention to share in the surplus of the invention. But when a user has inadvertently made irreversible investments without knowledge of the patent, an injunction can allow the inventor to hold up the user for a much larger amount.[22] In limiting the opportunity for such holdups, *eBay* effectively requires the courts to determine, among other things, how valuable the invention was to the user. The problem is most acute for non-practicing entities, which as an empirical matter are often limited to money damages.[23]

Nonetheless, neither the nonobviousness doctrine nor patent damages considers how much it cost the patentee to complete the invention. With nonobviousness, such consideration arguably is barred by statute,[24] and the emphasis on a hypothetical person having ordinary skill in the art[25] emphasizes that the courts are considering expected, rather than actual, ease of invention. With damages, the cost of completing the invention is not one of the many factors that the courts use in calculating damages.[26] In an article prepared for last year's version of this symposium, however, Ted Sichelman argued that the patent system should explicitly consider risk-adjusted R&D costs in calculating damages.[27] That is, a patentee would be entitled to recover its R&D investments. Just as the goal of

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17 *See, e.g.*, Christopher B. Seaman, *Reconsidering the Georgia-Pacific Standard for Reasonable Royalty Patent Damages*, 2010 B.Y.U. L. REV. 1661, 1678 (2010).

18 35 U.S.C. § 283 (2012); *see, e.g.*, Broadcom Corp. v. Emulex Corp., 732 F.3d 1325, 1339 (Fed. Cir. 2013) (granting a permanent injunction with a sunset period after finding patent infringement).

19 35 U.S.C. § 284 (2012).

20 eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388 (2006).

21 Mike Heins, *Selling Congress on eBay: Should Congress Force the ITC to Apply the eBay Standard?*, 22 FED. CIR. B.J. 589, 593 (2013).

22 *See generally* Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991, 2008–10 (2007).

23 *See* Christopher B. Seaman, *Permanent Injunctions in Patent Litigation After eBay: An Empirical Study*, 101 IOWA L. REV. 1949, 1970–71 (2016).

24 *See* Graham v. John Deere Co., 383 U.S. 1, 16 n.8 (1966) (holding that the degree to which the patentee toiled in completing the invention is irrelevant).

25 35 U.S.C. § 103 (2012); *see also* Joseph P. Meara, *Just Who Is the Person Having Ordinary Skill In The Art? Patent Law's Mysterious Personage*, 77 WASH. L. REV. 267, 273–78 (2002).

26 *See* Georgia-Pac. Corp. v. U.S. Plywood Corp., 318 F. Supp 1116, 1120 (S.D.N.Y. 1970) (listing factors relevant for calculating damages for infringement).

27 *See* Ted Sichelman, *Innovation Factors for Reasonable Royalties,* 25 TEX. INTELL. PROP. L.J. 277, 308–11 (2018).

nonobviousness might be thought to be to provide exclusivity only when necessary to induce the invention,[28] so too might the goal of patent damages be to provide just enough compensation to induce investments. Because research is an inherently risky activity, to motivate inventors to engage in research, these costs would be adjusted upward to compensate for risk. Damages would be calculated so that an inventor's total recovery (extrapolating to the entire market, not just the individual patent defendant) would make the research project as attractive *ex ante* as the inventing firm's next best investment. Sichelman proposes only that risk-adjusted costs should be a factor in the patent damages calculus,[29] but he hints that they could serve a larger role if initial experimentation were successful.[30] In a separate article in the same symposium, John Golden and Karen Sandrik also briefly consider the possibility of incorporating cost considerations into the reasonable royalty assessment.[31]

Reimbursement of inventors based on their costs similarly could play a role in reward alternatives to patent systems. The proposals for patent system alternatives that have gained prominence in the past two decades have focused on the challenge of determining how much to value inventions procured by such systems.[32] The classic prize approach is to offer a fixed prize for a particular invention sought by the prize sponsors, with the prize presumably to be paid even if the problem turns out to be much simpler than expected.[33] Reward proposals, meanwhile, have sought to compensate inventors in proportion to their diverse contributions but many have still sought to estimate invention value.[34] Some proposals seek to measure the demand for the invention directly,[35] while others seek to piggyback on the patent system to determine what an invention would have been worth if it remained under patent protection instead of receiving a prize.[36] Recognizing that some inventions may make contributions that cannot be measured in direct sales, and also that some

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28 *See* Abramowicz & Duffy, *supra* note 12, at 1678–79.

29 *See* Sichelman, *supra* note 27, at 311.

30 *See id.* at 323–324 (arguing that patent law should use a reliance damages regime based on R&D expenditures).

31 *See* John M. Golden & Karen E. Sandrik, *A Restitution Perspective on Reasonable Royalties*, 36 REV. OF LITIG. 335, 371 (2017).

32 *See generally* Michael Abramowicz, *Prize and Reward Alternatives to Intellectual Property,* 1 RESEARCH HANDBOOK ON THE LAW AND ECONOMICS OF INTELLECTUAL PROPERTY (Peter S. Menell, David L. Schwartz & Ben Depoorter eds., forthcoming 2018).

33 *See, e.g.*, Benjamin N. Roin, *Intellectual Property versus Prizes: Reframing the Debate*, 81 U. CHI. L. REV. 999, 1001–02 (2014).

34 *See, e.g.*, Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115, 225–35 (2003) (discussing factors that inform patent-prize proposals); AIDAN HOLLIS & THOMAS POGGE, THE HEALTH IMPACT FUND, MAKING NEW MEDICINES AVAILABLE FOR ALL 3 (Incentives for Global Health, 2008).

35 *See, e.g.*, Steven Shavell & Tanguy Van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525, 531–32 (2001).

36 Michael Kremer, for example, suggests an ingenious system of auctions that would result, with high probability, in a patent being sold to the government for an amount equal to or a multiple of the market's valuation of the patent. *See* Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON. 1137, 1146–48 (1998).

inventions may benefit individuals who cannot pay nearly the prices that inventors would charge,[37] some other reward proposals have endorsed valuation systems that take into account more general improvements to social welfare.[38] Despite this wide range of approaches, proposals have been unified in focusing on inventive contribution rather than on the cost of invention.

In a recent article, however, Hannah Brennan and coauthors (including Amy Kapczynski) defend what can be seen as a reward system that uses a cost-plus accounting metric.[39] In particular, Brennan et al. advocate that the government take advantage of statutory authority to purchase generic versions of certain medicines for less than 1% of their list price plus a reasonable royalty.[40] Brennan et al. note that exercising such a power could be analogous to eminent domain,[41] which prior advocates of reward systems have urged as a tool that could allow the government to take patents for just compensation,[42] effectively converting the patent system to a reward system. The key challenge for such a system is determining what constitutes a "reasonable royalty." Brennan et al. suggest that a baseline might be set based on the price charged by the infringer,[43] but that an award should deviate from this baseline to allow for recovery of risk-adjusted R&D costs.[44] Even if the government does not have perfect information, so long as the government gives sufficient compensation on average, there will be sufficient incentive to invent.

Under some assumptions, a patent or reward system should be able to function equally well either with an approach that aligns inventor returns with the value of innovations produced or with an approach that reimburses the risk-adjusted cost of producing those innovations. Potential inventors will monitor changes in the expected cost of inventing and the expected value of an invention, and they will invent (or try to) as soon as the expected cost drops low enough or the expected value rises high enough so that the portion of value that the inventor can appropriate will cover the risk-adjusted costs.[45] If expected costs and value change slowly over time, then invention will occur at the same time regardless of whether a cost metric

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37 *See, e.g.*, Ellen 't Hoen, *TRIPS, Pharmaceutical Patents, And Access to Essential Medicines: A Long Way From Seattle to Doha*, 2 CHI. J. INT'L L. 27, 28–29 (2002) (describing the barriers patent protections impose on drug access and affordability in developing countries).

38 Amy Kapczynski, *The Continuum of Excludability and The Limits of Patents*, 122 YALE L.J. 1900, 1954 (2013).

39 Hannah Brennan et al., *A Prescription for Excessive Drug Pricing: Leveraging Government Patent Use for Health*, 18 YALE J.L. & TECH 275, 310–18 (2016).

40 *See id.* at 275.

41 *See id.* at 308–10.

42 *See, e.g.*, Daniel R. Cahoy, *Patent Fences and Constitutional Fence Posts: Property Barriers to Pharmaceutical Importation*, 15 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 623, 672 (2005).

43 Brennan et al., *supra* note 39, at 314. Note that Brennan et al. implicitly assume that the infringement is by a company that sells to users rather than by users themselves. For simplicity, the model in Part IV of this paper adopts the reverse assumption, focusing on users as potential infringers.

44 *Id.* at 315.

45 For an article modeling the implications of inventors' waiting to invent until the value from invention is sufficiently high, *see* John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 459 (2004).

or a value metric is used to provide ultimate rewards. Thus, at least placing aside the complications of calculating various types of damages, on this theory, it should not matter whether damages are based on valuation or on cost.

In practice, however, expected costs may drop abruptly, following an exogenous improvement in technology,[46] and more rarely, expected value may increase abruptly, as a result of an exogenous change in demand.[47] When this occurs, it is possible that the expected cost of an invention will be considerably lower than its social value. Indeed, the expected cost may even be much lower than the proportion of value that the inventor can appropriate from a patent, if injunctions are available or if damages are based on the patent's value. It is in this case that cost-plus damages have the theoretical potential to increase social welfare. So long as cost-plus damages truly compensate for risk, an inventor will still have sufficient incentive (just enough incentive) to pursue the invention. Meanwhile, lower damages mean that prices will be lower for consumers, producing less deadweight loss. This may produce both efficiency and distributive gains.

The possibility of reducing unnecessary compensation for inventions is the heart of the case for cost-plus damages. But considering cost in the patent damages calculation can be justified on more prosaic grounds as well. Even if one believes that the ultimate purpose of patent damages is to measure the value of a patent to the infringer (or to users to whom the infringer sells the product), the cost of producing an invention may be a proxy for patent value. Easier inventions, all else being equal, will be less valuable than harder inventions; after all, if an invention were easy and valuable, then it probably would have been invented early. So, if cost is a proxy for value, then even if value is the conceptual touchstone of the patent damages inquiry, then it likely deserves at least some weight in the multifactor calculus.[48] Multifactorial balancing tests can be unwieldy,[49] but it is hard to see the harm in extending a test that already considers many factors to considering one more.[50] At least in some cases, there may be firm evidence about cost-plus damages and so this may be a good proxy for patent value.

Yet there is a strong argument that this is backward—that expected cost indeed should be seen as the ultimate touchstone of the patent damages inquiry. On this account, the inquiry considers factors that seem more related to value because

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[46] *See, e.g.*, Abramowicz & Duffy, *supra* note 12, at 1676 (invention dependent on a newly discovered research tool could not have been invented earlier).

[47] *See id.* at 1676–77 (citing the recently felt needs for security products following the Sept. 11 terrorist attacks and for filtering the red color band in night vision goggles as exogeneous changes in demand).

[48] *See* Georgia-Pac. Corp. v. U.S. Plywood Corp., 318 F. Supp 1116, 1120 (S.D.N.Y. 1970).

[49] *See, e.g.*, Martin H. Redish & Colleen McNamara, *Back to the Future: Discovery Cost Allocation and Modern Procedural Theory*, 79 GEO. WASH. L. REV. 773, 783 (2011).

[50] *See, e.g.*, Barton Beebe, *An Empirical Study of the Multifactor Tests for Trademark Infringement*, 94 CALIF. L. REV. 1581, 1614–15 (2006) (discussing how only some core factors are determinative in the outcome of multifactor tests because judges sway other factors to follow the outcome pointed to by core factors).

expected cost is too hard to measure directly. A risk-adjusted cost measure presents a number of evidentiary challenges. The most obvious of these is how we might determine the *ex ante* probability of success. This assessment requires decisionmakers to place themselves in the position of inventors at some prior point. A more serious concern is that decision making might be systematically biased. Empirical studies suggest that hindsight bias affects jurors in analyzing nonobviousness,[51] and the same might be true with cost-plus patent damages. This produces a more serious concern still: If inventors anticipate that decisionmakers will be infected by hindsight bias, they might believe that patent damages will be just a bit short of the level needed to compensate them for their investments. If patent damages focus on invention value and courts slightly underestimate that value, there will be a little bit less invention; but a systematic downward bias in estimating risk-adjusted costs could lead to *a lot less* invention. If one expected the courts never to allow enough damages to reimburse costs, then one would invent only if there were sufficient nonpatent incentives to do so.

There would, of course, be a simple remedy if risk-adjusted costs were systematically underestimated. Damages could be augmented by some percentage, enough on average to at least compensate for systematic bias. So long as the social value of an invention will generally be considerably higher than its expected cost,[52] the patent system could be generous in setting this percentage, hoping to guarantee inventors that they will receive no less than their risk-adjusted costs. But this exacerbates an entirely different risk: excessive spending. Suppose an inventor anticipates that it would cost $1,000,000 to have a 50% chance of invention. But if the inventor anticipates that successful investments are generally reimbursed at 10% more than is needed to compensate for risk-adjusted costs, then the inventor's incentive is to invest *more* than $1,000,000. After all, 10% of $1,000,000 is less than 10% of $10,000,000. A higher investment might only marginally increase the probability of invention, but no matter. An inventor who expects to receive a risk-adjusted reimbursement of a specific amount should not care about the probability anyway. This is a familiar problem with cost-plus pricing from other domains in which it is used, such as utility regulation[53] and government contracting.[54]

Thus, cost-plus damages introduce the danger that inventors will spend too much from a social welfare perspective. There remains, however, a critical restraint on reimbursement: Users might refuse to use the invention, at least unless they can

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51 Gregory N. Mandel, *Patently Non-Obvious: Empirical Demonstrations that the Hindsight Bias Renders Patent Decisions Irrational*, 67 OHIO ST. L.J. 1391, 1403–15 (2006).

52 Inventions are often thought to have high spillover benefits beyond what patentees can recover. *See, e.g.*, Kremer, *supra* note 36, at 1146 (describing the ideal patent buyout price as the social value of an invention, assuming the expected social benefit exceeds the cost).

53 *See, e.g.*, Paul L. Joskow & Richard Schmalensee, *Incentive Regulation for Electric Utilities*, 4 YALE J. ON REG. 1, 9–10 (1986) (describing a prudence test, which would allow for cost-plus utility regulation so long as costs are kept to a minimum).

54 *See, e.g.*, Robert C. Guell & Marvin Fischbaum, *Toward Allocative Efficiency in the Prescription Drug Industry*, 73 MILBANK Q. 213, 223 (1995) (discussing how the defense department and NASA's use of cost-plus pricing caused projected costs to increase).

negotiate a lower price. If the inventor spends a billion dollars on an invention, then a potential user who values it at a million dollars (even one with a billion dollars to spare) will not intentionally infringe if patent damages doctrine would impose a damages verdict with nine zeros. Thus, excessive spending on inventions will push up anticipated damages, thus vitiating the supposed principal benefit of cost-plus damages, but such a system will not lead users to pay more than they would if a victorious patentee could receive an injunction. Meanwhile, even courts measuring investments might count some excessive investments in research as not being investments at all, so there would be some limit on padding expense accounts. And if a little bit of gold-plating performs the same function as offering inventors some percentage above the minimum expected to be compensatory, then it could be beneficial on balance.

In short, the empirical effects of cost-plus damages are unpredictable. Different effects push in different directions from a welfare perspective. It seems unlikely that there will be opportunities for empirical analysis of cost-plus damages anytime soon. In the absence of data, this Article will seek to theorize as clearly as possible about these various effects of cost-plus patent damages. Part II will review recent proposals for cost-plus damages and highlight three central concerns: First, it is difficult to adjust for risk. Second, it is implausible to allocate the costs of entering into an industry across individual projects, yet these costs must be reimbursed if cost-plus damages are not to discourage entry. Third, cost-plus damages may lead to gold-plating—socially excessive research expenditures.

These problems notwithstanding, Part III will accuse the proponents of excessive modesty. If cost-plus damages work as the proponents anticipate, they can serve as much more than small tweaks. Properly functioning cost-plus damages have profound implications for patent doctrine, perhaps eliminating the need even for cornerstones like the nonobviousness doctrine and the patent term. Part IV will offer a simulation model that indicts the proponents of cost-plus damages for excessive optimism. It shows how cost-plus damages could be beneficial but also how slight misestimates of key parameters could lead to considerably worse outcomes than with standard approaches to damages. Finally, Part V concludes. Though there is an insufficient basis to switch to a patent damages system exclusively based on cost-plus damages, there is room for doctrinal experimentation with cost-plus damages as part of the broader analysis.

II. The Theoretical Case for Cost-Plus Damages and Rewards

The theoretical case for cost-plus damages can be made modestly or ambitiously. This Part will start with the modest recent proposals for cost-plus accounting, pointing out the core of the arguments, the limited direct application of these arguments, and some initial potential difficulties.

A. Brennan et al.'s Cost-Plus Eminent Domain

Brennan et al.'s proposal[55] is modest in several ways. First, the authors do not suggest any needed modifications to patent doctrine or indeed to the law more broadly, but instead only that the executive branch exercise an already existing statutory power.[56] Second, the authors' suggestion is limited to a particular area of technology, pharmaceuticals,[57] despite the potential for the statute to be applied in other technological fields. And third, the authors do not suggest that their approach be applied to all inventions in this field, but only for the relatively narrow area of life-saving technologies.[58]

The problem that Brennan et al. target is what they characterize as the high cost of life-saving medicines. They focus specifically on direct-acting antivirals, and even more specifically on sofosbuvir, one form of which the FDA has designated as a Breakthrough Therapy.[59] This drug offers promise for the treatment of the blood-borne virus HCV (Hepatitis C), but most versions of the medicine have a list price of nearly $100,000 for a standard course of treatment.[60] Even with discounts, many patients are unable to obtain the treatments.[61] Meanwhile, payors who can afford the treatment have used a significant percentage of their budgets on the treatment, thus reducing their ability to help patients with other problems.[62] The example is thus a vivid illustration of the familiar tension between dynamic and static incentives in innovation law.[63] Given the existence of a treatment, lower prices would benefit patients, but at least with some medicines, the ability to charge high prices may have been necessary to induce the R&D of the drug, including the high cost of clinical trials.[64]

Brennan et al.'s innovation is their suggestion that the United States government take advantage of a statute, 28 U.S.C. § 1498,[65] which provides that when the United States uses a patented invention without a license, the patentee's sole remedy shall be "for the recovery of his reasonable and entire compensation."[66] The statute also covers use "by a contractor, a subcontractor, or any person, firm, or corporation for the Government and with the authorization or consent of the

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55 *See* Brennan et al., *supra* note 39, at 283 (suggesting methods by which the government could use § 1498 to extend public access to generic medications).
56 *Id. at* 302–03.
57 *Id.* at 319.
58 *Id.*
59 *Id.* at 287–89.
60 *Id.* at 290 tbl. 1.
61 *Id.* at 291.
62 *Id.* at 292.
63 *See generally* Thomas Cheng, *Putting Innovation Incentives Back in the Patent-Antitrust Interface*, NW. J. TECH. & INTELL. PROP. 385, 388–90 (2013) (discussing the short-term conflict between patent law's dynamic incentive focus and antitrust law's static incentive focus to achieve the common goal of improving consumer welfare).
64 Brennan et al., *supra* note 39, at 293.
65 28 U.S.C. § 1498 (2017).
66 *Id.* § 1498(a).

Government."[67] Brennan et al. review legislative history confirming that the statute authorizes the United States to exercise its power of eminent domain to use patented inventions, subject to the traditional requirement to pay just compensation.[68] The statute, Brennan et al. note, has been used in a variety of contexts, for example when the Treasury Department used it to immunize banks from liability for use of a patented invention on the detection of fraudulent checks.[69] In the pharmaceutical context, Bayer cut the prices of its antibiotic ciprofloxacin after the Secretary of Health and Human services threatened to import generic versions during the anthrax crisis in 2001.[70] Brennan et al. also describe an earlier episode that led pharmaceutical companies to seek to limit the statute to cases of national security emergency, an effort that failed.[71]

Brennan et al. recommend that § 1498 should be invoked when the federal government determines that "drug pricing has created sizable deadweight loss."[72] They qualify this statement, however, by identifying two primary factors: first, whether "firms command rents in excess of risk-adjusted R&D costs plus a reasonable profit,"[73] and second, whether there would be a significant "magnitude of potential public health gain."[74] The first of these qualifications highlights that Brennan et al. are not concerned with deadweight loss simpliciter. Drug prices could be high because of high risk-adjusted costs, meaning either that the research itself was expensive or that it was highly unlikely to succeed *ex ante*. Indeed, the authors allow that with rare diseases, "high prices may be justifiable because firms must spread R&D costs over a much smaller patient population."[75] While allowing that government guidance might be needed to make application of these factors predictable,[76] Brennan et al. conclude that "new HCV treatments satisfy both factors and are a prime candidate for government use."[77] The government, however, likely would not need to invoke § 1498 in many contexts because the mere possibility of such invocation would lead companies to lower their prices.[78]

The crux of the Brennan et al. proposal is their recommendation for calculating damages. They recommend starting with a royalty representing the infringer's

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67 Brennan et al. note that the provision governing subcontractors was extended in 1942. Brennan et al., *supra* note 39, at 300 (citing Act of October 31, 1942, 77 Pub. L. No. 77-634 § 6, 56 Stat. 1013, 1014).

68 *See* Brennan et al., *supra* note 39, at 299–302.

69 *Id.* at 302 (citing Advanced Software Design Corp. v. Fed. Reserve Bank of St. Louis, 583 F.3d 1371, 1378–79 (Fed. Cir. 2009)).

70 *Id.* at 303.

71 *Id.* at 305.

72 *Id.* at 319.

73 *Id.*

74 *Id.*

75 *Id.*

76 Brennan et al. suggest that while courts could calculate damages, it would be better for agencies to "establish guidelines that will shape any bargaining around the courts' powers, thereby influencing courts' calculations and reducing uncertainty about how courts would assess damages." *Id.* at 326.

77 *Id.* at 320.

78 *Id.* at 321.

earnings. In the case of pharmaceuticals with low marginal cost, this would be a "very low baseline."[79] Thus, the more important aspect of their proposal is their recommendation that "these rates should be grossed up to ensure adequate incentives for innovation."[80] This gross up appears to encompass several components. First, it reflects the actual cost of R&D.[81] Second, it would adjust for the risk of failure.[82] The authors cite general statistics on the probability that new drugs will succeed in various stages of clinical testing, such as the 20% probability that a drug will advance from Phase II to III testing.[83] The authors recommend using "inputs specific to the drug or drug class in question" to determine failure rates.[84] Third, inventors would be entitled to "'reasonable' profits, perhaps keyed to approximate average industry returns."[85] Fourth, courts could "even incorporate an additional margin to compensate for the risk of error in their R&D assessments."[86] And fifth, the courts might prorate damages "to reflect the proportion of the global market that these payors represent."[87]

In theory, this approach should work. If pharmaceutical companies are earning far more than needed to compensate them for their investments, taking into account the possibility of failure, then there is no reason for them to earn any more. Deadweight loss should be reduced, and there may be distributive benefits to improving patients' welfare at the expense of shareholders'. In practice, the success of the approach depends on the government's ability to measure the relevant parameters accurately. The most difficult parameter to estimate is likely to be risk. In the case of HCV, the authors confess lack of knowledge of the relevant risk and thus assume a number based on industry averages. "We lack specific information on risk of failure for these drugs, so assume a 10 to 20% chance of success (with the lower bound of 10% representing the general likelihood a drug that begins trials succeeds)."[88]

If pharmaceutical companies expect the government to make similar assumptions, then they will not develop any drugs when they estimate less than a 10% chance of success. The allowance of profits and an error margin is designed to offset the risk that the government might underestimate risk-adjusted costs, but it is at least plausible that the government might underestimate even considering this. Today, a pharmaceutical company might invest in a drug with a 5% chance of success if the rewards—in lives saved and ultimately in profit—were sufficiently

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79 *Id.* at 315.
80 *Id.*
81 *Id.* at 316 (recommending that courts "estimate R&D outlays").
82 *Id.* ("Before investing $1, for example, a company will require a potential profit of $2 if there is a 50% risk that the product it is developing will fail.").
83 *Id.* (citing Joseph A. DiMasi et al., *Innovation in the Pharmaceutical Industry: New Estimates of R&D Costs*, 47 J. HEALTH ECON. 20, 24 tbl.2 (2016)).
84 *Id.*
85 *Id.* at 315.
86 *Id.* at 315–16.
87 *Id.* at 317.
88 *Id.* at 329.

high, but this will not occur if the pharmaceutical company expects the government to estimate no less than a 10% rate of success (unless the profit and error margins amount to more than 100%). Given an expectation of standard patent damages, sufficiently high social value will ultimately trigger invention for any cost and probability of success, but basing eminent domain damages entirely on cost and probability of success means that social value cannot serve this function.

The 10% success figure seems particularly inappropriate because it represents a crude empirical measure of *average* success. If that is the average, then some drugs presumably are developed even though pharmaceutical companies anticipate a much lower probability of success, while others have a higher degree of success. This highlights the stakes. If pharmaceutical companies expect the government to underestimate risk significantly in a world in which § 1498 is used aggressively, they may simply not develop a drug, regardless of the value of the drug. To be sure, the United States is just one market, but if the United States fails to give drug manufacturers a sufficient return for its prorated portion of the global market, then it seems unlikely that the manufacturers will get a sufficient return anywhere else either.

In a reward system that focuses on invention value, when an invention's value is underestimated, inventions that are of marginal social value will not be developed. But the Brennan et al. proposal is premised on the idea of converting inframarginal inventions—those that will surely be developed under the current system because the profits are so large—into marginal ones. So the danger that expectation of a risk misestimation would lead to nondevelopment of a drug becomes much greater. On the other hand, if they succeed, deadweight loss can be reduced without any harm to innovation incentives.

The deadweight losses from high pricing must be balanced against losses from drugs that might not be developed if potential innovators expect the government not to provide sufficient compensation to allow for profit. With zero marginal costs and linear demand, deadweight loss destroys one-fourth of the total potential surplus from an invention.[89] The failure to invent a drug that could be invented destroys the entire surplus from the invention. Moreover, this ignores the possibility that drug development may have beneficial spillover effects that the inventor cannot capture. This can occur when other companies develop "me-too" drugs[90] and more importantly once drugs enter the public domain. Thus, risk estimates must be sufficiently favorable to inventors so that the probability of discouraging invention is much lower than the probability of some unnecessary deadweight loss.

The case for § 1498, and by extension for a reward system that seeks to reimburse risk-adjusted R&D costs in any technological domain, thus depends on

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89 *See* Abramowicz, *supra* note 34, at 162 fig.2.

90 *See, e.g.*, Albert Wertheimer et al., *Too Many Drugs?: The Clinical and Economic Value of Incremental Innovations*, *in* 14 INVESTING IN HEALTH: THE SOCIAL AND ECONOMIC BENEFITS OF HEALTH CARE INNOVATION 77, 78 (Irena Farquhar et al. eds., 2005) (arguing that me-too drugs provide patients with valuable choices).

whether the government can be expected to make its estimates sufficiently accurately or sufficiently generously that the profit and error margin it allows will be enough not to dissuade even a small percentage of inventions. Part IV will return to this question by assessing how the government might improve its ability to make such estimates sufficiently well. Brennan et al., however, reasonably might answer that surely, the government could take the sofosbuvir-based drugs with a very generous payment that would without question provide sufficient return. After all, they emphasize that the drug has "likely already earned around *forty times* the cost of developing the drugs."[91] They thus conclude that "society has already vastly overpaid for the drugs, particularly considering how little treatment the $36 billion expenditure has purchased."[92]

Looking at this drug in isolation, their case indeed seems persuasive. Yet this persuasiveness is undermined at least somewhat by a familiar economic puzzle. If huge returns are available that greatly overcompensate pharmaceutical companies, why isn't there more entry into the market? There are at least two possible answers to this puzzle. The answer at which Brennan et al. hint is that there *is* a great deal of entry—indeed, an excessive amount of entry. "Reducing the profits available for blockbusters could even increase dynamic efficiency," they write, "because outsized rewards can induce wasteful racing wherein parties expend more effort to be first to obtain a reward . . .than society gains from their race."[93] Under standard industrial organization theory, rents must be dissipated in some way. For example, John Duffy offers a model of patent racing in which racing efficiently produces earlier invention and earlier entry of inventions into the public domain.[94] Yet even in Duffy's model, the number of entrants into a patent race may be inefficiently high. The Brennan et al. approach thus might be seen as a technique for reducing inefficient patent races. Perhaps the government will lower returns just enough so that only one or two firms will race to develop a drug that suddenly seems obtainable. In some circumstances, this might lead to only a slight reduction of the probability of invention or a slight delay in the date of invention.

The second answer to the puzzle is much less favorable to the Brennan et al. thesis. This answer is that rent dissipation occurs not only at the stage when R&D on a particular drug is conducted, but also at an earlier stage when entrepreneurs create pharmaceutical companies that have the institutional capability to conduct drug research and to market the drugs. A challenge in applying the Brennan et al. approach is that costs incurred even before a specific drug candidate is identified ought to be risk-adjusted as well, at least if their system is designed to be something other than an appropriation of pharmaceutical company wealth. But it may be very difficult to determine how to allocate these costs among projects and how to risk-

[91] Brennan et al., *supra* note 39, at 328.
[92] *Id.*
[93] *Id.* at 322.
[94] *See* Duffy, *supra* note 45, at 464–75 ("Racing to patent earlier (and thus to have the patent expire earlier) will therefore continue to be the predominant mechanism by which firms compete away the patent rents.").

adjust these expenses. One would need data not just on pharmaceutical companies that succeed, but also on those that fail. One would need to account for the possibility that the pharmaceutical company might have never produced a single successful drug as well as the possibility that the company might have produced some successful drugs but not enough to pay a market return to the initial investors. Some venture capital and other early forms of investment reflect very high failure rates, and thus the risk-adjusted costs inherent in these initial investments may be quite high. Failure to take them into account will discourage new companies from entering into the market in the hope of someday becoming a big pharmaceutical company.

There is another potential objection to the Brennan et al. approach that is quite different. Might the government overcompensate pharmaceutical companies? Perhaps the government might take a drug as a political favor to a pharmaceutical company that has contributed to the campaign. Of course, Brennan et al. highlight that the government should act only in the fact of great deadweight loss, but there is at least some danger that the government, once using this power, might abuse it. This potential leads to rent-seeking behavior of a different sort,[95] as pharmaceutical companies seek to influence the government in its exercise of the power. Indeed, the danger might be less that the government would pay too much in individual cases as that the legislative and administrative processes might be perverted so that the government would pay systematically too large a sum. One can advocate for a system with particular rules, but must also face the prospect that any actual implementation of a proposal may be quite different from what has been recommended.

If that is a danger, there is an argument that cost-plus damages should be used not as a tool when the government takes a patent, but instead as part of the patent damages calculation itself. Patent litigation is adversarial, and this should reduce at least the risk of excessive compensation of patentees. The traditional justification for a reward system as an alternative to the patent system is that it can reduce deadweight loss. The government exercising its § 1498 powers might well sell drugs at marginal cost, thus achieving this goal. But reluctance to raise taxes and spending may help explain the failure of reward systems to become more prominent than they are today. If the program is to be revenue neutral, then the government would need to pass its expenses along to consumers. This could still represent a dramatic decrease in deadweight loss by eliminating unnecessary overcompensation, but in principle a patent damages system could achieve much the same end. To see this, let us turn to Ted Sichelman's proposal.

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[95] *See generally* Gordon Tullock, *Rent Seeking: The Problem of Definition*, *in* TOWARD A THEORY OF THE RENT-SEEKING SOCIETY 97, 97–112 (James Buchanan et al. eds., 1980) (developing a theory of rent-seeking in politics).

B. Sichelman's Cost-Plus Damages

Sichelman's goal is not to create an alternative to the patent system but to reform the calculation of patent damages. Calculation of damages is necessary where an injunction is not fully compensatory, because infringement occurred before the issuance of the injunction,[96] or where an injunction cannot be entered, for example because the invention is a small component of a product and there is a danger that an injunction would allow the patentee to "hold up" the infringer.[97] Although patentees who lose profits can receive lost-profits damages, it is difficult to prove lost profits,[98] and so many practicing entities and all non-practicing entities have damages calculated on the basis of a "reasonable royalty."[99] The goal in a reasonable royalty case is for the court to reconstruct the hypothetical agreement that the parties would have reached on a licensing price.[100]

The canonical reasonable royalty case, still influential in the Federal Circuit,[101] is *Georgia-Pacific Corp. v. U.S. Plywood Corp.*[102] This case creates a multifactorial balancing test. Placing aside two factors that are not so much factors as overarching philosophy and procedural guidance,[103] Sichelman groups the factors into four categories: first, whether the patentee is a practicing entity;[104] second, the benefit provided by the technology over preexisting technologies;[105] third, the extent to which profit "should be credited to the invention as distinguished from non-patented elements";[106] and fourth, actual negotiations between either the patentee and other licensees or between the infringer and holders of similar patents.[107] We might loosely group all of these factors into one even larger category, representing the *value* provided by the invention. An invention, at least if the thrust of *Georgia-Pacific* is accepted, is more valuable when its inventor practices the invention, when

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96 *See, e.g.*, Finjan, Inc. v. Secure Computing Corp., 626 F.3d 1197, 1213 (Fed. Cir. 2010) (finding that a patentee should be awarded damages for pre-injunction infringement).

97 *See* Lemley & Shapiro, *supra* note 22, at 2009 ("[H]oldup is of particular concern when the patent itself covers only a small piece of the product, as is common in the industries in which so-called patent trolls predominate.").

98 *Id.* at 2017.

99 35 U.S.C. § 284 (2012) (requiring that at minimum, an infringer pay the patent holder "a reasonable royalty for the use of the invention").

100 *See, e.g.*, Uniloc USA, Inc. v. Microsoft Corp., 632 F.3d 1292, 1312 (Fed. Cir. 2011) ("The 25 percent rule of thumb is a tool that has been used to approximate the reasonably royalty rate that the manufacturer of a patented product would be willing to offer to pay to the patentee during a hypothetical negotiation.").

101 *See, e.g.*, Astrazeneca AB v. Apotex Corp., 782 F.3d 1324, 1332 (Fed. Cir. 2015) (indicating that the district court "employed the so-called *Georgia–Pacific* factors, the set of 15 factors drawn from the frequently cited opinion in *Georgia–Pacific Corp. v. U.S. Plywood Corp.*").

102 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970), *modified sub nom.* Georgia-Pac. Corp. v. U.S. Plywood-Champion Papers Inc., 446 F.2d 295 (2d Cir. 1971).

103 Sichelman, *supra* note 27, at 283 (discussing a factor that explains that the test is designed to mimic a hypothetical negotiation and a factor that allows expert opinion to be used).

104 *Id.* at 283–84 (discussing factors three through six).

105 *Id.* at 284–85 (discussing factors eight through eleven).

106 *Georgia-Pac.*, 318 F. Supp. at 1120; Sichelman, *supra* note 27, at 285–86 (discussing factor 13).

107 Sichelman, *supra* note 27, at 286 (discussing factors one, two, and twelve).

it represents a large technological advance, when it accounts for the success of products incorporating it, and when the market would ordinarily reward it with a high licensing price.

Sichelman offers a thorough critique of *Georgia-Pacific*. It may be unpredictable, especially because different courts will place different emphasis on different factors.[108] It may be especially difficult to apply to multicomponent products, leading to "the so-called royalty stacking and apportionment problems."[109] Juries may not have the cognitive capacity to apply the test effectively,[110] yet jury damages are generally upheld even if the basis for them is not clear.[111] Meanwhile, the portions of the test considering market royalties are circular, since those royalties are set in anticipation of what the courts will decide.[112] Jonathan Masur has shown that this can create a vicious cycle; if judicially calculated damages are too low, royalty rates in anticipation of levied damages will fall, and that will make judicially calculated damages fall in turn.[113] Sichelman also critiques reforms that seek to improve the courts' ability to gauge value. He agrees, for example, that the goal should be to assess a patent's contribution over prior art, but this can be difficult to assess "when the value of the invention turns on increased consumer demand,"[114] and especially when an invention is incorporated into a multicomponent product.

To promote his argument that patent law should focus on the risk-adjusted cost of inventions rather than on the value those inventions provide, Sichelman argues that the conceptual foundation of patent damages doctrine is flawed. Patent law, he argues, follows traditional tort law in seeking to return a victim to the status quo ante.[115] Patent law, however, "is not designed to remedy private wrongs," but "to promote innovation."[116] Compensatory damages may be excessive from a social welfare perspective "when a patent covers a minor component of a complex product,"[117] when patent rewards are far in excess of what is needed to induce invention,[118] and when infringement resulted from valid (if ultimately rejected) questions about "whether a given patent is infringed, valid, or enforceable."[119] In all of these situations, it may be appropriate to grant a patentee not what it would have

108 *Id.* at 287.
109 *Id.* at 288; *see, e.g.*, Lemley & Shapiro, *supra* note 22, at 2025–29 (describing case studies that "document examples of the royalty seeking problem outside the litigation context in the development of new technologies within a standard-setting organization").
110 Sichelman, *supra* note 27, at 289.
111 *Id.* at 289 (citing Monsanto Co. v. McFarling, 488 F.3d 973, 981 (Fed. Cir. 2007)).
112 *Id.* at 290–93.
113 *See* Jonathan S. Masur, *The Use and Misuse of Patent Licenses*, 110 NW. U. L. REV. 115, 116 (2015) (describing the dual trends of increasing patent litigation and decreasing damages awards).
114 Sichelman, *supra* note 27, at 295.
115 *Id.* at 297–98.
116 *Id.* at 298.
117 *Id.* at 301–02.
118 *Id.* at 302–03 (focusing especially on software patents).
119 *Id.* at 304.

received if a negotiation had been completed, but an amount sufficient to compensate for the costs of innovation.

As a remedy, Sichelman suggests incorporating cost considerations into the patent damages calculus. A court, he argues, should "examine the actual costs—R&D, commercialization, and related opportunity costs—of the invention at hand."[120] Sichelman recognizes that R&D costs must include not only wages, but also "amounts for materials, equipment, and facilities that can be allocated to work on the patented invention."[121] Commercialization costs, meanwhile, include not only marketing, but also "clinical and safety testing, pricing analysis, and other costs directly related to transforming the invention into a commercial product."[122] Finally, Sichelman insists that costs include "opportunity costs," i.e., the next best investment that a patentee could have made as an alternative to the patented product.[123]

Like Brennan et al., Sichelman recognizes the need to adjust for risk. Indeed, the approach that he recommends for performing the risk adjustment is similar: "Using retrospective cost accounting from survey data from multiple pharmaceutical companies, the average cost at each pre-clinical and clinical phase can be calculated."[124] As noted above,[125] this is potentially problematic. Risk may differ greatly from one project to another. If the *average* risk is the measure of risk for which inventors expect to be reimbursed, then inventors simply will not undertake inventions that have a high risk. Sichelman does note that the examination can be "more fine-grained," taking into account different risks at different stages and the specific type of relevant invention.[126] But there is still ample room for debate about the size of risk, and it is hard to know whether courts will tend to overestimate or to underestimate risk.

Even at a conceptual level, it is not easy to define the risk that one is estimating. The pharmaceutical example simplifies matters. A firm engages in a high-risk research project that either will produce a blockbuster drug (in the sense that many individuals would be willing to pay a great deal for it if unable to get it cheaper) or will fail. But in many inventive contexts, and even with pharmaceuticals, any project may lead to a number of different possible inventions, and any invention will have a distribution of potential success levels. A research project might "succeed" in earning a patent (or two) yet interest a much smaller number of consumers than expected or cost much more than expected to manufacture or require marketing expenses so great that the project would not have been worthwhile *ex ante*.

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120 *Id.* at 309.
121 *Id.*
122 *Id.* at 309.
123 *Id.* at 310.
124 *Id.* at 311–12.
125 *See* Brennan et al., *supra* note 39, at 317.
126 *See* Sichelman, *supra* note 27, at 312.

Thus, the court needs to know the distribution of potential success levels. Moreover, the court needs to know how this distribution changes at the time of each investment the firm makes, so that it can take account of changing success levels as a project moves closer to market. But even knowing all of these distributions does not resolve the court's inquiry. Cost-plus damages will meaningfully lower patent damages relative to alternatives only for the relatively successful portion of the distribution at each point in time. For relatively unsuccessful outcomes, cost-plus damages will be in excess of customers' willingness to pay. Willingness to pay will then be the limiting factor on profits, at least assuming those customers have adequate notice of the invention and negotiation occurs *ex ante*. Thus, the court's challenge in the cases in which the invention is successful is to reduce damages enough so that *ex ante*, the inventor would have had an incentive to undertake the investment, taking into account that in some cases, the inventor would be able to recover some fraction of its costs.[127]

One advantage of Sichelman's proposal over Brennan et al.'s, however, is that even if courts are expected to underestimate risk, the effect may be only marginal. This is because Sichelman suggests only that cost be one factor in the patent damages calculus, and thus its effects will operate largely on the margin. But Sichelman hints at the possibility that the use of cost-plus damages could be increased in the future.[128] And Brennan et al.'s proposal in principle could be adjusted so that cost is just one factor in the eminent domain inquiry as well. The problem remains that once cost is a sufficiently large factor in the calculus, investors will forego projects where they expect that the courts will substantially underestimate risk, even if the net social welfare benefits of those projects are expected to be high.

Just as Brennan et al. allow for reasonable profits and a margin of error, so too might underestimation of risk be a relatively small concern if the courts are generous in determining opportunity costs, and thus the interest rate that the courts will permit the patentee to receive on its risk-adjusted costs. Sichleman recognizes some problems with determining opportunity costs, however. In particular, there is a danger of circularity.[129] For many inventive entities, the opportunity cost is another project that also might result in the grant of a patent. But if that is so, the value of that alternative project would also depend on the structure of cost-plus damages. The inquiry thus becomes recursive and intractable. Measuring risk of the project at issue is hard enough; measuring risk of the best project not undertaken is a fool's errand.

Sichelman does not suggest scrutinizing the hypothetical next best project. Rather, Sichelman suggests that if a "firm requires an internal rate of return of 30% to perform such projects over time," then it should receive compensation for this

[127] *Id.* at 324.
[128] *Id.* at 323–25.
[129] *Id.* at 314.

internal rate of return.[130] But how would we know what rate of return a firm required? Presumably, we could look at how successful a firm's other projects are. But what if this is a firm's first project? And what if the firm has many projects, but all expect to be rewarded based on cost-plus damages? The circularity problem re-emerges. A firm might decline to undertake good projects because it wants courts to think it has a high internal rate of return. Moreover, if a firm believes that a court likely would underestimate the internal rate of return, then it may decide not to undertake certain projects that in fact are above its internal rate of return.

This analysis suggests that internal rate of return may not be the relevant concept. Indeed, one can make an argument that the relevant return is the return provided by a risk-free asset or close to that level. In principle, the risk that a particular research project will fail is idiosyncratic risk,[131] and so with well-functioning securities markets, this risk can be eliminated in a diversified portfolio.[132] Even if the risk is not entirely idiosyncratic—perhaps multiple firms will run into similar problems—the correlation of the risk with the market as a whole will be low, and so only a small interest rate should be necessary to induce investment.

But this argument has two problems. First, one can defend the idea of an "internal rate of return" on the basis that a successful company will not undertake marginal projects with slightly-above-market rates of return, because those projects may distract the firm from higher-return projects.[133] Thus, at least implicitly, risk-adjusted patent damages must compensate for these distraction costs. Second, firms are run by agents whose human capital is undiversified, and these agents will not be willing to undertake risky projects absent sufficient compensation. Cost-plus damages must take into account the salaries these workers require, but once they receive these salaries, workers may steer a firm in the direction of low-risk projects if high-risk projects do not provide a significant premium above what the market offers.

Thus, cost-based patent damages are likely to be more feasible if courts (or the legislature) simply pick a rate of return, or perhaps a few different rates of return based on crude factors such as industry. The rate of return must be one that will almost always be sufficient to compensate for the risks of development. This rate

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130 *Id.* at 310.

131 *See, e.g.*, Kevin G. Bender, *Giving the Average Investor the Keys to the Kingdom: How the Federal Securities Laws Facilitate Wealth Inequality*, 15 J. BUS. & SEC. L. 1, 17 (2015) (explaining the concept of idiosyncratic risk).

132 *See* Lee Drucker, *A Financial Perspective on Commercial Litigation Finance*, 12 N.Y.U. J.L. & BUS. 665, 671 (2016) ("Idiosyncratic risk is asset-specific risk that has little or no correlation with the market and can be mitigated by diversification.").

133 *See generally* Roy J. Epstein & Alan J. Marcus, *Economic Analysis of the Reasonable Royalty: Simplification and Extension of the Georgia-Pacific Factors*, 85 J. PAT. & TRADEMARK OFF. SOC'Y 555, 560 (2003) ("The IRR can be compared to the cost of capital to indicate project profitability. This is particularly useful in a royalty analysis because the documents in the litigation often already provide information on the cost of capital and the IRR of the infringing project.").

also should perform the function of Brennan et al.'s error margin.[134] That is, it must be high enough so that a firm that expects courts to underestimate risk will nonetheless think that the rate of return is so attractive as to compensate for such underestimation. Because the social costs of a decision not to engage in a research project as a result of expected underestimation of risks are much greater than the social costs of deadweight loss,[135] this will need to be a considerable rate of return indeed. The optimal rate will necessarily still allow for some false negatives—inventions that will be abandoned at loss of social value. But the cost of such false negatives is much greater than the cost of such false positives, so we must increase the permissible rate of return to a level where they will be quite rare. Developing an empirical model for figuring out the optimal rate may be quite difficult, and picking too low a rate could reduce innovation, while picking too high a rate might reduce the advantages of the cost-based approach or even increase deadweight loss.

It should be much more straightforward for the courts to estimate the costs incurred in the inventive process than to estimate either the needed rate of return or the level of risk faced by a particular firm. Indeed, one of the strengths of Sichelman's proposal is that costs are real numbers, backed by accounting, rather than hypothetical constructs. Yet even here there are risks. As with the Brennan et al. proposal,[136] there is the challenge of allocating costs across research projects that those costs may promote. Inventors will have an incentive to argue that costs were incurred in connection with a patented project rather than in conjunction with other projects producing different revenue streams. Especially when products incorporate patented and non-patented elements, or incorporate many different patents, these allocations will not be easy. A particular challenge involves allocating costs in creating an enterprise or in expanding it that must be amortized over a number of different projects. If the courts underestimate the proportion of these costs that should be attributed to a particular project, they will reduce incentives to enter the technological field, though not incentives of existing market participants to engage in invention.

An additional concern is that inventors may spend excessively. It may seem that it should not matter whether costs are reasonable, so long as they are genuinely undertaken to advance the project. In ordinary circumstances, after all, inventors' incentives in determining how much to invest are at least correlated with the public benefit from the invention that might result. An inventor that invests more is more likely to win a patent, while an inventor that invests less saves money. But with a cost-plus damages regime that reimburses all costs, the calculus changes. If the inventor concludes that there is a sufficiently high chance of winning the patent to make any investment worthwhile, then the inventor might as well invest more. If the permitted rate of return is attractive, then every dollar invested will return

[134] *See* Brennan et al., *supra* note 39, at 316 ("[C]ourts could . . . incorporate an additional margin to compensate for the risk of error in their R&D assessments.").
[135] *See* Abramowicz, *supra* note 34, at 125–26.
[136] *See supra* Part II.A. (discussing the difficulty of allocating entry costs).

considerably more than a dollar if the inventor is successful, so the inventor might as well invest as much as possible.

Investing more will increase the inventor's chance of winning. But oddly, this is a neutral consideration, since a higher chance of winning should produce a lower risk adjustment. The benefit of the investment is simply the greater return in the event the inventor wins the patent. A potential remedy is to limit the inventor to only reasonable investments. But that is not easy to define. Is it reasonable to hire ten scientists instead of five? To pay the president of the firm (who may also be the owner) an especially high salary? There are no easy answers to these questions. In principle, what ought to matter is the *expected* cost of invention. Even at a theoretical level, however, this is an elusive concept. If investing $1,000,000 would produce a 50% probability of invention, and investing $5,000,000 would produce a 100% probability of invention, is the expected cost $2,000,000 or $5,000,000? Moreover, focusing too much on expected costs vitiates the virtue of being able to focus on the *actual* costs spent by an inventor.

There are, however, at least three possible answers to this objection. First, the courts might use actual costs spent as a baseline for assessing risk-adjusted costs, but reserve the right to raise or lower the costs should they seem excessive. While this would trigger difficult questions about reasonable investment, inventors anticipating this might restrain their investment at least somewhat. Second, there is at least some limit on the amount of money that inventors can spend. Cost-plus damages serve effectively as a damages cap, but not as a damages floor. Users can always stay away from the invention, and so a patentee can only expect to recover high costs if the invention is valuable relative to the needed costs of production. Third, high spending may not be all bad. Because inventors can appropriate only some of the benefits of their inventions, they ordinarily might have incentives to spend *too little*.

III. Reform Possibilities for Patent Law

The various criticisms that Part II has levied at the admittedly ingenious proposals to use cost-plus accounting either for providing rewards for patents taken by eminent domain or for patent damages might be reduced to two broad yet opposite concerns. The first concern is about the possibility of undercompensation. The concern is not just that costs are difficult to calculate; virtually any methodology for determining patent damages will have its challenges. The concern is that even a slight shortfall in expected risk adjustment may lead to the failure to engage in research projects that would surely be undertaken in the traditional patent system. The only plausible way to respond to this concern is to offer a very substantial premium in the return permitted successful patentees, though this naturally reduces the benefit of cost-plus accounting. The second concern is that of excessive compensation. Conditional on the invention being produced, this may not make things any worse for users, who can still negotiate lower prices. But it reduces the benefit of cost-plus accounting still more. Moreover, the problem of excessive compensation does not simply cancel out with the problem of insufficient compensation. Compensation can be excessive because cost-plus damages caused excessive spending on research, yet simultaneously insufficient because the risk adjustment was too low.

If the cost-plus damages proposals were mere tweaks to patent law, these practical problems would probably be sufficient to doom them. But they should not be disregarded so easily. While the dangers of cost-plus damages are substantial, the potential benefits, should it be possible to overcome these problems, are high as well. This section imagines that the courts could develop a well-functioning patent damages doctrine based entirely on cost-plus accounting, substantially responding to the concerns raised here. In that case, cost-plus damages would have the potential to revolutionize patent law. Cost-plus damages solve a number of distinct problems of the patent system and thus could lead to a patent system that looks quite different from the patent system of today. In particular, there would be no need for a nonobviousness doctrine or even for a patent term. Patentable subject matter could be relaxed, and patent scope would become much less important.

A. Nonobviousness

The nonobviousness doctrine, as noted in the Introduction, is designed to avoid giving intellectual property rights unnecessarily. The Supreme Court in *Graham v. John Deere Co*. casts the problem this way,[137] and John Duffy and I have argued that whether a patent is needed to induce an invention should indeed be the touchstone of the nonobviousness analysis.[138] But even if one accepts our argument that a focus on inducement improves the administrability of nonobviousness doctrine, that doctrine has an unavoidable limitation: it is binary. Inducement, by contrast, is not binary. Even absent a patent system, most inventions would be invented *eventually*, and so the question is how much the patent system accelerates invention.[139] Even a properly functioning nonobviousness doctrine guided by the inducement standard will leave two problems: First, when a patent is granted, it may provide more protection than is needed to induce invention. Second, the absence of patent protection for inventions that will be invented soon anyway means that there may be no incentive to accelerate those inventions.

In principle, cost-plus damages can fix these problems. First, cost-plus damages eliminate the problem of excessive protection by restricting rents. An invention that is borderline nonobvious will no longer provide the patentee with a windfall. Second, with properly functioning cost-plus damages, there is little downside to granting a patent on a relatively trivial invention. So long as the

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[137] Graham v. John Deere Co., 383 U.S. 1, 11 (1966) ("The inherent problem was to develop some means of weeding out those inventions which would not be disclosed or devised but for the inducement of a patent."). The Court's language is infelicitous, as the Court's point was that the nonobviousness doctrine would filter out those inventions that would have been devised and disclosed even absent the inducement of a patent.

[138] *See* Abramowicz & Duffy, *supra* note 12, at 1596 (aspiring to "revitalize the inducement standard as the touchstone for understanding and refining the obviousness doctrine").

[139] *Id.* at 1599.

patentee is limited in the damages it can recover to the risk-adjusted costs incurred, the deadweight loss associated with the patent grant will be correspondingly low. The principal harm from a patent on a relatively obvious invention is that it may allow damages well above cost recovery and thus impose substantial deadweight loss, but cost-plus damages would limit recovery to risk-adjusted costs.

It might seem that a patent still ideally should not be granted in such a situation. By hypothesis, the invention would have been invented soon anyway, and any patent will produce at least some deadweight loss. But that is not so clear. The patent may at least slightly accelerate invention, providing benefits that may offset deadweight loss. Moreover, cost recovery may promote efficiency. The inducement test assesses whether existing firms in an industry would have had incentives to invent. But this ignores incentives to enter into the industry in the first place. A company is more likely to enter into an industry if it expects to be able to recover a category of its costs than if it does not. The law does not generally seek to deny producers the ability to pass along their costs to consumers.

Blocking windfall damages is not the only function of the nonobviousness doctrine. Perhaps the nonobviousness doctrine serves as a carrot that leads some inventors to make more significant contributions than they otherwise would.[140] Meanwhile, perhaps some inventions might be so trivial that they would not be worth the administrative costs of patentability. But these are second-order considerations. Many critics of the patent system in the United States view the relative generosity of the Patent and Trademark Office in granting patents as one of its chief flaws.[141] This is not an easy problem to solve doctrinally or administratively.[142] But bad patents that produce only modest rewards seem at least like a much smaller problem. If patent damages were assessed based on risk-adjusted costs, the primary function of the nonobviousness doctrine would be unnecessary, and any administrative deficiencies in enforcing it would be of little moment.

B. Patent Term

A related benefit of cost-plus patent damages is that it might be unnecessary to limit the patent term. A primary function of the patent term is to limit the extent to which a patentee can extract rents from the public. The patent term does this by allowing the patentee full power over price within the patent term and no power

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140 *Cf.* Michael J. Meurer & Katherine Strandburg, *Nonobviousness – The Shape of Things to Come: Patent Carrots and Sticks: A Model of Nonobviousness*, 12 LEWIS & CLARK L. REV. 547, 549 (2008) ("The nonobviousness threshold may be used as a 'stick' to induce researchers to pursue more difficult, socially preferred research projects.").

141 *See, e.g.*, Shawn P. Miller, *Where's the Innovation: An Analysis of the Quantity and Qualities of Anticipated and Obvious Patents*, 18 VA. J.L. & TECH. 1, 10 (2013) (citing ADAM B. JAFFE & JOSH LERNER, INNOVATION AND ITS DISCONTENTS: HOW OUR BROKEN PATENT SYSTEM IS ENDANGERING INNOVATION AND PROGRESS, AND WHAT TO DO ABOUT IT 8 (Princeton Univ. Press 2004)).

142 *See* Michael Abramowicz & John Duffy, *Ending the Patent Monopoly*, 157 U. PA. L. REV. 1541, 1546–58 (2009).

over price after the patent term. But cost-plus damages provide an alternative mechanism for restraining power over price. The patentee could collect damages until risk-adjusted costs were recovered. In setting damages against a particular defendant, a court might ordinarily assume a collection schedule of duration comparable to the patent term. But a patentee might choose to charge less and collect over a longer period of time. Indeed, the patent system might encourage this by applying a generously high discount in determining cost recoveries.

There are two primary benefits of such a regime. First, Ian Ayres and Paul Klemperer have argued that longer patents with reduced power over price may increase welfare relative to shorter patents with greater power over price.[143] The reason is that the last increment of monopoly pricing places the greatest strain on deadweight loss. Ayres and Klemperer suggest that probabilistic enforcement of a patent may be one way to reduce power over price;[144] restricting damages recoveries is another. Second, the current patent term may unduly induce incentives for creating inventions whose benefits will largely accrue after the patent term. The problem is recognized in the area of pharmaceuticals, where the local clinical trial process may mean that a patentee gets relatively few years of patent term.[145] The law partially adjusts for delays in that context,[146] but breakthrough inventions in many fields take a long time to commercialize. Cost-plus damages would allow creators of such breakthroughs to recover damages over a longer period of time. Someone who invested a billion dollars for a technological solution to global warming would probably not recover the investment, because potential users of the technology would just wait for it to enter the public domain.[147] Cost-plus damages would improve the ability of inventors to place long bets.

Like the nonobviousness doctrine, the patent term may have functions besides reducing the total return to inventors. It may, for example, reduce the nuisance of administrative costs associated with patents with little economic power. But there are simpler solutions to this problem, such as insisting on renewal fees so that patentees would not unnecessarily drag out patent lifetimes.

C. Patentable Subject Matter

Though the issue of cost-plus damages seems distant from the issue of patentable subject matter, limitations on patentable subject matter can be seen as

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143 Ian Ayres & Paul Klemperer, *Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies*, 97 MICH. L. REV. 985, 992–94 (1999).

144 *Id.*

145 *Compare* Henry G. Grabowski & John M. Vernon, *Effective Patent Life in Pharmaceuticals*, 19 INT'L J. TECH. MGMT. 98, 109–17 (2000) (estimating between ten and twelve years) *with* Amy Kapczynski et al., *Polymorphs and Prodrugs and Salts (Oh My!): An Empirical Analysis of "Secondary" Pharmaceutical Patents*, 7:e49470 PLoS ONE, Dec. 2012, at 4–5 (arguing that secondary patents can increase the effective patent term by 6–7 years).

146 *See* 35 U.S.C. § 156(a) (2012).

147 *See* Michael Abramowicz, *Orphan Business Models: Toward a New Form of Intellectual Property*, 124 HARV. L. REV. 1362, 1404 (2011).

reflecting concerns similar to those animating nonobviousness and the patent term. A principal concern of defenders of patentable subject matter limitations is that patents on abstract ideas might allow a patentee to obtain control over an entire field, potentially earning excessive rents and impeding further technological developments.[148] Meanwhile, some have argued that patentable subject matter should be used to exclude certain technological fields, such as software, where there may be considerable incentives to invent even absent patent incentives.[149] If many patents are granted on relatively trivial inventions in these fields, and if those patents place a burden on legitimate inventive activity, then a blanket patentable subject matter ban may be justifiable.

Patentable subject matter doctrine, however, is at best an unfortunate compromise. If a mathematician can devise a new theorem that has great practical import, why should that mathematician be any less entitled to a patent than a biologist or chemist making an equal contribution?[150] Meanwhile, while software technology appears to advance rapidly, it seems plausible that it might advance more rapidly if there were more theoretical computer scientists. Much of the software powering modern artificial intelligence applications reflects advances in algorithms,[151] and with greater patent incentives, those advances might have been made earlier than they were. The same is true of advances in basic research in biology and life sciences. Government funding of basic research is limited, so if the patent system could lead to increases in funding, that could increase social welfare. The challenge is for the patent system to increase incentives in these fields without risking inventors earning excessive control over a technological field.

At least in theory, cost-plus damages can achieve this goal. A mathematician (or university or private firm employing mathematicians) would be able to receive patents for contributions, but the market power that these patents would provide would be limited. This would have two significant benefits. First, it might help induce patents on many modest inventions in fields currently beyond the scope of patentable subject matter. The argument above concerning nonobviousness applies here; there is no need to filter out small inventions, so long as the return on these inventions is proportional. Second, eliminating the patentable subject matter hurdle could allow inventions that are quite significant, albeit not so significant as to entitle the inventors to injunctive relief or patent damages under traditional formulae.

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148 *See* Bilski v. Kappos, 561 U.S. 593, 611–12 (2010) ("Allowing patent petitioners to patent risk hedging would preempt use of this approach in all fields, and would effectively grant a monopoly over an abstract idea.").

149 *See generally* Lisa Larrimore Ouellette, *Patentable Subject Matter and Nonpatent Innovation Incentives*, 5 U.C. IRVINE L. REV. 1115, 1138–41 (2015) (discussing the nonpatent incentives for software innovation).

150 *See* John F. Duffy, *Rules and Standards on the Forefront of Patentability*, 51 WM. & MARY L. REV. 609, 623 (2009) ("[I]t should be a rare situation in which an entire class of patents complies with the nonobviousness requirement and yet still somehow discourages or impedes the development and spread of useful knowledge.").

151 *See, e.g.*, Image Assessment Using Deep Convolutional Neural Networks, U.S. Patent No. 9,536,293 (issued Jan. 3, 2017).

D. Patent Scope and Infringement

The doctrine of patentable subject matter has long been closely associated with the doctrine of patent scope. *O'Reilly v. Morse*,[152] for example, can be read either as a case about whether the telegraph is within patentable subject matter or about whether Samuel Morse claimed more than he had invented.[153] Patent scope is one of the most challenging areas of patent doctrine conceptually, because there are no obvious conceptual limiting principles. Should Morse have received a patent only on the particular mechanism that he devised, or, as he sought, on the use of electromagnetism "however developed for marking or printing intelligible characters, signs, or letters, at any distances"?[154] If a patent is too narrow, it might be too easy for others to free-ride on the inventor's contribution by changing the invention slightly; if a patent is too broad, then an inventor may receive a windfall beyond the contribution provided. The only way to answer this question in a particular context is to consider the specifics of the inventive contribution, but in our current system it is hard to give much more concrete guidance than that.

A working cost-plus damages system would make it feasible to grant broad patent scope without granting powerful monopoly rights. An inventor like Morse would be entitled, like any other, to receive his risk-adjusted returns on an invention that could not have been made without the insight that he provided. As this formulation suggests, patent law would no longer need to require inventors to engage in "peripheral claiming" wherein they carefully identify the metes and bounds of their invention.[155] The patent system could instead return to a system of central claiming. That does not mean that patents would have no bounds at all. The courts should be sure that an inventor was the first to have an insight represented by a central claim and that this insight was indeed necessary to the allegedly infringing product. But in principle, multiple inventors who contributed key insights could each receive patents on different related insights. In today's patent system, having a large number of patents that read on broad categories of technology can lead to inefficient royalty stacking.[156] But in a well-functioning cost-plus damages system, each contributor would be limited in what he or she could collect.

This utopian vision should not be confused with an endorsement. My discussion is predicated on the premise that the cost-plus damages system is well functioning. Yet in Part II.A, we identified concerns—that cost-plus damages might undercompensate if permissible returns are set too low and that inventors might spend excessively in anticipation of a significant return on investment. It is easy to imagine these problems ruining our utopian patent system. If returns were set too

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152 O'Reilly v. Morse, 56 U.S. 62 (1854).

153 *See* Aaron J. Zakem, *Rethinking Patentable Subject Matter: Are Statutory Categories Useful?*, 30 CARDOZO L. REV 2983, 2991–92 (2009).

154 *O'Reilly*, 56 U.S. at 112.

155 *See generally* Dan L. Burk & Mark. A. Lemley, *Fence Posts or Sign Posts? Rethinking Patent Claim Construction?*, 157 U. PA. L. REV. 1743, 1748–49 (2009).

156 *See* Lemley & Shapiro, *supra* note 22, at 2047.

low, Morse might have found another line of work. And if anyone could claim an insight central to later inventions, many inventors might have unnecessarily fancy offices and unnecessarily large salaries, contributing very small insights that others easily could have obtained without a patent. To address this, we would need to require patentees to limit their patent scope carefully. Indeed, if the problems are sufficiently severe, we might need to keep many features of the patent system designed to prevent inventors from receiving excess rents. We thus return to these problems to try to gauge their scope.

IV. Modeling Cost-Plus Damages

In principle, cost-plus damages can be implemented by allocating every expense by an inventor across all projects the inventor is undertaking, estimating the distribution of returns that the inventor would have expected in the traditional patent system at the time of each expense, determining the inventor's internal rate of return at the time of each expense, identifying a range of outcomes in which the inventor would earn more than was needed to incentivize the investments *ex ante*, and finally determining what rate of return should be allowed in those cases to ensure that the inventor would have had just enough incentives. We can further complicate the analysis by accounting for the distribution of possible measurement errors that the inventor or the court might make in assessing amounts, allocations, or probabilities.

This is too complicated. As Part II.A's critique of Brennan et al.'s and Sichelman's proposals indicated, it is difficult even to conceptualize how to calculate risk-adjusted returns, and such calculations would be even more difficult in practice to get exactly right. Any attempt to implement cost-plus damages is thus likely to require some crude approximation. Probably it will be infeasible to determine the risk associated with investments in creating a firm, since it will be difficult to allocate these investments among all past and future projects. At best, a court can estimate costs actually incurred for a particular research project and the risk associated with that project. Rather than attempt to determine the exact internal rate of return necessary to compensate investors, it will likely be more feasible simply to specify a permissible rate of return and to set that large enough to overcome the failure to include early stage costs.

The question is whether such a strategy can succeed. The government must set the permissible rate of return not so low that it thwarts investments and not so high that it generates excessive expenditures. Is it even plausible that there exists some permissible rate of return that would increase social welfare? And if so, how difficult might it be for the government to identify that rate of return? The ultimate challenge for the government is one of calibration. This paper's goal is not to perform that calibration, a task that, if achievable at all, would require a great deal of empirical work. Rather, the goal is to develop an approximate sense of how different parameters will affect social welfare and how precise the government will need to be in its calibration if it ultimately seeks to adopt a regime of cost-plus damages.

A. Analytical Model

We will begin with a simple analytical model. Assume that there is a fixed cost to research c, producing a probability p of a successful invention. Success results in an invention valued by users at v. Assume that standard damages will equal v, and the inventor is able to extract the full surplus of the value, thus receiving v. Thus, the *ex ante* expectation of revenue is pv, and the inventor will engage in research so long as $c < pv$.

With cost-plus damages, assume that the inventor can recover $\min(v, (1 + r)kc)$. Thus, r represents the permitted rate of return, and $k > 1$ if the courts will overvalue costs and $k < 1$ if the courts will undervalue costs. Note that the recovery will never be greater than v, because if the inventor set a price greater than v, then users will not use the invention. So, expected damages is $\min(pv, p(1 + r)kc)$. If $c > pv$, then c > $\min(pv, p(1 + r)kc)$, so, just as with standard damages, the inventor will not invent. If $c < pv$, then c will invent so long as $c < p(1 + r)kc$, i.e., $1/p < (1 + r)k$. This reflects that the rate of return r must be sufficient to compensate both for the risk associated with the possibility of research failure and also for any undervaluation of costs.

This highlights the primary effects of cost-plus damages placing aside concerns about excessive investment. If the rate of return r is set too low, then the inventor will not undertake research even in cases in which it would have been socially optimal (and also privately optimal with standard damages) to do so. But if the inventor *does* invent, then the amount paid to the inventor is reduced from v to $p(1 + r)kc$, which is less than or equal to v in cases in which invention occurs.

Suppose, however, that the inventor can choose c, producing a probability of success $p(c)$, where $p'(c) > 0$ and $p''(c) < 0$. That is, the inventor can spend more than the minimal amount needed to complete the invention, resulting in an increased probability of completing the invention but with decreasing marginal returns. With standard damages, an inventor will set c to maximize $p(c)v - c$, i.e., where $p'(c) = 1$. This is the point where both the marginal benefit of additional spending (from both the private and social perspectives, since the inventor is assumed to be able to extract the user's full value) equals the marginal cost.

But with cost-plus damages, the inventor will optimize $\min(p(c)v, p(c)(1 + r)kc) - c$. Assume that $p(c) = m/(1 + r)$ where m is some constant, i.e., that the permissible rate of return is expected to vary proportionately with the probability of invention. Then, the inventor is optimizing $mkc - c$. If $mk > 1$, then the inventor will set c so that $mkc = p(c)v$, i.e., up to the point where the inventor receives the same amount as the inventor would receive with standard damages. This is a worse outcome from a social perspective since damages are no lower but expenditures are higher.

This analytical model identifies the fundamental promise and dangers of cost-plus damages. But it is simplified in important respects. Critically, it imagines just one inventor. This ignores both the dynamics of entry when some entry costs are not likely to be reimbursed and the dynamics of rent-dissipating entry. A more realistic environment would include multiple potential inventors, each with its own estimate of the value of the invention and with varying costs of successful invention. Modeling many potential heterogeneous inventors is likely to be analytically intractable.

B. Simulation Model

Thus, we will turn to a simulation model that will allow for us to better estimate the implications of different parameter values. Simulations are helpful when the goal is to develop back-of-the-envelope calculations rather than to prove that under some assumptions, certain results will necessarily obtain. The purpose of this exercise is not to prove that cost-plus damages can or cannot work, but rather to test the sensitivity of a cost-plus damages regime to various parameters. Because a simulation makes it easy to plug in potential parameter values and see how that affects welfare outcomes, it is an appropriate tool for this project.

1. The Patent Damages Game

To describe the model, we will first explain the game that our computerized agents are playing and then describe the optimization protocol.

a. Game Structure

The model that follows is independent of the analytical model in Part IV.A, replacing its notation and assumptions. The extensive form game that we are modeling is one in which inventors first choose whether to enter into a market and later choose whether to attempt to create a particular invention, and if so, how much to invest in the effort. The justification for this approach is to reflect that one reason to create a firm capable of innovating is that doing so will provide later opportunities for innovation. In a more realistic model, a single entering firm might consider a wide range of opportunities over time and allocate its assets to working on the most attractive opportunities, and firms would survive or fail depending on their success. With our model, the cost of entry can be thought of as the proportion of the cost of entering a market that can be allocated to a particular opportunity that presents itself.

Assume that an inventor has initial wealth w_0. The inventor must choose whether to enter the market and pay an entry cost c_e. This choice is made solely on the basis of how many other inventors have so far decided to enter. Once entry is complete, an investment opportunity presents itself. The opportunity is to attempt to make an invention. For an *average* inventor to attempt the invention will require the inventor to spend a minimum of $s_{\min}$, where $s_{\min}$ is drawn from a uniform distribution (0, s). For a particular inventor i, the minimum amount is $s_i s_{\min}$, where s_i is drawn from a uniform distribution between 0.5 and 1.5. That is, inventors will differ in the cost efficiency of their inventive efforts, so inventors who can accomplish an invention at low cost will be more likely to make an attempt than inventors with high costs. An inventor who invents can choose m_i where $m_i \geq 1$. The inventor's total spending will be $m_i s_i s_{\min}$.

The probability that an inventor succeeds in making an invention is parameterized by three values, p_1 (representing the probability of success with a minimum investment), p_2 (representing the probability of success with an investment of twice the minimum), and p_{10} (representing the probability of success with an investment of ten times the minimum, which is the maximum permitted). We will define $p(m)$, the probability for a particular spending level, as a curve between these three points. More concretely, let $k = ln(1/9)/(ln(p_2 - p_1) / ln(p_3 - p_1))$. Then, for a particular m, $p(m) = p_1 + (p_3 - p_1)*(((m - 1)/9)^{1/k}))$. Note that $p(m)$ is the same for all inventors, but because s_i varies across inventors, two inventors spending the same amount have different probabilities of success. If more than one inventor succeeds at invention, the patent is granted to one of the succeeding inventors chosen at random (using a pseudo-random number generator).

The invention is embodied in a product that sells for zero marginal cost. The demand for the product is linear, and the highest amount any potential user values the product is v/n, where n represents the total number of potential users and v is drawn from a uniform distribution from the interval $(0, \overline{v})$. We can thus think of v as the total utility that all potential users would receive from the invention if everyone who valued the invention at all valued it as much as the highest valuing user. Because demand is linear, the average utility for a potential user is $v/(2n)$.

Each inventor i receives only a signal of v, namely $v + \delta_i$, where δ_i is drawn from a normal distribution with mean 0 and standard deviation σ. Each user j knows that its utility from the product would be $u_j v/n$, where $0 \leq u_j \leq 1$. Based on this signal, the inventor calculates $v_i = E(v)$, drawing valid Bayesian inferences considering the distributions of v and δ. Each inventor thus has a valid but noisy estimate of the highest valuation.

An inventor i who wins the patent chooses α where $0 \leq \alpha \leq 1$ and offers the product for sale to users at a price $I = \alpha v_i$. (Note that we are assuming that the inventor cannot price discriminate but must offer a single price to all users.) Each user may choose to accept this price, to infringe the patent, or to not use the product. If the user accepts the price, the product is sold at this price, and the inventor is assumed to collect all the revenue. If the user infringes, then a court chooses β to produce a court-ordered price of $C = \beta v_c$. When intentional infringement occurs, each side bears a litigation cost c_l, so a user j with valuation $u_j v/n$ receives a benefit of $u_j v/n - C - c_l$, and the inventor earns revenues of $C - c_l$. We define v_c to be the court's estimate of the valuation of the highest valuing user based on the court's own signal of v drawn from a distribution with the same standard deviation as the inventor's. Thus, a user with valuation $u_j v/n$ will infringe if $I > u_j v/n - C - c_l > 0$, i.e., if intentional infringement is cheaper than paying the offered price and is better than not using the product at all. A user who does not infringe will pay if $I < u_j v/n$. Note that because users know v, it will never be the case that some users infringe while other users pay. If the inventor prices sufficiently high, then some users will infringe while others will not use the product; otherwise, some users may pay the price while others will not use the product.

The approach that the court takes in setting β and thus C depends on the legal regime. In the *standard damages* frame, the court chooses $\beta = 0.5$. If $v_c = v$, then this is the profit-maximizing price that the inventor would choose if the inventor had perfect information. In the *cost-plus damages* frame, the court sets β so that $C = (1 + r)m_i s_i s_{\min} p'$, where r represents the permitted rate of return and p' represents the *ex ante* probability that eventual patent winner inventor i would win the patent. Note that if there was only one inventor, then $p' = p(m_i)$. Where multiple inventors attempt to complete an invention, the simulation calculates p' by using an algorithm that takes into account each investor's investment and probability of winning, as well as the randomization of the patent to one of the winning inventors. For example, if $r = 0.5$ and an inventor invests $1,000,000 producing a 0.2 chance of ultimately receiving the patent, then the inventor will receive $7,500,000. Note that cost-plus damages thus reward the inventors' investments in attempting to invent, but not investments in initially entering the market.

Given a set of investment decisions, the pricing decision of the winning patentee (if any), and the potential court's valuation, it is straightforward to estimate the final wealth of the patentee, w_f, and the combined utility of all users. We assume that the patentee and users are risk neutral and that private welfare W_{priv} can properly be represented as the sum of the users' utilities plus the change in each inventor's wealth. We further define social welfare W_{soc} as $W_{\text{priv}} + \theta v$, where the θv represents a spillover from invention that cannot be captured by the users or the patentee.

b. Optimization Protocol

Many of the parameters in the patent damages game can either be set as constant settings that are inputs into the optimization process or calculated on the fly as the game proceeds. For example, the users' decisions whether to infringe and the court's decision in cases in which infringement occurs can be simulated without need for any optimization. We also assume that the inventor sets $\alpha = \min(0.5, E(C)/v_i)$. That is, with standard damages, the inventor sets α to the profit-maximizing level conditional on $v = v_i$. With cost-plus damages, the inventor sets α to the inventor's best estimate of β, unless this is greater than the profit maximizing level of 0.5. Given these assumptions, only the inventor's decisions whether to enter the market and whether to invest need to be optimized.

An inventor i who has entered the market is assumed to decide on a value $m_i \in \{0\} \cup \{x \mid 1 \leq x \leq 10\}$. In making this decision, the inventor has several pieces of information besides inputs to the optimization process: the number of inventors who have entered the market (some of whom also may choose to try to invent), s_i, $s_{\min}$, and v_i. We optimize separately the decision whether to try at all (i.e., whether $m_i = 0$) and how much to try conditional on $m_i \geq 1$. The optimization process occurs over ten rounds; in each round, first the decision whether to try at all is optimized, and then the decision of how hard to try is optimized. Each round results in a strategy that chooses for the first potential entrant the investment amount that is expected to lead to the maximum score for any given set of inputs. All potential entrants but the first use the strategy that is the result of the optimization in the previous round, except in the first round, where all potential entrants but the first play $m_i = 0$. Using ten rounds allows the strategies to converge so that the strategy from the tenth round is quite close to the strategy resulting from the ninth round. (Qualitative results were the same when running the simulation over a smaller or larger number of rounds.)

To perform each optimization in a single round, a neural network optimization process is used. The neural network optimization process is described in more detail in a separate article concerning a different model,[157] but a capsule summary will be provided here: The game is played a large number of times (up to 25,000), with the first entrant choosing m_0 drawn at random from the permissible values (with all values between 0 and 1 converted to 0). A general regression neural network is constructed based on the plays of the game, where the inputs for each play of the game are s_i, $s_{\min}$, v_i, and m_0, and the output is the final wealth of the first potential entrant, w_f. The general regression neural network thus can produce a predicted score for each potential investment amount, given a set of inputs. The optimization process thus selects the maximum possible predicted score for each set of inputs.

The simulation can be conducted either by fixing the number of entrants at one or by optimizing the number of entrants given the optimization of the decisions on how much to invest. Fixing the number at one is useful for assessing the static effects of a change in patent damages on a single potential inventor; optimizing the number makes it possible to also consider how patent damages may affect entry into the market. Because the optimization of spending amounts takes into account how many firms have entered into the market, it is straightforward to optimize the number of entrants. The simulation plays the game a large number of times to estimate $E(w_f)$ with just one entrant. If this is less than w_0, then we assume that no firms will enter the market and thus no inventions will be produced. In this case, $W_{\text{soc}} = W_{\text{priv}} = 0$. Otherwise, the simulation plays the game repeatedly to determine the number of entrants n to make $E(w_f)$ as close to $w0$ as possible. This reflects the standard assumption in the industrial organization literature that entry will dissipate all rents.[158] If entering would earn an inventor positive economic profits, then entry would occur until those profits were dissipated. Note that the simulation allows *fractional entry*. For example, if the entry that dissipates profits is 1.5, then there will be a 0.5 probability of one entrant and a 0.5 probability of two entrants. In any play of the game, those who enter choose how much, if any, to invest in invention.

[157] *See generally* Mina Niknafs, Neural Network Optimization 1 (Feb. 6, 2016) (unpublished manuscript), *available at* http://courses.mai.liu.se/FU/MAI0083/Report_Mina_Nikanfs.pdf.

[158] *See* Michael Abramowicz, *An Industrial Organization Approach to Copyright Law*, 46 WM & MARY L. REV. 33, 51 (2004).

2. Single Entrant Model

To facilitate exposition of the results, we will start with a simplified version of the model. In this version, we assume that the number of entrants is fixed at one, i.e., that the entry-optimizing step is skipped. In other words, we imagine that a particular inventive opportunity is presented to a single firm. If that firm does not try to invent or does not succeed in an attempt, then the invention does not occur and no users enjoy any surplus from the invention. We repeat the entire optimization process once for the standard damages frame and a number of times under the cost-plus damages frame for different values of *r*. The goal is to see how changing the value of *r* will affect investments, the likelihood of invention, and private and social welfare.

For each of the optimizations, we set various parameters to specific values. While plausible values are chosen, it is worth emphasizing that the purpose is not to calibrate the model closely to the actual patent process. Rather, the goal is to assess the sensitivity of the model to *r*. If the success of cost-plus damages proves to be highly sensitive to *r*, we know that there is at least a risk that the government will not set the appropriate value of *r*, and because the other parameters in this Article may not be accurate, this Article cannot be seen as a definitive source for determining the optimal value of *r* if cost-plus damages were to be enacted. If cost-plus damages are successful across a wide range of *r* values, that should give us some confidence that cost-plus damages have potential, but can hardly be viewed as a conclusive demonstration for any particular value of *r*.

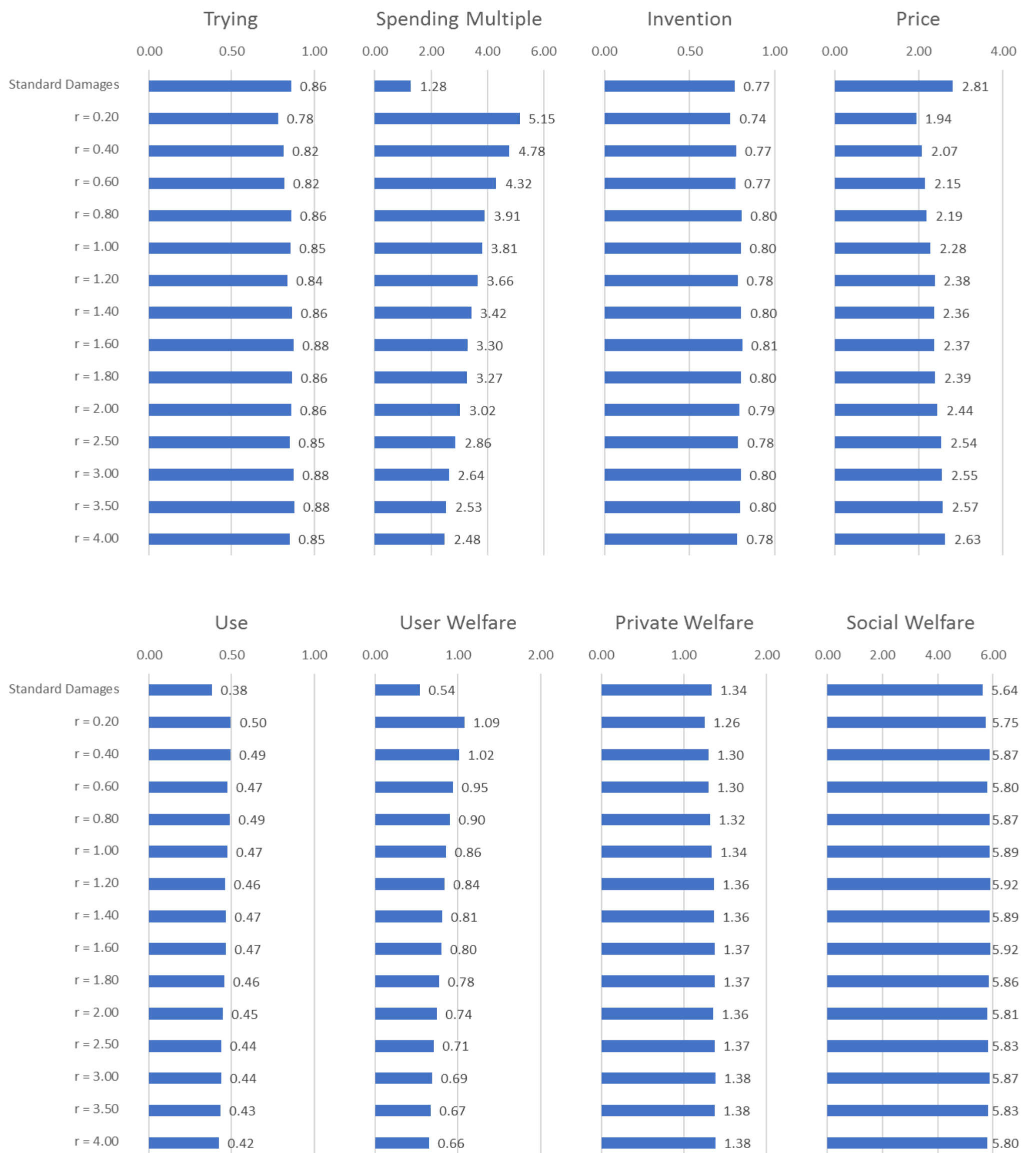
We have set the parameters as follows. We assume that $\overline{v} = 10$ and that $\sigma = 1$. We normalize *n* to 1. One might consider this to mean that if all users had the valuation of the highest valuing user, then in the average run of the simulation they would be willing to pay in total up to $5,000,000 for the invention. Meanwhile, $s = 0.5$, representing the top of the distribution from which the cost for the average inventor is drawn. The cost of litigation $c_l = 0.1$. We have set $\theta = 1.0$ so that we can consider social welfare in a world with high spillovers.

We will start with a baseline simulation, for which we have set p_1, p_2, and p_3 to 0.75, 0.8, and 0.9, respectively. In other words, the minimum investment produces a 75% chance of success, but higher levels of investment add only incrementally to success. These are arbitrary values—some inventions in the real world are much easier, some are harder—and we will deviate from this baseline to assess the robustness of the model later. Meanwhile, in this baseline, we begin with an assumption that the inventor knows the value of the invention. That is, $\sigma_n = 0$, so for each *I*, $v_i = v_c = v$. This is not a perfect information assumption, however, because the neural network optimization is necessarily imperfect. The neural network optimization figures out the "optimum" based on other, similar cases. It does not permit the inventor to calculate the exact amount of investment that would maximize its welfare.

We can now compare outcomes, including social welfare results, for standard damages and cost-based damages with different permitted rates of return given these baseline parameters. Consider first the spending multiple, i.e., the average value of *m* excluding those who set $m = 0$. This thus represents the amount spent by each inventor divided by the minimum spending amount. Even with standard damages, this amount is greater than 1, reflecting that at least in some situations (especially when the invention is estimated to be highly demanded), the inventor finds it optimal to invest more than the minimum to increase the probability of succeeding with invention. But the spending multiple is *much* greater for cost-plus damages. This is illustrated in the second panel of the top row of Figure 1. With cost-plus damages, greater investments allow greater recoveries, and so inventors invest much more, even though with our parameters, the marginal increase in the probability of invention from additional investment is relatively low.

There is *some* limit to gold-plating even with cost-plus damages. This is so for two reasons. First, users have an option besides paying damages. They can simply decide not to use the patented invention. Greater cost-plus damages limit the likelihood that users will be willing to engage in intentional infringement, and they thus increase the inventors' ability to charge close to the profit-maximizing price. But an inventor will not want to charge more than the profit-maximizing price (the same price charged in the standard damages model), so at some point, the benefits to gold-plating are reduced. Second, as permitted rates of return rise, there may be less need for gold-plating. If one can recover 400% of one's investment, then the investment need not be high to charge as much as one wants. This explains why the spending multiple gradually declines as the permitted rate of return increases.

Figure 1. Baseline (Single Entrant)



Because increased spending multiples increase the probability of invention, gold-plating has potential benefits. But in the model represented by Figure 1, with relatively low permitted rates of return, invention occurs less often with cost-plus damages than with standard damages. Because the effect of cost-plus damages is to restrict the inventor's ability to charge the profit-maximizing price, the inventor perceives a risk of spending more than can be recovered. Thus, the inventor is somewhat less likely to try to invent at all. With standard damages, an attempt to invent occurs 86% of the time, but with a permitted return of 20%, it occurs only 78% of the time. With higher permitted rates of return, the constraint on the inventor's pricing is reduced, and so the inventor is roughly as likely to try to invent as with standard damages. In Figure 1, once the permitted rate of return is approximately 80%, the effect of the spending multiple dominates, and the rate of invention is generally at least as much as with cost-plus damages.

Figure 1 also shows the effect on price and on the proportion of potential users who ultimately use an invention. The use metric is not conditional on invention, so when no invention occurs, that is counted as zero use. As one would expect, price is highest with standard damages, considerably higher than with a low permitted rate of return. As the permitted rate of return rises, damages increase, and price increases accordingly, though never higher than the amount that can be received with standard damages. Under the parameters represented by Figure 1, even though cost-plus damages slightly decrease the rate of invention with a low permitted rate of return, the increase in use conditional on invention results in more users using the invention overall. With high permitted rates of return, the higher prices mean that use returns closer to the level associated with standard damages.

The welfare consequences of this are also illustrated in Figure 1. User welfare is especially high with a low permitted rate of return. As the permitted rate of return rises, user welfare declines, but it still remains consistently above the user welfare level associated with standard damages. Private welfare takes into account both user welfare and the inventor's interests. The inventor fares much worse with cost-plus damages, and thus despite the benefits to users, total private welfare is lower with low permitted rates of return. Private welfare is greater than with standard damages once permitted rates of return exceed 100%; at this point, the inventor is only slightly adversely affected, and users still receive considerable gains. Finally, our measure of social welfare assumes that mere invention produces spillover effects. Once the permitted rate of return is sufficiently high that invention rates are not much affected by cost-plus damages, the combination of higher user welfare and high rates of invention maximize social welfare.

Figure 2. Low Probability of Invention (Single Entrant)

These welfare analyses make cost-plus damages appear promising. To consider the robustness of the results, we also ran the simulation with some changes in parameters. Figure 2 shows the effect of increasing the difficulty of invention. The simulations are the same as those in Figure 1, except that p_1, p_2, and p_3 are set to 0.35, 0.45, and 0.55, respectively. The story remains qualitatively similar to the story above. Naturally, the overall levels of trying to invent and of succeeding at invention are lower. But Figure 2 confirms that spending multiples are considerably higher with cost-plus damages and that this effect continues to dissipate with higher permitted levels of return. The pricing pattern is similar to that of Figure 1, with the lowest prices achieved with the lowest permitted rates of return, and the usage pattern is similar too, with more users able to take advantage of the invention with cost-plus damages, especially with relatively low rates of return. Very low permitted rates of return, however, bring a lower probability of invention and lower welfare overall, but again mostly the same pattern as Figure 1.

In addition, we assess the impact of valuation uncertainty by setting $\sigma_n = 1$. This means that potential inventors cannot be sure of the amount that the highest valuing user is willing to pay, and also that with standard damages, the court may err in setting this amount. With either form of damages, users (who know their own valuations) may believe that the inventor has priced the product too high and therefore choose to infringe. Figure 3 shows that valuation uncertainty makes the welfare case for cost-plus damages more equivocal. Welfare is lower across the board, because with valuation uncertainty, intentional infringement and litigation are more likely, and the cost of litigation is deducted from user welfare. Meanwhile, when cost-plus damages lead the inventor to decide not to invent, this will sometimes be because the inventor is greatly underestimating the value of the invention. Thus, some foregone inventions will be valuable, and a small decrease in the probability of invention thus makes a bigger difference.

Figure 3. Valuation Uncertainty (Single Entrant)

3. Racing Model

Our models so far have assumed that there is a single firm that considers whether to invent. This places to the side two important aspects of the analysis. First, we have ignored the question of whether a firm would have an incentive to enter the industry in the first place. Now, we assume that firms choose whether to enter the industry for the opportunity to compete for the invention. Second, we have ignored the effect of competition among multiple firms for invention. When multiple firms compete to invent, the probability of the invention's occurrence increases. Our racing model is simple. Consistent with the standard assumption in the industrial organization literature,[159] the number of entrants into the market will be the number that dissipates all rents to entrants. All entrants have an opportunity to decide whether to try to invent, based on both shared and private information, and if multiple entrants succeed, one chosen at random obtains the patent.

We start first with the analogue to Figure 1. That is, this is the baseline model in which the probability of invention for a successful invention is relatively high, 0.75. The cost of entry c_e is assumed to be 0.05. This may seem so low as to be insignificant, but we will see later that this choice is critical in assessing social welfare. Figure 4 shows the results. Entry is highest with standard damages, because there is the least restraint on pricing. This also means that the level of invention is highest with standard damages. In Figure 4, the "Trying" chart represents the number of firms that try to invent. In Figure 1, the single entrant was less likely to try to invent with cost-plus damages and low permitted rates of return. In Figure 4, the shape of the chart is similar, though the effect now is a direct result of the entry chart. Not every entrant will try to invent, but the relative low number of firms trying to invent in Figure 4 is attributable to reduced entry in those cases. Finally, the overall levels of invention are higher than in Figure 1. The more firms that try to invent, the greater the likelihood of success. Meanwhile, the advantage of standard damages in stimulating invention is slightly more pronounced as a result. There is more entry with standard damages because the profits available to inventors are greater, and this leads to more invention.

The effects on price and use are similar to those in Figure 1, though muted. Welfare effects are also qualitatively similar. (Note that because entry dissipates rents, private welfare is equal to user welfare, and the separate chart for private welfare is thus omitted.) The social welfare gains, however, are more prominent in Figure 4 with low permitted rates of return. This is because of the rent dissipation. The positive rents earned by a single entrant affected the social welfare measure in Figure 1, but those are irrelevant in Figure 4.

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[159] *See, e.g.*, *id.* at 50–51.

Figure 4. Baseline (Racing)

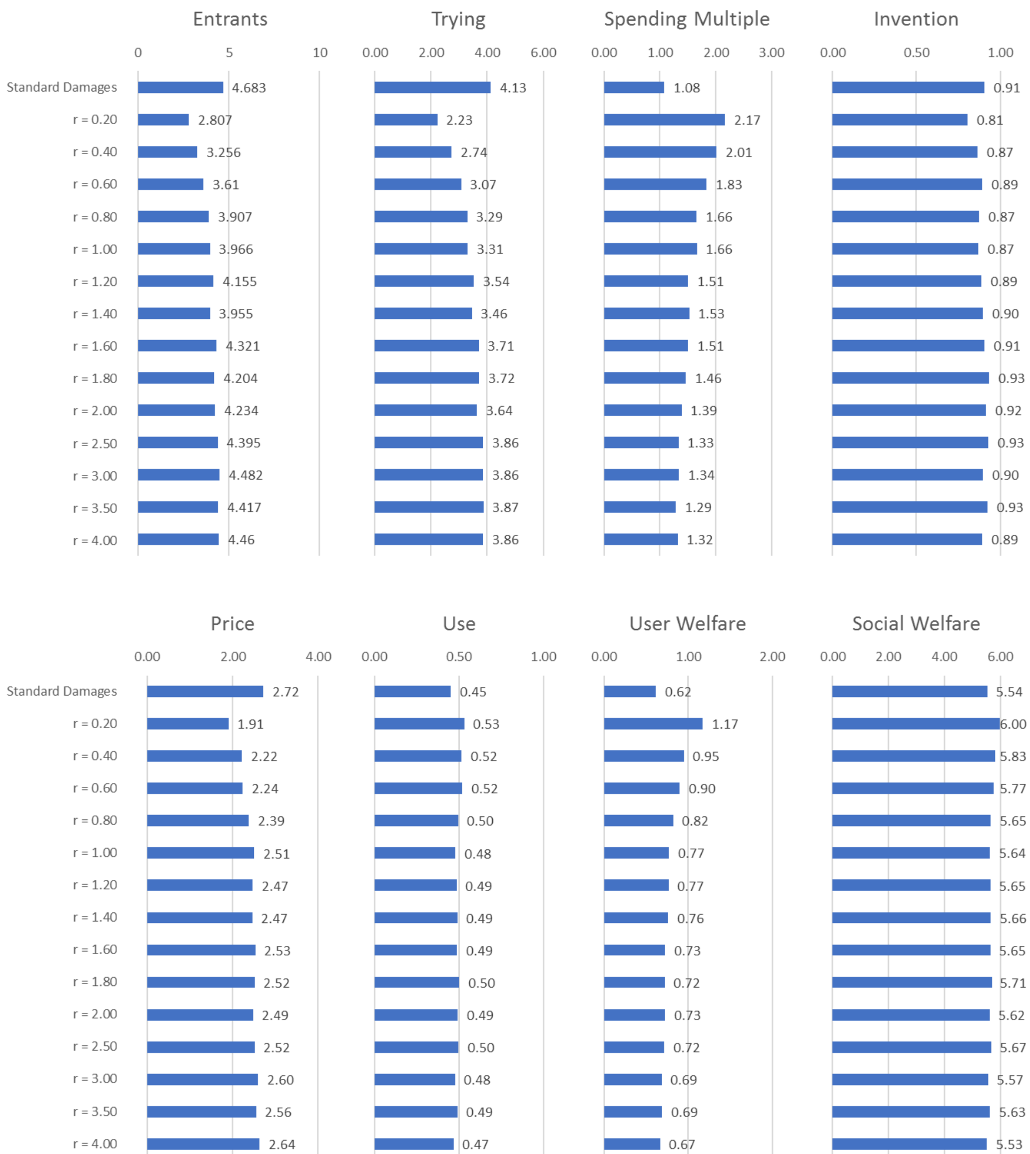


Figure 5 is the analogue to Figure 2. Figure 5 reflects a simulation in which a minimum investment produces only a 0.35 probability of successful invention. For the most part, the simulation results are qualitatively similar. But there is one noticeable difference: the bars corresponding to the 20% level of permitted return are missing. This absence reflects that at this level of return, it is not worth it for even a single firm to enter the market. Above, we noted that if inventors anticipate that they will not recover their risk-adjusted investments in attempting to invent, they will not invent at all. In our model, the inventors do recover their investments associated with the attempt to invent itself. (Our model simply assumes that the courts are accurate in measuring the probability of success.) But the inventors do *not* necessarily recover their investments in building a business that may be in a position to undertake the invention. Therefore, they may not build that business in the first place. This is what happens in these simulations. The rate of return is great enough to allow recovery of investments conditional on entry but not great enough to allow recovery of investments on entry itself.

Figure 6 adds an additional change to the simulation represented in Figure 5. In particular, the cost of entry is assumed to be $0.10 instead of $0.05. This may seem to be a very modest difference, especially considering that there may be users who value an invention at as much as $10. But this change has an important effect. Now, entry also fails to occur at a permitted rate of return as high as 80%. Intuitively, it might seem that an 80% rate of return is generous, especially considering that our model does not take into account discount rates associated with the time value of money. This might seem especially so given that the portion of the cost of entry allocated to the investment opportunity ($0.10) is considerably smaller than the average cost of a minimal attempt to produce the invention ($0.25). Even under these circumstances, the rate of return proves insufficient, and so all user welfare and social welfare that could have resulted from invention is lost. Even with higher rates of return, the effects of reduced entry are considerable. User welfare is only slightly higher than with standard damages, and the reduced incidence of successful invention drags social welfare below the level associated with standard damages until the permitted rate of return rises to approximately 120%.

Finally, we consider one other situation in which cost-plus damages are especially problematic: when users may infringe inadvertently. In Figure 7, the baseline parameters are reproduced but 10% of users infringe accidentally, without any calculus of whether using the invention might be beneficial. This scenario does not discourage entry—to the contrary. The existence of users who will have no choice but to infringe greatly increases entry and effort. There are benefits to this, of course, in the form of high entry. But the effects on users are disastrous. For all cost-plus damages levels, users experience *negative* utility. They are forced to pay damages in excess of the valuation of the products. Importantly, while inadvertent infringement is undesirable even with standard damages, the effect on user welfare

Figure 5. Low Probability of Invention (Racing)

Figure 6. High Entry Cost, Low Probability of Invention (Racing)

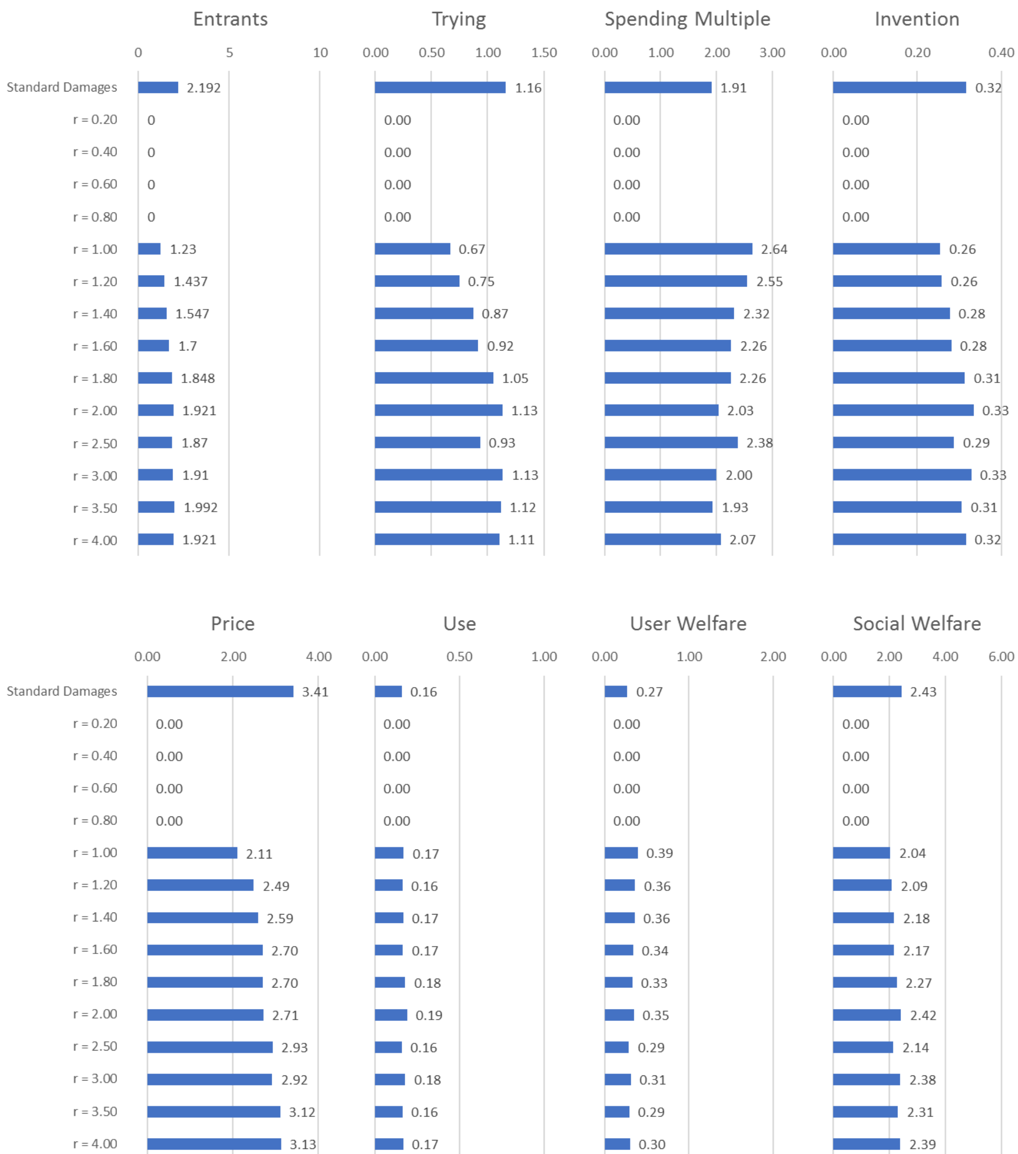
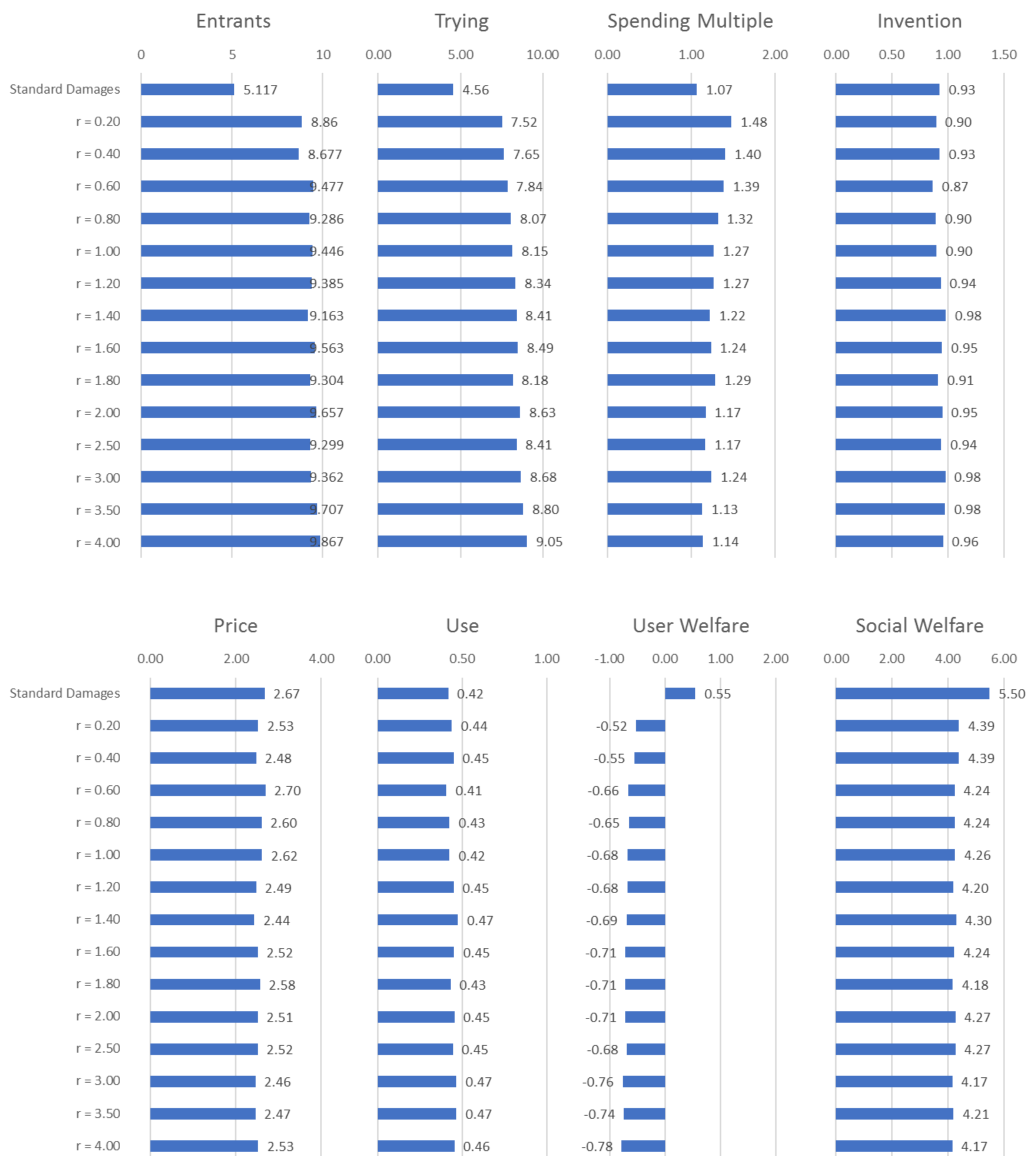


Figure 7. Inadvertent Infringement (Racing)



with standard damages is slight. This makes sense. If the damages the user must pay are tied to the court's estimate of the user's valuation of the invention, the user will suffer relatively little harm on average other than the cost of litigation. But if the user is responsible for paying risk-adjusted costs that may exceed the user's own valuation, users may end up much worse off. The result is much lower social welfare, despite the increase in the rate of invention. Thus, a cost-plus damages system would need to eliminate or greatly limit damages resulting from inadvertent infringement.

4. *Modified Proposals*

a. Hybrid Damages

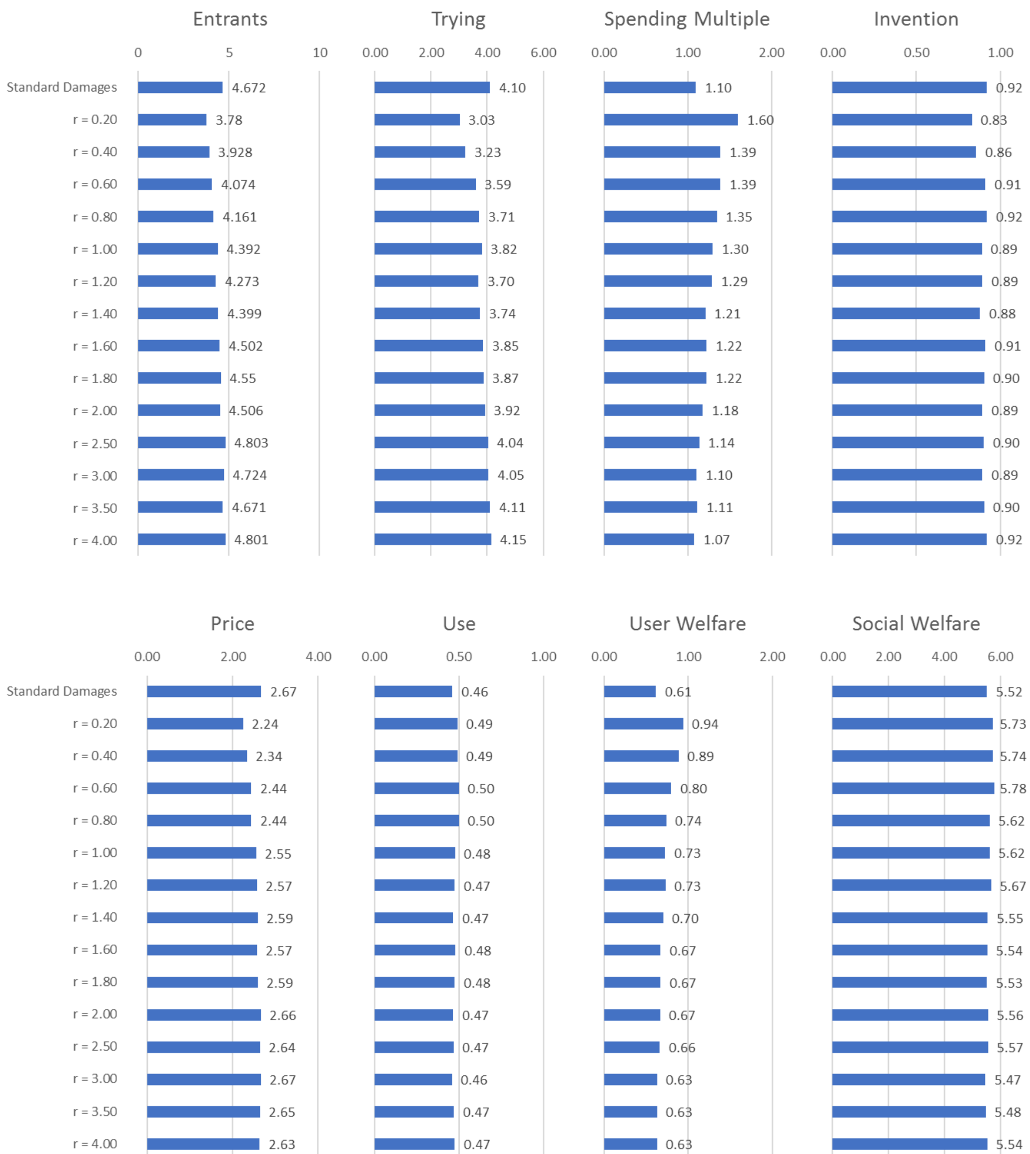
We have assumed so far that the choice between cost-plus damages and standard damages is all-or-nothing. This is a useful assumption for assessing the potential effects of introducing cost-plus considerations into the patent damages calculus, but we can imagine a patent damages system in which risk-adjusted R&D levels are merely another factor in the calculus. Indeed, this is what Sichelman suggests. Figure 8 reports the result of a simulation that replicates the challenging circumstances represented in Figure 6—with high entry costs and a low probability of invention—but with hybrid damages. In particular, we assume that damages are the average of standard damages and the specified level of cost-plus damages. Importantly, the disastrous results that we saw in Figure 6, with low permitted rates of return, vanish. Entry occurs in all cases (though presumably if the rate of return were sufficiently low, it would not). Meanwhile, there are some benefits to user welfare, but more modest than in some of the simulations above. The social welfare results, meanwhile, are equivocal at best because of the reduced rate of invention once cost-plus damages are introduced. Nonetheless, this suggests that including risk-adjusted R&D as a factor in the patent damages calculus is unlikely to lead to major problems.

b. Combined Investments

One of the two major problems with cost-plus damages that this article identifies is the risk that inventors will gold-plate, spending excessively to pad their costs and increase the amount of damages. A potential solution for this is to seek to transform risk-adjusted R&D costs to be more of a measure of *expected* risk-adjusted R&D costs. We will consider below whether it may be feasible for courts to assess how much an invention *should* cost. But there is another possible mechanism. Courts might consider the R&D costs of *all competitors in the patent race*, rather than the R&D costs of the winner alone. With multiple entrants, this will be a higher amount, but the risk-adjusted amount will not necessarily be larger. The relevant probability becomes the probability that *someone* will succeed, not just

Figure 8. Hybrid Damages, High Cost of Entry, Low Probability of Invention

Figure 9. Combined R&D



the probability that the particular inventor will succeed. Placing aside for now questions about whether courts can measure combined R&D, how would this affect welfare?

Figure 9 reports the results from running the simulation in this way. The most noticeable change is in the spending multiple. Unsurprisingly, when other competitors' investments help determine the risk adjustment, one will spend less. But the overall welfare effects are equivocal. User welfare and social welfare are not much changed. One reason for this is that with combined investments, entry rises. With a lower optimal cost of invention, more firms will try to invent. Thus, the savings from lower investment in invention by an inventor is more or less balanced by additional costs from entry.

The ultimate welfare balance will depend on the specific parameters. If additional investment generated greater gains in the probability of invention for any particular inventor than is allowed here (remember that our probability curves are relatively flat), then basing cost-plus damages on the successful inventor is probably optimal. On the other hand, if multiple research efforts are likely to be duplicative because there is only one way to try to achieve the invention, then the entry that is generated by combining investments is wasteful.

V. Conclusion

Cost-plus damages are high beta: if problems could be addressed, this approach to damages could revolutionize patent law. It addresses a fundamental problem with patent law, the danger that an inventor will obtain rents that are too large to the detriment of consumers. Other patent law doctrines, such as nonobviousness, the patent term, patentable subject matter, and patent scope, can be seen as mechanisms designed to address the same fundamental problem. And so, if cost-plus damages worked, these doctrines could be either unnecessary or at least not so critical. Those who worry that the patent office grants too many bad patents need worry no more, for a bad patent is typically a trivial one, which deserves at most a small reward. Cost-plus damages provide that small reward and restrict the patentee from receiving more.

The problem is that cost-plus damages might be miscalibrated. It is likely to be impossible to allocate all investment expenses across all projects. The much more plausible approach is to allow the inventor to recover expenses devoted to a particular project plus some percentage. Even this is difficult, since a single project may lead to multiple patents, but the risk adjustment can in principle be applied to these patents in combination. If the permitted rate of return is too small, then many inventors who might have invented might choose not to invent at all, because they anticipate earning back less than their risk-adjusted returns. The percentage must at least be large enough so that even if the courts are infected with hindsight bias, inventors will still expect the probability estimates to be high enough so that they will expect to make a profit on inventions that increase social welfare. But even this is not the whole of the undercompensation danger. The permitted rate of return must be high enough to allow businesses to recover the risk-adjusted costs of entry into those businesses. We have seen that even with seemingly low entry costs and seemingly high rates of return (as high as 80%), in some circumstances potential inventors will simply not enter the market and will never even consider invention. Miscalibrating permitted rates of return might have little effect in the short term, but in the long term could lead to greatly reduced entry.

A large permitted rate of return brings its own problems. This is especially true if there is a danger of inadvertent infringement. If cost-plus damages are to have any role in patent law, they would need to accommodate inadvertent infringers. For example, the law might provide that a good faith patent search provides immunity from liability. Or, less drastically, an inadvertent infringer might be allowed to opt for standard damages instead of cost-plus damages. This would reduce the incentive to invent for the purpose of mouse-trapping inadvertent infringers. Some of the criticisms of nonpracticing entities today suggest that they may seek to make their patents as inaccessible as possible in the hope of catching inadvertent infringers.[160] If these criticisms have any validity, the problem may become all that much more severe with cost-plus damages.

Even if the rate of return is set correctly, excessive spending by inventors will be a concern. The model of Part IV shows that in some conditions, cost-plus damages may improve social welfare even when inventors spend on invention many times more than they would spend in a world with patent damages. Nonetheless, if it were possible to discourage gold-plating, that could increase the attractiveness of cost-plus damages considerably. Perhaps the courts can simply determine how much the inventor *should* have spent on invention. But given that greater spending will generally increase the probability of invention, it will be difficult for the courts to do this with any accuracy, and shortchanging inventors may have the same adverse consequences as setting the rate of return unduly low.

Perhaps if the patent system was built entirely around cost-plus damages, some of these problems might be overcome. We have seen that spending declines markedly when the relevant spending is that of *all inventors*. In the present patent system, one doubts that it would be feasible for the courts to obtain data on all inventors. One could imagine a different system, however, in which inventors could receive risk-adjusted, cost-plus damages only on spending registered with the patent agency at the time of disbursement with clear indication of what the spending would be dedicated to. This data could be made public, so it could be used in intentional infringement litigation. Such a registry might also facilitate the calculation of risk. In principle, one could allow the public to make bets in prediction markets on the probability that the invention attempt would be successful.[161] This would provide the courts with contemporaneous evidence of risk-adjusted returns, saving the

[160] *See* Oskar Liivak & Eduardo Penalver, *The Right Note to Use in Property and Patent Law*, 98 CORNELL L. REV. 1437, 1448 (2013).

[161] *See generally* MICHAEL ABRAMOWICZ, PREDICTOCRACY xi-x (2007) (explaining how prediction markets work and how they could be used for public policy purposes).

courts from the challenge of hindsight bias. One could even imagine such a registry being used to limit excessive entry, allocating rights to enter to inventors with a high chance of success and a willingness to accept a low rate of return.[162]

But this would be a patent system quite different from the one that we have now, introducing its own set of challenges. We cannot get to this patent system without at least some much more modest experimentation with cost-plus damages. For now, there is likely to be little danger in allowing cost-plus damages to be a small factor in the patent analysis. We have seen that the worst dangers of cost-plus damages do not emerge under some assumptions even when cost-plus damages are as much as half of the patent damages calculus. Such experimentation could allow assessment of how feasible it is to calculate risk-adjusted costs and perhaps to determine whether gold-plating is occurring. This would not be easy to measure, but a slight change in policy could provide a natural experiment that might make changes over time apparent. Should cost-plus damages prove relatively tractable, further experimentation might be warranted.

This analysis also gives some support to Brennan et al.'s eminent domain proposal. The proposal might make economic sense at least when cost-plus damages multiples seem especially large and high costs are thus unnecessary. As long as eminent domain is unlikely *ex ante*, it seems unlikely to lead to excessive spending. Yet it is important to be cautious here too. It is expensive and risky to create a pharmaceutical firm that subsequently might be in a position to complete an invention, and the costs of entry into the industry must be compensated (yet are very hard to allocate and calculate). The government ideally would focus not just on whether the returns seem high relative to investment, but also on whether the invention depended on an exogenous technological development that suddenly made a difficult problem relatively easy. These are the cases in which even if some patent incentive is necessary, the needed incentive might be much lower than it currently is. By contrast, if in principle the invention could have been developed earlier using much the same approach, we should assume that the full patent system was necessary, and eminent domain therefore would not be appropriate.

Returning to the patent system, we might someday follow an analogous approach. We might allow the defendant an option of choosing cost-plus damages. But this option would be limited in two ways. First, the defendant would need to establish that the invention is of marginal nonobviousness, at least when nonobviousness is interpreted in economic terms. Second, the applicable rate of return would be set with generous estimates of the risk and generous adjustments for the reality that entry costs are not easily allocable to particular projects. With these two rules, it might be possible to isolate cases in which patents are windfalls for trivial achievements. This would both discourage excessive entry in such cases and reduce prices paid by consumers. At the same time, it would minimize the risk

162 For a proposal that excessive entry sometimes might be limited by auctioning the right to attempt to invent in a particular area, see Michael Abramowicz, *The Uneasy Case for Patent Races over Auctions*, 60 STAN. L. REV. 803 (2007).

that cost-plus damages might deter inventors from undertaking socially valuable projects because they expect their risk to be underestimated. Finally, because cost-plus damages would be the defendant's option, the tendency to spend excessively might be somewhat reduced.