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The Case for Tailoring Patent Awards Based on Time-to-Market

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ABSTRACT

One of the hallmarks of our patent system is that it provides a one-size-fits-all reward for innovation. The uniform patent laws offer insufficient incentives to develop some socially valuable inventions, and they offer excessive rewards for other inventions, which imposes an unnecessary tax on consumers and subsequent innovators. If the government could adequately tailor patent awards to account for differences in inventions' need for protection and the likelihood that patents will stifle subsequent innovation, it could spur additional innovation while resolving the current patent crisis. But this type of tailoring is generally thought to be impractical. Although we may know which economic determinants are relevant to a socially optimal patent strength, we lack a reliable way to directly measure and synthesize this information into a usable framework. Absent a principled and administrable system to determine which inventions need more protection than others, the uniform patent system is our best option.

This Article identifies a readily observable, cross-industry indication of optimal patent strength for different technologies—inventions' time-to-market. Some inventions take much longer to develop than others, and there is tremendous variation in the average time-to-market across industries. This Article first shows that there is a strong, positive correlation between the amount of time needed to complete an R&D project and the amount of patent protection (if any) necessary to motivate investment in that R&D project. A longer time-to-market for inventions is associated with higher out-of-pocket R&D costs, greater risk of failure, increased opportunity costs of R&D investments, and diminished value of future revenue streams from the developed invention because of discounting. Moreover, because imitators frequently avoid much of the increased R&D costs and uncertainty associated with a longer time-to-market, lengthier R&D times also usually correspond to a greater vulnerability to free riding. Second, this Article shows that a longer time-to-market is associated with a reduced likelihood of patents stifling subsequent innovation. Inventions with a longer time-to-market usually have longer commercial lifespans (product lifecycles) because the inventions that ultimately replace them in the market also generally take longer to develop. The slower rate of product turnover in these markets reduces the need for patent licensing between early and later innovators and gives companies more time to negotiate licenses when necessary, which diminishes the likelihood that patents granted on earlier inventions will stifle later improvements to those technologies. Similarly, because inventions with a lengthy time-to-market have higher total R&D costs, fields in which inventions typically have a lengthy time-to-market have higher entry costs. Those higher costs diminish the number of entrants in these markets and encourage later innovators to develop inventions that are more differentiated from earlier inventions. The reduced entry rate

61 UCLA L. Rev. 672 (2014)

and greater product differentiation once again decrease the need for patent licensing, thereby lessening the potential harm from patents stifling subsequent innovation.

Since a longer time-to-market is indicative of a greater need for patent protection and a lower risk of patents stifling subsequent innovation, time-to-market is likely a uniquely powerful indicator of the optimal patent strength for different types of inventions. Moreover, because time-to-market is relatively observable, the government can use it to create a framework for a principled and administrable system of tailored patent awards. Such a system would enable the government to strike a better balance between the benefits of promoting innovation with temporary monopoly rights and the social costs of restricting access to inventions.

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TABLE OF CONTENTS

INTRODUCTION

The patent system protects a wide array of technologies—everything from microbial fuel cells and radiolabeled pharmaceuticals to interactive cat toys and utensil holders for dishwashers.[1] One of the defining characteristics of the current patent system is that it applies a uniform set of rules to all inventions, and it does not discriminate based on technology or industry. This uniformity is also one of the most problematic aspects of the patent system. There is overwhelming evidence that the system's costs and benefits vary greatly across industries.[2] Patents are critical for stimulating innovation in some industries, but they arguably stifle innovation in others. The government knowingly overlooks these differences when it awards patent rights on inventions. The justification for this oversight is not that a uniform patent system is optimal but rather that we do not have enough information about inventions to create an administrable system for tailoring patent awards that would benefit the public. This Article identifies the basis for such a system—inventions' time-to-market. Certain types of inventions take much longer to develop than others, and a lengthier time-to-market strongly correlates with an increased need for patent protection and a lower risk that patents will stifle subsequent innovation. The government can use this relatively observable feature of inventions as the foundation for an objective and reasonably accurate system of tailored patent awards.

Scholars and policymakers have long recognized that our current patent laws cannot provide the optimal incentives for innovation.[3] Patents are essential for motivating investment in research and development (R&D) in some circum-

1. *See* Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980) (noting that "anything under the sun that is made by man" is eligible for patent protection).
2. *See* A PATENT SYSTEM FOR THE 21ST CENTURY 35 (Stephen A. Merrill et al. eds., 2004); FED. TRADE COMM'N, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY ch. 3 (2003) [hereinafter FTC]; Ashish Arora et al., *R&D and the Patent Premium*, 26 INT'L J. INDUS. ORG. 1153, 1170 (2008); Knut Blind et al., *Motives to Patent: Empirical Evidence From Germany*, 35 RES. POL'Y 655, 661–62 (2006); Stuart J.H. Graham et al., *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255 (2009); Richard C. Levin et al., *Appropriating the Returns From Industrial Research and Development*, 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783, 784; Edwin Mansfield et al., *Imitation Costs and Patents: An Empirical Study*, 91 ECON. J. 907, 909 (1981); Wesley M. Cohen et al., *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 2 (Nat'l Bureau of Econ. Research, Working Paper No. 7552, 2000).
3. *See* S. TEMP. NAT'L ECON. COMM., 76TH CONG., INVESTIGATION OF CONCENTRATION OF ECONOMIC POWER 157 (Comm. Print 1940); C. Michael White, *Why a Seventeen Year Patent?*, 38 J. PAT. OFF. SOC'Y 839, 842–45 (1956).

stances,[4] but they also limit the public's access to inventions through monopoly pricing. Given patents' social costs, firms should receive the least amount of patent protection necessary to incentivize the research, development, and commercialization of their inventions. Though different amounts of patent protection are necessary to incentivize different inventions, the patent system largely ignores these differences.[5] The government allows firms to patent almost any invention qualifying as useful, novel, and nonobvious,[6] regardless of its R&D costs and most of the other economically relevant factors.[7] After a patent is issued, it primarily operates as a one-size-fits-all reward for innovation, offering all patentees the same set of legal entitlements[8] and the same twenty-year term of protection.[9] This system inevitably provides excessive monopoly protection for a great many inventions, while also offering insufficient incentives for the development of others.[10]

It is now clear that the social costs of our one-size-fits-all patent system are much greater than was once imagined. The classic economic analysis of patents uses a stand-alone model of innovation, in which patent policy is largely defined by the tradeoff between increased innovation from stronger monopoly rights and the consumer deadweight loss from monopoly pricing. The more recent economic models recognize that innovation is a cumulative and additive phenomenon.[11] Researchers are constantly building on one another's inventions, and each step forward in technology generates knowledge spillovers that facilitate further technological advances.[12] In such a cumulative environment the patent system

4. *See* FTC, *supra* note 2, ch. 3 (comparing the importance of patent protection for innovation in pharmaceuticals, biotechnology, computer hardware, semiconductor industries, and software); Levin et al., *supra* note 2, at 816 (comparing the importance of patent protection in numerous different industries); Mansfield et al., *supra* note 2, at 915 (same).
5. *See* Clarisa Long, *Our Uniform Patent System*, FED. LAW., Feb. 2008, at 44, 47–48. Although the patent system relies almost entirely on facially neutral standards to determine whether inventions are patentable and the scope of the protection, there is enough ambiguity in these standards for courts to apply slightly different legal tests to different types of inventions. *See* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1577 (2003). But the technology-neutral statutes that govern patent law tightly circumscribe judicial tailoring of this sort.
6. *See* 35 U.S.C. §§ 101–103, 112 (2006).
7. *See infra* notes 117–123 and accompanying text (discussing the primary determinants of optimal patent strength).
8. *See* 35 U.S.C. § 271(a) (2006).
9. *See id.* § 154(a)(2).
10. *See infra* Part IV.
11. *See, e.g.*, Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29 (1991).
12. *See* WILLIAM J. BAUMOL, THE FREE-MARKET INNOVATION MACHINE: ANALYZING THE GROWTH MIRACLE OF CAPITALISM 11–12 (2002); ELHANAN HELPMAN, THE MYSTERY OF ECONOMIC GROWTH 42–46 (2004); Brett M. Frischmann & Mark A. Lemley, *Spillovers*, 107 COLUM. L. REV. 257, 268–69 (2007); Joel Mokyr, *The Contribution of Economic History to the*

not only restricts public access to inventions through monopoly pricing, it may actually impede future technological progress by making it harder for other firms to build on earlier discoveries.[13] Conversely, when the patent system fails to call forth a new invention by offering too little protection, the public loses not just that one invention but also all future advances that would have come from it. It is thus critical to both provide enough patent protection to motivate innovation and to avoid providing so much protection that it stifles innovation.

Nevertheless, the patent system continues to operate under uniform patent laws that mostly provide a one-size-fits-all reward for innovation. The patent system's failure to tailor patent awards adequately based on inventions' need for protection and the risk of stifling subsequent innovation is the central problem in patent policy. Indeed, it is possible the patent system's overall effect on innovation is negative because it fails to tailor its patent awards properly.[14] Constructing reliable empirical studies to measure the patent system's net impact on innovation is difficult.[15] But the available evidence suggests that the system's innovation-stifling effects are substantial in some fields, and might even outweigh the system's innovation-promoting effects.[16]

The problems associated with patent law's uniformity are not new, but they have grown worse over time.[17] The basic structure of modern patent law arose in the eighteenth and early-nineteenth centuries, when most innovation was mechanical in nature.[18] The advances in science, engineering, and business practices since then have continually created new technologies and industries with increas-

Study of Innovation and Technical Change: 1750–1914, *in* 1 HANDBOOKS IN ECONOMICS: ECONOMICS OF INNOVATION 11, 13 (Bronwyn H. Hall & Nathan Rosenberg eds., 2010).

13. *See* SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 127–57 (2004) (reviewing the literature on cumulative innovation).

14. *See* Peter S. Menell & Suzanne Scotchmer, *Intellectual Property Law*, *in* 2 HANDBOOK OF LAW AND ECONOMICS 1473, 1476 (A. Mitchell Polinsky & Steven Shavell eds., 2007) ("[T]he availability of intellectual property for innovation creates incentives for investment as well as potential impediments to diffusion and cumulative innovation. The net effects [on innovation] are quite complex to sort out from both theoretical and empirical perspectives."); Petra Moser, *Patents and Innovation: Evidence From Economic History*, 27 J. ECON. PERSP. 23, 40 (2013) ("Overall, the weight of the existing historical evidence suggests that patent policies, which grant strong intellectual property rights to early generations of inventors, may *discourage* innovation.").

15. *See* Bronwyn H. Hall & Dietmar Harhoff, *Recent Research on the Economics of Patents*, 4 ANN. REV. ECON. 541, 547 (2012).

16. *See* Hall & Harhoff, *supra* note 15, at 546–49; Mariko Sakakibara & Lee Branstetter, *Do Stronger Patents Induce More Innovation? Evidence From the 1988 Japanese Patent Law Reforms*, 32 RAND J. ECON. 77 (2001); Josh Lerner, *Patent Protection and Innovation Over 150 Years* (Nat'l Bureau of Econ. Research, Working Paper No. 8977, 2002).

17. *See* John M. Golden, *Principles for Patent Remedies*, 88 TEX. L. REV. 505, 546–50 (2010).

18. *See* Robert P. Merges, *As Many as Six Impossible Patents Before Breakfast: Property Rights for Business Concepts and Patent System Reform*, 14 BERKELEY TECH. L.J. 577, 584–88 (1999).

ingly divergent economic and technological characteristics. This ever-expanding set of technologies puts increasing strain on the uniform patent laws and the one-size-fits-all reward. The U.S. Congress occasionally passes broader patent reforms in response to more widespread industry complaints about the system,[19] but since these reforms generally apply equally to all patentable inventions, they often create their own set of problems.[20] Patent scholars often look for reforms that will correct problems in some industries without aggravating the patent system's shortcomings in others. But when every invention is subject to the same set of rules, these reforms are hard to find.

The drawbacks of relying on uniform patent laws became painfully apparent during the legislative debates leading up to the Leahy-Smith America Invents Act of 2011[21]—the first major U.S. patent reform legislation in almost sixty years. The impetus for this bill came from the information-technology (IT) industries—including software and computer hardware—in which the relationship between patents and innovation is thought to be "deeply dysfunctional."[22] Firms in these industries often report that they would develop most of their

19. *See* F. Scott Kieff & Henry E. Smith, *How* Not *to Invent a Patent Crisis*, *in* REACTING TO THE SPENDING SPREE: POLICY CHANGES WE *CAN* AFFORD 55, 59–62 (Terry L. Anderson & Richard Sousa eds., 2009) (noting that the history of patent reform in the United States follows a circular pattern, in which the government first strengthens the patent system to promote innovation and economic growth but later weakens it to prevent abuses of the patent system).

20. *See, e.g.*, 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 1–2 (2004) (arguing that the current patent crisis stems from the U.S. Congress's decision in 1982 to shore up the patent system by creating a specialized appellate court to hear all patent cases); *id.* at 95 (noting "the cyclical nature of historical patent controversies" and that "[f]ar too often, fixes to patent law have created as many problems as they have solved").

21. Pub. L. No. 112-29, 125 Stat. 284.

22. L. Gordon Crovitz, *Google, Motorola and the Patent Wars*, WALL ST. J., Aug. 22, 2011, http://online.wsj.com/article/SB10001424053111903639404576518493092643006.html; *see also* BRIAN KAHIN, COMPUTER & COMMC'NS INDUS. ASS'N, AGENDA FOR REFORM: PATENT REFORM FOR A DIGITAL ECONOMY (2006); Colleen V. Chien, *Reforming Software Patents*, 50 HOUS. L. REV. 325, 350–90 (2012); Iain M. Cockburn & Megan J. MacGarvie, *Entry and Patenting in the Software Industry*, 57 MGMT. SCI. 915, 916 (2011); Éloïse Gratton, *Should Patent Protection Be Considered for Computer Software-Related Innovations?*, 7 COMPUTER L. REV. & TECH. J. 223, 250 (2003); Peter S. Menell, *The Challenges of Reforming Intellectual Property Protection for Computer Software*, 94 COLUM. L. REV. 2644, 2645–47 (1994); Mark Aaron Paley, *A Model Software Petite Patent Act*, 12 SANTA CLARA COMPUTER & HIGH TECH. L.J. 301, 306 (1996); Mark H. Webbink, *A New Paradigm for Intellectual Property Rights in Software*, 2005 DUKE L. & TECH. REV. 12, ¶ 28; James Bessen, *A Generation of Software Patents* 20–21 (Bos. Univ. Sch. of Law, Working Paper No. 11–31, 2011); Eric Goldman, *Fixing Software Patents* (Santa Clara Univ. Sch. of Law, Legal Studies Research Papers Series No. 01-13, 2013); David A. Wheeler, Eliminate Software Patents (Aug. 2, 2011) (unpublished manuscript), *available at* http://www.dwheeler.com/essays/software-patents.html (containing links to numerous articles that are critical of software patents written by academics, venture capitalists, entrepreneurs, and industry executives).

inventions without patents, and they complain that the government grants unnecessary and excessive patent monopolies that adversely affect innovation.[23] These firms lobbied Congress for a variety of reforms to make patents easier to invalidate and harder to enforce. However, not every industry supported these policy proposals.[24] Firms in the pharmaceutical and biotechnology industries widely perceive patents to be critical for protecting their R&D investments,[25] and researchers in these industries express far fewer concerns about patents inhibiting follow-on innovation.[26] Indeed, these firms sometimes struggle to secure adequate patent coverage for their inventions,[27] and there is evidence that current limitations on the availability and strength of patent protection stifle important

23. *See* FTC, *supra* note 2, ch. 3, at 30–56.

24. *See* Jay P. Kesan & Andres A. Gallo, *The Political Economy of the Patent System*, 87 N.C. L. REV. 1341 (2009); Joe Matal, *A Guide to the Legislative History of the America Invents Act: Part I of II*, 21 FED. CIR. B.J. 435 (2012).

25. Patents are probably most effective at spurring innovation in the pharmaceutical industry, although they appear to have important effects in several other industries, including biotechnology, agrochemicals, medical devices, clean energy, and certain types of genetically modified crops. *See* INT'L DEV. RESEARCH CTR., MAKING CHOICES ABOUT HYDROGEN: TRANSPORT ISSUES FOR DEVELOPING COUNTRIES 38 (Lynn K. Mytelka & Grant Boyle eds., 2008); Douglas J. Cumming & Jeffrey G. MacIntosh, *The Determinants of R&D Expenditures: A Study of the Canadian Biotechnology Industry*, 17 REV. INDUS. ORG. 357, 364, 366–68 (2000); Hall & Harhoff, *supra* note 15, at 548–49; Gaynor Hartnell, *The Innovation of Agrochemicals: Regulation and Patent Protection*, 25 RES. POL'Y 379, 387 (1996); David E. Schimmelpfennig et al., *The Impact of Seed Industry Concentration on Innovation: A Study of US Biotech Market Leaders*, 30 AGRIC. ECON. 157, 166 (2004) (finding that patents significantly increase R&D spending related to genetically modified soybeans, while acknowledging that it is possible that patents inhibit R&D spending on other crops—like corn and cotton—for which other barriers to imitation make patents less important).

26. *See* A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 4–5; FTC, *supra* note 2, ch. 3. There are admittedly significant concerns about biotechnology patents stifling downstream innovation. *See* Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCIENCE 698 (1998); Clarisa Long, *Patents and Cumulative Innovation*, 2 WASH. U. J.L. & POL'Y 229, 237 (2000); Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 120–35 (1999). But relative to the information-technology (IT) industries, biotechnology companies appear to have an easier time navigating the intellectual property (IP) landscape in their fields. *See* A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 72; FTC, *supra* note 2, ch. 3. The U.S. Patent and Trademark Office (PTO) and the Federal Circuit have also been more aggressive in limiting the availability and scope of patents on upstream inventions in biotechnology than in other industries, primarily through the utility and written description requirements. *See* Ariad Pharm., Inc. v. Eli Lilly & Co., 598 F.3d 1336 (Fed. Cir. 2010) (en banc) (using the written description requirement to limit the scope of upstream biotechnology patents claiming drug compounds); *In re* Fisher, 421 F.3d 1365 (Fed. Cir. 2005) (using the utility requirement to invalidate patents on genetic material filed before researchers know any of the biological functions of the claimed genes).

27. *See* Benjamin N. Roin, *Unpatentable Drugs and the Standards of Patentability*, 87 TEX. L. REV. 503, 515–56 (2009).

lines of medical innovation.[28] Not surprisingly, the biopharmaceutical sector fought fiercely to block most of the reforms advocated by the IT sector.[29] After seven years of intense lobbying, few of the IT industries' desired reforms made it into the final legislation.[30]

The government could avoid many of these problems if it improved the existing technology-neutral patent laws to tailor the availability and strength of patent protection to match inventions' need for protection and the risk of patents stifling subsequent innovation. However, most of the economic factors directly related to inventions' optimal patent strength are difficult or impossible for the government to observe. Consequently, policymakers have been unable to devise an administrable set of technology-neutral rules to overcome the problems of uniformity.

Alternatively, the government can implement targeted patent reforms that apply only to fields that need those reforms. A growing number of legal scholars and economists advocate using technology-specific patent laws for this purpose.[31]

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28. *See id.* at 556; Eric Budish et al., Do Fixed Patent Terms Distort Innovation? Evidence From Cancer Clinical Trials (Mar. 20, 2013) (unpublished manuscript), *available at* http://economics.mit.edu/files/8651 (finding that because pharmaceutical companies file their patents early in R&D and the twenty-year patent term starts running on the filing date, the fixed patent term distorts R&D investments away from treatments for early-stage cancer and cancer prevention (which require lengthy clinical trials that erode a substantial portion of the firm's patent life) in favor of treatments for late-stage cancer (which allow for shorter trials and thus a longer effective patent life)); *cf.* Jocelyn Kaiser, *NIH's Secondhand Shop for Tried-and-Tested Drugs*, 332 SCIENCE 1492 (2011) (noting that the "NIH may also propose modifying patent laws to give companies financial incentives" for developing off-patent drugs for new uses, although this would be a "tremendous undertaking," and "for now, the agency is looking for leeway in existing laws" (internal quotation marks omitted)).
29. *See, e.g.*, Kesan & Gallo, *supra* note 24, at 1382.
30. *See* Charles Duhigg & Steve Lohr, *The Patent, Used as a Sword*, N.Y. TIMES, Oct. 7, 2012, http://www.nytimes.com/2012/10/08/technology/patent-wars-among-tech-giants-can-stifle-competition.html (noting that "lobbyists from high-tech corporations and the pharmaceutical industry . . . push[ed] conflicting proposals," which lawmakers and lobbyists said "paralyzed Congress's ability to make real changes," and that the America Invents Act ultimately "achieved mostly administrative fixes").
31. *See* JAMES BESSEN & MICHAEL J. MEURER, PATENT FAILURE: HOW JUDGES, BUREAUCRATS, AND LAWYERS PUT INNOVATORS AT RISK (2008); DAN L. BURK & MARK A. LEMLEY, THE PATENT CRISIS AND HOW THE COURTS CAN SOLVE IT 97 (2009); STEVEN SHAVELL, FOUNDATIONS OF ECONOMIC ANALYSIS OF LAW 154 (2004); Michael Abramowicz, *Orphan Business Models: Toward a New Form of Intellectual Property*, 124 HARV. L. REV. 1362, 1406–07 (2011); Michael J. Burstein, *Rules for Patents*, 52 WM. & MARY L. REV. 1747, 1761–62 (2011); Daniel R. Cahoy, *An Incrementalist Approach to Patent Reform Policy*, 9 N.Y.U. J. LEGIS. & PUB. POL'Y 587, 635–36 (2006); Michael W. Carroll, *One for All: The Problem of Uniformity Cost in Intellectual Property Law*, 55 AM. U. L. REV. 845, 847–49 (2006); Eric E. Johnson, *Calibrating Patent Lifetimes*, 22 SANTA CLARA COMPUTER & HIGH TECH. L.J. 269 (2006); Amir H. Khoury, *Differential Patent Terms and the Commercial Capacity of Innovation*, 18 TEX. INTELL. PROP. L.J. 373 (2010); Jonathan S. Masur, *Regulating Patents*, 2010 SUP. CT. REV.

The government could build technology-specific triggers into almost any of its existing policy levers, including everything from patent filing fees and the nonobviousness requirement to antitrust policies and defenses against patent infringement. The uniform twenty-year patent term is perhaps the most obvious candidate for reform.[32] It is difficult to imagine that a twenty-year monopoly provides the optimal incentives for the development of both artificial-heart technology and the slide-to-unlock software for smartphones. Many commentators—and even some industry executives—advocate shortening the patent term for software as a solution to the industry's current patent crisis.[33]

Nevertheless, there is a long history of resistance to differentiated patent awards in the United States.[34] Many patent scholars remain staunchly opposed

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275, 321–26; Peter S. Menell, *A Method for Reforming the Patent System*, 13 MICH. TELECOMM. & TECH. L. REV. 487, 495, 508 (2007); Peter S. Menell & Michael J. Meurer, *Notice Failure and Notice Externalities*, 5 J. LEGAL ANALYSIS 1, 50 (2013); Craig Allen Nard & John F. Duffy, *Rethinking Patent Law's Uniformity Principle*, 101 NW. U. L. REV. 1619, 1636–37 (2007) (recognizing that "some scholars have argued for *technological* diversity," although the authors themselves do not adopt that position); Joshua D. Sarnoff, *The Patent System and Climate Change*, 16 VA. J.L. & TECH. 301 (2011); F.M. Scherer, *Nordhaus' Theory of Optimal Patent Life: A Geometric Reinterpretation*, 62 AM. ECON. REV. 422, 427 (1972); White, *supra* note 3, at 842–45; William Fisher III, *The Disaggregation of Intellectual Property: How the Laws of Intellectual Property Have Grown—And Grown Apart*, HARV. L. BULL., Summer 2004, at 24, 29–31; Frank Partnoy, *Finance and Patent Length* 12–17, 29 (U. San Diego Law & Econ. Research Paper No. 19, 2001), *available at* http://papers.ssrn.com/abstract=285144; Richard A. Posner, *Why There Are Too Many Patents in America*, ATLANTIC, July 12, 2012, http://www.theatlantic.com/business/print/2012/07/why-there-are-too-many-patents-in-america/259725. Other scholars argue for tailoring through policies outside of the patent system, particularly in the pharmaceutical and biotechnology industries. *See* Arti K. Rai, *Building a Better Innovation System: Combining Facially Neutral Patent Standards With Therapeutics Regulation*, 45 HOUS. L. REV. 1037, 1056–57 (2008); Roin, *supra* note 27, at 557.

32. Several scholars have proposed tailoring the patent term. *See, e.g.*, S. TEMP. NAT'L ECON. COMM., *supra* note 3, at 157; SHAVELL, *supra* note 31, at 145–46; Abramowicz, *supra* note 31, at 1396–1420; Cahoy, *supra* note 31, at 619; Johnson, *supra* note 31, at 269; Khoury, *supra* note 31, at 374; Menell, *supra* note 31, at 493; Scherer, *supra* note 31; White, *supra* note 3; Partnoy, *supra* note 31, at 1; Posner, *supra* note 31.

33. *See, e.g.*, Paley, *supra* note 22, at 306; Webbink, *supra* note 22, ¶ 28; James Gleick, *Patently Absurd*, N.Y. TIMES, Mar. 12, 2000, at SM 44; DEFEND INNOVATION, https://defendinnovation.org/proposal/shorten-patent-term (last visited Dec. 23, 2013). A few prescient scholars advocated a shorter patent term for software before the crisis. *See* Peter S. Menell, *Tailoring Legal Protection for Computer Software*, 39 STAN. L. REV. 1329, 1365 (1987); Menell, *supra* note 22, at 2653; Pamela Samuelson et al., *A Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2308, 2408 (1994). There is also some support for this idea within the industry. *See, e.g.*, Jeff Bezos, *Bezos and O'Reilly Spearhead Call for Patent Reform: An Open Letter from Jeff Bezos on the Subject of Patents*, O'REILLY (Mar. 9, 2000), http://oreilly.com/news/amazon_patents.html ("[B]usiness method and software patents should have a much shorter lifespan than the current 17 years—I would propose 3 to 5 years." (emphasis omitted)).

34. A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 84.

to any departure from uniform patent laws,[35] mostly for practical reasons.[36] The economic theory of optimal patent strength does not provide a simple formula for calculating patent awards.[37] Scholars have identified a long list of factors that the government might need to consider when determining the appropriate strength of patent protection in an industry. Many of these factors are hard to assess, and the sheer number of them would make the inquiry unpredictable, unwieldy, and vulnerable to manipulation. Moreover, the dividing lines between technologies are highly permeable and tend to shift rapidly as technology changes. Firms can often draft their patent claims to select into categories offering greater protection, and technology-specific rules frequently become obsolete shortly after becoming law.[38] Unless the government can better link these rules

35. *See, e.g.*, JAFFE & LERNER, *supra* note 20, at 203–05; JAE HUN PARK, PATENTS AND INDUSTRY STANDARDS 162–63 (2010); Richard A. Epstein, *The Disintegration of Intellectual Property? A Classical Liberal Response to a Premature Obituary*, 62 STAN. L. REV. 455 (2010); Long, *supra* note 5, at 47–49; Qin Shi, *Patent System Meets New Sciences: Is the Law Responsive to Changing Technologies and Industries?*, 61 N.Y.U. ANN. SURV. AM. L. 317, 346–47 (2005); R. Polk Wagner, *(Mostly) Against Exceptionalism*, *in* PERSPECTIVES ON PROPERTIES OF THE HUMAN GENOME PROJECT 367, 368 (F. Scott Kieff ed., 2003); *cf.* Kieff & Smith, *supra* note 19, at 55, 68 (objecting to tailoring proposals that would arguably lead to more uncertainty over the availability, scope, and enforceability of patent protection); William D. Nordhaus, *The Optimum Life of a Patent: Reply*, 62 AM. ECON. REV. 428, 430 (1972) ("[A] fixed patent life is not optimal in theory, although it may be unavoidable in practice."). On the opposite end of the political spectrum, scholars who favor abolishing the patent system might be concerned that tailoring will weaken political support for the patent abolitionist movement by resolving some of the system's current problems. *See* Yochai Benkler, *The Idea of Access to Knowledge and the Information Commons: Long-Term Trends and Basic Elements*, *in* ACCESS TO KNOWLEDGE IN THE AGE OF INTELLECTUAL PROPERTY 217, 234 (Gaëlle Krikorian & Amy Kapczynski eds., 2010) (expressing hope that the IT industries will join forces with the access-to-medicines movement in the push for broad patent reform, but noting that "the risk of this kind of opportunistic alliance formation is that the partnership dissolves as some, especially those who are powerful and interest driven, obtain what they need and leave").

36. *See* A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 84; JAFFE & LERNER, *supra* note 20, at 203–04; PARK, *supra* note 35, at 162–63; Long, *supra* note 5, at 48–49.

37. *See, e.g.*, WILLIAM D. NORDHAUS, INVENTION, GROWTH, AND WELFARE 76–88 (1969); David S. Abrams, *Did TRIPS Spur Innovation? An Analysis of Patent Duration and Incentives to Innovate*, 157 U. PA. L. REV. 1613, 1615 (2009); Ian Ayres & Gideon Parchomovsky, *Tradable Patent Rights*, 60 STAN. L. REV. 863, 892 (2007); Nancy T. Gallini, *Patent Policy and Costly Imitation*, 23 RAND J. ECON. 52 (1992); Richard Gilbert & Carl Shapiro, *Optimal Patent Length and Breadth*, 21 RAND J. ECON. 106, 111 (1990); Louis Kaplow, *The Patent-Antitrust Intersection: A Reappraisal*, 97 HARV. L. REV. 1813 (1984); Ted O'Donoghue et al., *Patent Breadth, Patent Life, and the Pace of Technological Progress*, 7 J. ECON. & MGMT. STRATEGY 1, 2–5 (1998); Scherer, *supra* note 31; John F. Duffy, A Minimum Optimal Patent Term 5–7 (Jan. 9, 2003) (unpublished manuscript), *available at* http://ssrn.com/abstract=354282.

38. Many of the scholars who advocate tailoring patent awards on the basis of technology oppose explicit discrimination along technological lines. They argue instead that courts (or an agency) should use facially neutral legal standards to tailor patent awards to the needs for patent protection in each industry. *See, e.g.*, A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 83–85; BURK & LEMLEY, *supra* note 31, at 104–08; Rai, *supra* note 31.

to less manipulatable economic characteristics of inventions, creating technology-specific patent laws may be an exercise in futility.

This Article proposes a strategy for tailoring patent awards that would avoid the problems inherent in a uniform patent system by identifying an observable feature of inventions—their time-to-market—to use as a proxy for their optimal patent strength. The time-to-market for an invention is the time it takes to move from the initial idea to its first sale as a commercialized product. Within private industry, it is widely believed that firms must develop their inventions quickly to remain competitive and to earn adequate returns on their R&D investments.[39] As a result, firms typically try to complete their R&D projects as quickly as possible.[40] Nevertheless, there are significant differences in inventions' average time-to-market across industries,[41] mostly due to differences in the amount and difficulty of work needed to complete R&D projects.[42] This Article argues that inventions' time-to-market is a powerful predictor of the optimal amount of patent protection they should receive, and since time-to-market is observable, the government can use it for tailoring patent awards.

The crux of this Article is the claim that inventions' time-to-market strongly correlates with optimal patent strength. This claim has three components: First, the Article uses the framework provided by stand-alone models of innovation to show that inventions' time-to-market bears a close relationship to the amount of patent protection needed to motivate their development. The optimal patent award for inventions is primarily a function of their R&D costs, the risk of failure in R&D, the anticipated future revenue streams from the projects if they succeed, and the potential for imitation by rivals.[43] Inventions' time-to-market is a fairly reliable indicator of all four factors. Longer R&D times increase the costs of capital for an R&D investment while diminishing the value of future revenue streams because of discounting.[44] They are also correlated with higher out-of-pocket R&D costs and greater technological uncertainty.[45] Moreover, because imitators usually avoid much of the uncertainty involved in innovation, and because recent advances in reverse-engineering technology allow imitators to quickly copy most types of inventions (software being the main exception) at relatively little cost, longer R&D times are also generally associated

39. *See infra* notes 194–198 and accompanying text.
40. *See infra* notes 187–193 and accompanying text.
41. *See infra* Table 1; *infra* notes 220–239.
42. *See infra* notes 203–216 and accompanying text.
43. *See infra* Part IV.A.
44. *See infra* Part VI.A.1.
45. *See infra* Part VI.A.2.

with increased vulnerability to free riding from competitive imitation.[46] Inventions that take longer to reach the market therefore will likely need stronger patent rights as an incentive for their R&D, whereas inventions with a shorter time-to-market usually warrant weaker or no patent protection.

Second, the Article argues that because time-to-market affects the pacing of sequential innovation, it is a strong predictor of the extent to which patents are likely to stifle subsequent improvements in the inventions they protect. The cumulative-innovation models predict that stronger patent awards stifle innovation more than they promote it when three conditions are present: (1) Earlier innovators would develop their inventions irrespective of stronger patent rights, (2) the patents granted to earlier innovators cover many later improvements in their inventions technologies, and (3) there are high transaction costs in negotiating patent licenses between earlier and subsequent innovators. The time-to-market for inventions is inversely related to all three conditions.[47] Inventions that reach the market quickly tend to have a short product lifecycle (that is, they become obsolete faster), since it usually takes less time for firms to develop the newer inventions that replace them.[48] In industries in which R&D times and product lifecycles are short, patents are often less important than first-mover advantages for motivating R&D. Patents are also more likely to read onto (or cover) several future generations of improvements, imposing a greater burden on subsequent innovators. Moreover, the competitive costs of negotiating patent licenses are also higher because short R&D times give subsequent innovators less time to reach a deal, and negotiation delays erode a larger portion of their inventions' already short product lifecycle.[49] Inventions' time-to-market therefore provides a powerful indicator not only of inventions' need for patent protection. It also predicts whether those patents are likely to impede subsequent innovation.

Third, the Article argues that lengthy times-to-market alters the structure of markets to reduce likelihood that patents will stifle subsequent innovation.[50] When the time and expense of R&D is similar for innovators and subsequent innovators, a longer time-to-market operates as a barrier to entry, which reduces the social costs of older patents reading onto (and taxing) later improvements. As inventions' time-to-market increases, those inventions become less profitable, all else equal, and the market supports fewer entrants. Markets with fewer entrants will tend to have less fragmentation of patent ownership, lowering subse-

46. *See infra* Part VI.A.3.
47. *See infra* Part VIII.B.
48. *See infra* Part VI.B.1.
49. *See infra* Part VI.B.2.
50. *See infra* Part VI.C.

quent innovators' transaction costs in negotiating the necessary licensing deals for entry. The lower anticipated profits associated with longer R&D times would also reduce R&D spending, thereby diminishing the number of patent filings in these markets. Subsequent innovators therefore will have fewer patents to license or design around, reducing the tax on their later innovations. Additionally, as time-to-market increases, firms have higher R&D costs that they must recoup through sales revenue from their inventions, and therefore they are more likely to develop highly differentiated product to reduce price competition. To the extent that older patents are less likely to read onto these highly differentiated products, they are less likely to discourage that subsequent innovation. Moreover, as time-to-market increases, patents on earlier inventions tend to cover fewer generations of subsequent improvements before expiring, which again reduces the likelihood of patents stifling subsequent innovation.

Taken together, these insights suggest that the time-to-market for inventions should be a fairly reliable proxy for their optimal patent strength. A longer time-to-market correlates with all the major economic factors associated with increased need for patent protection, and it affects both the pacing of innovation and market structure in ways that reduce the likelihood of patents stifling subsequent innovation.

This observation has several important implications. First, by bridging the stand-alone and cumulative-innovation theories, it helps to defragment patent theory and reduce its indeterminacy. In the legal literature, patent scholars generally treat the stand-alone and cumulative-innovation models as entirely distinctive theories, using the stand-alone models to analyze some industries and cumulative-innovation models for others.[51] In the economic literature, scholars usually depict patent theory as almost entirely indeterminate because it offers little guidance in predicting when strong patent rights will either promote or stifle innovation.[52] This Article shows that the same economic factors relevant to optimal patent strength in stand-alone models also predict optimal patent strength in cumulative-innovation models. Consequently, this Article helps to unify the two approaches and takes a large step toward overcoming one of the critical points of indeterminacy in patent theory.

Second, by identifying an observable proxy for the otherwise complex set of factors that determine the social costs and benefits of patent protection in any given field, this Article helps to overcome the seemingly paralyzing problem of

51. *See infra* notes 372–379 and accompanying text.
52. *See infra* notes 379–382 and accompanying text.

"picoeconomics" in patent scholarship.[53] For at least the past thirty years, patent scholars have recognized that there is substantial heterogeneity both within and across industries in the technological and economic characteristics relevant to optimal patent strength.[54] Moreover, because of the very nature of innovation, those characteristics often change over time.[55] As a result, patent scholars have come to accept that "generalizations are extremely risky" in our field.[56] Much of the applied policy analysis in patent law scholarship is industry specific, and most of this work is directed at a small subset of well-studied industries—namely software, semiconductors, pharmaceuticals, and biotechnology.[57] But there are hundreds of other industries affected by the patent system, and over a quarter-million distinct types of technologies recognized by patent offices.[58] Without generalizations to predict and analyze the patent system's effect on innovation in different fields, efforts to translate patent theory into broader policy prescriptions may be a Sisyphean task. By identifying an observable feature of inventions that is correlated with both their need for patent protection and the risk of patents stifling later innovation, this Article takes the first major step toward overcoming this problem.

Third, and most importantly, the government can actually use the correlation between optimal patent strength and time-to-market to tailor patent awards because time-to-market is observable. This Article does not specify the exact details of how the government should tailor based on time-to-market, since it could design and implement such a system in countless different ways. Instead, the Article explores the versatility of tailoring based on time-to-market by discussing various design options in such a system. In particular, it describes how the government could tailor with uniform patent laws that adjust patent awards based directly on inventions' time-to-market or with technology-specific laws that tailor awards based on the average time-to-market in a field.

Part I of this Article summarizes the standard economic analysis of patents under the stand-alone model of innovation and explains that the standard analysis supports the case for tailoring patent awards. Part II discusses the newer cumulative-innovation models and argues that these models strengthen the case for

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53. *See* Levin et al., *supra* note 2, at 821 ("We might be inventing a new field of microeconomic analysis, or 'picoeconomics.' . . . But if we go down that path, our models will soon become as complicated as the world we are trying to explain."). "Pico-" is a prefix used in the metric system to denote the factor 10^{12}, or a trillionth in English.
54. *See supra* note 2.
55. *See* Golden, *supra* note 17, at 539–60.
56. *See* Levin et al., *supra* note 2, at 821.
57. *See* BURK & LEMLEY, *supra* note 31, at 95–96; FTC, *supra* note 2, ch. 3.
58. *See infra* notes 166–168.

tailoring. Part III outlines the primary economic determinants of optimal patent strength and shows that the current patent laws fail to tailor patent awards adequately because they ignore almost all these determinants. Part IV explains that this failure is largely due to the government's inadequate information about inventions, which prevents it from properly tailoring patent awards under uniform or technology-specific laws. Part V introduces the concept of time-to-market. It also argues that the government could use time-to-market for an administrable tailoring regime, since time-to-market is observable, it varies significantly across industries and technologies, and firms will be reluctant to game the system by delaying their R&D projects. Part VI is the heart of the Article. It shows that time-to-market strongly correlates with optimal patent strength in both the stand-alone and cumulative-innovation models. Part VII discusses the implications of this insight, arguing that it helps unify the stand-alone and cumulative-innovation theories, and provides policymakers with concrete guidance for how to tailor patent awards across and within industries. Part VIII discusses some of the design options when building a tailoring regime based on time-to-market.

I. THE CASE FOR TAILORING UNDER MODELS OF STAND-ALONE INNOVATION

Although patents perform a number of different economic functions, the system's primary goal has always been "[t]o promote the Progress of Science and useful Arts," as the U.S. Constitution prescribes.[59] The government awards firms temporary monopoly rights over their inventions to promote investments in innovation. Those awards are costly, however, to the extent that they restrict access to new inventions. This Part describes the classic (or stand-alone) models of innovation, which depict patent policy as a tradeoff between the benefits of promoting innovation with stronger patents and the resulting social costs of consumer deadweight loss.[60] In an ideal patent system, firms would receive just enough patent protection to motivate the R&D of their inventions. Since some inventions need more protection than others to reach the public, the reward for

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59. U.S. CONST. art. I, § 8, cl. 8. The classic economic view also characterizes patents as a tool for promoting innovation. *See* SUBCOMM. ON PATENTS, TRADEMARKS, & COPYRIGHTS OF THE S. COMM. ON THE JUDICIARY, 85TH CONG., AN ECONOMIC REVIEW OF THE PATENT SYSTEM 21 (Comm. Print 1958).

60. William Nordhaus was the first scholar to formally model the economic analysis of patent length when the government must select a single patent term for a heterogeneous group of inventions. *See* NORDHAUS, *supra* note 37, at 70–90. His classic model of optimal patent length describes how lengthening the term will lead to more innovation but will also create additional deadweight loss by extending the patents on all the inventions that firms would have developed with the shorter patent period. *Id.*

innovation under a one-size-fits-all patent system provides excessive protection against competition in many cases and inadequate protection in others.

The patent system operates to correct a particular market failure in the incentives for investing in R&D that can arise when it is easier to imitate an invention than it is to create it.[61] Many (but not all) investments in R&D are vulnerable to this type of free riding.[62] Indeed, firms routinely capitalize on their rivals' R&D by engaging in competitive imitation.[63] This strategy allows firms to save money on R&D and marketing[64] and to minimize their risk exposure by copying only technologically and commercially successful inventions.[65] The patent system addresses this free-rider deterrent to R&D investment by giving in-

61. *See* Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 615 (1962).

62. *See* Mansfield et al., *supra* note 2, at 908–10 (finding that the cost of imitating forty-eight innovations was, on average, roughly two-thirds the cost of creating them). There is tremendous variation in Mansfield's data, however, since half of the product innovations had imitation costs that were either less than 40 percent or more than 90 percent of the original R&D costs, suggesting that many inventions are either very difficult or fairly easy to imitate. *Id.* A survey of industrial R&D executives by Levin et al. also found that imitation is usually less expensive than innovation, but again with significant variation across inventions. *See* Levin et al., *supra* note 2, at 807–12. A survey of industrial R&D executives at Swiss firms concluded that imitating unpatented inventions costs 40 to 50 percent less on average than creating them. *See* NAJIB HARABI, INNOVATION VERSUS IMITATION: EMPIRICAL EVIDENCE FROM SWISS FIRMS 12 (1991), *available at* http://mpra.ub.uni-muenchen.de/26214.

63. *See* STEVEN P. SCHNAARS, MANAGING IMITATION STRATEGIES: HOW LATER ENTRANTS SEIZE MARKETS FROM PIONEERS 1 (1994) ("Imitation is not only more abundant than innovation, it is actually a much more prevalent road to business growth and profits."); Michele Kremen Bolton, *Imitation Versus Innovation: Lessons to Be Learned From the Japanese*, 21 ORGANIZATIONAL DYNAMICS 32 (1993). One recent survey found that fewer firms report pursuing a first-to-market strategy than a fast-follower strategy. *See* Marjorie Adams, Prod. Dev. & Mgmt. Ass'n, PDMA Foundation New Product Development Report of Initial Findings: Summary of Responses From 2004 CPAS, at 2, 27 (Sept. 2004) (Powerpoint Presentation), *available at* http://www.blackswanhome.com/uploads/documents/product/2004_CPAS%20Initial%20Findings.pdf.

64. *See* SCHNAARS, *supra* note 63, at 28–29; Gezinus J. Hidding et al., *The IT Platform Principle: The First Shall Not Be First*, WALL ST. J., Jan. 25, 2010, at R.4.

65. *See* SCHNAARS, *supra* note 63, at 23; Bolton, *supra* note 63, at 32–33. Industry surveys indicate that anywhere from 25 to 76 percent of R&D projects fail to produce a marketable invention. *See, e.g.*, Abbie Griffin, *PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices*, 14 J. PRODUCT INNOVATION MGMT. 429, 447–48 (1997); Henrique Rocha & Mauricio Delamaro, *Project/Product Development Process Critical Success Factors: A Literature Compilation*, 2 RES. LOGISTICS & PRODUCTION 273, 275 (2012); Adams, *supra* note 63, at 10. Among those R&D projects that succeed on a technological level, anywhere from 40 to 95 percent of the resulting inventions are commercial failures. *See* ORACLE, ACCELERATE PRODUCT INNOVATION AND MAXIMIZE PROFITABILITY: AGILE PRODUCT LIFECYCLE MANAGEMENT (2011), http://www.oracle.com/us/products/applications/agile/agile-product-lifecycle-mgmt-070032.pdf; Carmen Nobel, *Clay Christensen's Milkshake Marketing*, HARV. BUS. SCH. WORKING KNOWLEDGE, Feb. 14, 2011, at 1; Adams, *supra* note 63, at 10.

novators the exclusive right to make, use, and sell their inventions for a limited period of time, thus allowing them to earn monopoly profits on their inventions.[66]

This protection offered by patents is important for motivating at least some of private industry's R&D investments.[67] But many inventions would reach the public even without these legal barriers to imitation.[68] It takes time for other firms to develop and commercialize their own version of a rival's invention,[69] which gives the innovator time to recover some or all its R&D costs. This lead time sometimes translates into more lasting competitive advantages as well,[70] especially when the lead time is substantial,[71] when the firm's head start allows it to stay ahead of rivals by continually improving on its invention, or when there are switching costs that deter existing customers from buying the imitation.[72]

To the extent that the patent system effectively promotes innovation by shielding firms from competitive imitation, it serves a critical function in enhancing social welfare.[73] Inventions are information-based goods that are nonrivalrous—meaning that the idea for an invention can be used repeatedly by any number of people without diminishing in value and without anyone needing to repeat the initial investment in R&D that created it.[74] These features allow for increasing returns to scale on the use of the world's finite supply of labor and cap-

66. 35 U.S.C. § 271(a) (2006).
67. *See* Mansfield et al., *supra* note 2, at 913–14; Roin, *supra* note 27; Budish et al., *supra* note 28, at 1–2.
68. Surveys of industry executives reveal that firms in most industries would have developed the vast majority of their patented inventions even without that protection. *See* Levin et al., *supra* note 2, at 796–98; Mansfield et al., *supra* note 2, at 907–10; Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 MGMT. SCI. 173, 174 (1986).
69. *See* HARABI, *supra* note 62, at 2; Levin et al., *supra* note 2, at 807–12; Mansfield et al., *supra* note 2, at 910.
70. *See* William T. Robinson & Sungwook Min, *Is the First to Market the First to Fail? Empirical Evidence for Industrial Goods Businesses*, 39 J. MARKETING RES. 120, 126 (2002). The literature on first-mover advantages suggests that they are heavily contingent upon other factors, including whether the invention is an appropriable technology, which may depend on whether there is strong patent protection or trade secrecy available. *See* Marvin Lieberman, *First Mover Advantage*, *in* PALGRAVE ENCYCLOPEDIA OF STRATEGIC MANAGEMENT (Mie Augier & David J. Teece eds., forthcoming 2015).
71. *See* Marvin B. Lieberman & David B. Montgomery, *First-Mover (Dis)Advantages: Retrospective and Link With the Resource-Based View*, 19 STRATEGIC MGMT. J. 1111, 1117–21 (1998); Robinson & Min, *supra* note 70, at 127.
72. *See* Marvin B. Lieberman & David B. Montgomery, *First-Mover Advantages*, 9 STRATEGIC MGMT. J. 41, 42–43, 46–47 (1988).
73. Among other benefits, technological progress has allowed people to live increasingly longer and more comfortable lives. *See* Richard A. Easterlin, *The Worldwide Standard of Living Since 1800*, 14 J. ECON. PERSP. 7, 12 (2000).
74. *See* Paul M. Romer, *Endogenous Technological Change*, 98 J. POL. ECON. S71, S74–S75 (1990).

ital.[75] Innovation is therefore the primary driver of long-run economic growth and is thus responsible for much of the modern world's wealth.[76] Most of the funding for R&D that produces this innovation comes from private industry.[77] Empirical studies have consistently found that private sector R&D generates tremendous social value on average.[78] Those studies also find that the social rate of return from privately funded R&D is usually far greater than the profits firms earn from their investments.[79]

While the patent system confers benefits by stimulating innovation, it also imposes social costs because it reduces inventions' social value by restricting access to them. Patents entice firms to invest in R&D by allowing them to sell their inventions at supracompetitive prices. By their very nature, therefore, patents make it harder for consumers to afford new inventions. This pricing distortion results in deadweight loss, as those consumers who would buy patented inventions at their competitive (but not supracompetitive) prices are pushed out of the market.[80]

Given patents' social cost, the standard economic theory of patent policy holds that patents should be reserved for inventions that otherwise would not reach the public.[81] The intuition behind this principle is fairly obvious: While

75. *See* Paul M. Romer, *Two Strategies for Economic Development: Using Ideas and Producing Ideas*, *in* PROCEEDINGS OF THE WORLD BANK: ANNUAL CONFERENCE ON DEVELOPMENT ECONOMICS 1992, at 63, 64 (Lawrence H. Summers & Shekhar Shah eds., 1993).

76. *See* PHILIPPE AGHION & PETER HOWITT, ENDOGENOUS GROWTH THEORY 11 (1998); W. BRIAN ARTHUR, THE NATURE OF TECHNOLOGY: WHAT IT IS AND HOW IT EVOLVES 10 (2009); BAUMOL, *supra* note 12, at 13; RICHARD R. NELSON, THE SOURCES OF ECONOMIC GROWTH 31 (1996).

77. *See* NAT'L SCI. FOUND. (NSF), NATIONAL PATTERNS OF R&D RESOURCES: 2008 DATA UPDATE (2010).

78. *See* CONG. BUDGET OFFICE, R&D AND PRODUCTIVITY GROWTH: A BACKGROUND PAPER 23–28 (2005) [hereinafter CBO]; ZVI GRILICHES, R&D, EDUCATION, AND PRODUCTIVITY: A RETROSPECTIVE 70 (2000); Bronwyn H. Hall et al., *Measuring the Returns to R&D*, *in* 2 HANDBOOK OF THE ECONOMICS OF INNOVATION, *supra* note 12, at 1033, 1065–73 (surveying the economic literature).

79. *See* CBO, *supra* note 78, at 27–28; HELPMAN, *supra* note 12, at 43; Frischmann & Lemley, *supra* note 12, at 259–60 n.5; John M. Golden, *Innovation Dynamics, Patents, and Dynamic-Elasticity Tests for the Promotion of Progress*, 24 HARV. J.L. & TECH. 47, 61–63 (2010); Zvi Griliches, *The Search for R&D Spillovers*, 94 SCANDINAVIAN J. ECON. S29, S43 (1992); Hall et al., *supra* note 78, at 1073; Charles I. Jones & John C. Williams, *Measuring the Social Return to R&D*, 113 Q.J. ECON. 1119, 1134 (1998); R. Polk Wagner, *Information Wants to Be Free: Intellectual Property and the Mythologies of Control*, 103 COLUM. L. REV. 995, 1009 (2003).

80. *See* Arrow, *supra* note 61, at 616–17.

81. As Richard Posner once explained, "patents should be granted" when "[a]n invention might not be made (not so soon, anyway) unless the inventor could get a patent" but "[t]he balance tips against protection when the invention is the sort that was likely to be made, and as soon, even if no one could have patented it." Roberts v. Sears, Roebuck & Co., 723 F.2d 1324, 1345 (7th Cir. 1983) (en

patents reduce the social returns from innovation by restricting the public's access to new inventions, it is better for the public to have restricted access to inventions than no access at all. Conversely, when firms are willing to develop new inventions without the promise of patent protection, patents impose the social costs of monopoly pricing without the corresponding benefit of promoting innovation. Providing more protection than necessary can also cause wasteful R&D spending as firms race one another to capture those excessive rents—a phenomenon known as "patent racing."[82]

The same principle applies to determining the appropriate amount of protection to award each new invention. The ideal patent award for any given invention is one that is sufficient to motivate its development but that provides no more protection than necessary.[83] Although it may seem intuitive that firms

banc) (Posner, J., concurring in part and dissenting in part); *see also* Michael Abramowicz & John F. Duffy, *The Inducement Standard of Patentability*, 120 YALE L.J. 1590, 1590 (2011).

82. *See* JEAN TIROLE, THE THEORY OF INDUSTRIAL ORGANIZATION 399 (1988). *But see* Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 276–77 (1977) (arguing that patents reduce wasteful R&D spending from patent races because they are granted early in R&D and therefore end the race sooner). The amount of socially wasteful spending due to R&D racing may be relatively low. *See* Nicholas Bloom et al., *Identifying Technology Spillovers and Product Market Rivalry*, 81 ECONOMETRICA 1347, 1348–49 (2013); Paul A. David & Bronwyn H. Hall, *Heart of Darkness: Modeling Public-Private Funding Interactions Inside the R&D Black Box*, 29 RES. POL'Y 1165, 1167–68 (2000); Charles I. Jones & John C. Williams, *Too Much of a Good Thing? The Economics of Investment in R&D*, 5 J. ECON. GROWTH 65, 66 (2000). These findings suggest that patent racing is a secondary concern in patent policy, although it still plays an important role in patent scholarship. *See, e.g.*, WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 315–16, 327 (2003); John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 509–10 (2004); Einer Elhauge, *Tying, Bundled Discounts, and the Death of the Single Monopoly Profit Theory*, 123 HARV. L. REV. 397, 439–41 (2009).

83. *See* SHAVELL, *supra* note 31, at 145–46. John Duffy identifies an intriguing qualification to this orthodox view that patents should provide the minimum sufficient amount of protection. *See* Duffy, *supra* note 82, at 475–80; Duffy, *supra* note 37, at 3. Duffy argues that when the patent term is longer than needed to motivate an invention's development, competing firms will race to secure the profits from the patent by trying to be the first to file their application. Since the patent term runs from the filing date, Duffy contends that these patent races operate as "Demsetzian auctions," in which the winner is the firm willing to develop an invention in exchange for the shortest effective patent life. Duffy, *supra* note 82, at 491. Thus the effective patent term may be optimal (or close to optimal) even if the statutory patent term is too long, and the public benefits from receiving the invention earlier. In keeping with the literature on patent racing, Duffy utilizes a "production-function model" of R&D investing, which assumes that R&D opportunities are common knowledge and that firms can always accelerate their R&D projects by simply devoting more resources to them. These stylized assumptions consciously ignore the role of creativity in R&D and the cumulative nature of innovation. *See* SCOTCHMER, *supra* note 13, at 54. In reality, innovation may require creative insights that do not occur on a predictable schedule. *See infra* note 209. Moreover, many inventions are made possible by other recent technological developments, which individual firms generally cannot control. Given these external constraints on the pace of innovation,

should be rewarded with stronger protection for more valuable inventions, this view ignores the social costs of that reward.[84] If an invention needs a certain level of patent protection to reach the public, offering anything less will stifle its development, while offering anything more creates additional deadweight loss (and potentially leads to wasteful R&D spending in patent races) without any corresponding public benefit from increased innovation.

If the government could perfectly tailor patent awards, it could maximize the amount of socially valuable innovation incentivized without causing any unnecessary consumer deadweight loss. However, such a patent system is infeasible. Alternatively, the government can avoid the difficulties of tailoring by providing exactly the same patent award for all inventions. This approach has the benefit of simplicity, but it would grossly overreward some inventions and underreward others. In practice, patent systems always fall somewhere in between these two extremes. They impose eligibility requirements that attempt to screen out inventions that do not need patent protection as an incentive for R&D. They also contain a variety of policy levers that the government could use to adjust the duration or scope of protection that inventions receive, although most of those levers lie fallow.[85] In theory, the government could calculate the optimal patent strength for inventions given the constraints of uniformity.[86] But this optimal strength for patents would not be the first-best outcome. The public would be better off if the government could strengthen patents for those inventions that need additional protection and weaken patents for those inventions that will still reach the public with less protection.

II. THE CASE FOR TAILORING UNDER MODELS OF CUMULATIVE INNOVATION

The current impetus for patent reform mostly emanates from the IT sector, in which many commentators believe that patents are too easy to obtain[87] and provide too much protection to inventors.[88] These complaints are rarely about shielding consumers from the harms associated with monopoly pricing. They

there are limits to how early firms can discover and patent most new inventions, even under intense rivalry.

84. *See* Kaplow, *supra* note 37, at 1828.

85. *See infra* notes 142–145 and accompanying text.

86. *See* NORDHAUS, *supra* note 37, at 76; Kaplow, *supra* note 37, at 1825; Menell & Scotchmer, *supra* note 14, at 1488–90.

87. *See, e.g.*, JAFFE & LERNER, *supra* note 20, at 2.

88. *See, e.g.*, Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry*, 89 CALIF. L. REV. 1, 11–14, 33–37 (2001).

are about unnecessary and excessive patent grants taxing innovative companies and discouraging their R&D investments.[89] Patent scholars typically use models of cumulative innovation, in which each new invention is a stepping stone to the next, to explain the patent system's innovation-stifling effects. These cumulative-innovation models indicate that excessive patent grants cause more social harm than previously assumed because they can suppress subsequent technological advances by imposing a tax on later innovators. But the models also highlight the importance of providing adequate protection to call forth new inventions, since each step forward in technology will lead to later advances, and those later advances will be lost if no one takes the initial step. Cumulative-innovation models offer several insights into patent policy that bolster the case for tailoring patent awards. They also offer guidance for identifying situations in which longer patent terms might stifle subsequent innovation.

Although there is nothing new about the idea that patents can discourage innovation,[90] the stand-alone model does not explain how patents could have this effect.[91] The stand-alone model imagines a world in which innovative firms compete against copycat rivals. In this world, increasing the duration or strength of patent protection always spurs additional innovation, albeit at the expense of increased consumer deadweight loss from monopoly pricing.[92]

Beginning with the work of Suzanne Scotchmer, economists began to adjust these models to depict a world in which competition occurs among innovative firms that build on one another's inventions.[93] This form of competitive imitation has a different dynamic than that depicted in the stand-alone model. Although some competitive imitation is merely copycatting, rival firms often try to improve on the earlier invention when they develop their own version.[94] When these imitators succeed, their invention may push the original one off the market. The rival firms are free riding off the original innovator's R&D efforts, but they are also investing in their own R&D projects. The competitive imitators' innovations generate their own knowledge spillovers that will likely help

89. *See supra* note 22.
90. *See* SUBCOMM. ON PATENTS, TRADEMARKS, & COPYRIGHTS OF THE S. COMM. ON THE JUDICIARY, *supra* note 59, at 10–13.
91. *See supra* note 60 and accompanying text.
92. *See* Nancy T. Gallini, *The Economics of Patents: Lessons From Recent U.S. Patent Reform*, 16 J. ECON. PERSP. 131, 136 (2002).
93. Scotchmer, *supra* note 11; *see also* James Bessen & Eric Maskin, *Sequential Innovation, Patents, and Imitation*, 40 RAND J. ECON. 611 (2009); Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989 (1997); Menell & Scotchmer, *supra* note 14, at 1501–02 (reviewing the literature); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990).
94. *See* SCHNAARS, *supra* note 63, at 218–26; Bolton, *supra* note 63, at 32.

other researchers to improve on the technology further.[95] When competitive imitation occurs too quickly, however, it can undermine the incentives for investing in R&D in the first place.[96] If rivals capture too much market share away from the original innovator, that firm might not create the invention in the first place, and its rivals will have nothing on which to build.

The patent system provides a means of transferring profits from the later generations of innovators to the earlier ones, either through licensing or by delaying the later innovator's entry into the market. When firms patent their inventions, they usually try to draft the claims to cover not only direct imitations of their invention but also some of the subsequent improvements that they (or other firms) might make to it.[97] These forward-reaching patents are a deliberate feature of the system, since the later technological advances made possible by an invention are part of its social value.[98] Although these later discoveries are often patentable inventions in their own right, the initial patent still covers them—giving rise to what are known as "blocking patents."[99] Any firm that develops one of the later inventions will be unable to commercialize that technology without obtaining permission from (and usually paying royalties to) the firm that developed the earlier one. The later innovator might even be barred from the market entirely if the patentee of the original invention refuses to license it.

These models of cumulative innovation suggest that the patent system will have mixed effects on the incentives for R&D.[100] On the one hand, by allowing firms to extract licensing fees from follow-on innovators, the patent system encourages firms to create inventions that provide a stepping stone to later advances. In some cases, the original innovators might have been unwilling to create their inventions without the right to appropriate a portion of the value from the later advances those inventions enabled—particularly if rivals can enter the field

95. *See* Stephen J. Nickell, *Competition and Corporate Performance*, 4 J. POL. ECON. 724 (1996).
96. *See* Philippe Aghion et al., Patent Rights, Product Market Reforms, and Innovation (Feb. 19, 2013) (unpublished manuscript), *available at* http://scholar.harvard.edu/files/aghion/files/patent_rights.pdf.
97. For a discussion of the rules controlling firms' ability to draft broad patent claims covering later-arising improvements in their inventions, see Christopher A. Cotropia, *"After-Arising" Technologies and Tailoring Patent Scope*, 61 N.Y.U. ANN. SURV. AM. L. 151 (2005), Lemley, *supra* note 93, at 1000–01, 1003–05, and Charles W. Adams, Blocking Patents and the Scope of Claims (unpublished manuscript), *available at* http://www.stanford.edu/dept/law/ipsc/pdf/adams-charles.pdf.
98. *See* Wagner, *supra* note 79, at 103–10.
99. *See* Robert P. Merges, *A Brief Note on Blocking Patents and Reverse Equivalents: Biotechnology as an Example*, 73 J. PAT. & TRADEMARK OFF. SOC'Y 878, 878–80 (1991).
100. *See* SCOTCHMER, *supra* note 13, at 147.

quickly.[101] On the other hand, patents essentially operate as a tax on the technological advances that follow the initial invention. Just as the higher consumer price for inventions creates deadweight loss, the higher price for using inventions as research inputs can inhibit subsequent technological advances by limiting other firms' ability to use and improve on those inventions.[102]

This patent tax on subsequent innovators is unlikely to discourage later developments unless there are high transaction costs in licensing the earlier patented inventions.[103] Unfortunately, this is frequently the case,[104] mostly because of asymmetric information,[105] potential holdup problems,[106] and the fact that intellectual property (IP) licensing frequently requires complicated legal arrangements that are difficult (and expensive) to negotiate.[107] When subsequent innovators

101. *See* Menell & Scotchmer, *supra* note 14, at 1499; O'Donoghue et al., *supra* note 37; Scotchmer, *supra* note 11.

102. *See* BESSEN & MEURER, *supra* note 31, at 1–28; SCOTCHMER, *supra* note 13, at 127–57; Heller & Eisenberg, *supra* note 26, at 700–01; Lemley, *supra* note 93; Long, *supra* note 26; Merges & Nelson, *supra* note 93; Rai, *supra* note 26, at 120–35. Offering too much patent protection could also reduce a firm's incentive to continue investing in R&D by allowing it to rely on its monopoly rights rather than on new innovation for a competitive advantage. *See* Philippe Aghion et al., *Competition, Imitation and Growth With Step-by-Step Innovation*, 68 REV. ECON. STUD. 467, 468 (2001).

103. *See* Henry E. Smith, *Intellectual Property as Property: Delineating Entitlements in Information*, 116 YALE L.J. 1742, 1780 (2007); *see also* Menell & Scotchmer, *supra* note 14, at 1500–01 (discussing the relevance of transaction costs to whether patents stifle subsequent technological advances in an environment of sequential innovation).

104. *See* Heller & Eisenberg, *supra* note 26, at 700–01 (arguing that various transaction costs impede efficient licensing when upstream intellectual property (IP) rights are fragmented); Lemley, *supra* note 93, at 1052–59 (identifying a number of barriers to IP licensing). The substantial transaction costs involved in patent licensing are sometimes mitigated by the formation of patent pools or practices of widespread industry cross-licensing. *See* Ronald J. Mann, *Do Patents Facilitate Financing in the Software Industry?*, 83 TEX. L. REV. 961, 1006–09 (2005).

105. *See* SCOTCHMER, *supra* note 13, at 141–42 (describing how asymmetric information regarding the value of the technology can prevent licensing); Gallini, *supra* note 92, at 137 (discussing the practical barriers to negotiating a license ex ante—that is, before the subsequent inventor has sunk significant R&D costs creating the improvement).

106. *See* Jerry R. Green & Suzanne Scotchmer, *On the Division of Profit in Sequential Innovation*, 26 RAND J. ECON. 20, 21 (1995) (describing the importance of ex ante licensing because of the holdup problem); Merges & Nelson, *supra* note 93, at 865–67 (discussing how the threat of a holdup problem can discourage firms from attempting to license patents ex post—that is, after they have invested in R&D to create the improvement).

107. *See* Iain M. Cockburn, Is the Market for Technology Working? Obstacles to Licensing Inventions, and Ways to Reduce Them 6–7 (June 8, 2007) (unpublished manuscript), *available at* https://faculty.fuqua.duke.edu/~charlesw/s591/Bocconi-Duke/Bocconi/S2_2008_02_11_MFT/Cockburn_-_Is_the_Market_for_Technology_Working.pdf (reporting from a survey that IP deals usually require more attention from top management, more costly due diligence, and more challenging negotiations than non–IP deals, with 50 percent of attempted licensing deals failing to reach an agreement); *see also* Ashish Arora & Alfonso Gambardella, *Ideas for Rent: An Overview of Markets for Technology*, 19 INDUS. & CORP. CHANGE 775, 787–91 (2010) (noting that industry executives report that there are significant transaction costs in IP licensing stemming from uncertainty over the scope of patent rights, the value of the technology, and the transaction process).

cannot reach a deal with patentees of earlier inventions, the patentees' monopoly rights may inhibit subsequent advances in the protected inventions.

When situating the models of cumulative innovation within the larger literature on economic growth theory, they suggest that scholars have underestimated the potential benefits from tailoring patent awards. It is now well established that innovation is the primary driver of long-run economic growth, and therefore is critical for the advancement of social welfare.[108] The link between innovation and economic growth is in large part due to the positive externalities from R&D, especially the knowledge spillovers that facilitate subsequent innovation.[109] When the patent system fails to call forth a new invention by offering too little protection, the public loses not just that one invention but also all the future advances that would have come from it.[110] Granting too much protection ensures that the public will receive the initial invention but imposes an unnecessary tax on subsequent innovations, likely slowing or preventing some of those later advances.[111] Either way, the patent system is stifling the overall rate of technological progress. Tailoring is the only way to reduce the incidence of both types of errors.

In addition to highlighting the importance of tailoring, the models of cumulative innovation provide guidance for identifying industries in which stronger patents are more likely to stifle technological progress. Within models of cumulative innovation, the social costs of strengthening patent rights are primarily a function of the transaction costs of licensing and of the degree to which earlier patents read onto later inventions that other firms might discover and wish to develop.[112] The benefits of stronger patent rights outweigh these social costs only when the initial innovators need the additional protection to motivate their R&D investments.[113] These insights from the literature on cumulative innovation indicate that the patent awards should be weaker when (1) innovation is more cumulative, which forces innovative firms to license a large number of earlier patents to commercialize their inventions; (2) transaction costs are high; and (3) firms can appropriate a significant portion of the social value of their inventions without lengthy patent rights.[114]

108. *See supra* note 76 and accompanying text.
109. *See supra* notes 74–76 and accompanying text.
110. *See* Menell & Scotchmer, *supra* note 14, at 1499 ("[W]hen innovation is cumulative, the most important social benefit of an innovation may be the boost given to later innovators, and this may make the benefits harder to appropriate."); Wagner, *supra* note 79, at 1001–16.
111. *See supra* note 102.
112. *See* Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51, 67 (Adam B. Jaffe et al. eds., 2002).
113. *See* Menell, *supra* note 31, at 493–95; Menell & Scotchmer, *supra* note 14, at 1502.
114. A more comprehensive list would also include factors relevant to whether patents might facilitate subsequent innovation, which they likely do under some circumstances. *See* F. Scott Kieff,

III. INADEQUATE TAILORING UNDER THE CURRENT PATENT LAWS

Ideally, the patent system would provide protection for inventions only when necessary to incentivize their R&D and would provide the least amount of protection possible. It is clear that some inventions need much more protection than others, and that the social costs and benefits of patents differ dramatically across industries.[115] Nevertheless, the patent system currently engages in little tailoring on this basis. This Part begins by outlining the economic determinants of optimal patent strength that are most relevant for tailoring. It then shows how the current patent laws ignore all but one of these factors. These insights suggest that the patent system's troubles are far more deep seated than commonly recognized. Commentators often presume that the government could resolve most of the patent system's current problems by enforcing the existing patentability standards more stringently or through higher-quality examinations.[116] Since those existing standards fail to account for almost all the economic factors relevant to optimal patent strength, the potential gains from better enforcement of those laws is limited.

A. The Primary Determinants of Optimal Patent Strength

An invention's optimal patent strength is a function of both the invention's need for protection and the likelihood of a patent on that invention stifling later innovation. The four primary determinants of the amount of protection neces-

Coordination, Property, and Intellectual Property: An Unconventional Approach to Anticompetitive Effects and Downstream Access, 56 EMORY L.J. 327, 333–35 (2006). Patents can disclose technical information about inventions to other researchers, thus disseminating knowledge. *See* Wesley M. Cohen et al., *R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States*, 31 RES. POL'Y 1349, 1362–64 (2002); Lisa Larrimore Ouellette, *Do Patents Disclose Useful Information?*, 25 HARV. J.L. & TECH. 545, 556–57 (2012). Patents also probably lower the transaction costs of licensing relative to trade secrets. *See* Arrow, *supra* note 61, at 614–15; Roberto Mazzoleni & Richard R. Nelson, *Economic Theories About the Benefits and Costs of Patents*, 32 J. ECON. ISSUES 1031, 1038–40 (1998). *But see* Michael J. Burstein, *Exchanging Information Without Intellectual Property*, 91 TEX. L. REV. 227, 261–62 (2012) (arguing that patents are often unnecessary for transactions over information). The available empirical evidence—which is extremely limited—currently suggests that patents are more likely to hinder later advances in technology when granted on inventions the public would receive anyway. *See* Heidi L. Williams, *Intellectual Property Rights and Innovation: Evidence From the Human Genome*, 121 J. POL. ECON. 1, 24–25 (2013); Fiona Murray et al., *Of Mice and Academics: Examining the Effect of Openness on Innovation* 28–29 (Nat'l Bureau of Econ. Research, Working Paper No. 14819, 2009).

115. *See supra* note 2.

116. *See, e.g.*, A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 6 (recommending that courts "reinvigorate the non-obviousness standard" to resolve the patent system's current troubles); JAFFE & LERNER, *supra* note 20, at 178–79 (arguing for reform proposals that will improve the enforcement of the existing standards of patentability).

sary to incentivize an invention's R&D are: (1) R&D costs, (2) the risk of failure, (3) the anticipated revenue streams from the invention, and (4) the existence of other barriers to competitive imitation (particularly imitation costs) and alternative means of appropriating the returns from R&D.[117] Inventions that require more expensive R&D need stronger protection, on average, to generate enough revenue to recover their costs.[118] The same is true for R&D projects involving greater uncertainty, since the anticipated returns from an R&D investment must be sufficient to compensate for the risk of failure.[119] Inventions that generate lower annual sales revenues likely need stronger protection to be profitable, since it takes more time for the invention to produce enough revenue the firm to recover its R&D costs.[120] Finally, when inventions are easy to copy, patent expiration or the ability to easily design around a patent will open the door to steep price competition, which can quickly erode the innovator's profit margins. Unless there are strong first-mover advantages[121] or other means of appropriating the returns from R&D, inventions' patents must be sufficiently broad and lengthy to allow firms to recoup most of their total R&D investment before losing their monopoly protection.[122]

In addition to these four main determinants of an invention's need for protection, the government should also consider the main determinants of the extent to which patents may stifle subsequent innovation. As discussed in Part II, the literature on cumulative innovation indicates that stronger patent rights have a greater risk of inhibiting later technological advances when (1) innovation is highly cumulative, (2) transaction costs of patent licensing are substantial, and (3) weaker patents would be sufficient to call forth the earlier inventions.[123] While the third factor simply invokes all the considerations relative to optimal patent strength under the classic model, the first and second add new complexities. They suggest basing patent awards in part on the extent to which those patents will read onto future innovations that other firms might discover and wish to de-

117. *See, e.g.*, Menell, *supra* note 31, at 494 ("The most important considerations in assessing the need for patent protection are the cost of research and development (especially in relation to imitation costs), the technological risk associated with such research, and the availability of effective non-patent means of protection.").
118. *See, e.g.*, SHAVELL, *supra* note 31, at 146 ("[T]he desirable length of property rights should be higher the greater the development costs, other things equal.").
119. *See* Scherer, *supra* note 31, at 427.
120. *See id.* at 426–27.
121. *Cf.* Lieberman, *supra* note 70 (manuscript at 9) (outlining the various first-mover advantages that firms sometimes enjoy when they pioneer a market).
122. *See* F.M. SCHERER, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 384–90 (1970); Burk & Lemley, *supra* note 5, at 1584–85.
123. *See supra* notes 113–114 and accompanying text.

velop and on the likelihood that the costs of licensing will discourage those other firms from developing their inventions.

B. Current Patent Laws Ignore Most of the Primary Determinants of Optimal Patent Strength

Under the existing patent laws, most tailoring occurs at the threshold stage—when the government determines whether inventions are eligible for patent protection. Unfortunately, the legal standards governing this determination overlook most of the economic factors relevant to inventions' need for patent protection and to the likelihood of patents stifling subsequent innovation. The patent system will protect almost any invention that qualifies as useful, novel, nonobvious[124] and that falls within the broad reach of patentable subject matter.[125] The nonobviousness requirement is thought to be most important of these standards,[126] since it is supposed to be a "means of weeding out those inventions which would not be disclosed or devised but for the inducement of a patent."[127] But of the four primary economic determinants of inventions' need for protection, the legal test for nonobviousness considers only the risk of failure in R&D.[128] It ignores the R&D costs, the anticipated revenue streams from the invention, and the costs of imitation.[129] The standards of patentability also disregard the two primary determinants of the extent to which patents will stifle subsequent innovation—whether the invention is in a field in which innovation is highly cumulative and whether the transaction costs in patent licensing will be

124. *See* 35 U.S.C. §§ 101–103, 112 (2006). The utility requirement merely demands that inventions have a specific "real-world" value at the time of patenting. *In re* Fisher, 421 F.3d 1365, 1373 (Fed. Cir. 2005). The novelty requirement prevents firms from patenting inventions that have already been disclosed to the public. *See generally* Sean B. Seymore, *Rethinking Novelty in Patent Law*, 60 DUKE L.J. 919 (2011) (discussing the novelty requirement and the difficulty of applying the requirement in the context of complex fields).

125. Patentable subject matter encompasses "anything under the sun that is made by man" except for "laws of nature, physical phenomena, and abstract ideas." Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980) (citations omitted) (internal quotation marks omitted); *see also* Mayo Collaborative Servs. v. Prometheus Labs., Inc., 132 S. Ct. 1289, 1293 (2012).

126. *See* Abramowicz & Duffy, *supra* note 81, at 1593.

127. Graham v. John Deere Co., 383 U.S. 1, 11 (1966).

128. *See* KSR Int'l Co. v. Teleflex Inc., 550 U.S. 398, 417–18 (2007). Interestingly, the risk of technological failure would appear to be the least observable of the four primary determinants of an invention's need for protection, since it depends on researchers' subjective expectations at the time of invention. Learned Hand described this inquiry "as fugitive, impalpable, wayward, and vague a phantom as exists in the whole paraphernalia of legal concepts." Harries v. Air King Prods. Co., 183 F.2d 158, 162 (2d Cir. 1950).

129. *Cf.* SCOTCHMER, *supra* note 13, at 117–18.

high.[130] Thus the legal test for whether an invention is patentable glosses over most of the economic factors relevant to optimal patent strength.

These glaring oversights in the standards of patentability routinely allow firms to patent many inventions that they would have developed anyway. Indeed, industry surveys suggest that in most fields, firms depend on patent protection for only a small percentage of the inventions they actually patent.[131] This massive overinclusiveness problem is the inevitable result of having a system that will protect almost any invention clever enough to qualify as nonobvious, regardless of its R&D costs, future revenue streams, or imitation costs. The most infamous example of such an invention is Amazon.com's system of "one-click" Internet shopping.[132] At the time of its invention, the one-click system may well have been sufficiently novel and nonobvious to qualify for patent protection.[133] It

130. A number of scholars have argued that courts should use the § 101 patentable subject matter requirements to police the outer bounds of overly broad patents. *See* Rebecca S. Eisenberg, *Wisdom of the Ages or Dead-Hand Control? Patentable Subject Matter for Diagnostic Methods After In re* Bilski, 3 CASE W. RES. J.L. TECH. & INTERNET 1, 41–43 (2012); Mark A. Lemley et al., *Life After* Bilski, 63 STAN. L. REV. 1315, 1329, 1339–41 (2011); Allen K. Yu, *Within Subject Matter Eligibility—A Disease and a Cure*, 84 S. CAL. L. REV. 387, 445–46 (2011).

131. *See* Mansfield et al., *supra* note 2, at 915–17.

132. *See* U.S. Patent No. 5,960,411 (filed Sept. 12, 1997) (claiming "[a] method and system for placing an order to purchase an item via the Internet" in which, after "displaying information identifying the item," the customer can place the order with "only a single action being performed"). Shortly after it issued, Amazon.com's "one-click" patent became the poster child of "outrageous and improvidently granted patents." Lois Matelan, *The Continuing Controversy Over Business Method Patents*, 90 J. PAT. & TRADEMARK OFF. SOC'Y 125, 134 (2008).

133. The academic commentary on Amazon.com's "one-click" patent is nearly universal in concluding that it should be invalid for obviousness. *See* JAFFE & LERNER, *supra* note 20, at 74–76; Margo A. Bagley, *Internet Business Model Patents: Obvious by Analogy*, 7 MICH. TELECOMM. & TECH. L. REV. 253, 254–55, 271–76 (2001); Christina Bohannan & Herbert Hovenkamp, *IP and Antitrust: Reformation and Harm,* 51 B.C. L. REV. 905, 947–48 (2010); Alan Devlin & Neel Sukhatme, *Self-Realizing Inventions and the Utilitarian Foundation of Patent Law*, 51 WM. & MARY L. REV. 897, 944–45 (2009); John F. Duffy, *Inventing Invention: A Case Study of Legal Innovation*, 86 TEX. L. REV. 1, 12–13, 13 n.37 (2007); Jeanne C. Fromer, *The Layers of Obviousness in Patent Law*, 22 HARV. J.L. & TECH. 75, 86–87 (2008); Glynn S. Lunney, Jr., *E-Obviousness*, 7 MICH. TELECOMM. & TECH. L. REV. 363, 420 (2001); Michael J. Meurer, *Business Method Patents and Patent Floods*, 8 WASH. U. J.L. & POL'Y 309, 337 & nn.145–47 (2002); Carl Shapiro, *Patent System Reform: Economic Analysis and Critique*, 19 BERKELEY TECH. L.J. 1017, 1018–19, 1019 n.3 (2004). This widely accepted conclusion may be wrong. When Amazon.com invented "one-click" Internet shopping back in 1997, online retailers utilized a "shopping cart" method that required several steps to place an order and thus gave customers several opportunities to change their mind about the purchases. *See* Amazon.com, Inc. v. Barnesandnoble.com, Inc., 73 F. Supp. 2d 1228, 1232–37 (W.D. Wash. 1999). The industry standard was that 65 percent of items placed in shopping carts were abandoned before checkout. *Id.* at 1247. Needless to say, online retailers were well aware of these losses and looked for solutions. Though Amazon.com's "one-click" ordering ultimately emerged as one of the dominant strategies, in 1997 it was unclear whether customers would be comfortable with a one-click ordering system. *Id.* at 1236. More importantly, people generally assumed that on-line ordering required several steps to prevent accidental orders. Legend

probably did not need a patent to incentivize its R&D, however,[134] and almost certainly did not need twenty years of patent protection, as Amazon.com chief executive officer Jeffrey Bezos freely admits.[135]

The patent system's failure to consider R&D costs, future revenue streams, and imitation costs also causes it to deny patent protection to many inventions that require that protection to incentivize their R&D. This problem is particularly acute in the pharmaceutical industry,[136] in which it costs hundreds of millions of dollars to develop new drugs,[137] which rivals can imitate at a tiny fraction of that cost.[138] Not surprisingly, pharmaceutical companies generally consider strong patent protection a prerequisite for investing in a drug's development.[139] After more than a century of patent filings and published academic research that has identified millions of drug-like compounds, there are countless potentially valuable new drugs that firms cannot patent because they are no longer novel and nonobvious.[140] Since the patent system denies protection for these inventions

has it that when Amazon.com chief executive officer Jeffrey Bezos instructed his engineers to create a one-click ordering system, the idea seemed so absurd to them that it took Bezos three attempts to convince the engineers he was serious. Joel Spolsky recounts this story:

> [A] lot of people were upset by this . . . [patent] because they said this is obvious[.] . . . I hate to tell them but it wasn't obvious, nobody thought of it, really before Amazon did it . . . . [M]y proof is that when Jeff Bezos told his team to go create one click where you [are] just on the page, you click a button[,] and you get the book . . . . [T]hey went away and they came back with something that was I think four clicks[.] . . . [H]e said no, no I didn't mean one click add to cart and then take you to the cart[.] . . . I meant one click and the book . . . is put into a box and sent to your house[.] . . [T]hey said okay, and they came back . . . [with] something that had two clicks[,] and he said which part of one don't you understand[?] [A]nd they said no[,] you need a confirmation page[.] . . . [S]omebody might click by mistake, [and] you just cant [sic] start shipping things to people [because] . . . they followed a URL in their web browser[,] that's absurd[.] . . . [H]e said go back and freaking make it one click and they did[.] . . [W]hat they realized is that . . . most people don't click by mistake, like 99% of the people are not clicking by mistake[, and you can] just give them a nice undo on that [confirmation] page.

Mark Littlewood, *Joel Spolsky at Business of Software—Simplicity Is a Way of Avoiding Looking Like You Lack Value*, BLN (Nov. 23, 2011), http://thebln.com/2011/11/joel-spolsky-at-business-of-software-2009-simplicity-is-a-way-of-avoiding-looking-like-you-lack-value.

134. There are two reasons to suspect that the "one-click" shopping system did not require patent protection as an incentive for its development: (1) The R&D costs were probably relatively low and (2) competitive imitation does not erode the primary means through which the "one-click" system is designed to generate revenue, which is by preventing customers from deciding not to purchase an item during the checkout process. *See supra* note 133.
135. *See* Bezos, *supra* note 33.
136. *See generally* Roin, *supra* note 27.
137. *See* Joseph A. DiMasi et al., *The Price of Innovation: New Estimates of Drug Development Costs*, 22 J. HEALTH ECON. 151, 180–83 (2003).
138. *See* Roin, *supra* note 27, at 510–11.
139. *See id.* at 507–15.
140. *See id.*

even though firms will not develop them without a strong patent because of high R&D costs of easy imitation, the standards of patentability inhibit innovation.[141]

In addition to these shortcomings in the threshold requirements for patent protection, the system also fails to tailor the duration and scope of its awards based on the main economic determinants of optimal patent strength. Patents almost always offer innovators the same set of legal entitlements to exclude others from making, using, or selling the claimed invention,[142] and run for a fixed twenty-year term beginning on the patent's filing date.[143] Although the patent system individually tailors the scope of each patent monopoly, this tailoring mainly occurs through the enablement and written description requirements,[144] which are designed to prevent inventors from claiming "more than [what] was actually invented."[145] While these requirements help link the profits from a patent to the social value of the invention it protects, they do little to tailor patent awards based on an invention's need for protection or on the social costs of the monopoly rights conferred by a patent. The scope of patent protection for inventions thus remains largely invariant to their R&D costs, the costs of imitation, the likelihood of the patent reading onto subsequent innovations developed by other firms, and the expected magnitude of transaction costs in patent licensing between patentees and subsequent innovators. Even with better threshold requirements for patentability, the current one-size-fits-all reward for innovation would provide far too much protection for some inventions and not enough for others.

The government's failure to tailor patent awards according to the main economic determinants of inventions' optimal patent strength is a fundamental flaw in the system. These oversights all but guarantee that the system will fail to spur potentially critical new lines of innovation in areas that depend on strong patent protection. They also result in large numbers of unnecessary and excessive patent grants that harm consumers and risk stifling subsequent innovation. It is difficult to imagine how the government could overcome these problems without significant substantive changes to the patent laws to account for the economic

141. *See id.* at 515–55.
142. *See* 35 U.S.C. § 271(a) (2006).
143. *See id.* § 154(a)(2). Current law extends a firm's patent to compensate for certain PTO and regulatory delays. *See id.* § 154(b)(1)(B); *id.* § 156.
144. *See id.* § 112. Under these rules, firms can draft their patents to encompass anything novel and nonobvious that their patent disclosure "enables one of skill in the art to make and use [without undue experimentation]" and "conveys to those skilled in the art that the inventor had possession of . . . as of the filing date." Ariad Pharm., Inc. v. Eli Lilly & Co., 598 F.3d 1336, 1342, 1351 (Fed. Cir. 2010) (en banc).
145. Magsil Corp. v. Hitachi Global Storage Techs., Inc., 687 F.3d 1377, 1381 (Fed. Cir. 2012).

factors most relevant to inventions' need for patent protection and the likelihood of patents inhibiting future technological advances.

IV. THE MISSING FRAMEWORK FOR IMPLEMENTING A TAILORED PATENT SYSTEM

The patent system's failure to consider the primary economic determinants of optimal patent strength when awarding monopoly rights is regrettable, but it is also easy to explain. The government has trouble observing most of those determinants. As a result, the government's ability to tailor patent awards through technology-neutral rules is severely limited. The lack of information about individual inventions also inhibits the development of sound technology-specific laws, since the government often does not know when to offer stronger or weaker patent rights and has difficulty administering the dividing lines between technologies. This Part explains why the government's inadequate information about inventions is a barrier to better tailoring and how the government could overcome this problem if it found an observable feature of inventions strongly correlated with their optimal patent strength.

A. Barriers to Adequate Tailoring of Patent Awards Through Uniform Laws

One way to tailor patent awards according to inventions' need for protection is through uniform (that is, technology-neutral) laws.[146] Ideally, these uniform laws would condition the availability, duration, and scope of patent protection on the various economic factors that determine inventions' optimal patent strength. But the information necessary to gauge those factors is largely hidden from the government. Without an observable proxy for optimal patent strength, the government's capacity to tailor through uniform laws is extremely limited.

The government has great difficulty observing the features of inventions directly determinate of their need for protection—including R&D costs, risk of failure, anticipated revenue streams, and imitation costs—because firms rarely disclose this information. To measure the first factor, R&D costs, the government would need to audit individual firms. Not only would these audits be ex-

146. *See* Rai, *supra* note 31, at 1057 ("[F]acially neutral patent reform can achieve economic policy goals—including accommodating the legitimate interests of different industries—without forcing decisionmakers to make crude line-drawing determinations.").

pensive,[147] they might also be unreliable because of the inherent difficulty of properly allocating overhead costs among a firm's different R&D projects.[148] The second factor, the risk of failure in R&D, depends on the firm's subjective evaluations of technological and commercial uncertainty in its R&D project, which are difficult to estimate ex post.[149] The third factor, the anticipated net revenues from an invention, is largely a function of the expected consumer demand for that invention. Estimating consumer's willingness to pay for any unique good is challenging, and economists typically assume that the government is poorly suited to this task.[150] The government can try to observe the fourth factor, the costs of imitation, by auditing rival firms that imitate the invention to estimate their R&D costs. But much like audits on R&D costs, auditing profits would be costly and error prone.[151]

The government might have even less information about the economic characteristics of individual inventions needed to tailor their patent awards based on a patent's likely impact on subsequent innovation. As discussed in Part III.A, cumulative-innovation theory highlights two additional considerations relevant to optimal patent strength: (1) the extent to which an invention's patent will read onto future innovations that other firms might discover and wish to develop and (2) the transaction costs in patent licensing. Predicting the extent to which a patent will read onto later innovations is difficult because it requires predicting the future of technological innovation. The government would need to know the extent to which important future innovations will utilize the claimed invention and whether rival firms will discover clever ways to design around the patent. It

147. *Cf.* Tom Windram, *How to Realize the Benefits of the R&D Tax Credit*, MANUFACTURING.NET (July 15, 2008, 12:08 PM), http://www.manufacturing.net/Articles-How-To-Realize-The-Benefits-Of-The-R-D-Tax-Credit.aspx?menuid=242 (discussing some of the intricacies involved in monitoring R&D costs at the project level).

148. *See* SCOTCHMER, *supra* note 13, at 40–41; Stephen M. Maurer & Suzanne Scotchmer, *Procuring Knowledge*, *in* 15 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH 1, 5 (Gary D. Libecap ed., 2004).

149. *See supra* note 128 and accompanying text. Indeed, one of the main justifications for using patents (or prizes) instead of government contracts to finance R&D is that private industry is better situated to evaluate the technological and commercial uncertainty of an R&D project, as well as its potential payoff. *See* Menell & Scotchmer, *supra* note 14, at 1477.

150. *See* TIROLE, *supra* note 82, at 401. When the government has accurate information about consumer demand for inventions, scholars generally assume that there is a strong case for using the government to finance the rewards for innovation instead of tailoring patent awards. Gallini & Scotchmer, *supra* note 112, at 53–56; *cf.* Benjamin N. Roin, *Intellectual Property Versus Prizes: Reframing the Debate*, 81 U. CHI. L. REV. (forthcoming 2014) (explaining why the government might want to maintain the patent system to inform the reward for innovation, even when it has good information about the social value of inventions).

151. *See* MARK S. HOLMES, PATENT LICENSING § 4:6 (2012) (discussing the challenges of determining new revenues from an invention's sales).

would be easier to predict the extent to which other firms will want to develop subsequent innovations covered by the patent, since this risk factor depends on the market structure and the pacing of innovation in the implicated field.[152] But it might be hard to tailor on this basis without using technology-specific rules. Predicting the second factor, future transaction costs in licensing negotiations between the patentee and subsequent innovators, seems equally challenging given the highly context-specific nature of transaction costs.[153]

With limited information about inventions' R&D costs and the other main economic determinants of optimal patent strength, it would be difficult for the government to tailor patent awards based directly on these factors.[154] Given this limitation, it may be impossible to tailor patent awards adequately under uniform laws unless the government can identify a reliable proxy for the economic determinants of their optimal patent strength.

B. Barriers to Tailoring Patent Awards Through Technology-Specific Rules

An alternative to tailoring through uniform laws is to use technology-specific laws. Patent scholars raise four main objections to this form of tailoring, which all stem from the government's limited information about inventions.[155]

152. *See* SCOTCHMER, *supra* note 13, at 117–18.
153. *See* Douglas W. Allen, *Transaction Costs*, *in* 1 ENCYCLOPEDIA OF LAW AND ECONOMICS: THE HISTORY AND METHODOLOGY OF LAW AND ECONOMICS 893, 906–07 (Boudewijn Bouckaert & Gerrit De Geest eds., 2000).
154. *See* Abramowicz, *supra* note 31, at 1394–95.
155. In addition to these four objections to technology-specific patent laws, scholars often remark that technology-specific patent would violate the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). *See* BURK & LEMLEY, *supra* note 31, at 97; Eisenberg, *infra* note 393, at 365; Long, *supra* note 5, at 49. The precise scope of the TRIPS rule against technology-specific laws is unclear. *See* Graeme B. Dinwoodie & Rochelle C. Dreyfuss, *Diversifying Without Discriminating: Complying With the Mandates of the TRIPS Agreement*, 13 MICH. TELECOMM. & TECH. L. REV. 445, 453 (2007) (arguing that TRIPS allows (or should allow) for more technology-specific laws than is commonly assumed). But TRIPS clearly prohibits shortening the patent to less than twenty years for any category of patentable inventions. *Id.* at 454 & n.39. This TRIPS violation might not matter, however, if the United States were to implement a well-designed tailoring regime that weakens patent protection in industries in which strong patent rights are currently stifling overall innovation. Tailoring of this sort would likely benefit most or all of the United States' major trading partners. *Cf.* Walter G. Park, *Patent Systems in APEC: Role in Nontariff Trade Barriers and Strategic Trade Policies*, *in* THE ECONOMIC IMPLICATIONS OF LIBERALIZING APEC TARIFF AND NONTARIFF BARRIERS TO TRADE 6-1, 6-2 (1998) (noting that the strategic use of patent laws by domestic firms often creates substantial trade barriers for foreign firms). Not only do foreign firms typically hold fewer U.S. patents than their domestic counterparts, *see* Gaètan De Rassenfosse et al., *The Worldwide Count of Priority Patents: A New Indicator of Inventive Activity*, 42 RES. POL'Y 720, 720 (2012), they are less likely to enforce their U.S. patents in litigation and less likely to win when they do file suit. *See* Kimberly A. Moore, *Xenophobia in American Courts*, 97 NW. U. L. REV. 1497, 1504 (2003). Consequently, it is unclear

First, the government lacks sufficient information about the social costs and benefits of patents in most industries to determine which fields should receive stronger patent protection than others. Second, the economic analysis of optimal patent strength is far too complex and multifactorial to be readily applied by the government without substantial risk of arbitrariness or political manipulation. Third, technology-specific patent laws are notoriously difficult to implement because the boundaries between technologies are highly ambiguous and mutable, which makes it hard to categorize inventions properly. Unless the government can resolve the inevitable line-drawing questions based on the relevant economic characteristics of the inventions at issue (as opposed to their technological characteristics), firms will be able to draft their patents so that they fall within the categories offering more protection. Fourth, the technological and market conditions in R&D-intensive industries can change rapidly, and it would be hard for the government to adjust its technology-specific patent laws fast enough to keep up with these changes. While all four of these objections should be taken seriously, they could each be addressed if the government could observe a reliable proxy for inventions' optimal patent strength.

For many commentators and patent practitioners, there is a "fundamental principle of our law under which patent protection is available without discrimination as to field of invention or technology."[156] However, there is now overwhelming evidence that despite (or because of) our adherence to this nondisnondiscrimination principle, the patent system has severely disparate impacts on different industries.[157] As a sign of the growing disenchantment with the current patent laws, Richard Posner notes that the patent system's failure to "discriminate among types of inventions or particularly industries . . . is, or should be, the most controversial feature of that law," since "the need for patent protection in order to provide incentives for innovation varies greatly across industries."[158]

To the extent that an invention's technological characteristics provide a reliable proxy for their optimal patent strength, the government could correct many of the existing problems in patent policy by tailoring its awards through technology-specific laws. Most of the current proposals for tailoring are intended as solutions to the ongoing patent crisis in the IT industries, and often involve reforms

whether any of the other World Treaty Organization (WTO) member nations would challenge such a policy. Moreover, since most or all major U.S. trading partners would benefit from such a system, the sanctions for noncompliance might be extremely limited.

156. 142 CONG. REC. S11845 (daily ed. Sept. 30, 1996) (statement of Sen. Orrin G. Hatch) (quoting a letter by the Section of Intellectual Property Law of the American Bar Association written in opposition to a bill (which passed) limiting the enforceability of surgical-method patents).

157. *See supra* note 2.

158. *See* Posner, *supra* note 31.

directed at software patents.[159] But there are also calls for technology-specific rules (or their regulatory equivalents) to address problems in the pharmaceutical and biotechnology industries.[160] All these proposals for technology-specific patent reform are controversial.[161] Indeed, many of the scholars who argue most forcefully that patents stifle innovation in the IT sectors also argue against the adoption of technology-specific patent rules.[162]

The core objection to technology-specific rules is that we do not know enough about how the effects of patents differ across industries and technologies to tailor patent awards according to inventions' technological characteristics.[163] There are a few industries in which it is clear patents play a critical role in promoting innovation (such as pharmaceuticals, medical devices, and agricultural biotechnology),[164] and a few others in which the patent system clearly has a weaker—and arguably negative—effects on the overall rate of innovation (such as software and finance).[165] But there are hundreds of other distinct industries[166] about which scholars know far less concerning the patent system's effects on innovation.[167] The few data points we have from the handful of well-studied indus-

159. *See, e.g.*, Chien, *supra* note 22, at 350–90 (discussing various reform proposals for software patents); Goldman, *supra* note 22, at 7–11 (same).
160. *See, e.g.*, Rai, *supra* note 31; Roin, *supra* note 27, at 557.
161. *See supra* note 35 (citing various opponents to industry-specific tailoring).
162. *See* JAFFE & LERNER, *supra* note 20, at 203–05; PARK, *supra* note 35, at 162–63. Clarissa Long may have captured this sentiment best when she opined, "[t]he same might be said of a unitary patent system that Winston Churchill famously said about democracy: It's the worst form of patent system, except for all the others that have been tried." Long, *supra* note 5, at 49; *see also* Nordhaus, *supra* note 35, at 430 ("[A] fixed patent life is not optimal in theory, although it may be unavoidable in practice.").
163. *See, e.g.*, Anna B. Laakmann, *An Explicit Policy Lever for Patent Scope*, 19 MICH. TELECOMM. & TECH. L. REV. 43, 45 (2012) ("[T]he theoretical literature does not conclusively identify the specific contexts in which [stronger or weaker patent rights] does or should prevail. Indeed, academic patent scholarship reflects a 'stalemate of empirical intuitions.'"). For example, the National Academy of Sciences' 2004 report on patent reform advocates that we "preserve a formally unitary system," since "we do not know enough about innovative processes to advise Congress on the optimal characteristics of different classes of patents in different circumstances." A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 84–85. Mark Lemley offers this same justification for maintaining mostly technology-neutral laws, noting that we should "give IP protection only in those circumstances in which we need it. And if we could tell in advance what those circumstances were, we would adjust policy accordingly. But for the most part, we can't." Mark A. Lemley, *A Cautious Defense of Intellectual Oligopoly With Fringe Competition*, 5 REV. L. & ECON. 1025, 1031 (2009) (footnote omitted).
164. *See supra* note 25.
165. *See supra* notes 22–23.
166. The North American Industry Classification System (NAICS) recognized 1179 distinct industries in its original 1997 classification scheme. *See* James A. Walker & John B. Murphy, *Implementing the North American Industry Classification System at BLS*, MONTHLY LAB. REV., Dec. 2001, at 15, 18.
167. *Cf.* Golden, *supra* note 17, at 546–50 (noting that patent law's effects vary greatly across different industries because of technology specificity).

tries are not enough to support broad generalizations about which types of technologies should receive more protection than others. To make matters worse, there are over 260,000 distinct categories of technology recognized by the U. S. Patent and Trademark Office (PTO).[168] It is unclear if these technological categories can be ranked properly according to their need for protection based on technological characteristics. As Adam Jaffe and Josh Lerner explain:

> [T]he technology characteristics that could provide the basis for differential patent treatment are typically abstract and difficult to quantify empirically. . . . So while there is a theoretical case for a system that is not uniform, there is no theoretical or empirical basis for saying specifically how patent treatment should differ across specific technologies.[169]

A second objection to tailoring patent awards through technology-specific rules is that the economics of optimal patent strength are far too complicated to support an administrable system of rules for determining which technologies will receive more protection than others. We know pharmaceuticals generally require more protection than software, but in a system of differential patent awards, the government must also determine how to treat all the other industries and technological groups. Proponents of technology-specific tailoring have identified a host of economic factors that would be relevant to these determinations,[170] including R&D costs, technological risk, public funding for the research, adequacy of alternative means of appropriating the returns from R&D, value of patent disclosures, cumulativeness of innovation, transaction costs, network effects, clarity of patent scope, due diligence costs related to patent searches, problems related to patent leveraging and misuse, and other abuse problems.[171] The difficulty in applying this framework lies, not only in acquiring the relevant information for many of these factors but also in synthesizing these factors—which will often point in opposite directions—in a coherent fashion. Without an adequate sys-

168. *See* U.S. Patent & Trademark Office, Cooperative Patent Classification (CPC): General Introduction Into CPC 14 (July 10, 2012) (Powerpoint Presentation), *available at* http://www.cooperativepatentclassification.org/publications/UsptoUserDayGeneralIntro.pdf.
169. JAFFE & LERNER, *supra* note 20, at 203–04.
170. For example, Dan Burk and Mark Lemley outline a framework based on a variety of different economic theories of the costs and benefits of patenting. Under their proposed framework, the government would tailor its awards for each industry based on the economic theories that best characterize that industry. *See* Burk & Lemley, *supra* note 5, at 1675–95.
171. Menell, *supra* note 31, at 495 fig.1; *see also* Michael W. Carroll, *One Size Does Not Fit All: A Framework for Tailoring Intellectual Property Rights*, 70 OHIO ST. L.J. 1361, 1424–32 (2009) (adding several other concerns to the list of relevant to tailoring judgments, including administrability and political economy concerns).

tem to weigh the appropriate factors against one another, the government's tailoring decisions might be arbitrary and susceptible to political manipulation.[172]

A third objection to technology-specific patent laws relates to the difficulties of properly sorting inventions into discrete categories.[173] The dividing lines between technologies are porous and change over time, and many inventions fall within multiple distinct technological categories.[174] Consider, for example, the classification of a brain-computer interface technology, which may be akin to software, computer hardware, other electronics, medical devices, diagnostics, video game technology, or any other field that is likely to use these inventions.[175] Any system of technology-specific patent laws will inevitably encounter difficult line-drawing questions of this nature. As a result, proposals for technology-specific rules designed to affect one industry often run into political opposition from other industry groups that fear those rules will spill over to affect their own inventions.[176] Line-drawing problems can also make it hard to enforce technology-specific rules. Patent applicants often take advantage of the ambiguous boundaries between technologies by drafting their patent claims to select into favored categories. For example, when courts initially prohibited pure software patents, patentees responded by drafting software claims as "computer systems" that implemented software to get around the restriction.[177] Likewise, when the PTO created a "second look" program for business method patents to provide for a more rigorous examination process, patent applicants simply reframed their business-method claims so they could file their application in a different PTO division.[178]

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172. *See, e.g.*, A PATENT SYSTEM FOR THE 21ST CENTURY, *supra* note 2, at 84–85.
173. *See* BURK & LEMLEY, *supra* note 31, at 98–99.
174. *See* PARK, *supra* note 35, at 162–63.
175. *See* Jan B. F. van Erp et al., *Brain-Computer Interfaces for Non-medical Applications: How to Move Forward*, 45 COMPUTER-IEEE COMPUTER SOC'Y 26, 28 tbl.1 (2012).
176. The legislative history of 35 U.S.C. § 287(c)—which bars the enforcement of surgical-method patents against surgeons and hospitals—highlights the difficulty of drafting technology-specific rules narrowly enough to avoid opposition from powerful industry groups. *See* Gerald J. Mossinghoff, *Remedies Under Patents on Medical and Surgical Procedures*, 78 J. PAT. & TRADEMARK OFF. SOC'Y 789, 789–90, 794–95 (1996) (describing both the pharmaceutical industry's opposition to a ban on surgical-method patents because they feared the ban would affect method-of-use patents on drugs, and the eventual compromise bill that prohibits enforcing surgical-method patents against physicians and hospitals but not generic drug manufacturers).
177. *See* Cohen & Lemley, *supra* note 88, at 8–14. Many critics of software patents oppose outright prohibition on the grounds that it would be overinclusive and that it is hard to distinguish software patents from patents on other types of inventions that involve software. *See* BURK & LEMLEY, *supra* note 31, at 157–58; Cohen & Lemley, *supra* note 88; Goldman, *supra* note 22, at 1–6.
178. JAFFE & LERNER, *supra* note 20, at 204.

A related problem with technology-specific patent laws is that they can become obsolete quickly, since the technological and market conditions in R&D-intensive industries can change faster than legislators can respond.[179] The Semiconductor Chip Protection Act (SCPA) illustrates this problem.[180] Congress spent six years carefully crafting a sui generis regime of intellectual property rights for semiconductors.[181] Many scholars praised the resulting statute for attempting to protect innovators from low-cost imitation while avoiding excessive impediments to subsequent innovation.[182] By the time Congress passed the SCPA into law, however, changes in the economics of semiconductor R&D had rendered the statute unnecessary.[183]

To make a compelling case for tailoring patent awards through technology-specific rules, all four objections must be addressed. First, the government must have adequate information about the relevant economic characteristics of R&D in the different industries and technological fields. Second, the government needs a principled, transparent, and administrable framework for weighing that information to determine which inventions should receive more protection than others. Third, when resolving the line-drawing issues that inevitably arise when the government applies technology-specific rules to individual inventions, the government should be able to base its tailoring decisions on relevant economic factors, not arbitrary technological features. Fourth, the government must be able to adjust its tailoring rules quickly to account for changing economic and technological characteristics of industries relevant to their optimal patent strength. Otherwise, the public may well be better served with our untailored patent laws.

An observable proxy for inventions' optimal patent strength would address all four issues. The government could use that proxy to judge which industries or classes of technology need more protection than others do through a simple and transparent framework. Technology-specific categories will always involve difficult line-drawing problems in determining whether certain inventions belong within one category of technology or another. But if the government can observe the feature of these inventions that serves as a proxy for their optimal patent strength, it can resolve any line-drawing questions on the basis of that proxy. Finally, the government could adjust its patent awards for the different classes of

179. BURK & LEMLEY, *supra* note 31, at 98–99.
180. Semiconductor Chip Protection Act (SCPA) of 1984, 17 U.S.C. §§ 901–914 (2012).
181. *See* 3 PAUL GOLDSTEIN, GOLDSTEIN ON COPYRIGHT § 17.26 (3d ed. 2013).
182. *See, e.g.*, Pamela Samuelson & Suzanne Scotchmer, *The Law and Economics of Reverse Engineering*, 111 YALE L.J. 1575, 1596 (2002) (concluding that the basic structure of IP protection afforded under the SCPA "is fundamentally sound as applied to . . . [the semicondutor] industry").
183. Leon Radomsky, *Sixteen Years After the Passage of the U.S. Semiconductor Chip Protection Act: Is International Protection Working?*, 15 BERKELEY TECH. L.J. 1049, 1087 (2000).

technology in response to changes in the observable proxy for optimal patent strength, avoiding the problem of obsolescence associated with technology-specific rules.

V. THE FEASIBILITY OF TAILORING BASED ON TIME-TO-MARKET

This Part argues that the government could overcome the administrative barriers to tailoring outlined above by using inventions' time-to-market—that is, the amount of time from the initial idea for an invention to its first sale.[184] While the academic literature on patent policy devotes little attention to time-to-market, firms typically view time-to-market as critical to their inventions' profitability.[185] There is a vast trade literature on R&D project management, much of which is devoted to time-to-market issues.[186] In a later Part, this Article argues that time-to-market is a powerful proxy for inventions' optimal patent strength and, therefore, an appealing foundation for a system of tailored patent awards. This Part shows that tailoring based on time-to-market is both practical and administrable. It explains that the government could implement such a system without firms excessively gaming the system because delaying R&D projects is costly to firms. Since firms usually try to develop their inventions as fast as possible, time-to-market largely depends on the amount and difficulty of work involved in inventions' R&D. Tailoring based on time-to-market therefore links patent awards to important—and exogenous—characteristics of inventions. Given the tremendous heterogeneity in time-to-market across inventions, the government can use time-to-market to draw sharp distinctions between inventions. And most importantly, time-to-market is observable. The inquiry into time-to-market is even similar to other inquiries the patent system already makes.

A. Resistance to Gaming

Although the potential benefits from tailoring patent awards are substantial, those benefits could be lost if the government tailors based on features of inventions that are easily manipulable, since firms could game the system by

184. Time-to-market can also be defined as "the elapsed time from the beginning of idea generation to market introduction." Pinar Cankurtaran et al., *Consequences of New Product Development Speed: A Meta-Analysis*, 30 J. PRODUCT INNOVATION MGMT. 465, 465 (2013). There are several other terms for time-to-market, including "development cycle time," "product development time," "innovation time," "lead time," "project completion time," and "total time." *Id.*

185. *See infra* notes 187–193 and accompanying text.

186. *See* Preston G. Smith, *Accelerated Product Development: Techniques and Traps*, *in* THE PDMA HANDBOOK OF NEW PRODUCT DEVELOPMENT 173 (Kenneth B. Hahn ed., 2d ed. 2005).

altering that feature. At first glance, tailoring based on time-to-market appears highly susceptible to gaming. Firms always have the power to slow down their inventions' R&D, and they would have an incentive to delay if the government offers them stronger patent rights for inventions with longer times-to-market. But firms would still have powerful incentives not to delay their R&D projects under such a system. This Part examines the intense competitive pressure that pushes firms to rush their R&D projects and argues that, given this pressure, the government could tailor based on time-to-market without significantly distorting R&D times.

The accepted wisdom among many experts on new product development is that "[t]ime to market . . . is by far the most important factor affecting the internal rate of return ("IRR") on the product development investment."[187] As a result, most firms work hard to get their inventions onto the market as quickly as possible.[188] Industry surveys show that speeding time-to-market is among the top priorities for firms that invest in R&D.[189] According to Robert Cooper, a prominent consultant and author on product development strategy, industry has a "preoccupation with reducing cycle time and speeding new products to market."[190] A Capgemini report notes, "'[s]peeding time to market' is a typical mantra for many industries."[191] And in a popular trade book on product-

187. KIRK DOUGLASS, PIVOT INT'L, WHAT DOES PRODUCT DEVELOPMENT REALLY COST?: HOW INTERNAL RATE OF RETURN FOR A NEW PRODUCT IMPROVES SUBSTANTIALLY WITH A DECREASE IN TIME TO MARKET 4, http://www.pivotint.com/Pivot_what-does-product-development-really-cost.pdf.

188. *See* Abbie Griffin, *Product Development Cycle Time for Business-to-Business Products*, 31 INDUS. MARKETING MGMT. 291, 291 (2002) ("For the last 15 or more years, firms have worried about, and tried to shorten, the time it takes them to get new products to market." (footnote omitted)); Rocha & Delamaro, *supra* note 65 (reviewing the academic literature on the various management strategies deployed to reduce development cycle times and speed time-to-market).

189. *See* ACCENTURE, INNOVATION IN CONSUMER PRODUCTS: HOW TO ACHIEVE HIGH PERFORMANCE THROUGH NEW PRODUCT INNOVATION 13 (2008), http://www.accenture.com/SiteCollectionDocuments/PDF/ConsumerProductsGroupPoV_103008_fnl.pdf (reporting that "more than 70 percent of companies say that 'on time to market' is of great importance for new product success" and that along with R&D project costs, it was ranked highest in importance for "[k]ey success factors in new product introductions"); HADAS HARAN, TIME TO MARKET RESEARCH: HIGHLIGHTS AND KEY FINDINGS 8 (2011), *available at* http://www.osstransformation.com/DocDownload.aspx?assetid=28B8 (reporting findings from a survey that 70 percent of firms in the telecommunications industry say time-to-market is "very important" for remaining competitive in the field).

190. R.G. Cooper, *Your NPD Portfolio May Be Harmful to Your Business's Health*, VISIONS, Apr. 2005, at 22.

191. CAPGEMINI, SPEEDING TIME TO MARKET, INCREASING TIME IN MARKET & MAINTAINING MARKET VELOCITY: BEST PRACTICES IN DRIVING TOP-LINE GROWTH THROUGH INNOVATION & COLLABORATION 1 (2007), http://www.capgemini.com/sites/default/files/resource/pdf/tl_Speeding_Time_to_Market__Increasing_Time_in_Market____Maintaining_Market_Velocity.pdf.

development management strategies, the author describes the entire body of "development management precepts and practices with which most development personnel are currently familiar . . . as the *Time-to-Market Generation*, whose primary focus is developing individual products faster."[192] Even firms focusing on imitation as their primary R&D strategy rush their development efforts to secure a viable market position; indeed, the strategy of competitive imitation is now known as being a "fast follower."[193]

The literature on product-development management explains that firms rush their R&D projects for five critical reasons. First, any delay can give rival firms a chance to enter the market first and to capture a greater share of the potential sales.[194] Second, delays diminish the innovator's window of opportunity to earn a profit from its invention, since inventions always have a limited commercial lifespan.[195] Third, delays postpone the innovator's receipt of its return on investment, which diminishes the likelihood of breaking even on the project.[196] Fourth, delays increase the risk that changing technological or market conditions

192. MICHAEL E. MCGRATH, NEXT GENERATION PRODUCT DEVELOPMENT: HOW TO INCREASE PRODUCTIVITY, CUT COSTS, AND REDUCE CYCLE TIMES 5 (2004) (emphasis added).

193. *See* ROBERT G. COOPER & SCOTT J. EDGETT, PRODUCT INNOVATION AND TECHNOLOGY STRATEGY 128 (2009) ("The major challenge is that the fast-follower must be exactly that . . . fast!"); CONSTANTINOS C. MARKIDES & PAUL A. GEROSKI, FAST SECOND: HOW SMART COMPANIES BYPASS RADICAL INNOVATION TO ENTER AND DOMINATE NEW MARKETS 15, 119–38 (2005).

194. *See* ROBERT G. COOPER & SCOTT J. EDGETT, NEW PRODUCT DEVELOPMENT: LEAN, RAPID, AND PROFITABLE 12–13 (2005); E.L. CUSSLER & G.D. MOGGRIDGE, CHEMICAL PRODUCT DESIGN 142 (2d ed. 2011) ("Delaying is in itself a commercial risk; a competitor may reach the market first and even if their product is inferior, they are then likely to gain most of the market share. . . . We may risk losing less money by proceeding with a product idea which might not work than by delaying and risking loss of market share."); James A. Debardelaben et al., *Incorporating Cost Modeling in Embedded-System Design*, 14 IEEE DESIGN & TEST OF COMPUTERS 24, 25–26 (1997); Fred Langerak et al., *Balancing Development Costs and Sales to Optimize the Development Time of Product Line Additions*, 27 J. PRODUCT INNOVATION MGMT. 336, 339 (2010); Vincent A. Mabert et al., *Collapsing New Product Development Times: Six Case Studies*, 9 J. PRODUCT INNOVATION MGMT. 200, 203 (1992) ("It is abundantly clear to us that the threat of significant market share gains by competitors was a key stimulus in improving the new product development cycles at all of the companies.").

195. *See* COOPER & EDGETT, *supra* note 194, at 12–13 (stating that "speed yields higher profitability" because "[m]any products have a fixed window of sales opportunity"); Debardelaben et al., *supra* note 194, at 25–26 ("A recent survey showed that being six months late to market resulted in an average 33% profit loss, assuming a five-year product lifetime."); Langerak et al., *supra* note 194, at 339 ("The window of opportunity for a new product, in particular for product line additions, is finite. By taking too long to develop a new product, a firm may miss the window of opportunity. Customers already exposed to existing brands are not likely to postpone their purchase decision just to wait for a new product to come to market, especially if competitors already have introduced similar extensions." (citations omitted)).

196. *See* COOPER & EDGETT, *supra* note 194, at 12–13; DOUGLASS, *supra* note 187.

will dry up demand for the invention before commercialization.[197] Fifth, because management has trouble monitoring the quality and productivity of its engineers' work on R&D projects, tight project deadlines and rewards for rapid project completion are essential management tools for encouraging efficient work, avoiding cost overruns, and evaluating the performance of engineers and R&D project managers.[198]

Since most or all of these incentives to rush R&D would remain even if the government tailors patent awards based on time-to-market,[199] the government could almost certainly implement such a system without inciting an unacceptable level of gaming through intentional delays. Some gaming is probably inevitable, as is true of most laws.[200] But if the trade literature is correct that even short delays of a few months risk greatly reducing the returns from R&D,[201] these distortions will be modest. The government can further reduce the incentives for delay by minimizing instances in which it gives firms significantly stronger patent rights for relatively small increases in their inventions' time-to-market.[202]

B. Time-to-Market Is Largely Exogenous

It is better to tailor patent awards based on inventions' fundamental characteristics than their superficial features, since superficial features are easier to manipulate and their correlation with optimal patent strength may be fleeting. This Subpart shows that an invention's time-to-market primarily depends on the

197. *See* COOPER & EDGETT, *supra* note 194, at 13 (stating that "[m]arkets, competition and technology are all fluid and change at lightening speed," and "[t]he longer it takes to get to market, the greater the likelihood that everything has changed").

198. *See id.* at 12 ("[T]he longer a project lingers in development, the more inefficient and costly the project becomes"); Larry A. Mallak, *The Elusive Measure of R&D Productivity and Performance*, *in* THE TECHNOLOGY MANAGEMENT HANDBOOK 3-37 (Richard C. Dorf ed., 1999) (describing the costs and benefits of using time-to-market as a metric for measuring R&D performance).

199. If the government tailors patent awards based on time-to-market, only the second of the five incentives to rush R&D is likely to be weaker. Delays in R&D would still give firms less time on the market to profit from their inventions, but tailoring would offset that loss with a longer patent term or broader scope of protection. The first incentive to rush R&D, preventing competitors from getting to the market first, would remain even if the government tailors based on time-to-market—unless it gives firms broader patents to block those very competitors before they get to the market. Tailoring based on time-to-market would not affect any of the other three incentives to rush R&D: time-value of money, risk that demand for the invention will fall, and need to monitor employee effort and project performance with tight deadlines.

200. *See* Gideon Parchomovsky & Alex Stein, *The Distortionary Effect of Evidence on Primary Behavior*, 124 HARV. L. REV. 518 (2010).

201. *See supra* notes 194–195.

202. Alternatively, the government could tailor patent awards based on the average time-to-market for inventions in a field, which would remove the incentive for firms to delay individual R&D projects to receive stronger patent protection.

amount and difficulty of work required to complete its R&D—which are exogenous and fundamental to the R&D project.

Although firms are under intense pressure to shorten their inventions' time-to-market, there are limits to how quickly they can complete their R&D projects.[203] There is some room to speed up R&D by devoting additional labor and resources to the project, but these investments often have steep diminishing returns.[204] At a certain point, adding more people to a project can actually slow it down by creating coordination problems within the project team.[205] The website for a product-development consulting firm offers the following advice to companies about the costs (and limitations) of accelerating R&D times:

> If a project takes twice as long to conduct as required, one may need to triple, quadruple or more the assigned resources to halve the completion time. In fact in heavily resourced projects increasing resources can actually slow a project down. The time at which this happens is called the crash point. A relevant analogy to bear in mind is three women cannot have a baby in 3 months.[206]

In short, firms cannot speed through complicated and technologically challenging R&D projects simply by spending more money on them.[207]

Certain aspects of the R&D process are also inherently difficult to accelerate. Product testing that requires real-world trials tends to be unavoidably time-consuming.[208] The creative process that gives rise to inventions generally occurs on its own schedule.[209] Third parties control other aspects of the R&D timeline, including the amount of effort needed to satisfy premarket regulatory standards

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203. *See* Mabert et al., *supra* note 194, at 200.
204. *See* Langerak et al., *supra* note 194, at 338–39.
205. *See* FREDRICK P. BROOKS, JR., THE MYTHICAL MAN-MONTH: ESSAYS ON SOFTWARE ENGINEERING 21–26 (1995); Erran Carmel & Barbara J. Bird, *Small Is Beautiful: A Study of Packaged Software Development Teams*, 8 J. HIGH TECH. MGMT. RES. 129, 132 (1997).
206. *Tips & Facts—Organizing R&D for Success*, SENSORS RES., http://www.sensors-research.com/articles/tips.htm (last visited Dec. 23, 2013) (emphases omitted).
207. *See* Griffin, *supra* note 188, at 293 exh.1.
208. *See, e.g.*, ARNO VAN WINGERDE, TESTING OF ROTOR BLADES OF WIND TURBINES, http://www.ontario-sea.org/Storage/26/1788_Testing_of_Rotor_Blades_of_Wind_Turbines.pdf; Adams, *supra* note 63, at 21–22; *infra* note 237 and accompanying text.
209. *See* Kim Benz, Comment to *You Cannot Dictate Invention* (Jan. 2013), http://www.linkedin.com/groups/You-cannot-dictate-invention-Yet-2182.S.198306852?qid=9fe61f79-64b7-40ef-9c16-0661e4c07a37&trk=group_items_see_more-0-b-ttl ("You cannot put a time on an invention but you can put times on developing and bringing together the Needs and the Hows."); Felix H., Comment to *You Cannot Dictate Invention* (Jan. 2013), *supra* ("Managing a true R&D project is nothing like managing a regular development project, the primary difficulty is that no one knows if there is a solution to the problem at hand, let alone a timeline for delivering it.").

in areas such as pharmaceuticals,[210] medical devices,[211] aviation equipment,[212] and some securities products.[213]

With firms striving to complete their R&D projects as quickly as possible, the most important determinants of time-to-market are the project's size and complexity. In a review of academic literature on product-development times, Abbie Griffin notes that "[n]early all the empirical results" have reached the "unsurprising" conclusion that "[n]ewer, bigger, more complex, more technically challenging and more innovative projects are all associated with longer development times."[214] These findings indicate that an invention's time-to-market is primarily determined by exogenous constraints related to the amount of work needed to complete the R&D and the difficulty of that work. Indeed, many commentators believe that the main strategy firms have used to shorten their inventions' time-to-market is to select easier R&D projects,[215] shifting from more innovative and new-to-the-world inventions to incremental improvements.[216]

C. The Substantial Heterogeneity in Time-to-Market Across Inventions

The government cannot effectively tailor patent awards based on a feature of inventions unless that feature differs greatly across inventions. The government needs this heterogeneity to distinguish inventions according to their optimal patent strength reliably. Time-to-market easily satisfies this prerequisite for tailoring.

Table 1 draws on a variety of sources to present a picture of where various industries fall on the time-to-market spectrum. Financial products and pharmaceuticals rest at opposite ends, and development cycles in software and semiconductors are much closer to the former than the latter. This much is already known. Some of the other figures are a little surprising, however. Average R&D times within the health care and biotechnology industries cover an incredibly wide range of one to sixteen years, depending on the type of technology. Patent

210. *See* Wyeth v. Levine, 555 U.S. 555, 566–67 (2009) (discussing the Food and Drug Administration's (FDA's) premarket approval requirements for new drugs).
211. *See* Riegel v. Medtronic, Inc., 552 U.S. 312, 315–20 (2008) (discussing the FDA's premarket approval requirements for medical devices).
212. *See* Federal Aviation Act of 1958 § 603(a), 49 U.S.C. § 44704 (2006).
213. *See* John C. Coates IV, *Reforming the Taxation and Regulation of Mutual Funds: A Comparative Legal and Economic Analysis*, 1 J. LEGAL ANALYSIS 591, 632–34 (2009).
214. Griffin, *supra* note 188, at 292.
215. *See* Cooper, *supra* note 190, at 3.
216. *See* Robert G. Cooper, *Perspective: The Innovation Dilemma: How to Innovate When the Market Is Mature*, 28 J. PRODUCT INNOVATION MGMT. 2, 3 (2011); Griffin, *supra* note 188, at 292; Adams, *supra* note 63, at 39.

scholars have overlooked the extraordinarily lengthy R&D times for drilling technologies in the oil and gas industry, and the time-to-market for many types of clean-energy technologies is underappreciated.

Time-to-market also varies significantly across inventions within certain industries. This within-industry variation is greatest in sectors in which R&D times are longest, including pharmaceuticals, medical devices, clean energy, and oil and gas—industries in which some inventions take five or ten years longer to develop than others.[217] There is also substantial—albeit less dramatic—variation in time-to-market in industries with short R&D times, including software and semiconductors.[218] In general, developing a breakthrough technology or new-to-the-world product takes substantially longer than an incremental improvement or product-line extension.[219]

217. Much of this within-industry variation in time-to-market occurs along predictable lines. Certain types of drugs take much longer to develop than others. *See* Budish et al., *supra* note 28; DiMasi, *infra* note 238. First-in-class medical devices have substantially longer R&D times than incremental improvements on existing devices. *See* Combs, *infra* note 227. Compared to solar panel technology and fuel cells, wind power has a "very short" time-to-market. RUDOLF RECHSTEINER, WIND POWER IN CONTEXT—A CLEAN REVOLUTION IN THE ENERGY SECTOR 9 (2008).

218. *See* Harald Bauer et al., *Getting Mo(o)re out of Semiconductor R&D*, MCKINSEY ON SEMICONDUCTORS, Autumn 2011, at 60, 60 exh.1 (noting that the average R&D time for semiconductors ranges from eleven to twenty-six months, depending on whether the product is a design revision or an entirely new chip design); Sachin P. Kamat, *Time to Market*, IEEE CONSUMER ELECTRONICS MAG., Oct. 2012, at 40, 42 (reporting that average R&D times for standard mobile-phone software programs is four to six months, but if the new program is based on an entirely new technology, average R&D times are several times longer).

219. *See, e.g.*, Griffin, *supra* note 188, at 297 tbl.4 (reporting an average cycle time of 53.2 months for inventions that are new to the world, 36 months for new product lines, 22 months for next generation improvements, and 8.6 months for incremental improvements); Adams, *supra* note 63, at 13.

TABLE 1. AVERAGE TIME-TO-MARKET BY TECHNOLOGY

Technology	Average Time-to-Market
Financial products	Weeks to months[220]
Insurance products	3 to 12 months[221]
Consumer products	3 to 13 months[222]
Food & beverages	9 to 13 months[223]
Software	5 to 14 months[224]
Semiconductors	11 to 26 months[225]
In vitro diagnostics (incremental improvements)	1 to 2 years[226]
Medical devices (incremental improvements)	3 to 5 years[227]
Complicated manufacturing equipment	3 to 5 years[228]
Automobiles	3 to 5 years[229]
Gene-based biomedical research tools	5 years[230]
Solar panels	8 years[231]
Radiopharmaceutical diagnostics	7 to 9 years[232]
In vitro diagnostics (new diagnostic correlation)	7 to 9 years[233]
Agricultural chemicals	9 years[234]
Medical devices (first-in-class)	5 to 10 years[235]
Biotechnology crops	6 to 13 years[236]
Oil & gas drilling	16 years[237]
Pharmaceuticals	12 to 16 years[238]
Fuel cells	7 to 25 years[239]

220. *See* HEWLETT-PACKARD, FINANCE AMERICA CAPITALIZES ON A DIGITAL PUBLISHING SOLUTION FROM HP TO KEEP ITS PRODUCTS FIRST IN BROKERS' MINDS (2004), *available at* http://h10088.www1.hp.com/gap/download/FINANCE_AMERICA.pdf (noting that it is possible to create new financial products for mortgages "in about a week"); Press Release, Octavian, Octavian to Launch Its Innovative Financial Products Account Opener(TM) for Financial Services Companies (Jan. 22, 2008), *available at* http://www.reuters.com/article/2008/01/22/idUS141388+22-Jan-2008+PRN20080122.
221. *See* Andy Ferris, Deloitte Consulting, Product Development Issues: Speed to Market (Nov. 15, 2007) (Powerpoint Presentation at the Actuaries Club of the Southwest Fall Meeting), *available at* http://www.acsw.us/fall07/Ferris.pdf.
222. *See* ACCENTURE, *supra* note 189, at 4 fig.2.

223. *See* BORD BIA, CHANGING FOOD MARKETS AND MARKETING VISION FOR 2020, at 7 (2009) (citing figures from Deloitte showing that the average time-to-market for new food products is thirteen months); Stephanie Cernivec, *2012 New Product Development Survey: Forecasting a Year of Healthful Introductions*, BEVERAGE INDUSTRY, Jan. 2013, at 52 (reporting that the average R&D time for new beverages is nine to ten months); Jennifer Zegler, *2012 New Product Development Survey: A Return to Innovation Forecasted—With a Traditional Focus*, BEVERAGE INDUSTRY, Jan. 2012, at 56.

224. *See* MARTIN L. GRISS, HEWLETT-PACKARD, SOFTWARE REUSE: FROM LIBRARY TO FACTORY 6 (1993), *available at* http://www.hpl.hp.com/techreports/93/HPL-93-67.pdf (reporting an average time-to-market of six to nine months for software components); HARAN, *supra* note 189, at 8 (finding that 65 percent of service providers in the telecommunications industry report that they are able to bring new products to market in less than six months); JERRY KRASNER, TOTAL COST OF DEVELOPMENT: A COMPREHENSIVE COST ESTIMATION FRAMEWORK FOR EVALUATING EMBEDDED DEVELOPMENT PLATFORMS 10 tbl.1 (2003), *available at* http://www.eurotech-inc.com/info/pdf/total-cost-of-development.pdf (reporting an average time-to-market for embedded software platforms that ranged between eight and fourteen months); PETER RASMUSSEN, IMPROVED EFFICIENCY AND FASTER TIME TO MARKET WITH AGILE DEVELOPMENT PRACTICES (2010), *available at* http://www.ibm.com/smarterplanet/global/files/danske_bank.pdf (describing how Danske Bank reduced its average time-to-market for new IT products from fourteen months to nine months); Mary Wu, Agile Method to Improve Delivery of Large-Scale Software Projects 38 (May 2011) (unpublished manuscript), *available at* http://www-engr.sjsu.edu/ges/media/pdf/mse_prj_rpts/spring2011/Agile%20Method%20to%20Improve%20Delivery%20of%20Large-Scale%20Software%20Projects.pdf (reporting an average time-to-market of between five and nine months for software projects in the case study). The time-to-market for certain types of software can be much longer. *See, e.g.*, Kamat, *supra* note 218 (reporting that the average time-to-market for software applications on mobile devices is between seventeen and twenty-six months).

225. *See* RAHUL KAPOOR ET AL., MANAGING COMPLEXITY AND CHANGE IN THE SEMICONDUCTOR ECOSYSTEM: FINDINGS FROM THE WHARTON-ATREG INDUSTRY STUDY 5, 14 (2012); Bauer et al., *supra* note 218, at 60 exh.1.

226. *See* Rebecca Henderson & Cate Reavis, Eli Lilly: Recreating Drug Discovery for the 21st Century (Mar. 13, 2008) (unpublished manuscript), *available at* https://mitsloan.mit.edu/MSTIR/IndustryEvolution/RecreatingDrugDiscovery/Documents/07-043-Recreating-Drug-Discovery.pdf; *New Report Provides High-Level Data Benchmarks in Key Areas to Help Teams Achieve Success in their IVD Development and Marketing Efforts*, BUS. WIRE (Apr. 8, 2008, 12:00 PM), http://www.businesswire.com/news/home/20080408005068/en.

227. *See* Arthur H. Combs, Medical Device Development: Contrasting Key Elements With Drug Development (PowerPoint Presentation), *available at* http://wenku.baidu.com/view/91d2416648d7c1c708a145b2.html (last visited Nov. 6, 2013) (reporting that the average time-to-market for a basic new medical device is three to five years, with a minimum of two years and a maximum of ten).

228. *See* Abbie Griffin, *Modeling and Measuring Product Development Cycle Time Across Industries*, 14 J. ENGINEERING & TECH. MGMT. 1, 2 tbl.1 (1997) (reporting an average time-to-market of four to seven years for construction equipment and jet engines, and three to five years for copying equipment).

229. *See* CHARLES H. FINE ET AL., THE U.S. AUTOMOBILE MANUFACTURING INDUSTRY 21 (1996) (finding that the average time-to-market for U.S. automakers was fifty-two months); Ron Adner, *Match Your Innovation Strategy to Your Innovation Ecosystem*, 84 HARV. BUS. REV. 98, 103 (2006) (noting that an "average OEM takes three to four years to move a car from design to volume

production"); Griffin, *supra* note 228, at 2 tbl.1 (reporting that the average time-to-market for new cars is three to five years).

230. *See* LORI PRESSMAN, DNA PATENT LICENSING UNDER TWO POLICY FRAMEWORKS: IMPLICATIONS FOR PATIENT ACCESS TO CLINICAL DIAGNOSTIC GENOMIC TESTS AND LICENSING PRACTICE IN THE NOT-FOR-PROFIT SECTOR 15 (2012), *available at* http://www.uspto.gov/aia_implementation/gene-comment-pressman.pdf (finding that for the gene patents held by the National Institutes of Health (NIH) or a university that are licensed to private industry to be developed as a reagent, the average time from patenting to receiving the first royalties was five years).

231. *See "Enlightenment" on the Subject of Solar Cells*, MATERIALS RES. INST., http://www.mri.psu.edu/news/2006/2006_taylor_lecture (last visited Dec. 23, 2013).

232. *See* Richard G. Zimmermann, *Why Are Investors Not Interested in My Radiotracer? The Industrial and Regulatory Constraints in the Development of Radiopharmaceuticals*, 40 NUCLEAR MED. & BIOLOGY 155, 165 (2013).

233. *See* PRESSMAN, *supra* note 230, at 14–15 (reporting that the average time from patenting to first royalties is seven to nine years for the gene patents held by the NIH or universities that are licensed to private industry to create diagnostic tests). These figures refer to time-to-market for the correlation component of diagnostic innovation, in which the patented invention concerns the medical relevance of a particular observable feature that can guide treatment decisions. The development cycles for diagnostics greatly vary depending on the regulatory environment and whether it is an entirely new diagnostic or just an improvement in the testing technology for an older diagnostic.

234. *See* FRED WHITFORD ET AL.,PURDUE EXTENSION, PPP-71, THE PESTICIDE MARKETPLACE: DISCOVERING AND DEVELOPING NEW PRODUCTS 28 (2006), http://www.extension.purdue.edu/extmedia/PPP/PPP-71.pdf (noting that on average, "[i]t takes nine years, the review of 140,000 compounds, and $180 million to discover and develop a new pesticide product").

235. *See* Combs, *supra* note 227; Aaron V. Kaplan et al., *Medical Device Development: From Prototype to Regulatory Approval*, 109 CIRCULATION 3068 (2004) (describing the preclinical development and regulatory testing requirements for medical devices that make R&D times for first-in-class devices similar to new drugs).

236. *See* MICHAEL OLLINGER & LESLIE POPE, U.S. DEP'T. OF AGRIC. ECON., REP. NO. 697, PLANT BIOTECHNOLOGY: OUT OF THE LABORATORY AND INTO THE FIELD (1995) (reporting an average development time of six years for genetically modified crops); Andrew Barkley & Forrest G. Chumley, *A Double Haploid Laboratory for Kansas Wheat Breeding: An Economic Analysis of Biotechnology Adoption*, 15 INT'L FOOD & AGRIBUSINESS MGMT. REV. 99, 105 tbl.1 (2012) (reporting average development times for wheat ranging from six to twelve years); Monsanto, Annual R&D Pipeline Review: R&D Pipeline Resource 9 (Jan. 6, 2011) (Powerpoint Presentation), *available at* http://www.monsanto.com/SiteCollectionDocuments/Q1-2011-pipeline-update.pdf (stating that the average duration of R&D for a new biotechnology crop in their pipeline is between six and thirteen years, but that their reported "[a]verage development cycle [is] on the high end of duration estimates because of complexity of traits" involved in those products); *see also* PHILLIPS MCDOUGALL, CROP LIFE INT'L, THE COST AND TIME INVOLVED IN THE DISCOVERY, DEVELOPMENT AND AUTHORISATION OF A NEW PLANT BIOTECHNOLOGY DERIVED TRAIT 10 (2011) (reporting that it takes thirteen years on average to discover, develop, and secure the regulatory authorization to sell a new plant biotechnology trait).

237. *See* W. Howard Neal, Oil and Gas Technology Development (July 18, 2007) (unpublished manuscript); *id.* at 12 fig.IVF.1. This sixteen-year average time-to-market for oil & gas drilling technologies includes time to widespread commercial adoption. *Id.* at 12. Given the long development times of breakthrough drilling technologies, apparently all those inventions are funded by the government. *See* Stephen M. Cassiani et al., Exploration Technology 104 (July 18, 2007)

(unpublished manuscript), *available at* http://www.npc.org/study_topic_papers/21-ttg-explorationtech.pdf ("[D]evelopment of new, breakthrough, drilling-technology advances is necessarily long-range and requires significant pre-investment. All of the breakthrough technologies are funded to a large extent by national governments as well as large oil and gas companies.").

238. *See* Joseph A. DiMasi, *New Drug Development in the United States From 1963 to 1999*, 69 CLINICAL PHARMACOLOGY & THERAPEUTICS 286, 292 fig.6 (2001).

239. *See* PANAYOTIS CHRISTIDIS ET AL., EUROPEAN SCI. & TECH. OBSERVATORY, TRENDS IN VEHICLE AND FUEL TECHNOLOGIES: OVERVIEW OF CURRENT RESEARCH ACTIVITIES 6 (2003) (reporting that the development time-frame for fuel cells is between fifteen and twenty-five years); Sunita Satyapal, Technology Commercialization Showcase 2008: Hydrogen, Fuel Cells & Infrastructure Technologies Program 16–41 (2008) (Powerpoint Presentation), *available at* http://techportal.eere.energy.gov/commercialization/pdfs/2008_h2_fuel_cells.pdf (listing the estimated time-to-market (going forward) for a variety of fuel-cell technologies in various stages of development).

D. Time-to-Market and Average Time-to-Market Are Sufficiently Observable

Tailoring patent awards based on a particular feature of inventions is impractical unless the government can observe that feature. Although time-to-market is not perfectly observable, the government can estimate it much more reliably than it can any of the other economic factors relevant to optimal patent strength[240]—including inventions' risk of failure, which the patent system gauges under the nonobviousness test.[241] This Subpart discusses how the government could estimate individual inventions' time-to-market for tailoring patent awards with technology neutral laws. It also discusses how the government could estimate the average time-to-market for different types of inventions, allowing the government to tailor with technology-specific laws.

Estimating the time-to-market for individual inventions is often easy. For purposes of tailoring patent awards, the relevant starting point for an R&D project is when firms begin devoting significant labor and resources to creating the invention,[242] and the relevant endpoint is when firms begin earning revenue from their patented invention. The government can usually rely on the patent filing date as a rough proxy for the start of R&D, since firms typically file their applications early in the R&D process,[243] before entering the much more costly and time-intensive development phase.[244] For inventions sold as new products or as

240. *Cf. supra* notes 147–154 and accompanying text (explaining why the government has difficulty observing R&D costs, uncertainty, anticipated revenue streams, imitation costs, transaction costs, and the likelihood of patents reading onto future innovations).

241. *See supra* note 128.

242. Estimating the start of R&D is far more subjective if it includes the R&D project's "fuzzy front end"—the period when firms are looking for new R&D ideas and deciding whether (and when) to pursue particular projects. *See* Peter A. Koen et al., *Fuzzy Front End: Effective Methods, Tools, and Techniques*, *in* THE PDMA TOOLBOOK FOR NEW PRODUCT DEVELOPMENT 5 (Paul Belliveau et al. eds., 2002).

243. *See* IAIN M. COCKBURN & REBECCA HENDERSON, SURVEY RESULTS FROM THE 2003 INTELLECTUAL PROPERTY OWNERS ASSOCIATION: SURVEY ON STRATEGIC MANAGEMENT OF INTELLECTUAL PROPERTY, at I.3 (2003) (reporting survey results finding that most firms "*always* file patents as quickly as possible," with less than a third of firms reporting that they ever delay their filings for strategic reasons (emphasis added)); Christopher A. Cotropia, *The Folly of Early Filing in Patent Law*, 61 HASTINGS L.J. 65, 78–81 (2009); Kitch, *supra* note 82, at 269–71.

244. *See* ROGER G. COOPER, WINNING AT NEW PRODUCTS: ACCELERATING THE PROCESS FROM IDEA TO LAUNCH 41 fig.2.6 (2001); Aleixo & Tenera, *infra* note 283, at 798; Griffin, *supra* note 188, at 296 tbl.3; Jeffrey B. Schmidt, *Gate Decisions: The Key to Managing Risk During New Product Development*, *in* THE PDMA HANDBOOK OF NEW PRODUCT DEVELOPMENT, *supra* note 186, at 337, 343 ("[T]he cost and time to complete each subsequent stage of the NPD [new product development] process frequently increases dramatically."); Ted Sichelman,

discernible new features in existing products, the date of commercialization is a public event, and thus it is easy to observe. Calculating time-to-market is simple in these cases.[245]

Observing time-to-market is costlier—but still feasible—when the patent filing date is not an adequate proxy for the start of R&D, which is true for inventions requiring unusually extensive prepatenting research relative to their postpatenting development. Only a small minority of private-sector inventions will fit this description,[246] but it may be common for university inventions.[247] In these cases, the government would want to calculate time-to-market based on the actual start of the R&D. Fortunately, R&D usually leaves a trail of documentation and work product evidencing the project's start date.[248] The patent system is well practiced at inquiring into R&D start dates under the old priority rules.[249] These inquiries are clearly manageable but much more costly than relying on the patent filing date.[250]

Observing time-to-market is also costlier though feasible when firms do not publicize their inventions' commercialization. Firms use some inventions internally instead of commercializing them.[251] They also license some inventions

Commercializing Patents, 62 STAN. L. REV. 341, 372–73, 373 n.183 (2010) ("[I]n practice, it appears that post-invention development and commercialization expenses dwarf pre-invention expenses in nearly all industries."); Adams, *supra* note 63, at 21–22.

245. For inventions with lengthy R&D times, the government often will not know their time-to-market when it issues the patents because the inventions are still in R&D. In these cases, the government would need to tailor after the patent grant, such as when the government awards patent-term extensions to drugs for time spent in clinical trials. *See* 35 U.S.C. § 156 (2006).
246. *See supra* note 244.
247. *Cf.* Jeannette Colyvas et al., *How Do University Inventions Get Into Practice?*, 48 MGMT. SCI. 61 (2002) (conducting a detailed case study of eleven patented university inventions). Since university researchers primarily rely on grant money to finance their research, the government could use their grant applications and reports to estimate their R&D start dates.
248. *See* John W. Boger, *Laboratory Notebooks: Why They Are So Important*, BONEZONE, Fall 2009, at 14, 15–16, *available at* http://www.hrfmlaw.com/img/articles/Laboratory_Notebooks_Why_They_Are_So_Important_article_571719.pdf (discussing the various reasons why researchers keep detailed laboratory notebooks documenting their daily work on R&D projects); Anthony C. Tridico & Arpita Bhattacharyya, *Don't Throw Away Lab Notebooks: Record-Keeping Under AIA*, FINNEGAN (Nov. 8, 2012), http://www.finnegan.com/resources/articles/articlesdetail.aspx?news=8cde8320-e197-421a-9071-7e401cf62457 (same).
249. *See, e.g.*, Brown v. Barbacid, 436 F.3d 1376 (Fed. Cir. 2006).
250. The United States' experience with interference hearings—in which courts would determine which party was the first to conceive of a particular invention for purposes of establishing priority—suggests that this type of inquiry is manageable but costly. *See* David S. Abrams & R. Polk Wagner, *Poisoning the Next Apple? The America Invents Act and Individual Inventors*, 65 STAN. L. REV. 517, 533–36 (2013); Mark A. Lemley & Colleen V. Chien, *Are the U.S. Patent Priority Rules Really Necessary?*, 54 HASTINGS L.J. 1299 (2003).
251. *But see* Note, *The Disclosure Function of the Patent System (or Lack Thereof)*, 118 HARV. L. REV. 2007, 2014–17 (2005) (noting that firms generally do not patent the inventions they use behind

to third parties to complete their development or to incorporate them into larger, complex products.[252] And in some cases, firms abandon their inventions before finishing their development or licensing them.[253] In these cases, the relevant endpoint for calculating time-to-market is when the patentee first implemented the invention internally, licensed it,[254] or halted work on its R&D, in that order. Although these events are not public, they are observable in that firms will have internal records documenting the events. Moreover, the patent system already inquires into the nonpublic commercialization dates when it applies the prior-sale and prior-use bars,[255] and it inquired into R&D timelines under the old (pre-2011) priority rules.[256]

In situations in which calculating time-to-market requires knowledge of nonpublic events, the government could conduct individual investigations into each invention's time-to-market, but it probably wants to avoid that administrative burden. As an alternative, the government could rely on patentees to self-report the relevant dates for calculating time-to-market and deter fraud with occasional investigations and significant penalties for misreporting. Since violations could be readily ascertained in most cases, the risk of detection in patent litigation or a PTO reexamination proceeding alone might be sufficient to deter most fraud, assuming the penalties are adequate.

An alternative to estimating time-to-market for individual inventions is for the government to observe the average time-to-market for different types of inventions. This is fairly easy to observe in most cases. The government could put together a reasonably accurate estimate of the average time-to-market in different fields using only publicly available information. Given private industry's pre-

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closed doors because detecting infringement is difficult and the patent would disclose to competitors how to make and use the invention).

252. *See* Jon Dudas & David Kline, *Thank the Founding Fathers for the Open Market in Patents*, FORBES, Sept. 17, 2013, http://www.forbes.com/sites/forbesleadershipforum/2013/09/17/thank-the-founding-fathers-for-the-open-market-in-patents (discussing the long history of inventors licensing their patents instead of commercializing the technology themselves).

253. *See* COCKBURN & HENDERSON, *supra* note 243, at I.2 (finding that on average, firms hold roughly 20 percent of their patents for the option value of "potential future own business").

254. The licensing date is usually the correct endpoint for time-to-market because the inventor's R&D efforts are finished and the licensing agreement can begin generating revenue for the inventor. However, if the firm that licenses the invention and plans to develop it into a commercialized invention must depend on the inventor's patent to protect its investment, then time-to-market should be calculated from the start of R&D to commercialization date for the final product.

255. 35 U.S.C. § 102(b) (2006).

256. *See id.* § 102(g) ("In determining priority of invention under this subsection, there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other."); Brown v. Barbacid, 436 F.3d 1376, 1380–32 (Fed. Cir. 2006).

occupation with getting its inventions to the market as quickly as possible,[257] figures on the time-to-market for new products receive a lot of attention and tend to be widely reported within industries.[258] To improve its estimates, the government could commission its own studies to acquire technology-specific averages within each field.[259] Most firms already maintain careful records of the duration of their own R&D projects for internal evaluation purposes,[260] so the figures necessary for estimating the average time-to-market for most technologies already exist. The government just needs to request them.[261]

Since the average time-to-market in a field is generally observable, the government could tailor based on time-to-market while avoiding the main objections to technology-specific rules. The simplicity of such a system avoids the need for a much more complicated and error-prone inquiry into the economics of innovation in each field. There is also less room for favoritism in setting rewards when the tailoring is based on a single, observable variable. The government could adjust its technology-specific patent awards over time as the average time-to-market changes for technologies, thereby preventing the rules from becoming outdated. Crucially, this system of tailoring patent awards based on time-to-market allows the government to resolve the line-drawing questions that inevitably arise when implementing technology-specific rules.[262] To the extent that the government can observe the time-to-market for the individual inventions at issue in these line-drawing disputes, it could use that information to resolve those disputes and sort the inventions into their proper category.

257. *See* Cooper, *supra* note 190.

258. *See, e.g.*, *supra* notes 220–239 and accompanying text. The Product Development Management Association (PDMA) conducts an extensive cross-industry survey every five years that collects more detailed information about the average time-to-market in various fields. *See About PDMA Foundation*, PDMA FOUND., http://www.pdma.org/p/cm/ld/fid=13 (last visited Dec. 23, 2013).

259. When devising the different categories of inventions for purposes of calculating their average time-to-market, the government would want to create categorical divisions between industries and technologies that (1) group together inventions with similar R&D characteristics, especially in their times-to-market and (2) can be easily administered. Ideally, categorical divisions between inventions will map onto features that are directly related to inventions' R&D time (such as whether the invention is subject to a particular regulatory scheme that typically demands a lengthy time-to-market).

260. *See* Griffin, *supra* note 188, at 291–92.

261. Although it is conceivable that firms might try to deceive the government with fraudulent reports, it is not likely to be a serious problem. The upside to this fraud would be small unless there are very few firms producing a particular type of technology, since any exaggerated (or deflated) figures submitted by one company would be watered down when the government computed the industry average. Moreover, fraudulent figures might look suspicious to the government when it has access to other firm's reported times-to-market, so the risk of detection might be high. If the government were still worried about fraud, it could use the threat of random audits to encourage truthful reporting.

262. *See supra* notes 173–183 and accompanying text.

Depending on the costs of these case-by-case inquiries, the government could use fewer categories when tailoring to reduce the number of line-drawing questions that arise.[263] In short, tailoring based on average time-to-market avoids the primary barriers to technology-specific tailoring.

VI. TIME-TO-MARKET AS A PROXY FOR OPTIMAL PATENT STRENGTH

This Part argues that inventions' time-to-market can serve as a reliable proxy for both their need for patent protection and the risk that patents will inhibit subsequent innovation. First, this Part argues that inventions' time-to-market will be closely associated with the amount of patent protection necessary to motivate their R&D. Longer R&D times are correlated with higher R&D costs, greater uncertainty in R&D, reduced future revenue streams, and greater vulnerability to free-riding imitation—all four of the primary economic determinants of the need for patent protection. Second, this Part argues that because shorter times-to-market lead to shorter product lifecycles (that is, a faster rate of product turnover in the market), they are associated with a greater risk of stronger patents stifling innovation. Third, this Part argues that for inventions that necessarily have longer times-to-market, the time and expense of R&D affects the structure of their market in ways that substantially reduce the likelihood of patents stifling subsequent innovation.

A. The Relationship Between Time-to-Market and the Need for Patent Protection

This Subpart argues that the time-to-market for inventions is perhaps the single most reliable proxy for their optimal patent strength as characterized by the stand-alone model of innovation. For the patent system to successfully call forth the inventions that depend on it, the duration and scope of patent protection available must be sufficient for firms to anticipate a profit from the necessary investment in R&D.[264] As discussed in Part III.A above, the need for patent protection under the stand-alone model is primarily a function of R&D costs, the risk of failure in R&D, the anticipated revenue streams from the invention, and the costs of imitation. A longer time-to-market increases the total cost of R&D because it ties up capital for longer, and it decreases the value of future revenue streams generated by the invention's sales because of discounting. Inventions with longer R&D times also typically require higher out-of-pocket R&D

263. *See infra* Part VIII.B & VIII.C.
264. *See* Scherer, *supra* note 31, at 426.

expenses and involve a greater risk of failure. Moreover, lengthy R&D times are associated with a greater vulnerability to free riding because the time and expense of imitating an invention rarely increase proportionally with the time and expense of the innovator's R&D project. Taken together, these factors suggest that an invention's time-to-market will have a tremendous impact on the amount of protection needed to motivate investment in its R&D.

1. Time-to-Market and the Time Value of Money

The more time it takes for an invention to reach the market, the longer firms must wait to see a return on their investment. This means that the investment has higher opportunity costs. Those costs are particularly important with R&D projects, since the costs of capital for R&D tend to be higher than for other types of investments[265]—especially when funded by outside investors.[266] If a firm's cost of capital is in the range of 10 to 12 percent, which appears to be typical for R&D,[267] the anticipated time-to-market has a dramatic effect on total project costs.[268] In the pharmaceutical industry, in which it is estimated that the average capitalized cost of bringing a new drug to market is approximately $1.2 billion, over half of those costs are due to the time value of money invested in R&D.[269] Interviews of R&D managers outside of the pharmaceutical industry also verify that firms "are thinking about the cost of capital," and that "the estimated time completion period[s] are important factors to support a project."[270]

The time firms spend developing their inventions also diminishes the present value of the future revenue streams those inventions might generate, which makes it harder for firms to recoup their R&D investments. Anticipated reve-

265. *See* Partnoy, *supra* note 31, at 19; Charles P. Himmelberg & Bruce C. Petersen, *R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries*, 76 REV. ECON. & STAT. 38, 38–42 (1994).
266. *See* Bronwyn H. Hall & Josh Lerner, *The Financing of R&D and Innovation*, 1 HANDBOOKS IN ECONOMICS: ECONOMICS OF INNOVATION, *supra* note 12, at 609, 613–618 (explaining that information asymmetries, moral hazard, and tax disadvantages all increase the costs of financing R&D with external capital).
267. *See* Frank Kerins et al., *Opportunity Cost of Capital for Venture Capital Investors and Entrepreneurs*, 39 J. FIN. & QUANTITATIVE ANALYSIS 385 (2004).
268. *See* MARC A. ANNACCHINO, NEW PRODUCT DEVELOPMENT: FROM INITIAL IDEA TO PROJECT MANAGEMENT 47 (2003); MICHAEL GALLAHER ET AL., NAT'L INST. OF STANDARDS & TECH., U.S. DEP'T OF COMMERCE, ECONOMIC ANALYSIS OF THE TECHNOLOGY INFRASTRUCTURE NEEDS OF THE U.S. BIOPHARMACEUTICAL INDUSTRY 5-1 to 5-26 (2007).
269. *See* Joseph A. DiMasi & Henry G. Grabowski, *The Cost of Biopharmaceutical R&D: Is Biotech Different?*, 28 MANAGERIAL & DECISION ECON. 469, 475 (2007).
270. *See* Roli Varma, *Project Selection Models or Professional Autonomy?*, 17 PROMETHEUS 269, 277 (1999).

nues are always discounted to reflect the costs of capital when firms weigh those revenues against the cost of R&D and the risk of failure.[271] The more time it takes for an invention to begin generating sales revenue, the more those revenues are discounted. Assuming a discount rate in the range of 10 to 12 percent, R&D times will have a large effect on the net present value of most R&D projects.[272]

These discounting effects alone might justify tailoring patent awards based on inventions' time-to-market. Indeed, Frank Partnoy makes this exact argument in a prior (unpublished) article questioning the wisdom of awarding twenty-year monopolies over new financial products.[273] Partnoy uses a model of optimal patent length that depicts R&D investments as annuities. On that basis, he argues that the patent term should vary with interest rates,[274] a firm's cost of capital, the time-to-market for inventions in a field, and a few other factors.[275] He notes that one of the clearest implications of his model is that R&D times have a substantial impact on optimal patent life.[276]

2. Time-to-Market and the Costs and Uncertainty of R&D

While the time value of money alone indicates that there should be a strong correlation between time-to-market and optimal patent strength, other forces

271. *See* David J. Brunner et al., *R&D Project Selection and Portfolio Management: A Review of the Past, a Description of the Present, and a Sketch of the Future*, *in* HANDBOOK OF TECHNOLOGY AND INNOVATION MANAGEMENT 215, 216–220 (Scott Shane ed., 2008); Marcus Hartmann & Ali Hassan, *Application of Real Options Analysis for Pharmaceutical R&D Project Valuation—Empirical Results From a Survey*, 35 RES. POL'Y 343, 345–46, 348 (2006); Petri Suomala, *Life Cycle Dimension of New Product Development Performance Measurement*, 8 INT'L J. INNOVATION MGMT. 193 (2004).

272. *See, e.g.*, COOPER & EDGETT, *supra* note 194, at 11 ("[I]f one can get to market earlier, revenues are realized earlier. Since money has a time value, often the costs of delay—even just one month—are huge."); DOUGLASS, *supra* note 187; F. Peter Boer, *Risk-Adjusted Valuation of R&D Projects*, 48 RES. TECH. MGMT. 50 (2003) (noting that the time value of money frequently plays a decisive role in the decisions about which R&D projects to fund).

273. *See* Partnoy, *supra* note 31.

274. Varying the patent term along with fluctuating interest rates might be unnecessary because firms try to smooth their R&D investments to avoid any short-term changes in their workforce of scientists and engineers. *See supra* note 266 and accompanying text.

275. *See* Partnoy, *supra* note 31, at 22–27, 43–45. Partnoy emphasizes four variables in his calculation of optimal patent length: the "expected flow rate of profits" (that is, overall profits from the invention), the "*structure* of the expected flow rate of profits" (whether the profits are front-loaded), the "length of time until the flow rate of profits begin" (development time), and the "cost of capital." *Id.* at 23, 24. Amir Khoury offers a much briefer—and less formal—discussion of the relationship between time-to-market and optimal patent length, but he reaches a similar conclusion. *See* Khoury, *supra* note 31, at 408.

276. *See* Partnoy, *supra* note 31, at 22–27; *id.* at 27 ("Conservatively, assume the difference between the timing of the first cash inflow for the financial services and pharmaceutical industries is five years. It is a straightforward conclusion that the optimal patent term for financial products is roughly five years shorter than that for drugs." (footnote omitted)).

will further strengthen this correlation. Time-to-market not only has a direct effect on the innovator's costs of capital and the future revenues streams the invention generates. It is also associated with higher out-of-pocket R&D expenses and greater uncertainty.[277]

When an invention takes a long time to reach the market, it is not usually due to a lack of effort by the patentee.[278] Under most circumstances, firms try to get their inventions to market as quickly as possible.[279] Consequently, inventions' time-to-market largely depends on their R&D's complexity and the amount of labor involved.[280] Over 50 percent of costs in the typical R&D project are the wages of scientists and engineers.[281] Since a longer time-to-market generally corresponds to additional work hours devoted to the project,[282] it will also correspond to higher total out-of-pocket R&D costs.

Inventions with a longer time-to-market also tend to involve a much greater degree of technological and commercial uncertainty and therefore a higher risk of failure in R&D.[283] Studies find that inventions' time-to-market is strongly correlated with the complexity and technical difficulty of their R&D, along with the innovativeness and general newness (the amount of change from previous versions of similar products) of the invention.[284] Industry surveys find that the average time-to-market for a new-to-the-world invention is anywhere from three to six times longer than for an incremental invention.[285]

277. From the perspective of a firm managing a particular R&D project, the relationship between R&D time and out-of-pocket R&D expenses usually runs in reverse—firms can accelerate their R&D projects—up to a point—by devoting more resources to them. *See supra* notes 203–213 and accompanying text (noting that efforts to accelerate R&D projects by increasing expenditures often face steep diminishing returns). But assuming that firms are already trying to strike the profit-maximizing balance between cost and speed in their R&D, the projects with longer R&D times will involve higher out-of-pocket R&D costs on average.

278. *See supra* notes 208–216 and accompanying text.

279. *See supra* notes 188–96 and accompanying text.

280. *See supra* notes 214–216 and accompanying text.

281. *See* Hall & Lerner, *supra* note 266, at 612.

282. *Cf.* Paulo Soares Figueiredo & Elisabeth Loiola, *Enhancing New Product Development (NPD) Portfolio Performance by Shaping the Development Funnel*, 7 J. TECH. MGMT. & INNOVATION 20, 24 (2012) (noting that project managers often use "the average number of man-hours per project at each stage . . . as a proxy for complexity"); Preston G. Smith & Donald G. Reinertsen, *Shortening the Product Development Cycle: Here Are 10 Areas in Which R&D Managers Can Help to Shorten the Cycle Time for New Products and Projects*, 1992 RES. TECH. MGMT. 44, 45 ("The degree of complexity in a project determines the effort needed and thus the length of the development cycle.").

283. *See* Gonçalo G. Aleixo & Alexandra B. Tenera, *New Product Development Process on High-Tech Innovation Life Cycle*, 58 WORLD ACAD. SCI., ENGINEERING & TECH. 794, 795 (2009); Griffin, *supra* note 188, at 293 exh.1.

284. Griffin, *supra* note 188, at 292; *id.* at 293 exh.1 (reviewing the literature on the factors associated with increases in product development times).

285. *See supra* note 219 and accompanying text.

3. Time-to-Market, Imitation Costs, and Vulnerability to Free-Riding Imitation

Subparts VI.A.1 and VI.A.2 above argue that a longer time-to-market for inventions usually reflects a greater need for patent protection because it corresponds to higher R&D costs, greater uncertainty, and diminished revenue. In theory, imitation costs could significantly weaken this correlation. Imitation is usually faster and less expensive than innovation,[286] but in most cases, imitators must replicate at least some of the innovator's R&D efforts. To the extent that a longer time-to-market corresponds to higher imitation costs, that effect will partially offset the relationship between time-to-market and optimal patent strength.[287] This Subpart gauges the likely significance of this offsetting effect by examining how longer R&D times for innovators affect imitation costs. It concludes that the effect is small in all but a few industries, since copycat imitators generally avoid most—and sometimes all—of the higher R&D costs, greater uncertainty, and lower sales revenue associated with innovators' longer time-to-market.

Imitators have three critical advantages over innovators that greatly weaken the relationship between longer R&D times and higher imitation costs. First, by reverse engineering and then copying an invention, imitators often avoid most or all of the work at the research stage in R&D. Indeed, one of the main benefits of a so-called fast follower strategy is that firms can start their R&D work at the development stage, avoiding the time and expense that research entails.[288] By imitating proven products, they also sidestep the need for costly market testing to identify product features that are attractive to customers.[289]

Second, imitators are increasingly able to free ride on a large portion of the innovator's investment at the development stage of R&D, including their work

286. *See supra* note 62.

287. There may be situations in which longer R&D times corresponds to even longer imitation times, such as when firms devote additional time to an invention's R&D to make it harder to reverse engineer. *See generally* SHANE K. CURTIS ET AL., ASME, ON BARRIERS TO REVERSE ENGINEERING MECHANICAL COMPONENTS (2010) (discussing various strategies firms use to increase the costs of reverse engineering their products).

288. *See* Mansfield et al., *supra* note 2, at 911–12; John F. Engel et al., *High Performance Business: Innovation Unbound*, OUTLOOK, 2006, at 26, 35 ("Fast-follower organizations specialize in starting the innovation process at the development stage. They let others come up with the initial ideas, then reverse engineer them, improve them or implement them so that their offerings are of a higher quality at a more competitive price."). If innovators can patent their inventions and partially protect them through secrecy, imitators may need to replicate some of the innovator's research.

289. *See generally* Michael Abramowicz & John Duffy, *Intellectual Property for Market Experimentation*, 83 N.Y.U. L. REV. 337 (2008); *see also* Sichelman, *supra* note 244, at 351–52.

in product design, prototyping, and product testing.[290] Historically, rival firms that wanted to copy an invention often had to replicate much of innovator's development-phase investments.[291] But over the past two decades there have been tremendous advances in the technology for reverse engineering physical products.[292] With access to precise three-dimensional imaging tools,[293] computer-aided design (CAD) programs,[294] and rapid prototyping equipment,[295] imitators can now skip most of the design and prototyping work that can take months or years for innovators to complete.[296] Moreover, by copying the essential features

290. *See* SCHNAARS, *supra* note 63, at 195–210, 218–21; Sichelman, *supra* note 244, at 360–62.

291. *See* Mansfield et al., *supra* note 2, at 913 ("[F]or many of these electronics and machinery innovations, it would have been quite difficult for imitators to determine from the new product how it is produced, and patents would not add a great deal to imitation cost (or time)."). The more recent legal and economic scholarship on imitation costs generally assumes that imitators still need to replicate most or all of the innovator's development work. *See, e.g.*, Samuelson & Scotchmer, *supra* note 182, at 1588.

292. *See* Vinesh Raja, *Introduction to Reverse Engineering*, *in* REVERSE ENGINEERING: AN INDUSTRIAL PERSPECTIVE 1, 1–3 (Vinesh Raja & Kiran J. Fernandez eds., 2008).

293. *See generally* PETER MARKS, CAPTURING A COMPETITIVE EDGE THROUGH DIGITAL SHAPE SAMPLING & PROCESSING (DSSP) (2005). Advances in three-dimensional imaging technology now permit firms to measure the precise physical dimensions of even complicated physical products, allowing them to "benchmark [their] competitor's designs" to imitate or improve on them. Michael Raphael & Todd Grimm, *The Brainstorm: Reverse Engineering*, PRODUCT DESIGN & DEV. (June 22, 2009, 11:38 AM), http://www.pddnet.com/news/2009/06/brainstorm-reverse-engineering.

294. Karl Matthews, *The Brainstorm: Reverse Engineering*, *supra* note 293 (noting that firms now have access to sophisticated computer-aided design (CAD) software that can "extract the original design intent from a scan of a physical model, kick-starting the process of modeling and adapting that design in CAD"); Abby K. Monaco, *The Brainstorm: Reverse Engineering*, *supra* note 293 (explaining how CAD software now allows firms to "reverse engineer [circuits] into a fully intelligent layout design in a matter of hours," which "means that any portion of a legacy design . . . can be revived . . . much faster than it would take to redesign the same circuitry from scratch").

295. *See* C.K. CHUA ET AL., RAPID PROTOTYPING: PRINCIPLES AND APPLICATIONS 13 (3d ed. 2010) (reporting that with rapid prototyping, "the time to produce any part—once the design data are available—will be fast and can be in a matter of hours"); T. Suresh Babu & Romy D. Thumbanga, *Reverse Engineering, CAD\CAM & Pattern Less Process Applications in Casting—A Case Study*, 5 INT'L J. MECHANICS 40 (2011).

296. *See* M. Jurkovic et al., *Rapid Product Development by Reverse Engineering*, *in* VIRTUAL AND RAPID MANUFACTURING: ADVANCED RESEARCH IN VIRTUAL AND RAPID PROTOTYPING 817, 820 (Paulo Jorge Bártolo et al. eds., Taylor & Francis Grp. 2008) ("The reconstruction and manufacture with [rapid prototyping] technologies of defined products is possible in very short time applying reverse engineering."); Carlos Henrique Pereira Mello et al., *Integrating Reverse Engineering and Design for Manufacturing and Assembly in Product Redesigns: Results of Two Action Research Studies in Brazil*, *in* REVERSE ENGINEERING: RECENT ADVANCES AND APPLICATIONS 187 (Alexandru C. Telea ed., 2012); Ian McLoughlin, *Reverse Engineering of Embedded Consumer Electronic Systems*, 2011 IEEE 15TH INT'L SYMP. 1; *How Reverse Engineering Can Cut Product Development Times*, ENGINEERLIVE, http://www.engineerlive.com/content/17376 (last visited Dec. 23, 2013); Randy Torrance & Dick James, *IC Reverse Engineering—A Design Team Perspective*, EDN NETWORK (Mar. 11, 2010), http://www.edn.com/design/integrated-circuit-design/4312346/IC-reverse-engineering-a-design-team-perspective (using case studies to describe the "significant[,] immediate[,] and lasting" competitive benefits of reverse engineering in

of the original invention, imitators can often avoid some or all of the costly product testing important for commercialization.[297]

There are certain types of inventions that remain difficult to reverse engineer despite these advances, including complex biological compounds[298] and computer software.[299] Imitators in these fields must often reproduce a large portion of the innovators' development activities, which should weaken the relationship between time-to-market and optimal patent strength. But the technology for reverse engineering complex biological compounds is advancing rapidly,[300] and the current impediments to copycat imitation are unlikely to last.[301] Reverse engineering software may remain time-consuming so long as firms can patent and commercialize their new software programs without disclosing the source code, but it is still usually faster and less expensive than forward engineering.[302]

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semiconductors, including one case study in which a firm "derisked the design effort for less than 3% of the [innovator's] R&D budget, saving eight times the investment in . . . [reverse engineering] in R&D costs alone, and it cut 24 months and $500,000 off the design, saving a multimillion-dollar business and retaining market leadership").

297. *See, e.g.*, Monaco, *supra* note 294. Imitators' ability to free ride on innovators' product testing varies by industry, in part because regulators sometimes require imitators to run the same tests as the innovator. *See* WEGO WANG, REVERSE ENGINEERING: TECHNOLOGY OF REINVENTION 12 (2010).

298. *See, e.g.*, FED. TRADE COMM'N, EMERGING HEALTH CARE ISSUES: FOLLOW-ON BIOLOGIC DRUG COMPETITION app. A (2009). In general, reverse engineering times have declined at a slower rate in the life sciences and medical-device industries compared to most other manufactured goods. *See* WANG, *supra* note 297, at 17.

299. *See generally* Holger M. Kienle & Hausi A. Müller, *The Tools Perspective on Software Reverse Engineering: Requirements, Construction, and Evaluation*, 79 ADVANCES IN COMPUTERS 189 (2010). Software publishers sometimes use licensing restrictions to prohibit the reverse engineering of their products. *See* Pamela Samuelson, *Reverse Engineering Under Siege: Is Reverse Engineering a Lawful Way to Acquire Trade Secrets?*, COMM. OF THE ACM, Oct. 2002, at 15, 17. Enforcing these agreements against rivals is difficult, however, since rivals can reverse engineer the software behind closed doors and produce code that will look different from the innovator's code. *See* Karen Mercedes Goertzel & Booz Allen Hamilton, *Protecting Software Intellectual Property Against Counterfeiting and Piracy*, CROSSTALK, Sept./Oct. 2011, at 6, 6–7.

300. *See* Steven A. Berkowitz et al., *Analytical Tools for Characterizing Biopharmaceuticals and the Implications for Biosimilars*, 11 NAT. REV. DRUG DISCOVERY 527, 527 (2012); Savanna Steele et al., *Better Development of Biosimilars*, DRUG DISCOVERY & DEV., June 11, 2013, http://www.dddmag.com/articles/2013/06/better-development-biosimilars ("[T]echniques for characterizing the structural composition of biologic agents are advancing rapidly with the molecular structural characterization of these agents anticipated to approach 100% in the next five to 10 years.").

301. *See Momenta Pharmaceuticals' Management Presents at 38th Annual dbAccess Health Care Conference (Transcript)*, SEEKING ALPHA (May 29, 2013, 5:17 PM), http://seekingalpha.com/article/1468641-momenta-pharmaceuticals-management-presents-at-38th-annual-dbaccess-health-care-conference-transcript?part=single.

302. *See, e.g.*, Joel Huselius, *Reverse Engineering of Legacy Real-Time Systems: An Automated Approach Based on Execution-Time Recording* 16–17 (Malardalen Univ. Press Dissertations No. 43, 2007).

Third, imitators generally avoid the often-substantial risk of technological failure during the early stages of R&D[303] and the high risk of commercial failure in producing a new-to-the-world product.[304] When calculating optimal patent strength, the risk of failure has a multiplier effect on out-of-pocket R&D costs in determining total R&D costs. Assuming imitators face less uncertainty than innovators, then the total costs of imitation will increase at a much lower rate than the total costs of innovation, even if the absolute time and expense of imitating an invention are identical.

4. Conclusion: The Ratio Test

Patent scholars occasionally simplify the economic analysis of optimal patent strength into a quick rule of thumb: The need for patent protection is a function of the ratio of total R&D costs to total imitation costs.[305] As discussed above, a longer time-to-market is associated with higher R&D costs, greater uncertainty, and higher costs of capital. Consequently, there should be a strong and robust relationship between R&D time and total R&D costs. Since a longer time-to-market diminishes the future sales revenue from the invention, innovators also need more time on the market to recoup their R&D investments. A longer time-to-market only weakly correlates with higher imitation costs. As a result, increases in time-to-market generally correspond to a higher ratio of total R&D costs to total imitation costs. Longer times-to-market is therefore associated with increased vulnerability to free riding from competitive imitation. These insights suggest that time-to-market is an incredibly powerful predictor of optimal patent strength.

B. The Relationship Between Time-to-Market, the Pace of Innovation, and the Risk of Patents Stifling Subsequent Innovation

This Subpart identifies a second mechanism through which time-to-market affects the optimal patent strength of inventions—the relationship be-

303. *See* Lieberman, *supra* note 70 (manuscript at 3) (discussing how "followers can 'free ride' . . . the R&D of pioneering firms, which may resolve key uncertainties about the best technological approaches and salient customer needs" and thus "avoid the costly experimentation and potential mistakes committed by early entrants prior to this stage"); Mansfield et al., *supra* note 2, at 911–12; *supra* notes 64–65 and accompanying text.

304. *See* COOPER & EDGETT, *supra* note 193, at 128 ("The advantages of the fast-follower strategy are evident. Risk is mitigated . . . .").

305. *See, e.g.*, Burk & Lemley, *supra* note 5, at 1585 (observing that the need for patent protection is primarily determined "by the ratio of R&D cost to imitation cost").

tween time-to-market and the pacing of innovation. Many commentators have remarked that patents are more likely to stifle subsequent innovation in industries with short product lifecycles.[306] This Subpart begins by explaining why product lifecycle lengths are largely a function of the time-to-market for new products: Older products stay on the market for longer when the newer products that eventually replace them take longer to develop. This Subpart then uses insights from cumulative-innovation theory (as outlined in Part II) to argue that inventions' optimal patent strength is lower when R&D times and product lifecycles are shorter.

1. Product Lifecycle Length Is Largely a Function of Time-to-Market

The pacing of sequential innovation is much faster in some industries than in others.[307] All inventions are eventually replaced by newer technologies, but depending on the industry, that process is likely to take anywhere from a few years to two or more decades.[308] In a survey conducted by the Intellectual Property Owner's Association, roughly a quarter of respondents said that the product lifecycles in their industries are typically shorter than the time it takes to get a patent.[309] At the other end of the spectrum, some individual products covered by a patent typically remain on the market long after the patent expires.[310]

The patent literature often depicts product lifecycles as an independent variable,[311] but in reality, inventions' lifecycles are closely related to their time-to-market. Evidence for this relationship is found in industry surveys on the

306. *See, e.g.*, Samuelson et al., *supra* note 33, at 2408; Michael Valek, *Should Software Patents Have Shorter Life Spans Than Other Patents?*, CNET (Apr. 11, 2008, 4:41 PM), http://news.cnet.com/8301-13796_3-9917345-79.html; *cf.* BURK & LEMLEY, *supra* note 31, at 96 ("Most commonly, scholars suggest that the rapid market cycles in software justify shorter terms of protection for software patents.").

307. *See* L. Kamran Bilir, *Patent Laws, Product Lifecycle Lengths, and Multinational Activity*, AM. ECON. REV. (forthcoming), *available at* http://www.ssc.wisc.edu/~kbilir/Bilir_IP_and_MNCs.pdf; Christian Broda & David E. Weinstein, *Product Creation and Destruction: Evidence and Price Implications*, 100 AM. ECON. REV. 691, 701 tbl.5 (2010).

308. *See* Francesca Cornelli & Mark A. Schankerman, *Patent Renewals and R&D Incentives*, 30 RAND J. ECON. 197, 197 (1999); Gideon Parchomovsky & R. Polk Wagner, *Patent Portfolios*, 154 U. PA. L. REV. 1, 14–15 (2005).

309. *See* COCKBURN & HENDERSON, *supra* note 243, at C.8. The average pendency time at the PTO is between three and four years. *See* LONDON ECON., ECONOMIC STUDY ON PATENT BACKLOGS AND A SYSTEM OF MUTUAL RECOGNITION: FINAL REPORT TO THE INTELLECTUAL PROPERTY OFFICE 57 (2010).

310. *See* Henry Grabowski & John Vernon, *A New Look at the Returns and Risks to Pharmaceutical R&D*, 36 MGMT. SCI. 804, 809 (1990) (estimating that a patented drug has a product lifecycle of twenty-five years on average).

311. *See, e.g.*, Goldman, *supra* note 22, at 2.

time-to-market of new products, which show that time-to-market "strongly correlate[s]" with product lifecycle length within and across firms.[312] The explanation for this relationship is obvious. Products become obsolete when newer products that improve on them enter the market. The process of creating these subsequent improvements typically begins when firms can observe the original product and identify possible shortcomings in its design, which allows them to start designing a better version of it.[313] When it takes a long time for firms to develop and commercialize these subsequent improvements, the old products will stay on the market for longer.[314]

As would be expected, the reported product lifecycle times in various industries appear to correlate with those industries' average R&D times. Cycle times are generally shortest in the fields in which new inventions reach the market quickly, such as consumer products,[315] software,[316] semiconductors, and computer hardware.[317] These products are usually obsolete within a few years of entering the market. Meanwhile, it often takes twenty or more years for inventions to become obsolete in pharmaceuticals,[318] oil and gas exploration,[319] and some clean-energy technology,[320] in which R&D times are among the longest.[321] The relationship between time-to-market and product lifecycle length also seems to hold for inventions within a given industry. In medical devices, for example, the technological lifespan of foundational patents on new-to-the-world devices can last well over a decade, but the product lifecycle for the incremental improvements

312. Griffin, *supra* note 188, at 297 (reviewing the literature and reporting results consistent with the claim); *see also* Eric H. Kessler & Alok K. Chakrabarti, *Innovation Speed: A Conceptual Model of Context, Antecedents, and Outcomes*, 21 ACAD. MGMT. REV. 1143 (1996).
313. *See* COOPER & EDGETT, *supra* note 193, at 128 ("[T]he pioneer has shown the way, and through the pioneer's successes and mistakes, the fast-follower learns and improves."); Raphael & Grimm, *supra* note 293.
314. Part VI.C offers an additional explanation for the correlation between time-to-market and product lifecycle length related to the effects of longer R&D times and higher R&D costs on market structure.
315. *See* Broda & Weinstein, *supra* note 307, at 701 tbl.5.
316. *See id.* (finding that the product turnover rate for computer software was the third highest among the top one-hundred modules included in the consumer price index); *see also* FTC, *supra* note 2, ch. 3, at 45–46.
317. *See* Aaron Aboagye et al., *Finding the Next $100 Billion in Semiconductor Revenues*, MCKINSEY ON SEMICONDUCTORS, Autumn 2012, at 4, 5 ("Fully half of the [semiconductor] industry's revenue, for instance, is derived from products that are less than six months old."); s*ee also* FTC, *supra* note 2, ch. 1, at 34–35, 35 n.224.
318. *See* Grabowski & Vernon, *supra* note 310, at 809 (estimating that a patented drug has a product lifecycle of twenty-five years on average).
319. *See* Neal, *supra* note 237, at 12 fig.IVF.1, 14.
320. *See* BERNICE LEE ET AL., WHO OWNS OUR LOW CARBON FUTURE?: INTELLECTUAL PROPERTY AND ENERGY TECHNOLOGIES 48 (2009).
321. *See supra* notes 231–239 and accompanying text.

in those devices is roughly two years[322]—corresponding well to the difference in R&D times between first-in-class devices and incremental improvements.[323]

2. Time-to-Market and Product Lifecycle Length Are Closely Correlated to Optimal Patent Strength in Cumulative-Innovation Models

The argument that rapid product turnover calls for shorter or narrower patents is fairly intuitive and dates back to at least the early 1940s.[324] More recently, patent scholars have argued that the short product lifecycles typical in software justify eliminating software patents or shortening their duration, often on the ground that the short lifecycles allow firms to recoup their R&D investments primarily through first-mover advantages.[325] This Subpart builds on these insights by using cumulative-innovation theory to explain why optimal patent strength increases as R&D times and product lifecycle length increases.

New products always have a finite commercial lifespan—a lifecycle that begins when those products first enter the market and ends when they exit because of lack of demand—because newer products eventually render them obsolete. The patents that protect each of these products are written to cover the underlying idea for the invention and thus have a broader scope than just one product. Much like the individual products they protect, patents eventually become obsolete because newer, unrelated technologies replace the ones they cover. But the technological lifespan of a patent can be substantially longer than the lifecycle of the individual products falling within its claim scope. As a result, patents frequently read onto several generations of future improvements in a technology.[326] The ability to draft patent claims covering subsequent improvements can provide important incentives for innovation. But these forward-reaching patents can also

322. *See* INST. OF MED., PUBLIC HEALTH EFFECTIVENESS OF THE FDA 510(K) CLEARANCE PROCESS: BALANCING PATIENT SAFETY AND INNOVATION: WORKSHOP REPORT 20 (Theresa Wizemann ed., 2010); CHRIS ROZEWSKI & WALTER THOMSON, IMPROVING MANUFACTURABILITY, REDUCING COST, AND EXTENDING PRODUCT LIFE—PROCESSES AND PITFALLS UNIQUE TO MEDICAL DEVICES (2004).

323. *See supra* notes 227, 235 and accompanying text. Product lifecycles are also much longer with fuel cells and solar panel technology relative to wind energy, consistent with the much longer R&D times for the former technologies relative to the latter. *See* RECHSTEINER, *supra* note 217, at 9; Bilir, *supra* note 307 (manuscript tbl.2).

324. *See* S. TEMP. NAT'L ECON. COMM., *supra* note 3, at 157 ("Technology moves now with a speed once undreamed of—its swift march dictates a shortening of the life of a patent. Industries move at very different tempos—unlikeness suggests life spans accommodated to their distinctive requirements.").

325. *See* BURK & LEMLEY, *supra* note 31, at 96 & n.8 (citing numerous examples of this argument).

326. *See* Lemley, *supra* note 93, at 1000–05.

stifle later improvements, since other firms cannot develop and commercialize them without a license from the patentee.[327]

As discussed in Part II, the models of cumulative innovation indicate that patents should be weaker when (1) the patents granted on earlier innovations are more likely to cover many subsequent innovations, (2) transaction costs are high, and (3) earlier innovations are less likely to require strong patent protection as an incentive for their R&D investments. Shorter R&D times and product lifecycles are related to all three of these factors in ways that call for weaker patents.

First, in industries characterized by rapid product turnover, older patents are more likely to cover later technological advances, and thus they are more likely to stifle that subsequent innovation. For the reasons explained in Part VI.C below,[328] innovation tends to be incremental when R&D times and product lifecycles are short.[329] Each follow-on generation of a technology is a "smallish step rather than [a] breakthrough."[330] As a result, there is less technological space between those generations, and earlier patents frequently read onto one or more generations of future advances.[331] There appears to be much less overlap between older patents and follow-on innovations in fields with lengthy product lifecycles.[332] This is in part because there is more technological distance separating the generations in such fields,[333] and in part because foundational patents will be closer to (or past) expiration by the time subsequent innovators need to license them.[334] In industries in which new technologies quickly replace older ones, therefore, earlier patents seem more likely to operate as a tax on later advances.

Second, in addition to increasing the amount of licensing required to commercialize subsequent innovations, short R&D times and product lifecycles will

327. *See* O'Donoghue et al., *supra* note 37, at 2–3.
328. As explained in Part VI.C below, technology is less likely to progress through incremental improvements in fields in which new product development is inherently expensive and time consuming, since those costs deter firms from developing minor technological advances that would need to compete on price against existing technologies.
329. *See* C. Merle Crawford, *The Hidden Costs of Accelerated Product Development*, 9 J. PRODUCT INNOVATION MGMT. 188, 191 (1992). *See generally* Langerak et al., *supra* note 194; B.A. Lukas & A. Menon, *New Product Quality: Intended and Unintended Consequences of New Product Development Speed*, 57 J. BUS. RES. 1258 (2004).
330. Steve Lohr, *In the High-Tech Patent Wars, an Inventor's Lament*, N.Y. TIMES BITS BLOG (Oct. 15, 2012, 8:00 AM), http://bits.blogs.nytimes.com/2012/10/15/in-the-high-tech-patent-wars-an-inventors-lament.
331. The resulting burden on subsequent innovators is multiplied when they commercialize products that encompass numerous distinct patentable inventions—that is, when the technology is "complex" as opposed to "discrete." *See* Levin et al., *supra* note 2; Shapiro, *supra* note 133; Cohen et al., *supra* note 2.
332. *Cf.* FTC, *supra* note 2, ch. 3, at 2.
333. *See infra* notes 362–364 and accompanying text.
334. *See* Menell & Scotchmer, *supra* note 14, at 1482.

exacerbate the competitive costs of those transactions. Industry surveys indicate that patent licensing tends to require unusually difficult and costly due diligence, and that the negotiations are much harder to finalize because of the complexity of the agreements and high stakes involved.[335] Firms can attempt to design around prior innovators' patents instead of licensing them, but this strategy adds time to R&D.[336] When firms develop an invention with a short time-to-market, they have less time to negotiate a complex licensing deal or to implement a design-around strategy without having to delay their product launch. Moreover, because the PTO does not publish patent applications until eighteen months after they are filed,[337] firms might not learn about a patent that they must license or design around until late in their R&D project, which further increases the risk of licensing delays. Since inventions with short R&D times also typically have short product lifecycles, any such delay will reduce an already narrow window of opportunity for the firm to earn a profit from its R&D investment.[338]

Third, patents are likely less important to incentivize innovation in fields with short R&D times and product lifecycles because innovators are more likely to enjoy strong first-mover advantages.[339] The first-to-market usually has a head start in the race to produce the next generation of their invention, and in a field in which product lifecycles are short, rivals have less time to catch up.[340] Innovators may be able to maintain relatively high profit margins by continually staying ahead of their rivals.[341] The innovator's head start is thought to be much less significant in industries with extended product lifecycles.[342] Innovators can quickly lose their informational advantages over rivals through departing employees and

335. *See* Cockburn, *supra* note 107, at 6, 9.

336. *See* U.S. DEP'T. OF JUSTICE & FED. TRADE COMM'N, ANTITRUST ENFORCEMENT AND INTELLECTUAL PROPERTY RIGHTS: PROMOTING INNOVATION AND COMPETITION 61 (2007).

337. *See* 35 U.S.C. § 122(b)(1) (2006).

338. *See* Necmi Karagozoglu & Warren B. Brown, *Time-Based Management of the New Product Development Process*, 10 J. PRODUCT INNOVATION MGMT. 204, 204 (1993); Langerak et al., *supra* note 194, at 339; *supra* notes 194–197. Some of the industries with short product lifecycles develop institutional responses to these transaction costs, including large patent pools and massive cross-licensing deals between large rivals. *See* Mann, *supra* note 104, at 1006–09. Many commentators believe that these tactics tend to worsen the problem, however, in part because new entrants may be priced out of the market unless they have access to a large pool of patents. *See, e.g.*, JAFFE & LERNER, *supra* note 20, at 59–64 (discussing disadvantages of cross-licensing).

339. *See* JAFFE & LERNER, *supra* note 20, at 57; Bronwyn H. Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry*, 1979–1995, 32 RAND J. ECON. 101 (2001); Samuelson et al., *supra* note 33, at 2408; Ted Sichelman & Stuart J.H. Graham, *Patenting by Entrepreneurs: An Empirical Study*, 17 MICH. TELECOMM. TECH. L. REV. 111, 137 (2010); Goldman, *supra* note 22, at 2.

340. *See* FTC, *supra* note 2, ch. 1, at 35 n.224.

341. *See* Aghion et al., *supra* note 102, at 468.

342. *See* Bilir, *supra* note 307.

other channels.[343] Lengthy R&D times and product lifecycles can give rivals more time to capitalize on these opportunities, allowing them to catch up with the innovator before it can develop the next generation of its product. Also, because first-mover advantages tend to fade over time,[344] firms in industries with extended product lifecycles are more likely to depend on patent protection to appropriate the returns to their R&D.[345]

The controversy surrounding software patents provides a stark example of how incremental innovation and short product lifecycles can greatly exacerbate the patent system's tendency to stifle subsequent innovation, perhaps to the point of overwhelming the system's beneficial effects.[346] Most new inventions in software are incremental advances over existing technology, and programmers routinely build on one another's code to create these improvements.[347] Many commentators believe that first-mover advantages without patents offer sufficient incentives for the vast majority of these inventions.[348] But firms often patent them anyway. While the industry's breakneck pace of innovation quickly renders many software patents obsolete,[349] some patents are broad enough to read onto several future generations of incremental advances.[350] Subsequent innovators must either license or design around these forward-reaching patents.[351] The resulting delays and cost increases in R&D have become painfully apparent

343. *Cf.* Frischmann & Lemley, *supra* note 12, at 268–69 (reviewing the literature on how departing employees can stimulate innovation by taking ideas for innovative products and services from their previous employer to a new employer).

344. *See* Lieberman & Montgomery, *supra* note 71, at 1121; Kamel Mellahi & Michael Johnson, *Does It Pay to Be a First Mover in E.Commerce? The Case of Amazon.com*, 38 MGMT. DECISION 445, 447 (2000) (noting that "switching costs in industrial markets often dissipates over time as buyers become more knowledgeable about competing products").

345. A recent study by Kamran Bilir tests this proposition by looking at which multinational firms are more likely to locate their manufacturing in countries with weaker IP protection and finds that product lifecycle length is one of the most important predictors. *See generally* Bilir, *supra* note 307.

346. *See* Wheeler, *supra* note 22; Julie Samuels, Oracle v. Google *Shows the Folly of U.S. Software Patent Law*, WIRED (Apr. 23, 2012, 4:05 PM), http://www.wired.com/wiredenterprise/2012/04/opinion-samuels-google-oracle. Other flaws in the patent system, such as ambiguous claim language, appear to exacerbate the innovation-inhibiting effects of software patents. *See* BESSEN & MEURER, *supra* note 31, at 56–57; Menell & Meurer, *supra* note 31.

347. *See* FTC, *supra* note 2, ch. 3 at 45.

348. *See, e.g.*, Goldman, *supra* note 22, at 4.

349. *See* Mann, *supra* note 104, at 979.

350. *See* Note, *Everlasting Software*, 125 HARV. L. REV. 1454 (2012); Mark A. Lemley, *Software Patents and the Return of Functional Claiming* 1–4 (Stanford Pub. Law Working Paper No. 2117302, 2012), *available at* http://www.stanford.edu/dept/law/ipsc/Paper%20PDF/Lemley,%20Mark%20-%20Paper.pdf.

351. *See* U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, *supra* note 336, at 61; Mann, *supra* note 104, at 978–79.

to most people in the industry. One survey found that 80 percent of software engineers now believe patents are slowing down innovation in their field.[352]

C. The Relationship Between Time-to-Market, Market Structure, and Optimal Patent Strength

The arguments set forth in Subparts VI.A and VI.B demonstrate that time-to-market correlates with optimal patent strength under both the classic stand-alone and cumulative models of innovation. This conclusion runs counter to the widespread assumptions that the cumulative-innovation models generate very different policy prescriptions than the stand-alone models,[353] and that the determinants of optimal patent strength under the two theories bear little relation to one another.[354] This Subpart challenges these views by showing that the same exogenous economic forces that create a need for greater patent protection under the stand-alone model (by lengthening inventions' time-to-market and by raising R&D costs) also reduce the likelihood of patents stifling future innovation under the cumulative model. These forces make inventions with lengthy R&D times less profitable, all else equal, which discourages entry into the market. Consequently, as time-to-market and R&D costs increase, there will be fewer patents in a field for subsequent innovators to design around and lower transaction costs in licensing because of less fragmentation in patent ownership. The increasing costs of entry will also cause subsequent innovators to direct their

352. *See* Alex Blumberg & Laura Sydell, *When Patents Attack*, NPR (July 22, 2011, 8:04 PM), http://www.npr.org/blogs/money/2011/07/26/138576167/when-patents-attack.

353. *See infra* note 372.

354. The most notable exception is James Bessen and Michael Meurer's argument that patent rights with ambiguous boundaries are more likely to stifle subsequent innovation and generate weaker incentives for innovation. BESSEN & MEURER, *supra* note 31, at 8–11, 106–07. The first part of their argument is well grounded. Ambiguous claim language and poor notice properties should lead to more litigation, unnecessary licensing demands, and holdup problems—all conditions that increase the likelihood of patents stifling later technological advances. The second part of their argument—the claim that ambiguous patent boundaries offer weaker incentives for innovation because they are harder to enforce—rests on shakier ground. Ambiguous patent boundaries may give imitators a chance to escape liability, but they also expand the range of possible infringers. Moreover, patents with clearly defined boundaries often provide less protection against innovation because they are easier to design around, much like clearly defined tax provisions. Although most patents are susceptible to design around efforts, *see* COCKBURN & HENDERSON, *supra* note 243, at C-10, ambiguous claim language increases design-around costs by making it harder to predict whether courts will view the design around as falling within or outside the patent's scope. *Cf.* John M. Golden, *Injunctions as More (or Less) Than "Off Switches": Patent-Infringement Injunctions' Scope*, 90 TEX. L. REV. 1399, 1406–09 (2012) (arguing that injunction orders with unclear boundaries in patent infringement cases can discourage socially desirable design arounds). When the precise boundaries of a patent are clear and rivals can identify a viable design-around strategy, they can enter the market with minimal risk of liability for patent infringement.

R&D investments toward more differentiated inventions that are less likely to infringe existing patents. Moreover, as time-to-market increases, patents on earlier inventions will cover fewer generations of subsequent improvements.

In the stand-alone model of optimal patent strength, it is easy to understand why inventions with a longer time-to-market should receive greater patent protection on average. The patent system is supposed to provide enough protection to motivate the development of socially valuable inventions while avoiding excessive patent grants that create unnecessary deadweight loss. In other words, patents should make it profitable to invest in the R&D of socially valuable inventions, but not too profitable. As discussed in Part V.A, all else equal, an extended time-to-market makes inventions far less profitable because it (1) drives up the opportunity costs of R&D investments, (2) diminishes the value of resulting inventions' future revenue streams, (3) is associated with higher out-of-pocket R&D expenses, (4) correlates with a higher risk of failure, and (5) is associated with a greater vulnerability to free-riding imitation.[355] Inventions with longer times-to-market therefore need more protection on average to provide firms with a sufficient incentive to invest in their R&D.

It is less obvious why there would be any relationship between the time-to-market for an invention and the likelihood of its patent-stifling future innovation. The latter harm is a function of transaction costs and the degree to which an invention's patent reads onto later improvements. When rival firms develop an improvement that an earlier patent covers, they cannot enter the market without a license from the patentee. If there are transaction costs in licensing, the licensing fees demanded by the patentee may discourage some subsequent innovators from entering the market.[356] At first glance, neither element appears related to the main economic determinants of optimal patent strength in the stand-alone model: R&D costs, uncertainty, future revenue streams, and imitation costs.[357]

355. *See supra* Part IV.A.
356. *See supra* notes 103–107 and accompanying text (explaining why the transaction costs in IP licensing are often high).
357. Most economic models of cumulative innovation treat patents' innovation-stifling effects as a function of patent scope or the threshold of innovativeness required for patenting. *See* Menell & Scotchmer, *supra* note 14, at 1501–05 (reviewing the literature). The literature often attributes "cumulativeness" to whether patents are awarded on the smaller individual components (or inputs) of much larger and more complicated commercialized products, which leads to more licensing. *See* Heller & Eisenberg, *supra* note 26; Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991 (2007); Merges & Nelson, *supra* note 93; Arti K. Rai, *Fostering Cumulative Innovation in the Biopharmaceutical Industry: The Role of Patents and Antitrust*, 16 BERKELEY TECH. L.J. 813 (2001); Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, 1 INNOVATION POL'Y & ECON. 119, 122–23 (2001);

This previously overlooked relationship between the determinants of optimal patent strength in the two models arises from time-to-market's effect on market structure. In fields with lengthy R&D times (and therefore higher total R&D costs and discounted sales revenue), the higher costs and lower returns from R&D diminish the profits from producing inventions. As a result, innovators in fields with lengthy R&D times are more likely to need strong patent protection to recoup their R&D investments. Additionally, as time-to-market increases, the market supports fewer entrants (or the introduction of fewer inventions) competing over the same segment of consumer demand.[358] With fewer entrants, there is less need for patent licensing between earlier and later innovators, and thus a lower risk of patents stifling subsequent innovation.

There are three reasons why the higher costs of entry associated with longer R&D times reduces the likelihood that patents will stifle subsequent innovation. First, because the higher costs of entry result in fewer entrants into these markets, patents—and patent thickets—typically become a less significant barrier to entry. The smaller number of entrants reduces the fragmentation of patent ownership in the market, which facilitates licensing by reducing transaction costs (because there are fewer firms with which to negotiate)[359] and by minimizing the effects of "royalty stacking."[360] Moreover, with fewer firms (or fewer research teams within each firm) carrying out R&D to produce new products for these markets, the number of patents in the field should be lower. Fewer patents make it easier for

Rosemarie Ham Ziedonis, *Don't Fence Me in: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms*, 50 MGMT. SCI. 804 (2004).

358. *See* JOHN SUTTON, SUNK COSTS AND MARKET STRUCTURE: PRICE COMPETITION, ADVERTISING, AND THE EVOLUTION OF CONCENTRATION 27–43 (1991). Of course, having fewer entrants in these markets may also be associated with increased consumer deadweight loss from patent monopolies. Also, to the extent that longer R&D times reduce the amount of competition in a market by making entry less profitable, they might also reduce the pressure on firms to develop their inventions as quickly as possible, since there is less risk that a competitor will beat them to the market. Lengthy R&D times in a field therefore might have a feedback effect that further lengthens the time-to-market in that industry. But since firms have several other compelling reasons to rush their R&D projects (including the time value of money, the risk that consumer demand will change, and as a means of encouraging their employees to manage R&D projects efficiently), the magnitude of this effect should be relatively small. *See supra* Part V.A.

359. *See* Iain M. Cockburn et al., *Patent Thickets, Licensing and Innovative Performance*, 19 INDUS. & CORP. CHANGE 899, 900 (2010) (finding that increased fragmentation of patent ownership in a market is associated with diminished innovation by firms that must license IP).

360. *See* Lemley & Shapiro, *supra* note 357; Shapiro, *supra* note 357, at 122–23. *But see* Einer Elhauge, *Do Patent Holdup and Royalty Stacking Lead to Systematically Excessive Royalties?*, 4 J. COMPETITION L. & ECON. 535, 565–67 (2008) (arguing that under some circumstances royalty stacking can lead to lower licensing fees).

firms to design new products without infringing any of the patents held by other firms,[361] thereby avoiding the need for licensing.

Second, a longer time-to-market encourages firms to develop inventions that are more differentiated from existing products, thereby reducing the likelihood that the patents granted on earlier inventions will cover later advances. As time-to-market increases, firms must develop inventions with higher profit margins or that capture a larger share of the market in order to recoup their increasing total R&D costs. Consequently, firms in these markets are more likely to direct their R&D investments toward the production of differentiated products—those that significantly improve on existing technologies or that occupy a different niche of the market, as opposed to incremental improvements—to insulate themselves from price competition.[362] This is especially true in industries

361. This argument is based on the assumption that it is easier for firms to create a new product without infringing any of the existing patents in a field when there are fewer patents to design around. *See, e.g.*, U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, *supra* note 336, at 61 n.20 ("[D]esign-around is very expensive . . . [and] is worse in industries where a large number of patents have potentially read on a given product because the likelihood of stepping on a landmine is so great."). One possible counterargument is that markets with fewer entrants will tend to have broader patents that are harder to design around, since there will be less prior art in the field to restrain firms from drafting broader claims. Even in a field with little prior art, however, patent scope is still limited by the enablement and written description requirements. 35 U.S.C. § 112 (2006).

362. *See* JOHN SUTTON, TECHNOLOGY AND MARKET STRUCTURE: THEORY AND HISTORY (1998); John Sutton, *Market Structure: Theory and Evidence*, *in* 3 HANDBOOK OF INDUSTRIAL ORGANIZATION 2301, 2313 (Mark Armstrong & Robert H. Porter eds., 2007). The pharmaceutical industry exemplifies the effects of lengthy R&D times and high R&D costs in redirecting R&D investments away from incremental improvements and toward highly differentiated products. Developing a new drug usually takes over a decade and requires hundreds of millions of dollars in out-of-pocket spending. *See* DiMasi & Grabowski, *supra* note 269. New molecular entities that provide an incremental improvement over existing drugs (for example, a drug with the same mechanism-of-action as existing drugs but is more selective in hitting the target), sometimes known as "me-too" drugs, typically have a lower risk of failure in clinical trials than a more innovative, first-in-class drug. *See* Mervyn Turner, *Embracing Change: A Pharmaceutical Industry Guide to the 21st Century*, *in* TRANSLATIONAL MEDICINE AND DRUG DISCOVERY 329 (Bruce H. Littman & Rajesh Krishna eds., 2011). But these me-too drugs are also much less likely to offer patients significant therapeutic value relative to older drugs operating through the same mechanism of action. *See* Hongyu Zhao & Zongru Guo, *Medicinal Chemistry Strategies in Follow-on Drug Discovery*, 14 DRUG DISCOVERY TODAY 516, 516–17 (2009). At the same time, me-too drugs and first-in-class drugs often have relatively similar R&D costs and time-to-market, since both types of drugs are subject to the same FDA clinical trial requirements. *See* PETER BARTON HUTT ET AL., FOOD AND DRUG LAW: CASES AND MATERIALS 576–733 (3d ed. 2007) (describing the FDA's premarket regulatory approval requirements for new drugs). Not surprisingly, firms have trouble recouping their large, sunk R&D costs with me-too drugs that have only minor advantages over existing products, since the lesser degree of product differentiation forces them to compete on price. *See* FRANKEL GRP., THE CURRENT STATE OF PHARMACEUTICAL INDUSTRY RESEARCH AND DEVELOPMENT: THE BIO/PHARMACEUTICAL BUSINESS MODEL–INNOVATION OPTIONS (2012), http://www.frankelgroup.com/docs/default-source/default-document-library/fg-advisory-board-whitepaper-aug2012.pdf?sfvrsn=2; PAREXEL,

in which the time and expense of developing new products are similar for modest as well as substantial improvements over existing technology.[363] Assuming that increased product differentiation between early and later inventions in these markets corresponds to a greater degree of technological differentiation, patents on earlier inventions are less likely to cover later advances in fields with lengthy R&D times and high R&D costs. Conversely, when R&D costs are low and

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WHITE PAPER: DRUG INNOVATION, APPROVAL, MARKET ACCESS, AND THE "NEW NORMAL" 9 (2010); Nigel Gregson et al., *Pricing Medicines: Theory and Practice, Challenges and Opportunities*, 4 NATURE REV. DRUG DISCOVERY 121 (2005); Charles G. Smith, *Defining the Actual Research Approach to the New Drug Substance*, *in* THE PROCESS OF NEW DRUG DISCOVERY AND DEVELOPMENT 329, 331–32 (Charles G. Smith & James T. O'Donnell eds., 2d ed. 2006) ("Companies that introduce truly unique NCEs into major markets . . . make considerably more profit for the company from the patented NCE than ever would have been possible with a 'me-too' drug for use in the same disease."); Turner, *supra*, at 329–30. Consequently, "lack of differentiation is frequently cited as a reason for discontinuation in the development of new drugs." Zhao & Guo, *supra*, at 516 (footnote omitted); *see also* P. Honig & R. Lalonde, *The Economics of Drug Development: A Grim Reality and a Role for Clinical Pharmacology*, 87 CLINICAL PHARMACOLOGY & THERAPEUTICS 247, 249 (2010) ("[M]any compounds are being dropped in late phase because of failure to differentiate in a commercially meaningful way from existing therapies . . . ."). Therefore pharmaceutical companies primarily (and increasingly) focus on developing new drugs meant to offer substantial therapeutic benefits over existing drugs or to meet an unmet medical need. *See* KI Kaitin & JA DiMasi, *Pharmaceutical Innovation in the 21st Century: New Drug Approvals in the First Decade: 2000–2009*, 89 CLINICAL PHARMACOLOGY & THERAPEUTICS 183 (2011) (noting that while the number of new drug approvals fell between 2000 and 2009, the number of "priority review" approvals increased); B. Munos, *A Forensic Analysis of Drug Targets From 2000 Through 2012*, 94 CLINICAL PHARMACOLOGY & THERAPEUTICS 407, 407 (2013) ("The 'fast follower' strategy, sometimes advocated as a means to lower the risk of drug research and development (R&D), does not therefore appear to be very effective because most followers fail to make it to market."); Fabio Pammolli et al., *The Productivity Crisis in Pharmaceutical R&D*, 10 NATURE REV. DRUG DISCOVERY 428, 436 (2011) ("Innovation in pharmaceuticals is a cumulative process . . . . However, both private and public payers discourage incremental innovation . . . . As a consequence, R&D investments tend to focus on new therapeutic targets, which are characterized by high uncertainty and difficulty, but lower expected post-launch competition."). Indeed, the pharmaceutical industry releases a total of only about twenty-seven novel drugs in the average year, and the FDA normally considers roughly half of those products to represent a significant departure from existing medical treatments. *See* Munos, *supra*, at 406; *Summary of NDA Approvals & Receipts, 1938 to the Present*, U.S. FOOD & DRUG ADMIN., http://www.fda.gov/AboutFDA/WhatWeDo/History/ProductRegulation/SummaryofNDAApprovalsReceipts1938tothepresent/default.htm (last updated Jan. 18, 2013).

363. In most of the fields in which the time-to-market for new inventions is unusually long—including pharmaceuticals, oil and gas extraction, and clean energy—much of the delay is due to product-testing requirements that impose a similar burden on innovative products and incremental advances (but not on exact imitations). *See* FUEL CELL TODAY, THE FUEL CELL TODAY: INDUSTRY REVIEW 2011, at 20 (2011) (noting that the development of fuel cell technology for cars "is not a quick process and many years of development and testing must be undertaken to ensure the product is fit for market before introducing it to the public"); GALLAHER ET AL., *supra* note 268 (describing the time and expense of clinical development for new drugs); Neal, *supra* note 237, at 9–10 (explaining that most of the development time (and costs) for new extraction technologies is associated with "proof of concept" tests and field testing).

firms can commercialize their new products quickly, subsequent innovation is more likely to proceed incrementally,[364] and the patents granted on earlier inventions are more likely to read onto those later advances.

Third, a longer time-to-market diminishes the instances of licensing between earlier and later innovators because it slows down the pacing of sequential innovation. As discussed above, most ideas for improving on an existing invention occur after the invention is made available to the public, which allows rival firms to identify its shortcomings.[365] As the time-to-market increases for these subsequent improvements, there will be a longer time lag between the introduction of the initial invention and the improvements that follow. Patents granted on the initial inventions will cover fewer generations of improvements before they expire, which reduces the need for licensing. In extreme cases, the subsequent innovations may take so long to reach the market that the earlier patents will have expired before they enter.[366] The argument in the prior paragraph provides another explanation for why lengthy R&D times result in a longer time lag between initial inventions and their improvements. As time-to-market and R&D costs increases, subsequent innovators have greater difficulty recouping their R&D investment without an invention that substantially improves on the earlier invention, and that type of invention will often take longer to reach the market.[367] In short, patents are less likely to stifle subsequent improvements in markets characterized by lengthy R&D times because they expire after a smaller number of product lifecycles.

VII. IMPLICATIONS

A. Implications for Patent Theory

The arguments outlined in Part VI above show that time-to-market is strongly correlated with optimal patent strength under both stand-alone and cumulative-innovation models. This insight has at least two important implica-

364. Innovation in the software industry fits this description. *See supra* note 347 and accompanying text.

365. *See supra* note 313 and accompanying text.

366. *See* Menell & Scotchmer, *supra* note 14, at 1482–83.

367. New products that offer a substantial improvement over existing inventions usually have longer R&D times than incremental improvements. *See* Griffin, *supra* note 188, at 296 ("A number of researchers have hypothesized that higher innovativeness is associated with longer [development] cycle times, and several have already found empirical support for this hypothesis." (footnote omitted)); *supra* notes 284–287 and accompanying text. Moreover, if the research needed to identify a substantial improvement requires a greater degree of inventiveness relative to identifying incremental improvements, substantial improvements may take longer to discover on average.

tions for the theoretical literature on patent policy. First, it partially unifies the stand-alone and cumulative-innovation theories and thus helps to defragment patent theory. Second, it takes a major step toward overcoming a critical indeterminacy in patent theory by showing that the same economic conditions that call for stronger patent protection to incentive innovation also predict that patents are less likely to stifle subsequent innovation.

Cumulative-innovation theory presents a more complex model of optimal patent strength than the stand-alone model.[368] In the context of stand-alone innovation, optimal patent strength is a function of the tradeoff between promoting innovation with longer monopoly rights and the consumer deadweight loss from restricting public access to new inventions.[369] These models predict that longer patents will *always* translate into more innovation.[370] In models of cumulative innovation in which subsequent innovators build on earlier inventions, patents transfer profits from later innovators to the earlier ones. The optimal patent strength is the point that maximizes benefits from promoting earlier innovations relative to the harm from taxing later technological advances.[371] Thus, cumulative-innovation models focus on the tradeoff between promoting innovation with longer or broader monopoly rights and stifling innovation by forcing subsequent innovators to pay licensing fees for longer periods of time or over a wider range of inventions.

It is generally assumed that these two theories generate very different predictions regarding the optimal strength of patent protection.[372] Since cumulative-innovation theory holds that excessive patent grants will stifle subsequent innovation in addition to causing unnecessary deadweight loss, patent scholars frequently invoke it as a justification for restricting patent rights beyond what would be optimal under the classic economic analysis.[373] Of course, the cumulative-innovation models also predict greater harm from providing too little protection, since

368. *See* Menell & Scotchmer, *supra* note 14, at 1479.
369. *See* NORDHAUS, *supra* note 37.
370. *See* Gallini, *supra* note 92, at 136.
371. *See* SCOTCHMER, *supra* note 13.
372. *See* Gallini, *supra* note 92, at 136 ("Extending the single-invention model to incorporate these [cumulative] features can overturn fundamental predictions of the basic model." (citation omitted)); Long, *supra* note 26, at 246; Merges & Nelson, *supra* note 93, at 916.
373. *See* John H. Barton, *Patents and Antitrust: A Rethinking in Light of Patent Breadth and Sequential Innovation*, 65 ANTITRUST L.J. 449, 455–61 (1997); Bessen & Maskin, *supra* note 93; Frischmann & Lemley, *supra* note 12, at 257–58; Peter S. Menell, *Governance of Intellectual Resources and Disintegration of Intellectual Property in the Digital Age*, 26 BERKELEY TECH. L.J. 1523, 1544–45 (2011) (noting that beyond the standard economic theory of IP that focuses on the "non-rivalrous characteristic" of inventions, "[m]ost intellectual property scholars consider cumulative innovation to be a critical rationale for limiting intellectual property rights in both time and strength of rights"); Merges & Nelson, *supra* note 93, at 916.

the public loses the initial invention and any subsequent innovations that would have followed.[374] This dynamic makes it difficult to extract any definitive policy guidance from the theory. As Suzanne Scotchmer and Nancy Galling note, "the complexities of cumulativeness seem to defy clear, unqualified design implications."[375] Nonetheless, it is presumed that the two theories' policy implications greatly differ.[376]

This separation between stand-alone and cumulative models has led to a fragmentation in patent theory, particularly in the legal literature.[377] Scholars primarily use the cumulative-innovation models to analyze patent policy in the IT industries, biotechnology, and other fields in which there is widespread licensing between innovative firms.[378] But when analyzing patent policy for pharmaceuticals and in other industries with "discrete" inventions, scholars typically apply the stand-alone model in their policy analysis.[379] Because of this fragmentation, patent scholars often dismiss policy analysis as applied to stand-alone inventions as being irrelevant to cumulative inventions, and vice versa.

374. *See* SCOTCHMER, *supra* note 13, at 142–49; Wagner, *supra* note 79; *supra* note 110 and accompanying text.

375. Gallini & Scotchmer, *supra* note 112, at 67; *see also* Menell, *supra* note 31, at 492 ("Cumulative innovation . . . substantially complicates the design of patent protection.").

376. *See, e.g.*, Menell & Scotchmer, *supra* note 14, at 1479 (explaining that "the policy levers" in patent law "operate differently in the contexts of stand-alone innovations and innovations that lay a foundation for future innovations—referred to as 'cumulative innovation'"). The extent of the divergence causes Menell and Scotchmer to divide the "policy levers" section of their chapter on intellectual property law in the *Handbook of Law and Economics* into two separate sections: one for stand-alone innovation and the other for cumulative innovation. *Id.*

377. As Dan Burk and Mark Lemley explain, the "various different theories of patent law succeed in explaining the application of patent law to particular industries but fail when applied outside the narrow context of those industries." Burk & Lemley, *supra* note 5, at 1578. Similarly, Stephen Maurer notes, "[i]t has become conventional for legal scholars to stylize the economics literature in terms of competing theories" and that "[d]espite small variations from author to author, this [practice] continues to dominate contemporary academic discussion." Stephen M. Maurer, *Ideas Into Practice: How Well Does U.S. Patent Law Implement Modern Innovation Theory?*, 12 J. MARSHALL REV. INTELL. PROP. L. 644, 649–51 (2013).

378. *See* FTC, *supra* note 2, ch. 3; Cohen & Lemley, *supra* note 88; Menell, *supra* note 33; Merges & Nelson, *supra* note 93. In other words, scholars apply the cumulative-innovation models to industries in which innovation possesses the characteristics most relevant to the model. *See, e.g.*, Menell & Scotchmer, *supra* note 14, at 1499–1500 (explaining that "[a]utomobiles, aircraft, electric light systems, semiconductors, and computers fall within this category" of cumulative technologies, whereas "[s]ome chemical technologies are hybrids of discrete and cumulative models," while "[c]umulativeness plays a particularly important role [in computer software], whether in operating systems, technical interfaces, peripheral devices or application programs").

379. *See* FTC, *supra* note 2, ch. 3; Einer Elhauge & Alex Krueger, *Solving the Patent Settlement Puzzle*, 91 TEX. L. REV. 283 (2012); Dana P. Goldman et al., *The Benefits From Giving Makers of Conventional 'Small Molecule' Drugs Longer Exclusivity Over Clinical Trial Data*, 30 HEALTH AFF. 84 (2011); C. Scott Hemphill & Mark A. Lemley, *Earning Exclusivity: Generic Drug Incentives and the Hatch-Waxman Act*, 77 ANTITRUST L.J. 947, 948 (2011); Roin, *supra* note 27.

In the economic literature, scholars view the separation between the stand-alone and cumulative-innovation models as a crucial point of indeterminacy in patent theory.[380] While patents promote innovation by allowing patentees to appropriate a greater portion of the social returns from their inventions, they also stifle innovation by taxing downstream innovators. The existing theoretical literature offers little guidance in predicting when one effect trumps the other,[381] and there is little empirical evidence available to resolve this dispute.[382] As a result, academic debates over patent policy often reflect a "stalemate of empirical intuitions."[383]

This Article pushes against the perceived fragmentation and indeterminacy of patent theory by bridging the stand-alone and cumulative-innovation models. As shown in Part VI.C above, to the extent that initial and subsequent innovators both have similar R&D times and costs, the characteristics of inventions most closely associated with the need for stronger patent protection under the stand-alone model are also associated with a diminished likelihood of patents stifling future innovation under the cumulative model. The exogenous forces that lengthen R&D times for inventions (and correspondingly increase their total R&D costs while discounting future sales revenues) also affect the market's structure, reducing the likelihood of patents stifling subsequent innovation in three distinct ways. First, there will be less fragmentation of patent ownership and fewer patents for subsequent innovators to license or design around. Second, the patents on existing products are less likely to cover later inventions because subsequent innovators have a strong incentive to develop differentiated products. Third, patents usually cover fewer generations of subsequent technological advances because there is a longer time lag between each generation. These insights suggest that the policy implications of the stand-alone and cumulative-innovation models overlap to a much greater extent than currently recognized. They also reduce patent theory's indeterminacy by identifying a clear signal predicting when patents are more or less likely to promote innovation.

380. *See, e.g.*, Hall & Harhoff, *supra* note 15, at 546–47 ("It is fair to say that the theoretical work . . . does not deliver a clear message about the effectiveness of the patent system in encouraging innovation, although it does supply interesting insights into which design features . . . could be used to tune the system."); Moser, *supra* note 14, at 23 ("[P]roviding stronger patents for early generations of inventors may also weaken incentives to invest in research and development for later generations . . . , so that the overall effects of stronger patents on innovation are difficult to predict.").

381. *See supra* note 375 and accompanying text.

382. *See supra* note 15 and accompanying text.

383. *See* Laakmann, *supra* note 163, at 45.

B. Implications for Patent Policy

The policy implications of the correlation between time-to-market and optimal patent strength are obvious: Patent awards generally should be stronger for inventions with longer R&D times than for inventions with shorter R&D times. Consistent with this insight, most patent scholars already assume that strong patent protection is more important for promoting innovation in the pharmaceutical and biotechnology industries relative to the IT sector, and that patents are more likely to stifle innovation in the IT sector than in pharmaceuticals and biotechnology. This Article is the first to provide a unified theoretical explanation supporting this assumption, and it links that theoretical explanation to an easily observable feature of inventions.

By showing that there is a strong correlation between time-to-market and optimal patent strength, this Article helps to place all the other industries along the spectrum of optimal patent strength. For example, the time-to-market inquiry suggests that oil and gas drilling technologies, fuel cells, and solar panels probably need much stronger patent rights to motivate their development compared to wind-energy technologies.[384] It also indicates that innovation in the consumer-product industries is generally much closer to software than pharmaceuticals in terms of optimal patent strength. And it suggests that the optimal patent strength for semiconductors is greater than for software but is probably weaker than for automobiles and complex manufacturing equipment.[385] Time-to-market also provides a proxy for predicting how strong patents will affect innovation in the hundreds of other industries that have received little attention from patent scholars and in which little is known about how patents affect the incentives for R&D.

Another implication of the link between time-to-market and optimal patent strength is that certain types of inventions within each industry may need more protection than others. The first-in-class medical devices that often take ten years to develop presumably require stronger patent protection than the more rapidly developed incremental-improvement devices that follow them.[386] In these cases, the initial device is a stepping-stone technology, followed by "incremental improvements leading to longer-run significant advances. As such, earlier devices can provide considerable bases of information on the safety and efficacy of the next generation."[387] Providing strong protection for the first generation of these

384. *See supra* notes 237–266.
385. *See supra* note 225.
386. *See supra* notes 227, 235.
387. *See* KATHI E. HANNA ET AL., NAT'L ACAD. OF SCI., INNOVATION AND INVENTION IN MEDICAL DEVICES: WORKSHOP SUMMARY 4 (2001).

products might be essential to motivate investment in their R&D, but offering that same protection to the incremental improvements that follow may unnecessarily stifle innovation.

The correlation between time-to-market and optimal patent strength also has critical implications for innovation policy in the diagnostics industry. It normally takes much longer to clinically validate a medical correlation (for example, to show that a particular drug is more or less likely to be effective depending on some observable variable) than to develop the necessary testing equipment.[388] Consequently, the medical correlation is much more likely to need stronger patent protection than the testing equipment. This suggests that the U.S. Supreme Court's recent decision in *Mayo Collaborative Services v. Prometheus Laboratories*[389]—which held that firms cannot patent the use of a medical correlation in medical practice and instead must rely on patents covering the diagnostic testing equipment—may have been exactly the wrong result.[390]

Tailoring patent length within the pharmaceutical industry might be particularly beneficial to the public. Drug patents seem to play a critical role in motivating private sector R&D, but they also impose substantial costs on consumers and taxpayers. Pharmaceutical companies spend tens of billions of dollars on R&D each year to develop a relatively small number of new products.[391] These products tend to generate substantial revenues for their manufacturers up until the end of their patent term.[392] Generics usually enter the market as soon as those patents expire,[393] forcing the pharmaceutical companies to compete with

388. *See supra* note 233.

389. 132 S. Ct. 1289 (2012).

390. *Id.*

391. *See* Joseph Golec & John Vernon, *Measuring US Pharmaceutical Industry R&D Spending*, 26 PHARMACOECONOMICS 1005, 1005 (2008); Munos, *supra* note 362, at 407.

392. *See* Charles Clift, *The Value of Patent Term Extensions to the Pharmaceutical Industry in the USA*, 5 J. GENERIC MED. 201 (2008); Henry Grabowski & Margaret Kyle, *Generic Competition and Market Exclusivity Periods in Pharmaceuticals*, 28 MANAGERIAL & DECISION ECON. 491, 499–500 (2007).

393. There is an extensive academic literature on the various strategies drug companies sometimes use to keep generics off the market beyond the expiration of their core drug patents. *See, e.g.*, Hemphill & Lemley, *supra* note 379, at 948 ("Pharmaceutical patent owners have responded to Hatch-Waxman with a sophisticated program of 'product lifecycle management,' which is code for finding ways to extend exclusivity as long as possible."). Most of these strategies usually fail. *See* Rebecca S. Eisenberg, *The Role of the FDA in Innovation Policy*, 13 MICH. TELECOMM. & TECH. L. REV. 345, 354 & n.37 (2007); *cf.* C. Scott Hemphill & Bhaven N. Sampat, Weak Patents Are a Weak Deterrent: Patent Portfolios, the Orange Book Listing Standard, and Generic Entry in Pharmaceuticals (Dec. 2011) (unpublished manuscript), *available at* http://conference.nber.org/confer/2012/IPKE/sampat.pdf (finding little evidence that later-filed patents affect the date of generic entry). Moreover, the average effective patent life for new drugs—the time from regulatory approval to generic entry—has remained unchanged at eleven to twelve years for much of the past thirty years. *See* Grabowski & Kyle, *supra* note 392, at 497 fig.4; C. Scott Hemphill & Bhaven N.

products that are practically identical to their own and cost a quarter of the price on average.[394] More so than in any other industry, the revenues that pharmaceutical companies earn from their patents appear to have a significant effect on their willingness to invest in R&D.[395] Although it is not certain that a longer patent term would motivate additional drug development, it is very likely that it would have this effect.[396] Indeed, there are certain types of drugs that firms will rarely develop because the twenty-year patent term is too short given the amount of time it takes to complete their R&D—including early-stage and preventative treatments for cancer[397] and Alzheimer's disease.[398] On the other hand, high

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Sampat, *Evergreening, Patent Challenges, and Effective Market Life in Pharmaceuticals*, 31 J. HEALTH ECON. 327, 328 (2012). This suggests that to the extent these strategies are effective, they may be an important part of the patent system's incentives for drug development.

394. *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-12-371R, DRUG PRICING: RESEARCH ON SAVINGS FROM GENERIC DRUG USE 1 (2012). Pharmaceutical companies typically lose about 70 percent of their sales within the first six months of generic competition. *See* Press Release, Datamonitor, US Most Susceptible to Brand Erosion Post Patent Expiry (Jan. 13, 2011), *available at* http://about.datamonitor.com/media/archives/5293. Pharmaceutical companies often try to insulate themselves from generic competition by switching consumers to related drugs that are still patented. *See* Hemphill & Lemley, *supra* note 379, at 960–62. But with insurers now using tiered formularies and other strategies to encourage the use of low-cost generics, these strategies are increasingly ineffective, and drug companies currently lose most of their market to generic competition shortly after losing patent protection. *See* Murray Aitken et al., *Prescription Drug Spending Trends in the United States: Looking Beyond the Turning Point*, 28 HEALTH AFF. 151 (2008).

395. *See* Budish et al., *supra* note 28; Mansfield, *supra* note 68, at 175 n.8; Mansfield et al., *supra* note 2, at 915; Roin, *supra* note 27, at 545–56.

396. *See* Budish et al., *supra* note 28 (finding that private industry invests substantially less in the R&D of drugs with a longer time-to-market because they receive a shorter effective patent life); Goldman et al., *supra* note 379, at 87. There is ample evidence that pharmaceutical R&D spending is sensitive to changes in reimbursement rates and other factors affecting the revenues generated by their drugs. *See, e.g.*, Margaret E. Blume-Kohout & Neeraj Sood, *Market Size and Innovation: Effects of Medicare Part D on Pharmaceutical Research and Development*, 97 J. PUB. ECON. 327 (2013) (finding that Medicare Part D increased pharmaceutical R&D spending).

397. *See* Powel H. Brown, *Chemoprevention Clinical Trials: It Is Time to Turn Success Into Progress*, 16 CANCER EPIDEMIOLOGY BIOMARKERS PREVENTION 1531, 1531–32 (2007); Jennifer J. Griggs et al., *Successes and Satisfaction Factors in Oncology Career Paths*, *in* ACHIEVING CAREER SUCCESS IN ONCOLOGY: A PRACTICAL GUIDE (Laura F. Hutchins ed., 2008); Ronald B. Herberman et al., *Cancer Chemoprevention and Cancer Preventive Vaccines—A Call to Action: Leaders of Diverse Stakeholder Groups Present Strategies for Overcoming Multiple Barriers to Meet an Urgent Need*, 66 CANCER RES. 11,540 (2006); Frank L. Meyskens Jr. et al., *Regulatory Approval of Cancer Risk-Reducing (Chemopreventive) Drugs: Moving What We Have Learned Into the Clinic*, 4 CANCER PREVENTION RES. 311, 311 (2011); James L. Mulshine, *Fostering Chemopreventive Agent Development: How to Proceed?*, 22 J. CELLULAR BIOCHEMISTRY (Supp.) 254 (1995); Rena Conti, *Balancing Safety, Effectiveness, and Public Desire: The FDA and Cancer*, COMMONWEALTH FUND, Apr. 2003, at 1, 2.

398. *See* Jeffrey L. Cummings, *Controversies in Alzheimer's Disease Drug Development*, 20 INT'L REV. PSYCHIATRY 389 (2008); Harald Hampel et al., *Biomarkers for Alzheimer's Disease: Academic, Industry and Regulatory Perspectives*, 9 NATURE REV. DRUG DISCOVERY 560, 568 (2010); Eric Karran et al., *The Amyloid Cascade Hypothesis for Alzheimer's Disease: An Appraisal for the Development*

drug prices also strain the health care system, create consumer deadweight loss, and stifle some subsequent innovation.[399] Not surprisingly, it is difficult to determine an optimal patent length that applies generally to all drugs.[400] Tailoring based on time-to-market may be the best—and perhaps the only—way to avoid this painful tradeoff between the costs and benefits of strong patent protection for drugs.

VIII. VERSATILITY AND DESIGN FEATURES IN TAILORING BASED ON TIME-TO-MARKET

The core objection to tailoring patent awards is not based on a defense of the status quo. It relates to the difficulty of determining which inventions need more protection than others.[401] The arguments outlined above suggest not only that it is possible to have a socially beneficial system of tailored patent awards but that it is much easier than anyone has imagined. Time-to-market is correlated with each of the primary economic determinants of optimal patent strength. Since time-to-market is observable, the government can use it to tailor patent awards. This Article is not meant to specify the exact details of how to implement such a system. The government could tailor patent awards based on time-to-market in countless different ways, ranging from minor modifications to existing patent doctrines to an entirely new regime of intricate technology-specific patent laws operating to link patent awards to time-to-market. Of course, the potential benefits and drawbacks from tailoring based on time-to-market depend on how the government designs the system. This Part identifies and briefly discusses the major design choices available to the government when tailoring based on time-to-market. These design options highlight the potential

of Therapeutics, 10 NATURE REV. DRUG DISCOVERY 698, 709 box 3 (2011); Zaven S. Khachaturian et al., *A Roadmap for the Prevention of Dementia: The Inaugural Leon Thal Symposium*, 4 ALZHEIMER'S & DEMENTIA 156, 157 (2008); Tom Rooney, Addressing the R&D Challenges (Sept. 21, 2011) (PowerPoint Presentation), *available at* http://www.theparliament.com/fileadmin/theParliament/pdfs/ThomasRooney.pdf.

399. *See* Carol Ann Homon & Richard M. Nelson, *High-Throughput Screening: Enabling and Influencing the Process of Drug Discovery*, *in* THE PROCESS OF NEW DRUG DISCOVERY AND DEVELOPMENT, *supra* note 362, at 79, 80 ("As patents on chemical matter expire after 20 years, these archived compounds would be starting points for the synthesis of new compounds that could be protected by patent.").

400. *Compare* Goldman et al., *supra* note 379 (arguing that longer exclusivity periods would generate immense social welfare gains), *with* Aaron S. Kesselheim et al., *Extensions of Intellectual Property Rights and Delayed Adoption of Generic Drugs: Effects on Medicaid Spending*, 25 HEALTH AFF. 1637, 1646 (2006) (questioning the gains from longer exclusivity periods relative to the social costs of higher drug prices).

401. *See supra* Part IV.

versatility using time-to-market to tailor patent awards, while also drawing attention to the limitations of such a system.

A. Choice of Policy Levers

The first design feature to consider when tailoring patent awards based on time-to-market is the choice of policy levers. Perhaps the easiest way to tailor patent awards based on time-to-market would be through a variable patent term,[402] since patent length is the least complicated policy lever in patent law.[403] But there are dozens of other policy levers the government might use for tailoring. It could adjust the availability of patent protection by tightening or loosening the threshold requirements for patent protection or by charging higher or lower filing fees for patent applications. It could adjust the scope of inventions' patent protection through a variety of different policy levers, including the enablement and written description requirements, the claim-construction rules, defenses to patent infringement, remedies, and antitrust laws. It could even use policies outside of the patent system to adjust the incentives for innovation based on inventions' time-to-market, including with government grants and R&D subsidies, taxes credits, prizes, and regulatory barriers to entry.[404] An analysis of each of these different policy levers is beyond the scope of this Article.

B. Actual Versus Average Time-to-Market

A second design option is whether to tailor patent awards based on each invention's time-to-market or the average time-to-market in that field.[405] The government could estimate individual inventions' time-to-market and tailor the availability and strength of patent protection through uniform laws. Alternatively, the government could tailor using technology-specific laws that adjust the

402. Since the current twenty-year patent term runs from the filing date and most patent applications take several years to issue, policies that dramatically shorten the patent term for some inventions might need to include patent-term extensions for the PTO's review time. Alternatively, the patent term could run from the date of issuance instead of the filing date.

403. A variable patent term would almost certainly violate the TRIPS agreement, but if the U.S. shortens the patent term in selective fields in a manner that promotes overall innovation by reducing the system's innovation-stifling effects, the risk of enforcement may be small. *See supra* note 155.

404. *See* Eisenberg, *supra* note 393, at 365 (discussing the use of FDA exclusivity periods to tailor the protection available to pharmaceutical companies against generic competition); Rai, *supra* note 31 (same); Roin, *supra* note 27 (same).

405. The two approaches are not mutually exclusive. For example, the government could tailor based on average time-to-market with technology-specific rules, but then it could also create carve-out categories that offer stronger protection to inventions with R&D times that are significantly longer than the average invention in their class.

availability and strength of patent protection based on the average time-to-market for different types of inventions. Both approaches are feasible because the government can observe individual inventions' time-to-market and the average time-to-market in different fields.[406] But depending on the circumstances, the costs of accurately observing time-to-market may be higher under one approach than the other.

While the government can easily observe the actual time-to-market of some inventions, these individualized inquiries are much costlier for other types of inventions.[407] In cases in which estimating actual time-to-market is expensive and the government cannot adequately incentivize truthful self-reporting,[408] it may need to rely on average time-to-market as proxy for inventions' actual time-to-market.[409] The government could easily estimate the average time-to-market for inventions in most fields[410] and then draft technology-specific laws that link the availability and strength of patent protection to average time-to-market. The advantage of this approach hinges on whether the government can accurately (and cheaply) sort individual inventions into their proper technological category. Technology-specific rules inevitably lead to line-drawing disputes.[411] Since the government is using average time-to-market as a proxy for inventions' actual time-to-market, it can (and should) resolve these line-drawing questions by inquiring into the individual invention's time-to-market. But assuming those inquiries are costly, the government will want to devise its technology-specific categories to minimize the number of line-drawing disputes—either by sorting inventions into fewer categories or using technology-specific laws with clearer boundaries (as described below). Although these approaches reduce administrative costs when tailoring based on average time-to-market, they also limit the system's flexibility and prevent fine-grained tailoring.

406. *See supra* notes 240–263 and accompanying text.

407. *See supra* notes 242–256 and accompanying text (noting that it is costly—but still feasible—to observe time-to-market for inventions that firms do not publicly commercialize and inventions for which the patent filing date is not an acceptable proxy for the start of an invention's R&D).

408. *Cf. supra* notes 256–257 and accompanying text (arguing that the government could encourage firms to accurately self-report the dates relevant to their inventions' time-to-market by monitoring misreporting for patents involved in litigation or PTO reexaminations and imposing significant penalties for fraud).

409. *See supra* notes 257–263 and accompanying text. In addition to reducing administrative costs, tailoring based on average time-to-market also minimizes the risk that firms will game the system by delaying their R&D projects. Offering firms stronger patent protection for inventions with longer R&D times could cause firms to intentionally delay their R&D projects. However, as discussed in Part V.A, firms have many other powerful incentives to finish developing their inventions as quickly as possible, which greatly reduces this risk of gaming.

410. *See supra* notes 257–261 and accompanying text.

411. *See supra* notes 173–178 and accompanying text.

C. Granularity of the Different Categories of Inventions and Patent Awards

A third design feature is how many different categories of patent awards the government creates, and the granularity with which it assigns different inventions or technologies to those categories. One can imagine a highly gradated patent system with hundreds of different categories of protection, in which relatively small differences in inventions' actual or average time-to-market determine their category. A much simpler system would offer just two levels of patent protection. Of course, there are countless design opportunities in between these two extremes. For example, the government could institute a highly gradated system of tailored patent awards for inventions in industries with lengthy R&D times (in which there tends to be substantial heterogeneity across inventions in their time-to-market), while using minimal tailoring for inventions in industries with short R&D times (in which there tends to be much less heterogeneity).[412]

The optimal degree of specificity when tailoring based on time-to-market largely depends on the government's access to information about R&D times. More complicated and granular systems require better information. If tailoring occurs through a complicated and highly granular set of technology-specific rules, the government would also need to update its categories more frequently. Additionally, the more complicated and granular systems will often leave more opportunities for patent applicants to game the system, either by fudging the numbers on their time-to-market or by drafting their patent claims to self-select into technological categories offering stronger patent protection. As the complexity and granularity of the system increases, therefore, the government needs better information to administer the system properly and to prevent abuse.

D. Difference in Patent Strength Awarded Across Categories

A fourth design feature is the degree to which the availability and strength of patent protection differs across categories. If the government were to implement a variable patent term, it could set the upper bound at thirty years and the lower bound at six months. This approach would dramatically reduce the amount of patent protection awarded for some inventions and substantially increase the protection awarded for others. The government could also use a narrower range of patent terms when tailoring, perhaps maintaining the current twenty-year term as the upper bound and setting the lower bound at ten to fif-

412. *See supra* notes 217–219 and accompanying text.

teen years. Inventions with the longest R&D times would still receive the same term of protection, while inventions with the shortest time-to-market would receive a smaller but still substantial patent award.

The optimal degree of variation in patent awards when tailoring based on time-to-market depends on two factors. The first is the social costs of providing either too much or too little protection to inventions. To the extent that an error in one direction has larger costs, the government should be less willing to adjust its patent awards in the direction of the more costly error. Questions about whether the government should error on the side of providing too much or too little protection tend to be controversial, although that same controversy exists under the uniform patent laws.[413]

The second factor is the strength and robustness of the relationship between R&D times and optimal patent strength. The arguments outlined in Part VI suggest that this relationship is strong enough to support a fairly large amount of tailoring, but time-to-market is not a perfect proxy for optimal patent strength. Although R&D times correlate with what are generally viewed to be the most important determinants of an invention's need for protection, those individual correlations will be stronger in some industries than in others.[414] Moreover, time-to-market cannot possibly correlate with all the different economic factors potentially relevant when setting patent awards. Some inventions may need more patent protection than predicted by their time-to-market alone because they require large postmarketing investments in commercialization[415] or because they have a slower commercial uptake.[416] Other inventions might need less patent protection than predicted by their time-to-market because innovators enjoy strong first-mover advantages through network effects.[417] Patents also may be more likely to stifle subsequent innovation in industries in which the boundaries of patent claims are "fuzzy."[418] None of these factors are likely to counteract

413. *See supra* note 400.

414. For example, the correlation between time-to-market and the need for patent protection is probably weaker for software than most other technologies, since the time-to-market of software programs is more strongly correlated to their imitation costs. *See supra* notes 299, 302 and accompanying text. Additionally, the correlation between time-to-market and R&D costs is weaker for software than most other technologies because firms can more easily divide complicated software R&D projects into numerous discrete components that engineers can develop concurrently. *See* Figueiredo & Loiola, *supra* note 282, at 24.

415. *See* Abramowicz & Duffy, *supra* note 289; Sichelman, *supra* note 244, at 360.

416. *See* Partnoy, *supra* note 31, at 16–17.

417. *See* Lieberman, *supra* note 70 (manuscript at 3) (noting that network effects "are most common in the information technology sector").

418. *See generally* BESSEN & MEURER, *supra* note 31; Menell & Meurer, *supra* note 31, at 12 (noting the social cost of the "chilling effect" of property rights with unclear boundaries). It is also possible that patents are more likely to stifle subsequent innovation in fields in which commercialized

the basic relationship between time-to-market and optimal patent strength, but they may make the relationship noisier. In industries in which these factors are more important, the government should be less willing to introduce large variations in patent awards based solely on time-to-market.

E. Considering Additional Factors Besides Time-to-Market

A fifth decision feature is whether to tailor based on time-to-market alone or integrate other factors relevant to inventions' optimal patent strength into tailoring decisions. Although there is virtue in simplicity, the government's tailoring framework does not need to be based exclusively on time-to-market. If it has access to other relevant information that could be incorporated into a reliable framework for determining which inventions warrant greater protection than others, those factors can (and should) be considered. Variations in the time-to-market for inventions provide a solid foundation for tailoring patent awards, but the framework could be enriched when appropriate.

F. Choice of Government Actors to Design and Implement the System

A sixth design feature is the choice of government actors to craft and implement the system of tailored patent awards. Congress, agencies, courts, or some combination of the three could make these decisions. A number of scholars now support using the courts or regulators (usually the PTO) to craft rules that would tailor patent awards for each industry and field of technology.[419] Most remain wary of allowing Congress to draft technology-specific rules, usually on the ground that the legislative process is slow and too vulnerable to political manipulation.[420] A comparative institutional analysis of these different institutions is beyond the scope of this Article.[421]

products are "complex," in that they contain numerous components covered by separate patents. *See* Heller & Eisenberg, *supra* note 26; Lemley & Shapiro, *supra* note 357; Merges & Nelson, *supra* note 93, at 881; Shapiro, *supra* note 357; Rai, *supra* note 357; Ziedonis, *supra* note 357. Patents can also promote subsequent innovation in some cases. *See supra* note 114.

419. *See* Burk & Lemley, *supra* note 5; Burstein, *supra* note 31; Johnson, *supra* note 31; Masur, *supra* note 31; *cf.* Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 302–03 (2003). There is also some discussion about whether particular industries should be allowed to craft their own technology-specific patent laws. *See, e.g.*, Alan Devlin, *Systemic Bias in Patent Law*, 61 DEPAUL L. REV. 57, 57–58 (2011); *see also* Partnoy, *supra* note 31, at 12–13.

420. *See* Arti K. Rai, *Engaging Facts and Policy: A Multi-institutional Approach to Patent System Reform*, 103 COLUM. L. REV. 1035, 1128 (2003).

421. Several prominent patent scholars argue against technology-specific tailoring on grounds that political economy concerns would undermine the system and potentially worsen the patent system's

CONCLUSION

The patent system allocates patent rights for inventions without regard to most of the economic factors relevant to their need for protection, and provides what amounts to a one-size-fits-all reward that ignores variations in the social costs and benefits of patents across industries. The primary justification for maintaining this system is that the government lacks sufficient information about inventions to tailor patent awards properly through an administrable system. This Article shows that inventions' time-to-market could serve as a reliable proxy for their optimal patent strength, and that because time-to-market is relatively observable, the government could use it as a framework for an administrable system of tailoring patent awards.

performance. *See* BURK & LEMLEY, *supra* note 31, at 100; JAFFE & LERNER, *supra* note 20, at 204; Long, *supra* note 5, at 48. This author will address these objections in a later article.