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The Many Faces of Bayh-Dole

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I. INTRODUCTION

Promoting technological innovation is important to the U.S. economy, as evidenced by the enactment of the America Invents Act three years ago.[1] But what if Congress had also passed a law to promote innovation based on scientific and technological research, but that law was stifling innovation instead? This is the concern that various critics have expressed about the Patent and Trademark Law Amendments Act of 1980, otherwise known as the Bayh–Dole Act.[2] The Bayh–Dole Act allows universities and other recipients of federal research funds to retain the patent rights to their research on the premise that this will foster further development and commercialization of research that would otherwise be underutilized.[3] Critics have challenged this premise, however, arguing that Bayh–Dole is at best unnecessary and at worst a drag on innovation.[4] The Bayh–Dole Act has thus become somewhat controversial, particularly with regard to patents on federally funded research performed at universities. As this article explains, however, the answer to the question of whether university patenting under Bayh–Dole is good or bad is that it depends: sometimes university patenting is helpful, sometimes it is harmful, but most of the time, it is just irrelevant.

In this regard, the debate over the Bayh–Dole Act touches on age-old issues about the patent system in general and the modern-day role of universities within that system. The patent system is popularly characterized as incentivizing investments in research and development ("R&D") by providing an opportunity to appropriate the returns on that investment.[5] This characterization has been chal-

1. Leahy–Smith America Invents Act, Pub. L. No. 112–29, § 3, 125 Stat. 284 (2011) (codified in scattered sections of 35 U.S.C.).

2. Bayh–Dole Act, Pub. L. No. 96–517, 94 Stat. 3015 (1980) (codified as amended at 35 U.S.C. §§ 200–212).

3. Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663, 1664 (1996); Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347, 395–400 (2000); Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 97–98 (1999).

4. *E.g.*, Dovid A. Kanarfogel, *Rectifying the Missing Costs of University Patent Practices: Addressing Bayh–Dole Criticisms Through Faculty Involvement*, 27 CARDOZO ARTS & ENT. L.J. 533 (2009); *see also* text accompanying notes 115–122, 158–235, *infra*.

5. *See, e.g.*, David S. Olson, *Taking the Utilitarian Basis for Patent Law Seriously: The Case for Restricting Patentable Subject Matter*, 82 TEMP. L. REV. 181, 184 (2009).

lenged, however, and many question the link between patent protection and investments in R&D.[6] Alternative explanations for the patent system—that patents incentivize not so much investments in R&D itself but, rather, in commercializing its application[7] or that patent exclusivity does not incentivize invention itself but rather only races to be the first to invent[8]—have also been questioned.[9] And if universities are institutions of higher learning driven not by profit but by a mission to serve the public, and if their research is typically funded through grants, not through appropriating patent returns, what need do they have for patent protection? Incentivizing universities to invest in R&D is not the point of the Bayh–Dole Act, however.[10] The Bayh–Dole Act was designed to promote the use and commercialization of inventions after R&D is complete, but even so, universities are generally not commercial actors with either expertise or interest in marketing and commercialization.[11] Rather, university research traditionally has been thought to benefit society the most when dedicated to the public domain to be used freely by others.[12] How, then, can the Bayh–Dole Act foster the use of federally funded research by allowing and even encouraging universities and other funding recipients to retain patent exclusivity over that research, rather than dedicating it to the public domain?

The reality is that, like the patent system itself, the effect of the Bayh–Dole Act is not homogeneous. Whether university patenting under Bayh–Dole promotes or frustrates subsequent innovation or whether it has any role at all depends not only on the technology in question but also on its developmental stage, industry familiarity

6. *See, e.g.,* Tun-Jen Chiang, *Defining Patent Scope by the Novelty of the Idea*, 89 WASH. U. L. REV. 1211, 1239 (2012); John F. Duffy, *Rules and Standards on the Forefront of Patentability*, 51 WM. & MARY L. REV. 609, 619–20 (2009); Rebecca S. Eisenberg, *Wisdom of the Ages or Dead-Hand Control? Patentable Subject Matter for Diagnostic Methods After* In re Bilski, 3 CASE W. RESERVE J.L. TECH. & INTERNET 1, 45 (2012).

7. *See, e.g.*, Michael Abramowicz, *The Danger of Underdeveloped Patent Prospects*, 92 CORNELL L. REV. 1065 (2007); Ted Sichelman, *Commercializing Patents*, 62 STAN. L. REV. 341 (2010).

8. *See, e.g.*, John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439 (2004) (arguing that patents inspire socially beneficial patent races); Mark A. Lemley, *The Myth of the Sole Inventor*, 110 MICH. L. REV. 709 (2012) (same).

9. *See* Wesley M. Cohen et al., *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)*, 4 (Nat'l Bureau of Econ. Research, Working Paper No. 7752, 2000), http://www.nber.org/papers/w7552 (noting that most firms patent for reasons other than profit from commercialization or licensing).

10. Rai, *supra* note 3, at 97.

11. *See, e.g.*, DAVID C. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH–DOLE ACT IN THE UNITED STATES 88–91 (2004).

12. Eisenberg, *supra* note 3, at 1727.

with the technology at issue, and multiple other factors. This article examines the three main roles that university patenting may play and, more importantly, the conditions under which university patenting is likely to assume each role.

First is the role that university patenting and Bayh–Dole were intended to play—that of encouraging development and commercialization of university research.[13] In some albeit limited circumstances, university patenting under Bayh–Dole may play a salutary role by affording forward protection for downstream development stages that might otherwise be copied by others. A somewhat more likely alternative possibility is that university patenting covers inventions funded not just by federal research funds but also by private industry funding and, as such, helps to incentivize investment of private funds in university research. In some instances, university patents, like all patents, may also act to prevent under-development of technologies that have rival-in-use applications.

A second role that university patenting may play is, as many critics suggest, to hinder rather than promote downstream use and development of federally funded research. Scholars such as Professors Michael Heller, Rebecca Eisenberg, and Mark Lemley have at various times expressed concern that Bayh–Dole-enabled patents may create anticommons that stunt development in biotechnology, nanotechnology, and other university-based research areas.[14] It is true that patents on foundational technologies are likely to create bottlenecks that interfere with development of downstream applications. For a variety of reasons, however, anticommons and other hold-up problems are otherwise not as prevalent as many believe.

The third and most likely role for Bayh–Dole patents is that they are simply irrelevant. As this author has written elsewhere,[15] in the "science-based" fields typically the focus of university research, technological and economic uncertainty, long development cycles, tacit knowledge, lack of funding, and even regulatory and safety issues are much more significant and rate-limiting factors than patents are to commercialization.[16] Indeed, most university patents

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13. *Id.* at 1664; Peter Lee, *Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer*, 100 CAL. L. REV. 1503, 1508 (2012).

14. *See, e.g.*, Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698 (1998); Mark A. Lemley, *Patenting Nanotechnology*, 58 STAN. L. REV. 601 (2005).

15. Emily Michiko Morris, *The Irrelevance of Nanotechnology Patents*, __ NEV. L. REV. __ (forthcoming 2016).

16. Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, 97 YALE L.J. 177, 197–205 (1987).

in these fields simply lie dormant.[17] Most importantly, Bayh–Dole does not obligate universities to patent all of their eligible research, and most university research is not patented at all, as universities rationally find the costs of patenting far outweigh any potential benefits.[18]

This article therefore examines the characteristics that may influence what role the Bayh–Dole Act and university patenting on upstream technologies plays in the development of their downstream applications. The discussion here is not meant to be exhaustive, and will give only an overview of how university patenting can affect downstream innovation. Part I reviews the stated purpose of the Bayh–Dole Act and how it fits into the various theories of how not only the patent system but also university-based research fosters invention and innovation. Part I goes on to take a closer look at the commercialization theory of patenting in particular, pointing out that patents on university research may in fact facilitate downstream development in circumstances where other means of appropriating returns on downstream investments would otherwise be lacking. Part II shifts the focus and examines the risk that upstream patenting by universities may instead retard downstream development by increasing the transaction costs and decreasing the returns on commercialization investments. Part II explains that, despite the concerns expressed by many critics of the Bayh–Dole Act, the risk of anticommons or other hold-up problems is actually not as great as they fear, although hold-ups may be a concern for truly foundational technologies or for technologies that are cumulative or complementary. Finally, Part III explains that, for what is by far the most sizable portion of university research, patents are simply immaterial. In the science-based technologies commonly the subject of university research, other factors play a much more dominant role in determining the likelihood that university research can ultimately be further developed for commercialization, if that research is in fact even patented.

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17. Margo A. Bagley, *Academic Discourse and Proprietary Rights: Putting Patents in Their Proper Place*, 47 B.C. L. REV. 217, 259 (2006); Dov Greenbaum, *Academia to Industry Technology Transfer: An Alternative to the Bayh–Dole System for Both Developed and Developing Nations*, 19 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 311, 359–60 (2009); Brian J. Love, *Do University Patents Pay Off? Evidence from a Survey of University Inventors in Computer Science and Electrical Engineering*, 16 YALE J.L. & TECH. 285, 308–12 (2014).

18. David E. Adelman, *The Irrationality of Speculative Gene Patents*, *in* 16 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER 123, pt. III. B (Gary D. Libecap ed., 2005).

I. UNIVERSITY PATENTING UNDER BAYH–DOLE AS BENEFICIAL

The Bayh–Dole Act addresses patenting and commercialization of federally funded research, and its effects are multifold. First, Bayh–Dole standardizes federal agency policies on funded research, rather than leaving it to the individual agencies to dictate whether funded research may be patented and if so, who held the rights.[19] Second, Bayh–Dole allows the government to retain a non-exclusive, paid-up license to practice the patented invention and to "march in" and take steps if the grant recipient does not make reasonable efforts to bring the patented invention to the public.[20] To date, however, no federal agency has exercised its march-in rights under the Act.[21] Third, Bayh–Dole prevents exploitation of U.S.-funded research by non-U.S. entities by requiring that manufacturing under subject patents occurs "substantially in the United States."[22] Much along the same lines, the Bayh–Dole Act also favors small businesses, as the Act expresses a preference for patent licensing to small businesses where feasible.[23]

Bayh–Dole's main and most oft-noted purpose is to foster technology transfer of government-funded "upstream" research for development into "downstream" applications.[24] Prior to the enactment of Bayh–Dole, the perception was that much of this research could have had significant practical value and benefit to the public but that private industry was reluctant to invest in developing and commercializing it.[25] In particular, the perception was that research was particularly prone to underutilization if it was either unpatented or if the government held the patent rights, and that patent rights were often important to either grant recipients or

19. Eisenberg, *supra* note 3, at 1671; Frischmann, *supra* note 3, at 398.

20. 35 U.S.C. §§ 202(c)(2), 203 (2012).

21. Peter S. Arno & Michael H. Davis, *Why Don't We Enforce Existing Drug Price Controls? The Unrecognized and Unenforced Reasonable Pricing Requirements Imposed upon Patents Deriving in Whole or in Part from Federally Funded Research*, 75 TUL. L. REV. 631 *passim* (2001); Frischmann, *supra* note 3, at 403.

22. BUREAU OF NAT'L AFFAIRS, INTELLECTUAL PROPERTY TECHNOLOGY TRANSFER 32, 207 (Aline C. Flower ed., 2d ed. 2014) [hereinafter BNA]; Rebecca S. Eisenberg, *A Technology Policy Perspective on the NIH Gene Patenting Controversy*, 55 U. PITT. L. REV. 633, 648 (1994). How much this provision benefits the U.S. economy is unclear, and the provision may contradict the free-trade approach of current U.S. policy in international trade. *Id.* at 651.

23. BNA, *supra* note 22, at 33–34, 207.

24. Eisenberg, *supra* note 3, at 1664; Lee, *supra* note 13, at 1508; Rai, *supra* note 3, at 97–98.

25. *See* Eisenberg, *supra* note 3, at 1680–90 (summarizing the data and interviews on which this perception was based).

downstream licensees.[26] The U.S. government responded by encouraging funded contractors to retain the patent rights to their research in hopes that this would help incentivize its development.[27] In the wake of the Bayh–Dole Act, university patenting increased dramatically,[28] and the amount universities invest in patenting has risen.[29]

A. *Bayh–Dole and the Reward Theory of Patenting*

How patents on federally funded research remedy the perceived under-development of that research, however, is not immediately obvious. Patent exclusivity is often described as an incentive to invest in technological R&D by allowing investors to appropriate returns *ex post* through supracompetitive prices for access to the covered invention.[30] This "reward" theory of patenting seems wholly inconsistent with the Bayh–Dole Act, however.[31] Research funded *ex ante* through government or other monies does not require the incentive of returns from patent exclusivity.[32] In fact, the type of research and development that governments are most likely to fund *ex ante* are exactly those that the prospect of patent exclusivity is

26. *See generally* Eisenberg, *supra* note 3; F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions*, 85 MINN. L. REV. 697 (2001).

27. *See generally* Eisenberg, *supra* note 3; Lee, *supra* note 13; Michael S. Mireles, *Adoption of the Bayh–Dole Act in Developed Countries: Added Pressure for a Broad Research Exemption in the United States?*, 59 ME. L. REV. 259, 260 (2007). A related statute, the Stevenson–Wydler Technology Innovation Act of 1980, directs federal agencies to transfer federally owned technology to both state and local governments and to the private sector. As later amended and expanded, Stevenson–Wydler also now allows government-funded and operated laboratories to enter into cooperative research and development agreements ("CRADAs") with private contractors and to license, exclusively or non-exclusively, or even to assign title to, any resulting patents. Arno & Davis, *supra* note 21, at 644 (referring to amendments Federal Technology Transfer Act of 1986); Eisenberg, *supra* note 3, at 1707–08 (referring also to the National Technology Transfer and Advancement Act of 1995); Wei-Lin Wang, *A Critical Study on the Cooperative Research and Development Agreements of U.S. Federal Laboratories: Technology Commercialization and the Public Interest*, 9 NANOTECH. L. & BUS. 50, 50, 54–55 (2012).

28. David E. Adelman, *A Fallacy of the Commons in Biotech Patent Policy*, 20 BERKELEY TECH. L.J. 985, 989 (2005); Mireles, *supra* note 27, at 264.

29. Kristen Osenga, *Rembrandts in the Research Lab: Why Universities Should Take a Lesson from Big Business to Increase Innovation*, 59 ME. L. REV. 407, 419 (2007) (and sources cited therein) (noting that university expenditures on patenting increased almost six-fold between 1991 and 2004).

30. Eisenberg, *supra* note 22, at 648; Donald G. McFetridge & Douglas A. Smith, *Patents, Prospects, and Economic Surplus: A Comment*, 23 J.L. & ECON. 197, 198 (1980).

31. Brett Frischmann, *Commercializing University Research Systems in Economic Perspectives: A View from the Demand Side*, *in* 16 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER 155, 175 (Gary D. Libecap ed., 2005); McFetridge & Smith, *supra* note 30, at 198.

32. Eisenberg, *supra* note 3, at 1666–67; Arti K. Rai & Rebecca S. Eisenberg, *Bayh–Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 300–01 (2003).

unable to incentivize. Basic research, particularly in complex and unpredictable fields such as biotechnology and nanotechnology, is often too uncertain and distant in value to be attractive investments for private firms, even when protected by patents.[33] Governments address this market failure by using tax dollars to subsidize research of sufficient academic or other social value. To allow fund recipients to then patent their research would in effect charge the public twice: once in the form of tax-supported government research grants *ex ante* and again in the form of supracompetitive market prices *ex post*.[34]

Although patent protection is unnecessary to incentivize fully funded university research, not all university research is funded solely through government grants. Modern-day university research is increasingly sponsored by both the government and private industry, particularly in engineering, the applied sciences, and some areas of biotechnology.[35] Although private industry and investors are generally not interested in university-initiated research and early-stage inventions,[36] relationships between universities and industry have become more common post Bayh–Dole,[37] and private firms have increased their sponsorship of university research on projects of mutual interest[38] such that private funding of biomedical research long ago outpaced government funding.[39] Private outsourcing to university laboratories is particularly likely when the research at issue is thought to be of low or uncertain commercial

33. Eisenberg, *supra* note 3, at 1698–99; Frischmann, *supra* note 3, at 352.

34. Eisenberg, *supra* note 3, at 1666; Frischmann, *supra* note 3, at 347; Mireles, *supra* note 27, at 261; Jacob H. Rooksby, *University Initiation of Patent Infringement Litigation*, 10 J. MARSHALL REV. INTELL. PROP. L. 623, 631 (2011).

35. *See* Wesley M. Cohen et al., *Links and Impacts: The Influence of Public Research on Industrial R&D*, 48 MGMT. SCI. 1 (2002); Richard C. Levin et al., *Appropriating the Returns from Industrial Research and Development*, 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783.

36. *See* Richard Jensen & Marie Thursby, *Proofs and Prototypes for Sale: The Licensing of University Inventions*, 91 AM. ECON. REV. 240, 245 (2001); Roberto Mazzoleni & Richard R. Nelson, *Economic Theories About the Benefits and Costs of Patents*, 32 J. ECON. ISSUES 1031, 1040 (1998).

37. *See, e.g.*, David Blumenthal et al., *Relationships Between Academic Institutions and Industry in the Life Sciences—An Industry Survey*, 334 NEW ENG. J. MED. 368, 369 (1996) (finding that 90% of U.S. life-sciences companies have some relationship with academia); Wesley M. Cohen et al., *Industry and the Academy: Uneasy Partners in the Cause of Technological Advance*, *in* CHALLENGES TO RESEARCH UNIVERSITIES 171, 179–83 (Richard G. Noll ed., 1998); Jay P. Kesan, *Transferring Innovation*, 77 FORDHAM L. REV. 2169, 2177 (2009).

38. Blumenthal et al., *supra* note 37, at 369, 371–72; Cohen et al., *supra* note 37, at 183.

39. Adelman, *supra* note 28, at 989–90 (noting that private funding has constituted the majority of biomedical research funding since 1992); *see also* Blumenthal et al., *supra* note 37, at 369 (quantifying industry financial support for university biotech research in early 1990s).

potential or too general in application[40] or, conversely, where the research can be readily commercialized.[41] Not surprisingly, private firms sponsoring such university research typically demand exclusive licenses to any resulting patents.[42]

In other words, in cases where university research is industry-sponsored, even in part, Bayh–Dole actually aligns with the reward theory of patenting. Unlike government agencies, private actors presumably invest in R&D only if they can prevent competitors from free-riding on those investments. By protecting private investments, patents may help to incentivize industry sponsorship of university research in much the same way patents are thought to help incentivize investment in purely private R&D. Furthermore, to the extent that patenting university research can attract private funding to supplement or even supplant government funding, Bayh–Dole may be beneficial.[43] In fact, one of the motivations behind Bayh–Dole was to increase private funding of academic and other government-funded research by offering the lure of patent exclusivity.[44] Evidence that the Act has had the desired effect is apparent in the rise of industry funding for university research over the last thirty years, roughly concurrent with the time period since passage of Bayh–Dole.[45] On the other hand, some studies suggest that Bayh–Dole was the *result* of increases in industry co-funding of university research after World War II and the consequent demand for patent protection.[46]

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40. *See* Riccardo Fini & Nicola Lacetera, *Different Yokes for Different Folks: Individual Preferences, Institutional Logics, and the Commercialization of Academic Research*, *in* 21 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH: SPANNING BOUNDARIES AND DISCIPLINES: UNIVERSITY TECHNOLOGY COMMERCIALIZATION IN THE IDEA AGE 1, 10–12 (2010) (and sources cited therein).

41. *Id.* at 10.

42. Jensen & Thursby, *supra* note 36, at 252.

43. Eisenberg, *supra* note 3, at 1700; Richard R. Nelson, *The Market Economy, and the Scientific Commons*, 33 RES. POL'Y 455, 463 (2004).

44. Eisenberg, *supra* note 3, at 1700; Greenbaum, *supra* note 17, at 343. Although Bayh–Dole does not allow universities to assign the rights to their patents ahead of time if the covered research is also funded in part through federal funds (because Bayh–Dole reserves the government's right to veto such transfers), the potential to patent and exclusively license the research is made clear under the Act. Sean M. O'Connor, *Intellectual Property Rights and Stem Cell Research: Who Owns the Medical Breakthroughs?*, 39 NEW ENG. L. REV. 665, 669, 687 (2005).

45. BNA, *supra* note 22, at 236–38; Cohen et al., *supra* note 37, at 183; Fini & Lacetera, *supra* note 40, at 10–11.

46. Jeannette Colyvas et al., *How Do University Inventions Get into Practice?*, 48 MGMT. SCI. 61, 63 (2002); David C. Mowery, *The Bayh–Dole Act and High Technology Entrepreneurship in U.S. Universities: Chicken, Egg, or Something Else?*, *in* 16 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER 39, 51 (Gary D. Libecap ed., 2005). *But see* Donald Siegel et al., *Assessing the Impact of Organizational Practices on the Productivity of*

To say that patenting under Bayh–Dole may attract private sponsorship of university research nevertheless begs the question: Why should public funds continue to be used for such research? One possibility is that for at least some percentage of industry-sponsored university research, the combination of both government funding and patent protection is necessary.[47] The potential for patent exclusivity helps attract private investment, but the addition of some level of government funding may be needed to reduce the risk of such investments, further incentivizing private funding.[48] The proportion of university research to which this combination effect might apply is likely small at this time, but private funding of university research continues to expand in magnitude.[49]

B. Bayh–Dole and the Commercialization Theory of Patenting

That being said, the main goal of the Bayh–Dole Act was not to incentivize basic research but rather to stimulate its development into practical applications. For many years prior to the enactment of Bayh–Dole, the perception was that too little of government-funded research benefitted the public in anything other than a purely academic sense, and permitting grant recipients to patent their research was thought to encourage the further development and research necessary to bring an invention to the market.[50] This latter function attributed to the patent system obviously does not reflect the traditional reward theory but rather the more recent "commercialization" theory of patenting.

The commercialization theory of patenting recognizes that even after investment in R&D has successfully resulted in a patentable invention, significant further investments may be required to develop the invention into a marketable commodity. For example, the invention may require significant further investment in technical refinements, safety testing, evaluation and development for compatibility with other technologies. Construction of manufacturing resources and distribution channels, education and training, study

University Technology Transfer Offices: An Exploratory Study, 32 RES. POL'Y 27, 31 (2003) (describing "surge" in university patenting and licensing).

47. Michael Abramowicz & John F. Duffy, *Intellectual Property for Market Experimentation*, 83 N.Y.U. L. REV. 337, 366–78 (2008).

48. Suzanne Scotchmer, *Patents in the University: Priming the Pump and Crowding Out*, 61 J. INDUS. ECON. 817, 840 (2013).

49. BNA, *supra* note 22, at 235–38; Fini & Lacetera, *supra* note 40, at 10–11.

50. Eisenberg, *supra* note 3, at 1669; Lee, *supra* note 13, at 1508; Rai, *supra* note 3, at 97–98.

of consumer preferences, and marketing may also require considerable financial outlays.[51] Although inventive ideas themselves are not rivalrous, investments in them are,[52] and private downstream developers will want exclusive rights to technologies as a means of protecting their commercialization efforts.[53] For inventions that require significant further development for commercial exploitation, patents may help establish private appropriability over those later investments.[54] Regardless of whether patent protection can incentivize R&D already funded through other means, patent exclusivity may thus help to incentivize its subsequent commercialization.[55] In this way, patent protection of government-funded research "pays for" additional value beyond initial invention costs.

The commercialization theory of patenting takes a page from Edmund Kitch's seminal prospect theory. Kitch likens patents to property rights over mining or fishing prospects. He argues that, just as exclusive fishing and mining rights to develop prospects generate socially optimal fishing and mining efforts, patents provide exclusive rights to develop inventive concepts in socially optimal ways.[56] If they were instead left to the common pool—or in the case of inventive concepts, to the public domain—these prospects would be underutilized.[57] Specifically, Kitch's prospect theory of patenting postulates that granting broad patent rights early, after invention but before commercialization, enables the patent holder to protect investments in developing the covered invention from free-riding or even duplication by competitors, and to coordinate development with others possessing complementary resources.[58]

Nonetheless, the importance of patents in stimulating downstream development is a matter of debate. Both Kitch's prospect theory and the commercialization theory of patenting suffer from a number of flaws, primarily because both theories overestimate the power of patents to facilitate commercialization.[59]

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51. Abramowicz, *supra* note 7 *passim*; Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1036–37 (1989); Kieff, *supra* note 26, at 707–12.

52. Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 276 (1977).

53. BNA, *supra* note 22, at 252.

54. Mazzoleni & Nelson, *supra* note 36, at 1040–42.

55. Eisenberg, *supra* note 3, at 1669.

56. Kitch, *supra* note 52, at 274–75.

57. Eisenberg, *supra* note 51, at 1040–41.

58. Kitch, *supra* note 52, at 276–80; Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839, 871 (1990).

59. *See, e.g.*, Lemley, *supra* note 8 *passim*.

As a first matter, it is not clear that a single patent holder or licensee is always in the best position to decide or even to recognize how to develop an inventive "prospect."[60] For many inventions, particularly the embryonic technologies most likely to arise from basic university research, how to commercialize the technology and the ways in which it may become relevant are often uncertain and even unforeseeable. Although the faculty researcher who invented the patented concept may have ideas for its application, neither faculty nor their universities are commercial actors with expertise in identifying new technological and market niches.[61] Universities may instead license their patents to industry for commercialization, but a single firm with exclusive rights is unlikely to possess the resources necessary to identify and pursue all viable applications for such early-stage technologies.[62] Free access to the technology instead will allow a broader range of potential downstream applications to be developed, without the transaction costs of having to negotiate a license with a patent holder.[63]

Second, even assuming that exclusive rights to an invention were necessary for commercialization, it is not clear that patents provide adequate protection for commercialization costs. Patents can protect commercialization investments only if others cannot copy those commercialization efforts without infringing the upstream patent. For example, commercialization of a patented invention often involves creation of or coordination with other complementary technologies and improvements to create a marketable product.[64] If competitors can find a workable substitute for the patented part, they can copy the remainder of product without infringing the patent. Alternatively, if the patented invention can easily be designed around, patent protection does little to preclude return-dissipating competition.[65] Where the patented invention is used only for R&D in creating new products, and is therefore no longer necessary once

60. Merges & Nelson, *supra* note 58, at 843, 863, 872.

61. *See* MOWERY ET AL., *supra* note 11, at 91.

62. *Id.* On the other hand, some argue that patent holders, after having already made the often sizeable investment to invent, may be highly likely to make the further investments necessary to develop their inventions. Abramowicz, *supra* note 7, at 1068.

63. Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989, 1049–50 (1997); Nelson, *supra* note 43, at 463–67. For further discussion of the transaction costs created by patent exclusivity, see text accompanying notes 175–76, *infra*.

64. *See* Abramowicz, *supra* note 7, at 1087–88; Lemley, *supra* note 8, at 740.

65. Craig Allen Nard, *A Theory of Claim Interpretation*, 14 HARV. J.L. & TECH. 1, 40–41 (2000); *cf.* Ashish Arora et al., *R&D and the Patent Premium*, 26 INT'L J. INDUS. ORG. 1153, 1164–65 (noting that the value of a patent may depend on the ease with which it can be "invent[ed] around").

that product has been developed, patent protection is almost useless in providing appropriability over the downstream product.[66]

Finally, timing is important as well. The U.S. Patent & Trademark Office's ("PTO's") examination of patent applications often lasts for years, and the decision whether to issue the patents is often made long after commercialization and market entry costs have already been incurred.[67] Yet other inventions take so long to commercialize that the relevant patents expire soon after or even before commercialization has been achieved.[68] In none of these cases can patent protection be said to provide adequate incentive for commercialization.

Likewise, even assuming some form of exclusivity were necessary for commercialization, in many—and some would argue most[69]—instances, non-patent exclusivity already protects commercialization efforts.[70] Many technologies enjoy effective exclusivity for some period of time because of exclusive access to tacit knowledge or research tools and materials; because competitors are unwilling to assume the high fixed capital cost of establishing manufacturing facilities; because of the reputational benefits of being the original innovator; and so on.[71] These factors are all first-mover advantages that can supply some degree of exclusivity that delay competitors from entering the market.[72] Similarly, branding and marketing can also help firms maintain an edge in the market and earn returns sufficient to compensate for investments in downstream development.[73]

Last but not least, firms can also seek more direct protection for their commercialization investments. Many downstream developments, combinations with complementary technologies, and improvements are themselves separately patentable inventions in whole or in part; in these cases, patent protection of the original, upstream invention served no purpose other than to hinder its downstream commercialization.[74] Downstream commercialization

66. Rebecca S. Eisenberg, *Limiting the Role of Patents in Technology Transfer*, 5 J. NIH RES. 20, 22 (1993).

67. Lemley, *supra* note 8, at 740.

68. *Id.*; Sichelman, *supra* note 7, at 365.

69. Frischmann, *supra* note 31, at 171.

70. Mazzoleni & Nelson, *supra* note 36, at 1048.

71. Mowery, *supra* note 46, at 57.

72. Frischmann, *supra* note 3, at 368.

73. Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1618 (2003).

74. Eisenberg, *supra* note 22, at 643; Mazzoleni & Nelson, *supra* note 36, at 1041; Rai & Eisenberg, *supra* note 32, at 302; Henry E. Smith, *Intellectual Property as Property: Delineating Entitlements in Information*, 116 YALE L.J. 1742, 1745 (2007).

efforts that do not yield patentable inventions might be protectable through trade secrecy[75] (or, in the case of many pharmaceuticals, through various regulatory exclusivities granted by the Food and Drug Administration[76]). Many upstream inventions therefore do not need patent exclusivity in order to attract commercialization investments.[77]

Given that (as discussed in more detail in the next section[78]) patent rights can lead to deadweight losses, transaction costs, and under-development, among other problems, it would seem better to err on the side of denying patents to university research and other government-funded, basic research. University research patents in many cases are, at best, redundant or irrelevant and, at worst, counter-productive. As Kitch himself noted, appropriate upstream patent protections depend not just on pre-invention conditions but also on the anticipated post-invention environment: covering downstream developments can boost the incentive effect of upstream patenting, but by the same token, can also increase the social costs of such patenting in terms of deterring downstream development by others.[79] The Bayh–Dole Act and upstream patenting of basic university research may nonetheless foster commercialization in some, albeit limited, circumstances.

A first possible scenario occurs when downstream development cannot be protected through patents or other means of exerting exclusivity.[80] When copying costs are low but appropriability is uncertain, short-lived, or unavailable, private firms will be deterred from investing in commercialization, especially if the commercialization process is resource-intensive.[81] In this situation an upstream patent may be able to provide some level of appropriability for downstream development efforts.[82] Patents on upstream inventions may also provide broader protection than patents on downstream developments when the latter are too narrow to cover all commercialization costs.

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75. Mazzoleni & Nelson, *supra* note 36, at 1039.

76. Rebecca S. Eisenberg, *The Role of the FDA in Innovation Policy*, 13 MICH. TELECOMM. & TECH. L. REV. 345, pt. III (2007) (referring to these regulatory exclusivities as "pseudo-patents").

77. *Contra* Mazzoleni & Nelson, *supra* note 36, at 1048.

78. *See* discussion *infra* Part II.

79. Merges & Nelson, *supra* note 58, at 843.

80. *Cf.* Sichelman, *supra* note 7 (discussing the commercialization theory of patents); *see also* Colyvas et al., *supra* note 46, at 65 (noting that firms often will develop upstream research even without exclusive rights if they anticipate that they can otherwise appropriate returns on their downstream applications).

81. Kieff, *supra* note 26, at 708–09; Mazzoleni & Nelson, *supra* note 36, at 1041.

82. Mazzoleni & Nelson, *supra* note 36, at 1040.

The primary type of commercialization cost that is difficult to protect is information; information can be quite costly to collect but is almost costless to copy. For example, identifying a market and consumer demand and refining an invention accordingly is often very important, especially for new technologies, and yet costly.[83] Trade secrecy can sometimes offer protection, but information such as market definitions and consumer preferences are often self-revealing and impossible to maintain as secrets.[84] Competitors can easily free ride on other types of market information as well. Investments in educating distributors and consumers about the new technology benefits not only first movers but also second and later market entrants by effectively reducing the cost of subsequent market entry.[85] Moreover, because commercializing technologies in biotechnology, nanotechnology, and other university-derived fields is typically complex and unpredictable, with high failure rates and long development cycles, commercialization is costly and high-risk but low in expected value.[86] Private capital is therefore generally reluctant to invest in commercializing new university-based technologies.[87] This reluctance dissipates, however, as the market for the new technology becomes more established, giving later market entrants the benefit of declining capital costs over time.[88]

Other types of commercialization efforts suffer from similar difficulties in appropriability. Applications of patented university research may not themselves be patentable: examples include methods of medical treatment based on biotechnology research, or computer software and interfaces for newly invented hardware, both of which may be unpatentable subject matter under recent Supreme Court and Federal Circuit precedent.[89] Improvements on university research for the purposes of commercialization may also be unpatentable for failure to meet the statutory requirements for non-

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83. *See generally* Abramowicz & Duffy, *supra* note 47; Kieff, *supra* note 26; Sichelman, *supra* note 7.

84. Sichelman, *supra* note 7, at 352.

85. Kieff, *supra* note 26, at 709.

86. Heather Hamme Ramirez, Comment, *Defending the Privatization of Research Tools: An Examination of the "Tragedy of the Anticommons" in Biotechnology Research and Development*, 53 EMORY L.J. 359, 378 (2004).

87. Frank T. Rothaermel & Marie Thursby, *Incubator Firm Failure or Graduation? The Role of University Linkages*, 34 RES. POL'Y 1076, 1077–78 (2005). For more on science-based technologies, see text accompanying notes 95–99, *infra*.

88. Kieff, *supra* note 26, at 709.

89. *E.g.*, Alice Corp. v. CLS Bank Int'l, 134 S. Ct. 2347, 2351–52 (2014) (holding software-based business transactions to be unpatentable subject matter); Mayo Collaborative Serv. v. Prometheus Labs., Inc., 132 S. Ct. 1289, 1305 (2012) (holding method of treatment based solely on medical knowledge to be unpatentable subject matter).

obviousness.[90] Software, diagnostic databases, and even improvements can be kept as trade secrets, but trade secrecy does not protect against independent creation or reverse engineering.[91]

Moreover, because of their high-risk profiles, the expected value of commercializing new university-based technologies is often low for the first market entrant.[92] Even small reductions in the appropriability of commercialization returns could therefore deter market introduction, given the often steep costs of commercializing university-based technologies.[93] Upstream patents on university research can thus help mediate the risk of underutilization by providing forward protections over downstream development. Upstream patents can reduce the need for patents on downstream developments, but again, only if the upstream patents are of sufficient breadth that others cannot copy the downstream developments without infringing.[94]

The extent to which commercialization of university research needs the forward protections of upstream patenting is likely limited, however. University research quite often focuses on science-based fields such as the modern fields of biotechnology and nanotechnology.[95] In science-based (or "research-based") technologies, advances come from outside the norm of private industry, and derive instead from basic research and "a continuing flow of new scientific understandings and techniques largely emanating from university research."[96] Because they are driven by the desire for scientific knowledge rather than direct practical application, science-based technologies are typically embryonic and usually involve

90. Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51, 66 (Adam Jaffe et al. eds., 2002); *see also* 35 U.S.C. § 103 (prohibiting patents on inventions that "would have been obvious at the time the invention was made to a person having ordinary skill in the art").

91. Frischmann, *supra* note 3, at 368; Kieff, *supra* note 26, at 728.

92. Mowery, *supra* note 46, at 44–45 (and sources cited therein); Ramirez, *supra* note 86, at 378.

93. Kieff, *supra* note 26, at 724 (noting the exceptionally high costs of commercializing biotechnology); Rothaermel & Thursby, *supra* note 87, at 1078.

94. Gallini & Scotchmer, *supra* note 90, at 66.

95. Martin Meyer, *Socio-Economic Research on Nanoscale Science and Technology: A European Overview and Illustration*, *in* SOCIETAL IMPLICATIONS OF NANOSCIENCE AND NANOTECHNOLOGY 217, 231 (Mihail C. Roco & William Sims Bainbridge eds., Nat'l Sci. Found. 2001) (nanotechnology as science-based); Merges & Nelson, *supra* note 58, at 904–05 (biotechnology as science-based); William J. Simmons, *Nanotechnology as a Nascent Technological Model for Immediate Substantive United States and Japan Patent Law Harmonization*, 17 ALB. L.J. SCI. & TECH. 753, 819 (2007) (nanotechnology). Other historically science-based fields include catalysis, superconductivity, and semiconductors. Merges & Nelson, *supra* note 58, at 904–05.

96. Mazzoleni & Nelson, *supra* note 36, at 1047; *see* Nelson, *supra* note 43, at 457–59.

multiple development stages.[97] These stages are frequently technologically significant and patentable or otherwise protectable in their own right.[98] Forward protection from upstream patenting on the initial university research stage is therefore likely unnecessary or even counter-productive, as discussed in further detail in Parts II and III. University research in engineering or other applied sciences, on the other hand, may be less likely to enjoy secondary patentability or first-mover advantages, as research in these areas tends to be much less rudimentary and involves fewer technological steps for commercialization.[99] University research in the applied sciences may also more frequently enjoy industry funding. For both of these reasons, patents on university research may be more important and beneficial in these areas.

A second possible scenario in which upstream patents may facilitate downstream development occurs when university research is "rival-in-use." Rival-in-use refers to upstream technologies that can be used to develop downstream applications that compete directly with one another.[100] If a firm does not have some type of exclusivity over the downstream application, the firm may opt not to enter the market at all, especially if subsequent market entrants might be able to free-ride on some of the firm's commercialization efforts; in a worst-case scenario, no one would have the incentive to develop the application at all.[101] If on the other hand, the rival-in-use technology is patented and licensed exclusively to a downstream developer, the application could be commercialized without fear of returns being competed away by others.[102] In this way, the rival-in-use problem is simply a variation on the commercialization theory, under which the forward protection of an upstream patent helps to incentivize development of downstream applications not

97. Merges & Nelson, *supra* note 58, at 880, 907–08; Mowery, *supra* note 46, at 44–45 (and sources cited therein); Nelson, *supra* note 43, at 457–59; Ramirez, *supra* note 86, at 378.

98. Colyvas et al., *supra* note 46, at 66; Mazzoleni & Nelson, *supra* note 36, at 1041; Merges & Nelson, *supra* note 58, at 880, 907–08; Rothaermel & Thursby, *supra* note 87, at 1078.

99. David C. Mowery & Bhaven N. Sampat, *The Bayh–Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments?*, 30 J. TECH. TRANSFER 115, 116 (2005).

100. NATIONAL RESEARCH COUNCIL, A PATENT SYSTEM FOR THE 21ST CENTURY 72–73 (Stephen A. Merrill et al. eds., 2004) [hereinafter A PATENT SYSTEM]; John P. Walsh et al., *Effects of Research Tool Patents and Licensing on Biomedical Innovation*, *in* PATENTS IN THE KNOWLEDGE-BASED ECONOMY 289, 331 (Wesley M. Cohen & Stephen A. Merrill eds., 2003).

101. Arno & Davis, *supra* note 21, at 640–41; Eisenberg, *supra* note 22, at 644.

102. *See* Eisenberg, *supra* note 22, at 644; McFetridge & Smith, *supra* note 30, at 198; NATIONAL RESEARCH COUNCIL, MANAGING UNIVERSITY INTELLECTUAL PROPERTY IN THE PUBLIC INTEREST 71–78 (Stephen A. Merrill & Anne-Marie Mazza eds., 2010) [hereinafter NRC].

otherwise protected. Again, however, most science-based technologies enjoy the benefit of some form of downstream exclusivity, whether it be secondary patents, first-mover advantages, or exclusive access to resources. These types of exclusivities are usually sufficient to protect commercialization investments.[103]

In fact, university research may occasionally give rise to patent races, in which firms vie to be the first to file for patent rights over the same downstream application.[104] Patent races can create utility by spurring more rapid invention than might otherwise have occurred, and the sooner that firms complete their inventions and receive their patents, the sooner those patents expire and release the invention to the public.[105] If firms invest too heavily in being first, however, they dissipate the social gains from early invention and patenting, creating inefficiencies.[106] As with rival-in-use problems, upstream patenting and exclusive licensing of those patents can alleviate patent races by limiting the number of downstream contenders.[107]

Of course, as instantiations of commercialization theory and Kitch's prospect theory, relying on upstream patenting to alleviate rival-in-use problems and patent races or to redress lack of downstream appropriability, raises all the usual criticisms. The forward protections of upstream patents are seldom coextensive with their downstream applications and may expire too early or issue too late to be helpful.[108] Universities may not be well positioned to decide which downstream applications to license or to which firm to grant an exclusive license, and licensing itself creates a drag on commercialization. But where rival-in-use, patent race, and unappropriability problems pose greater obstacles to commercialization than do transaction costs, the benefits of coordination through upstream patents may outweigh the costs. Moreover, patent races and rival-in-use problems, although rare, may be more common in science-based industries such as those based on federally funded university research, where upstream breakthroughs often suggest particular downstream applications and attract multiple firms interested in

103. Mazzoleni & Nelson, *supra* note 36, at 1047–48.

104. Mazzoleni & Nelson, *supra* note 36, at 1047; Scotchmer, *supra* note 48, at 819. *But see* text accompanying notes 315–325, *infra* (discussing why downstream developers are far more likely to underinvest in commercializing university research).

105. Duffy, *supra* note 8 *passim*; Gallini & Scotchmer, *supra* note 90, at 68–69; Merges & Nelson, *supra* note 58, at 908. Some scholars, however, believe that patent races are not that common. *E.g.*, Mazzoleni & Nelson, *supra* note 36, at 1047.

106. McFetridge & Smith, *supra* note 30, at 202; Merges & Nelson, *supra* note 58, at 871.

107. Merges & Nelson, *supra* note 58, at 871; Scotchmer, *supra* note 48, at 838–39.

108. *See* Lemley, *supra* note 8, at 740.

those prospects.[109] Patent races based on university research may be particularly common in pharmaceuticals, where university research often triggers private industry R&D.[110]

Ultimately, the utility of upstream patenting depends not only on pre-invention costs but also on a number of post-invention conditions, including the cost of commercializing the patented invention and the appropriability of returns on those investments.[111] Where commercialization investments are not protected by some type of exclusivity, upstream patenting may be important, particularly where developing downstream applications is complex, uncertain, and costly.[112]

Despite the large increase in university patenting, evidence of a concomitant increase in actual tech transfer is sparse. How much of the growth in university patenting stems from Bayh–Dole and how much stems from expansion in government research spending is unclear. For example, much of the increase in university-based biomedical research patenting occurred simultaneously with an increase in government funding for such research.[113] Empirical evidence on the efficacy of patenting government-funded research is equivocal at best, with conflicting studies showing only modest effects, if any.[114]

C. Bayh–Dole and the Academic Ethos

The efficacy of university patenting under the Bayh–Dole Act aside, many critics worry about Bayh–Dole's potential effect on university research incentives and the social norms and culture of academic research.[115] Universities are generally regarded as bastions

109. Mazzoleni & Nelson, *supra* note 36, at 1047–48.

110. Mowery & Sampat, *supra* note 99, at 117.

111. Burk & Lemley, *supra* note 73, at 1584–87; Kieff, *supra* note 26, at 747; Merges & Nelson, *supra* note 58, at 843.

112. *See* Abramowicz, *supra* note 7, at 1070; Kieff, *supra* note 26; Mazzoleni & Nelson, *supra* note 36, at 1047–48.

113. David C. Mowery & Arvids A. Ziedonis, *Academic Patents and Materials Transfer Agreements: Substitutes or Complements?*, 32 J. TECH. TRANSFER 157, 158 (2007). *But see* Eisenberg, *supra* note 3, at 1702–05 (questioning whether pre-Bayh–Dole government patents were actually underutilized).

114. Love, *supra* note 17, at 324–26; Charles R. McManis & Sucheol Noh, *The Impact of the Bayh–Dole Act on Genetic Research and Development*, *in* PERSPECTIVES ON COMMERCIALIZING INNOVATION 435, 461–84 (F. Scott Kieff & Troy A. Paredes eds., 2011).

115. *E.g.*, Rai & Eisenberg, *supra* note 32; Katherine J. Strandburg, *Curiosity-Driven Research and University Technology Transfer*, *in* 16 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER 93 (Gary D. Libecap ed., 2005).

of learning and academic pursuit, not as for-profit institutions.[116] Encouraging universities to view research projects in terms of their patent value could derogate from the societal role of universities as creating and curating an intellectual commons for the good of society.[117] This ideal is embodied in the Mertonian norms of communalism, disinterestedness, and universalism—that is to say, free sharing of research results, objectivity in generating those results, and objectivity in evaluating others' results.[118] Commentators fear that the Bayh–Dole Act has diverted university researchers from these norms, altering their choices in research topics and leading to less sharing among researchers. Both historical and modern-day evidence, however, suggests that Bayh–Dole has not significantly affected the nature of university research.

Critics quite understandably fear that Bayh–Dole's focus on patenting may distort university research away from research for research's sake in favor of more commercially oriented research.[119] Again, universities are popularly viewed as entities whose position as government-funded institutions outside of market forces allows them to pursue knowledge for the sake of knowledge, not for the pursuit of profit or even practical application. This knowledge may incidentally have practical value as a matter of serendipity,[120] but presumably its greater value is in filling the void left by purely profit-driven research.

At this point in time, however, no evidence suggests that university researchers have altered their choice of research topics.[121] Despite Bayh–Dole, academic research choices continue to be driven more by researcher interests than by commercial value.[122] Many university faculty members are reluctant even to consider the patent or commercial value of their research.[123] To the extent that

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116. *See, e.g.*, DEREK BOK, UNIVERSITIES IN THE MARKETPLACE: THE COMMERCIALIZATION OF HIGHER EDUCATION 18 (2003).

117. Nicholas S. Argyres & Julia Porter Liebeskind, *Privatizing the Intellectual Commons: Universities and the Commercialization of Biotechnology*, 35 J. ECON. BEHAV. & ORG. 427, 431 (1998) (referring to ROBERT C. MERTON, THE SOCIOLOGY OF SCIENCE (1973)); Eisenberg, *supra* note 16, at 182 (same).

118. *See, e.g.*, Argyres & Liebeskind, *supra* note 117, at 441; Bagley, *supra* note 17, at 227–28; Eisenberg, *supra* note 16, at 182–84. The fourth Mertonian norm, organized skepticism, refers to the reproducibility of others' research. Eisenberg, *supra* note 16, at 184.

119. *See, e.g.*, NRC, *supra* note 102, at 35 (and sources cited therein) (noting this concern).

120. Nelson, *supra* note 43, at 456, 461 (describing the ideal of a "Republic of Science") (citing Michael Polanyi, *The Republic of Science*, 1 MINERVA 54 (1962)).

121. NRC, *supra* note 102, at 35; Jerry G. Thursby & Marie C. Thursby, *University Licensing and the Bayh–Dole Act*, 301 SCI. 1052, 1052 (2003).

122. Frischmann, *supra* note 31, at 175.

123. Argyres & Liebeskind, *supra* note 117, at 447–48; Donald S. Siegel & Phillip H. Phan, *Analyzing the Effectiveness of University Technology Transfer: Implications for Entrepreneurship Education*, 13 (Rensselaer Polytechnic Inst., Working Paper in Econ. No. 0426, 2004),

university patenting has increased, the evidence suggests that faculty are simply patenting more of their research but not actually changing the type of research they conduct.[124] And not surprisingly, university patenting occurs in only a few areas of research, namely biotechnology and medicine, agriculture, and electronics.[125]

To say that university research topics remain non-commercial is not to say that topics are chosen without regard to potential practical application, however. Unlike their counterparts in other industrialized nations, the decentralized and heterogeneous universities in the U.S. have long had a relationship with local industry, both as a means of establishing prestige and as a means of attracting political and financial support.[126] In fact, the relationships between academia and private industry launched entirely new areas of technology long before Bayh–Dole.[127] A common oversimplification of the relationship between the two is that technology develops in a linear fashion from basic scientific research to practical industrial application.[128] The relationship between basic and applied research is more complex, however, such that the two often feed one another and coevolve.[129] Furthermore, in order to compete for limited government research funding, academic researchers must often demonstrate the practical potential of their research proposals. Federal funding of university research has long been predicated on the expectation of some practical benefit, particularly in defense, energy, and health,[130] and government funding generally has become increasingly application-oriented as the public demands greater practical returns on its tax dollars.[131] Much university re-

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http://www.economics.rpi.edu/workingpapers/rpi0426.pdf; Interview with Marie Kerbeshian, Vice President of Tech. Commercialization, Ind. Univ. Res. & Tech. Corp., in Indianapolis, Ind. (Mar. 5, 2015).

124. NRC, *supra* note 102, at 3, 35; Thursby & Thursby, *supra* note 121, at 1052.

125. MOWERY ET AL., *supra* note 11, at 2–3; Mazzoleni & Nelson, *supra* note 36, at 1047; Mowery, *supra* note 46, at 16.

126. Mireles, *supra* note 27, at 265; Mowery & Sampat, *supra* note 99, at 118.

127. MOWERY ET AL., *supra* note 11, at 15.

128. Nelson, *supra* note 43, at 457–59. Carl Shapiro has described this linear model as the "move from pure R to applied R and ultimately to D" in R&D. Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, *in* 1 INNOVATION POLICY AND THE ECONOMY 119, 120 (Adam B. Jaffe et al. eds., 2001).

129. MOWERY ET AL., *supra* note 11, at 94–95; Nelson, *supra* note 43, at 457–59.

130. MOWERY ET AL., *supra* note 11, at 24–26; Greenbaum, *supra* note 17, at 336–37.

131. Cohen et al., *supra* note 35, at 2; Interview with Marie Kerbeshian, *supra* note 123. Indeed, it is because of its practical orientation that university research is patentable at all. Robert A. Lowe et al., *What Happens in University–Industry Technology Transfer?: Evidence from Five Case Studies*, *in* IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY–INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH–DOLE ACT 152, 185 (David C. Mowery et al. eds., 2004).

search can therefore be described as falling within "Pasteur's Quadrant": research that is valuable both as groundwork for later downstream technologies and as knowledge *per se*.[132]

Regardless of whether patenting university research under Bayh–Dole leads to a more commercially oriented selection of research topics, some point out that fear of patent infringement liability may hamper other academics in studying areas closely related to the patented subject matter.[133] So far, fear of infringement does not seem to pose much of a problem.[134] Researchers, especially academics, often just ignore patents in conducting their own research on the belief that an experimental-use exemption exempts them from liability.[135] The Federal Circuit has effectively held that no such experimental-use exception applies to university research,[136] but patent infringement by university researchers is often not worth policing, and patent holders have been reluctant thus far to sue academic infringers; some firms even encourage such infringement, as it provides them with further knowledge about their patented technologies.[137] That being said, universities are increas-

132. MOWERY ET AL., *supra* note 11, at 24–26; Nelson, *supra* note 43, at 456–57 (referring to practically oriented research within "Pasteur's Quadrant") (citing DONALD E. STOKES, PASTEUR'S QUADRANT: BASIC SCIENCE AND TECHNOLOGICAL INNOVATION (1997)).

133. *E.g.*, Rochelle Dreyfuss, *Protecting the Public Domain of Science: Has the Time for an Experimental Use Defense Arrived?*, 46 ARIZ. L. REV. 457 (2004); Strandburg, *supra* note 115.

134. *See* Adelman, *supra* note 18, at 133; Rebecca S. Eisenberg, *Noncompliance, Nonenforcement, Nonproblem? Rethinking the Anticommons in Biomedical Research*, 45 HOUS. L. REV. 1059, 1080 (2008).

135. A PATENT SYSTEM, *supra* note 100, at 72; Walsh et al., *supra* note 100, at 324–25; John P. Walsh et al., *The View from the Bench: Patents and Material Transfers*, 309 SCI. 2002 (2005); *see also* Mark A. Lemley, *Ignoring Patents*, 2008 MICH. ST. L. REV. 19 (noting that industry researchers also often ignore patents).

136. Madey v. Duke Univ., 307 F.3d 1351, 1362 (Fed. Cir. 2002) (no experimental-use exemption applies where research is the "legitimate business" of the alleged infringer); *see also* A PATENT SYSTEM, *supra* note 100, at 73, 76–77.

137. *See* Adelman, *supra* note 18, at 142–43, 151; Heller & Eisenberg, *supra* note 14, at 700–01; Lemley, *supra* note 14, at 623; Mireles, *supra* note 27, at 275–76 (and sources cited therein); Victor H. Polk, Jr. & Roman Fayerberg, *When Patented Technologies Get Put to Experimental Use: Practical Considerations for Nanotech R&D*, 8 NANOTECH. L. & BUS. 152, 153–54 (2011); Walsh et al., *supra* note 100, at 317, 326–27 (noting that many firms claim reluctance to sue university researchers for patent infringement).

ingly becoming the instigators and even targets of patent enforcement threats,[138] especially as the perception of universities as commercial actors continues to grow.[139]

Furthermore, in science-based technologies such as biotechnology and nanotechnology, R&D opportunities currently outnumber capacity, and researchers have ample freedom to operate within these fields.[140] Patents in these fields can often be avoided by pursuing alternative research avenues or by otherwise redirecting R&D efforts to design around the patents.[141] For example, despite a large volume of overall patenting in the broad field of biotechnology,[142] the concentration of patenting in any one subfield of biotechnology remains small, posing few barriers to entry by others.[143] Nanotechnology likely offers a similarly wide range of research avenues, given the even larger number of subfields that fall under its broad umbrella.[144] For example, carbon nanotubes are frequently referred to as basic nanotechnology "building blocks,"[145] but for many applications organic and polymer nanotubes may provide

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138. A PATENT SYSTEM, *supra* note 100, at 73, 76–77; Christopher Brown, *Ayresian Technology, Schumpeterian Innovation, and the Bayh–Dole Act*, 43 J. ECON. ISSUES 477, 479 (2009); Lemley, *supra* note 14, at 622; *see also* Janice M. Mueller, *No "Dilettante Affair": Rethinking the Experimental Use Exception to Patent Infringement for Biomedical Research Tools*, 76 WASH. L. REV. 1, 1–4 (2001) (describing Roche's suit against universities and others for alleged infringement of patents on the PCR patents).

139. Kesan, *supra* note 37, at 2183; Peter Lee, *Patents and the University*, 63 DUKE L.J. 1 *passim* (2013); Nelson, *supra* note 43, at 466. If the infringement occurs among public universities and research institutions, however, the Supreme Court's decision in *Florida Prepaid* may provide sovereign immunity from suit. A PATENT SYSTEM, *supra* note 100, at 78–79; Eisenberg, *supra* note 134, at 1092.

140. *See* Adelman, *supra* note 28, at 1003–15 (noting that most diseases offer more potential research targets than there are available researchers); David E. Adelman & Kathryn L. DeAngelis, *Patent Metrics: The Mismeasure of Innovation in the Biotech Patent Debate*, 85 TEX. L. REV. 1677 *passim* (2007); Walsh et al., *supra* note 100, at 304–05.

141. A PATENT SYSTEM, *supra* note 100, at 72; Eisenberg, *supra* note 134, at 1064; Eisenberg, *supra* note 66, at 22; Walsh et al., *supra* note 100, at 324.

142. Adelman & DeAngelis, *supra* note 140, at 1687 (but noting a decline in biotech patents issued as utility standards and PTO resources tightened).

143. *Id.* at 1701–06 (noting that most subclasses of biotechnology contained fewer than 100 patents); Michael Lounsbury et al., *The Politics of Neglect: Path Selection and Development in Nanotechnology Innovation*, *in* 21 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND ECONOMIC GROWTH: SPANNING BOUNDARIES AND DISCIPLINES: UNIVERSITY TECHNOLOGY COMMERCIALIZATION IN THE IDEA AGE 27, 31–32 (Gary D. Libecap ed., 2010) (measuring ease of entry by patent saturation in subcategories of nanotechnology).

144. Because of its obvious potential for applications in a wide range of technologies, including material science, telecommunications, energy, medicine, and textiles, research in nanotechnology may also be unusually cross-disciplinary in effect. Lemley, *supra* note 14, at 614–15.

145. *See, e.g.*, Lemley, *supra* note 14, at 613–14; Graham Reynolds, *Nanotechnology and the Tragedy of the Anticommons: Towards a Strict Utility Requirement*, 6 U. OTTAWA L. & TECH. J. 79, 86 (2009).

technologically meaningful alternatives.[146] And although all three types of nanotubes are protected under a variety of patents, downstream developers do at least have a wider range of competitive options, which may help to mitigate the risk of an anticommons.[147] A separate question, of course, is whether the available alternatives serve as well as the patented technologies, or whether they are only inferior substitutes that force others to invest in finding alternatives,[148]—although this question is true of all patents, regardless of their number or whether they cover upstream research.

Critics also voice concerns that the emphasis on patenting under the Bayh–Dole Act may discourage publication, collaboration, and other forms of information sharing.[149] Universities traditionally placed their research into the public domain through publication and other means under the so-called Mertonian ethic communalism in scientific research.[150] Tech transfer between universities and between universities and private industry has long been thought to occur most effectively through these mechanisms.[151] Indeed, one of the virtues of funding university research through tax dollars prior to the Bayh–Dole Act was that it freed universities from the need to privatize and propertize their research in order to recoup costs.[152]

Empirical studies have in fact suggested that faculty researchers who patent more tend to collaborate less with other researchers.[153] Studies also show that a significant number of agreements between private industry and universities require that the academic side de-

146. Lounsbury et al., *supra* note 143, at 48–50. The authors point out, however, that other political, financial, and cultural factors may influence which paths R&D eventually takes. *Id.*

147. *But see* DAN L. BURK & MARK A. LEMLEY, THE PATENT CRISIS AND HOW THE COURTS CAN SOLVE IT 152 (2009) (noting that even upstream research can face anticommons and patent thickets where research efforts are clustered on the same few topics).

148. Heller & Eisenberg, *supra* note 14, at 700; Eisenberg, *supra* note 16, at 219 n.217; Wolrad Prinz zu Waldeck und Pyrmont, *Research Tool Patents After* Integra v. Merck--*Have They Reached a Safe Harbor?*, 14 MICH. TELECOMM. & TECH. L. REV. 367, 388 (2008).

149. *See generally* Eisenberg, *supra* note 16; Rai & Eisenberg, *supra* note 32; Love, *supra* note 17, at 322–23; Rai, *supra* note 3; Strandburg, *supra* note 115. *But see* Cohen et al., *supra* note 37, at 179 (noting greater collaboration between universities and private industry post-Bayh–Dole).

150. Dreyfuss, *supra* note 133, at 463–64; Peter Lee, Note, *Patents, Paradigm Shifts, and Progress in Biomedical Science*, 114 YALE L.J. 659, 671 (2004) (citing ROBERT K. MERTON, THE SOCIOLOGY OF SCIENCE: THEORETICAL AND EMPIRICAL INVESTIGATIONS 270–78 (Norman W. Storer ed., 1973)).

151. Dreyfuss, *supra* note 133, at 464.

152. Eisenberg, *supra* note 3, at 1667.

153. *See, e.g.*, Tania Bubela et al., *Commercialization and Collaboration: Competing Policies in Publicly Funded Stem Cell Research?*, 7 CELL STEM CELL 25 (2010) (studying Canadian researchers); Matthew Herder, *Choice Patents*, 52 IDEA 309 (2012) (studying cancer researchers in the U.S.).

lay publishing until, or in some cases even after, a patent application has been filed.[154] But others note that, long before the Bayh–Dole Act and long before patenting university research took hold, academic reality often violated the Mertonian ideal of communalism, with competition for grant money, tenure standards, and the desire to establish one's reputation often leading to withholding of data and materials and refusals to collaborate.[155] Nonetheless, the patents themselves do disclose information,[156] and universities have begun to push back against requests to delay publishing.[157] University researchers also continue to transfer knowledge through collaboration, student placement, consultation, and other means, as discussed in further detail below.

III. UNIVERSITY PATENTING UNDER BAYH–DOLE AS BURDENSOME

So far, this article discussed only the potential benefits of university patenting under the Bayh–Dole Act, but as many have recognized, the Act may incur a number of potential costs as well. Critics of the Bayh–Dole Act express concern that, far from facilitating downstream development, patents on federally funded research will in fact hinder such development. For example, Professors Rebecca Eisenberg, Michael Heller, Mark Lemley, and a number of others have suggested that patents on upstream university research have the potential to obstruct "downstream" development of applications of that research. These critics argue that, by adding unnecessarily to the number of patents that must be licensed, Bayh–Dole also added to the cost and difficulty of downstream development.[158] Moreover, the Act also introduced universities as a new class of patent holders that lack both the expertise and inclination to license

154. Blumenthal et al., *supra* note 37, at 371; Eric G. Campbell et al., *Data Withholding in Academic Genetics: Evidence from a National Survey*, 287 J. AM. MED. ASS'N 473, 478 (2002).

155. Robert P. Merges, *Property Rights Theory and the Commons: The Case of Scientific Research*, 13 SOC. PHIL. & POL'Y 145, 146 (1996); Nelson, *supra* note 43, at 463.

156. NRC, *supra* note 102, at 31.

157. *Id.* at 33–34; *see also* Fiona E. Murray et al., *How Does the Republic of Science Shape the Patent System? Broadening the Institutional Analysis of Innovation Beyond Patents*, 1 U.C. IRVINE L. REV., 357, 373 (2011) ("[A] firm cannot easily compel scientists to secrecy (except under narrow conditions of trade secrecy) anymore than scientists can assert their rights to free publication if this would eviscerate any commercial return."). *But see* MOWERY ET AL., *supra* note 11, at 7 (expressing concern that Bayh–Dole will eventually have negative effects on university choice of research topics, disclosure of results, conflicts of interest, and so on).

158. *See generally*, Heller & Eisenberg, *supra* note 14; Lemley, *supra* note 14.

their patents effectively.[159] The combined effect of all of these changes in patenting patterns is to inflate overall transaction costs and hinder downstream development. By patenting government-funded, basic research, Bayh–Dole leads to overly fragmented rights and the "tragedy of the anticommons."[160] Professors Heller and Eisenberg cite biotechnology, genetics in particular, as a possible example of an anticommons at work,[161] and Professor Lemley cites nanotechnology development as another possible example.[162] No evidence so far, however, supports the contention that Bayh–Dole creates anticommons in these fields or any other, although patents on truly foundational patents under Bayh–Dole may pose significant obstacles to downstream development.

A. *Does University Patenting Lead to Anticommons and Other Hold-Up Problems?*

At their core, property rights are the right to exclude others from using a particular resource.[163] Others who want to use the resource for any reason must first obtain permission, often in exchange for some type of consideration; this may create inefficiencies, particularly if the proposed use is socially beneficial. The mere fact of fragmented rights means that returns on any subsequent development must now be split among a larger number of rights holders, decreasing the return per holder and thereby decreasing the incentive any given rights holder has to invest in development at all. And the larger the number of property rights involved, the greater the difficulty, the greater the potential inefficiencies, and the greater the risk of an "anticommons," or property rights that are so fragmented that underuse is a certainty.[164] Because patents also give the right to exclude others from making or using the covered inventions, patents can likewise create a drag on downstream development of

159. Celestine Chukumba & Richard Jensen, *University Invention, Entrepreneurship, and Start-Ups*, 13, 18–19 (Nat'l Bureau of Econ. Research, Working Paper No. 11475, 2005), http://www.nber.org/papers/w11475; Interview with Marie Kerbeshian, *supra* note 123.

160. *See* Eisenberg, *supra* note 22, at 640; Heller & Eisenberg, *supra* note 14, at 698.

161. Heller & Eisenberg, *supra* note 14.

162. *See generally* Lemley, *supra* note 14; *see also* Raj Bawa, *Nanotechnology Patent Proliferation and the Crisis at the U.S. Patent Office*, 17 ALB. L.J. SCI. & TECH. 699 (2007).

163. Michael A. Carrier, *Cabining Intellectual Property Through a Property Paradigm*, 54 DUKE L.J. 1, 52–58 (2004). These rights are not absolute, of course, and are subject to a number of limitations. *Id.*

164. *See generally* Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998); Heller & Eisenberg, *supra* note 14, at 698.

commercializable applications or even for research.[165] Simply the fact that a given application might be subject to one or more upstream patents would tend to reduce incentives to create the downstream application because the upstream patent holders will extract a share of the returns, leaving less for the downstream inventor.[166]

And just as over-fragmentation of property rights creates an anticommons, over-fragmentation of patent rights to a given technology can cause underuse and under-development.[167] For example, a single product may depend on the combination of separately patented but complementary components; the product will not be made if the individual patent rights cannot be coordinated.[168] In other cases a patent may cover a downstream development. In cumulative technologies, upstream patents, such as university research patents, and downstream development or improvements patent rights must be vertically coordinated in order to make or use a product or process.[169] Patent floods are also common in university-based technologies, as scientific breakthroughs lead to sudden increases in patent applications.[170] Patent floods in turn can lead to patent thickets, in which patent rights become particularly dense and overlapping, because of either broad patent scope or floods of simultaneously filed but overlapping applications that strain the PTO's resources.[171] Patent thickets also arise when many complementary patents are needed to produce a single good.[172] Semiconductors, biotechnology, and computer software are examples of fields in which patent thickets are thought to be most prevalent.[173]

165. Specifically, the Patent Act grants a patent holder the right to exclude others from making, using, selling, or offering to sell the subject invention. 35 U.S.C. § 154.

166. Michael J. Meurer, *Business Method Patents and Patent Floods*, 8 WASH. U. J.L. & POL'Y 309, 323 (2002).

167. Adam Mossoff, *The Rise and Fall of the First American Patent Thicket: The Sewing Machine War of the 1850s*, 53 ARIZ. L. REV. 165, 166–67 (2011).

168. Michael Mattioli, *Communities of Innovation*, 106 NW. U.L. REV. 103, 113 (2012). These types of complementary technologies are sometimes referred to as Cournot compliments. *Id.* at 113–14 (discussing AUGUSTIN COURNOT, RESEARCHES INTO THE MATHEMATICAL PRINCIPLES OF THE THEORY OF WEALTH 103–04 (Nathaniel T. Bacon trans., Augustus. M. Kelley ed., 2d ed. 1838)).

169. Burk & Lemley, *supra* note 73, at 1612–13; Nelson, *supra* note 43, at 464; Shapiro, *supra* note 128, at 123.

170. Merges & Nelson, *supra* note 58, at 907–08.

171. Burk & Lemley, *supra* note 73, at 1627; Meurer, *supra* note 166, at 324–25; Shapiro, *supra* note 128, at 120.

172. Burk & Lemley, *supra* note 73, at 1627–28.

173. *Id.*

Similarly, many commentators are concerned that university patenting in nanotechnology is not just prolific but also "broad, overlapping, and fragmented" in ownership.[174]

All the same, in a Coasean world of zero transaction costs, even highly balkanized patent rights could be easily assembled when beneficial. In the real world, however, valuation difficulties, conflicting interests, and rent-seeking can frustrate agreement among multiple owners to use their patent rights jointly.[175] In fact, the costs of simply having to transact with patent rights or resource holders further reduce the returns on downstream development investments. Thus, underutilization can occur when the increased transaction costs of fragmented patent rights create obstacles to further innovation and use.[176]

One particular twist that Bayh–Dole adds to the mix, moreover, is the concomitant growth in universities as patentees; university patenting has increased by about sixteen fold since Bayh–Dole was enacted.[177] Because universities do not and cannot commercialize their own research, universities must now incur the costs of identifying and transacting with private firms to develop the patented technology into usable end products.[178] More significantly, universities are not only unwanted market actors, but also institutions with interests in and internal structures very different from any other market actor. The unique position of universities as patent licensors under Bayh–Dole thus further exacerbates transaction costs: not only do patents now exist where they had not before, but also private industry must now transact with universities more often than they had before.[179]

As a first matter, almost thirty-five years after Bayh–Dole was enacted, universities are still quite new to the world of commercializing intellectual property and lack the experience and expertise for patent licensing.[180] Indeed, universities are still reluctant to view themselves as commercial entities,[181] and university Technology

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174. Reynolds, *supra* note 145, at 83 (citing Press Release, Lux Research, Inc., Nanotechnology Gold Rush Yields Crowded, Entangled Patents (Apr. 21, 2005), http://www.prnewswire.com/news-releases/nanotechnology-gold-rush-yields-crowded-entangled-patents-54373177.html).

175. Heller & Eisenberg, *supra* note 14, at 698.

176. Mossoff, *supra* note 167, at 166–67.

177. Lemley, *supra* note 14, at 617; Frank Murray et al., *Defense Drivers for Nanotechnology Commercialization: Technology, Case Studies, and Legal Issues*, 9 NANOTECH. L. & BUS. 4, 31 (2012).

178. Lemley, *supra* note 14, at 626.

179. *See, e.g.*, Blumenthal et al., *supra* note 37, at 370.

180. MOWERY ET AL., *supra* note 11, at 88–91; Chukumba & Jensen, *supra* note 159, at 13, 18–19; Interview with Marie Kerbeshian, *supra* note 123.

181. Osenga, *supra* note 29, at 421.

Transfer Offices ("TTOs") simply do not have the market-based orientation that private commercial entities do.[182] Second, universities have very different internal authority structures from commercial firms, and even the different constituencies within a university often have agendas that differ from one another, further complicating matters.[183] Third, and most important, universities have very different interests and incentives than do private firms, leading to difficulty agreeing. For example, universities may overestimate the relative value of their contributions to downstream development, as the academic mindset typically prizes research over applications and ideas over products.[184] Universities may also demand restrictions on publication rights, restrictions on licensing or transfer of protected technologies or materials to other institutions, or reach-through licenses to downstream products, allowing them to extract an even greater share of any returns and leaving less for the downstream inventor.[185] Horizontally positioned entities with similar values and interests, by contrast, will find it easier to come to agreement, particularly if they are repeat players.[186] This last factor is what I have previously termed a "qualitative," as opposed to a "quantitative" anticommons, in which, regardless of the number of rights holders, the heterogeneity of transacting parties and the divergence of their respective interests and incentives can complicate agreement transaction costs.[187]

Finally, because so much of university research is research-oriented rather than application-oriented and therefore quite basic, the overall effect of Bayh–Dole is to allow modern-day researchers to patent "incomplete" inventions that have no immediate utility other than as subjects for further development by others.[188] As a

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182. *See generally* Argyres & Liebeskind, *supra* note 117; Fini & Lacetera, *supra* note 40 *passim*.

183. *See* Argyres & Liebeskind, *supra* note 117, at 446; Jensen & Thursby, *supra* note 36, at 244; Interview with Marie Kerbeshian, *supra* note 123; *see also* Blumenthal et al., *supra* note 37, at 370 (reporting university bureaucracy and regulations as the most frequent obstacle to life science companies forming research relationships with universities).

184. Heller & Eisenberg, *supra* note 14, at 701.

185. A PATENT SYSTEM, *supra* note 100, at 71; Heller & Eisenberg, *supra* note 14, at 699; Osenga, *supra* note 29, at 427.

186. JOHN C. MILLER ET AL., THE HANDBOOK OF NANOTECHNOLOGY: BUSINESS, POLICY, AND INTELLECTUAL PROPERTY LAW 76 (2005); Jensen & Thursby, *supra* note 36, at 244; *see also* Heller & Eisenberg, *supra* note 14, at 700 (noting heterogeneity of interests increases transaction costs); Smith, *supra* note 74, at 1776 (same).

187. Mark D. West & Emily Michiko Morris, *The Tragedy of the Condominiums: Legal Responses to Collective Action Problems After the Kobe Earthquake*, 51 AM. J. COMP. L. 903, 928 n.69 (2003).

188. Merges & Nelson, *supra* note 58, at 884; Arti K. Rai, *Fostering Cumulative Innovation in the Biopharmaceutical Industry: The Role of Patents and Antitrust*, 16 BERKELEY TECH. L.J. 813, 839–40 (2001).

result, university inventions require significant additional investment before they yield usable products of any value, but universities can still demand licensing or royalty fees for their upstream patents, effectively allowing universities to extract rents from downstream developers. And because university technologies are typically more conceptual and less concrete, the boundaries of their patent rights may also be more vague and abstract, creating patent rights that are not only broader in scope but also more suspect in validity.[189] The resulting poor quality patents further aggravate transaction costs because of the difficulties of valuing the patent and agreeing on whether it needs to be licensed,[190] and licensing what turns out to be an invalid patent creates unnecessary drag on downstream development.[191] These three elements—a high volume of patents, early-stage inventions, and university patent ownership—all may contribute to underutilization of university research.

If exploitation and commercialization of government-funded university research is the goal, releasing research into the public domain, rather than patenting it, is often more efficient.[192] Public-domain status permits access to all downstream firms interested in creating social value from the research and simultaneously fosters competition among the firms. Given that inventive concepts are nonrivalrous, there is no reason not to allow as many entities as possible to try their hands at creating downstream applications, and for many technologies competition is more effective than monopoly in spurring efficient development.[193] If Eisenberg, Heller, Lemley and other critics are correct, why not favor a competitive environment in the case of government-funded research, particularly where incentives to invent would be unaffected?[194]

For the most part, the vast majority of university research is freely available to all competitors. Again, university patenting is largely limited to a few select fields and is important to only a few industries—biotechnology and medicine, agriculture, and electronics.[195] In those fields where patenting does occur, only a small amount of government-funded research has been patented since

189. Rai, *supra* note 188, at 839–40 (vague patent boundaries broader in preemptive scope); Reynolds, *supra* note 145, at 99 (vague patents more likely to be invalid).
190. Reynolds, *supra* note 145, at 99.
191. Shapiro, *supra* note 128, at 125.
192. Eisenberg, *supra* note 3, at 1702, 1710–11.
193. Burk & Lemley, *supra* note 73, at 1604–08 (and sources cited therein); Merges & Nelson, *supra* note 58, at 843–44.
194. Merges & Nelson, *supra* note 58, at 843–44.
195. MOWERY ET AL., *supra* note 11, at 2–3; Mazzoleni & Nelson, *supra* note 36, at 1047; Mowery, *supra* note 46, at 16.

Bayh–Dole was enacted, and an even smaller percentage has been licensed,[196] presumably because extremely little of this research has been of commercial interest[197] and because research choices continue to be driven more by academic interest than by commercial value.[198] In addition, TTOs often face resistance from their own faculty researchers, who would rather their research be freely available to others through the public domain.[199] Even university administrators can often be reluctant to invest in patenting faculty research, as university resources are limited and the returns from patents on upstream research are too uncertain to warrant the costs.[200] Patents may yield additional reputational benefits as objective measures of productivity for both the university and its individual researchers,[201] but for the most part it is prohibitively expensive to patent university research when publication and other signals may serve just as well.[202] University TTO managers report that universities will not assume the high costs of filing and prosecuting patents when industry has expressed little or no interest in the technology,[203] and will only do so when required by their private sponsors or when a licensee for the patented technology has already been identified.[204] In addition, because university research often focuses not on inventing new technologies but on understanding naturally occurring phenomena and on advancing theories to explain those phenomena, much if not most of that research is too "basic" to be patentable; even if technologically valuable, discoveries and theories about natural laws and phenomena are unpatentable subject matter under § 101 of the Patent Act.[205] And again, even when the results are patentable, faculty often prefer that their

196. Love, *supra* note 17, at 303–04; Walsh et al., *supra* note 100, at 309.

197. Frischmann, *supra* note 31, at 175; Love, *supra* note 17, at 308–12; Osenga, *supra* note 29, at 421.

198. NRC, *supra* note 102, at 35.

199. Interview with Marie Kerbeshian, *supra* note 123.

200. Osenga, *supra* note 29, at 421.

201. Lee, *supra* note 150, at 676; Love, *supra* note 17, at 332–34.

202. Adelman, *supra* note 18, at pt. III; Kesan, *supra* note 37, at 2184; *see also* A PATENT SYSTEM, *supra* note 100, at 38 (noting that each patent prosecution cost between $10,000 and $30,000 in 2004 and the figure was rising).

203. BNA, *supra* note 22, at 225, 227–32; Adelman, *supra* note 18, at pt. III; McManis & Noh, *supra* note 114, at 454; Siegel & Phan, *supra* note 123, at 7.

204. Jensen & Thursby, *supra* note 36, at 244.

205. *See* 35 U.S.C. § 101 (explaining scope of Patent Act); *see also* Peter Lee, *The Evolution of Intellectual Infrastructure,* 83 WASH. L. REV. 39, pt. I.B.3 (2008); Mark Williamson & James Carpenter, *Traversing Art Rejections in Nanotechnology Patent Applications -- No Small Task*, 7 NANOTECH. L. & BUS. 131, 137–38 & n.40 (2010) (and cases cited therein).

research remain in the public domain,[206] fostering free competition among interested downstream developers.

Nonetheless, university patenting has clearly risen in volume since the Bayh–Dole Act, and this could have a profound impact on downstream development, particularly if the fact of patenting correlates with potential commercial value. Again, patents stifle downstream development where innovation is cumulative or complementary, such as in the fields of semiconductors, electronics, computers, and computer software, where new inventions build on existing technologies and where new inventions are only one part of a larger invention.[207] Although patents in these fields are hardly unique to universities, to the extent that university patents have increased the overall level of patenting, Bayh–Dole may have exacerbated the costs of horizontal or vertical coordination of patent rights.[208] Similarly, in technologies such as computer software, semiconductors, and genetics, where unpatented alternative development avenues or complements are less plentiful and where university research is less basic and more incremental, university patents are not unique but all the same can aggravate patent thickets and further deter downstream development.[209]

And even in the science-based technologies, where the field is less crowded and major advances over prior art are possible,[210] university patents may still pose hold-up problems, given that university research is a dominant influence in these fields. In particular, a few critical upstream technologies may be fundamental enough that patent exclusivity over them could significantly stifle downstream development.[211] All upstream technologies by definition serve primarily as bases for downstream research and development, but a few upstream inventions are so key that they serve as foundations for entire fields of technology; without these foundational inventions, further progress in their respective fields would be difficult or impossible.[212] Commonly cited as examples of foundational inventions are research tools such as Cohen and Boyer's

206. Argyres & Liebeskind, *supra* note 117, at 447–48; Siegel & Phan, *supra* note 123, at 13; Interview with Marie Kerbeshian, *supra* note 123.

207. Merges & Nelson, *supra* note 58, at 881; Michael S. Mireles, *An Examination of Patents, Licensing, Research Tools, and the Tragedy of the Anticommons in Biotechnology Innovation*, 38 U. MICH. J.L. REFORM 141, 168 (2004).

208. Burk & Lemley, *supra* note 73, at 1612–13; Nelson, *supra* note 43, at 464; Shapiro, *supra* note 128, at 123.

209. Shapiro, *supra* note 128, at 121–22.

210. Merges & Nelson, *supra* note 58, at 884.

211. Nelson, *supra* note 43, at 464; Walsh et al., *supra* note 100, at 305–06.

212. Brett M. Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 MINN. L. REV. 917, 928 (2005); Brett M. Frischmann & Mark A. Lemley, *Spillovers*,

patented process for creating recombinant DNA and Cetus's patented polymerase chain reaction ("PCR") process for reproducing DNA, both of which are considered bedrock technologies that made possible the modern fields of genetics and molecular biology.[213] While patent protection was arguably more warranted for Cetus's privately developed PCR process than for the Cohen–Boyer recombinant DNA process, which was invented at Stanford University through government grants, the patents on both processes effectively allowed the upstream patent holders to extract rents from their downstream licensees.[214] While the example of Cetus's privately developed PCR process demonstrates that foundational inventions are not unique to universities,[215] university researchers are more likely to hit upon foundational inventions, particularly in the science-based technologies, just by virtue of the nature of their research.[216] Even then, very little of university research is truly foundational in the sense of having a broad base application to its technology as a whole,[217] but patents on the few inventions that are foundational, although technically not an anticommons problem, do have the potential to obstruct both upstream and downstream R&D.[218]

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107 COLUM. L. REV. 257, 294 (2007); Lee, *supra* note 205, at 89–91. Foundational inventions are also known as "common-method research tools," Adelman, *supra* note 18, at 139, or "platform technologies," McManis & Noh, *supra* note 114, at 485.

213. Lee, *supra* note 205, at 93–94; Walsh et al., *supra* note 100, at 305–06. Harvard's onco-mouse, human embryonic stem cell lines, interoperability standards in information technology, and probe microscopy have also been cited as examples of foundational technologies. Lee, *supra* note 205, at 94–96; Morris, *supra* note 15, at __; Mowery, *supra* note 46, at 55–57; Walsh et al., *supra* note 100, at 305–09.

214. Mowery, *supra* note 46, at 55 & n.20; *see also* Lemley, *supra* note 14, at 611 & n.47 (noting that, although the Cohen–Boyer patents did not bar access to downstream developers, they did raise the cost of R&D in molecular biology, and noting that Cetus's patents were held unenforceable many years later). Although time and technological progress often provide new alternatives that make earlier foundational technologies obsolete, Kieff, *supra* note 26, at 730–31; Lee, *supra* note 205, at 86–91 (noting that what constitutes a foundational invention changes as its technological field evolves), the delays and costs of waiting for alternatives to emerge contribute to the problems posed by foundational patents.

215. For example, the foundational research for gallium-nitride, used in broad-spectrum semi-conductors, is unusual in that private industry, rather than universities, was responsible for most of the foundational research for the invention. Lowe et al., *supra* note 131, at 161.

216. For example, the onco-mouse, human embryonic stem cells, and the CD34 stem-cell antigen are all foundational patents stemming from university research. Walsh et al., *supra* note 100, at 305–09.

217. A PATENT SYSTEM, *supra* note 100, at 72; Adelman, *supra* note 28, at 1020; Adelman, *supra* note 18, at 139; McManis & Noh, *supra* note 114, at 486.

218. Adelman, *supra* note 18, at 139; McManis & Noh, *supra* note 114, at 486–87; Walsh et al., *supra* note 100, at 305.

Nevertheless, the mere fact of university patenting is not itself sufficient to cause either qualitative or quantitative hold-up problems. As a first matter, university patents do not appear to be any lower in quality than patents from other sources. Although the overall quality of university-sought patents did briefly decline after passage of Bayh–Dole, that decline appears to have been restricted to TTOs that were new to patenting post-Bayh–Dole and ameliorated over time.[219] TTOs that had established patent practices pre-Bayh–Dole, by contrast, continued to file and receive patents equivalent in quality to non-academic patents within the same classes.[220] Second, despite the increase in university patents, the number of patents on average that need to be licensed for any given downstream development project remains small.[221]

Perhaps more significant is the fact that heterogeneity of interests, such as those that exist between non-profit universities and profit-driven private industry, can actually mitigate rather than cause hold-up problems.[222] For example, firms can be reluctant to license upstream patents from competitors for fear of revealing information about their own development plans,[223] but universities are not market competitors and present no such risks. Similarly, universities may license their patents more freely because they are not constrained with concerns about cannibalizing their own products.[224] Further, of the few university inventions that are foundational, evidence suggests that many patents, like the Cohen–Boyer recombinant DNA patents, are licensed liberally and non-exclusively, [225] and in the case of the Cohen–Boyer process, licensed on a sliding scale for relatively low fees.[226] And while some universities, such as Harvard, MIT, and the University of Wisconsin, have garnered significant revenues from patent licensing and enforcement

219. MOWERY ET AL., *supra* note 11, at 129–48.

220. Specifically, studies show that, as TTOs gain experience, their patents are of similar "importance" (as defined by number of forward citations) and "generality" (as defined by number of forward citations outside of the patent's class) as non-academic patents within the same classes. David C. Mowery & Arvids A. Ziedonis, *Academic Patent Quality and Quantity Before and After the Bayh–Dole Act in the United States*, 31 RES. POL'Y 399 (2002); Bhaven N. Sampat et al., *Changes in University Patent Quality After the Bayh–Dole Act: A Re-examination*, 21 INT'L J. INDUS. ORG. 1371, 1379 (2003).

221. Eisenberg, *supra* note 134, at 1078–79; Walsh et al., *supra* note 100, at 294.

222. Heller & Eisenberg, *supra* note 14, at 700.

223. Eisenberg, *supra* note 66, at 22.

224. Rai, *supra* note 188, at 830–31. Some argue, however, that universities should take a more business-oriented approach in order to avoid creating qualitative anticommons. *See, e.g.*, Osenga, *supra* note 29.

225. Adelman, *supra* note 18, at pt. III; Walsh et al., *supra* note 100, at 323.

226. Lee, *supra* note 205, at 93–94; Walsh et al., *supra* note 100, at 305–06.

in a few notable cases,[227] the vast majority of faculty even at those high-profile schools show little interest in trying to profit from their research.[228] To be sure, lack of faculty interest in the commercial value of their research may actually hamper tech transfer,[229] just as university or government agency policies to license patents as broadly as possible may frustrate private licensees who would prefer exclusivity.[230] Although these are instances in which heterogeneity of interests do have a negative impact on licensing, it is important to note that these problems occurred even before Bayh–Dole was enacted, and are not due to *patent exclusivity* (and indeed, as the discussion in Part I suggests, patent exclusivity may attract private investments in commercialization).[231]

Regardless of how foundational a patent might or might not be, the fact remains that patents can and often do create additional costs that, at the margin, may deter or delay later downstream development.[232] Even modest or royalty-free licenses are counterproductive, especially when cumulative.[233] Unless we can demonstrate that university patenting under Bayh–Dole actually facilitates commercialization, perhaps we should err on the side of releasing all university research into the public domain to allow free competition in using and developing that research. Again, the empirical evidence thus far is equivocal at best as to whether the increase in university patenting has actually impeded downstream development, however,[234] largely because of the difficulties of testing such a hypothesis.[235]

B. *Proposed Solutions to Bayh–Dole Hold-Up Problems*

Given that we have no reliable evidence at this time that Bayh–Dole has caused hold-up problems, the many proposals for "fixing" Bayh–Dole may be somewhat premature or, as one scholar phrased

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227. *See* Mowery, *supra* note 46, at 52–54; Walsh et al., *supra* note 100, at 306–09.

228. Jerry G. Thursby & Marie C. Thursby, *Pros and Cons of Faculty Participation in Licensing*, *in* 16 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH: UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER 187, 200 (Gary D. Libecap ed., 2005).

229. *See id.* at 193–95 (arguing that faculty interest and involvement is critical for commercialization of university research).

230. Heller & Eisenberg, *supra* note 14, at 700.

231. *See supra* text accompanying notes 80–94.

232. Frischmann, *supra* note 212, at 996–97; Walsh et al., *supra* note 100, at 304 (suggesting that royalty stacking of biomedical patents makes a difference only at the margins).

233. Shapiro, *supra* note 128, at 125.

234. Mireles, *supra* note 27, at 261, 274 (citing various empirical studies on the effect of Bayh–Dole); Osenga, *supra* note 29, at 410; Wolrad Prinz zu Waldeck und Pyrmont, *supra* note 148, at 387–88 (summarizing empirical studies on effects of Bayh–Dole).

235. McManis & Noh, *supra* note 114, at 440, 475.

it, "legislative solutions for what are, at best, potential problems in the operation of the Act."[236] One category of proposals is to tighten the patentability and patent eligibility standards, such as the utility requirement and patentable subject matter restrictions, to make it more difficult to patent much of the upstream research currently being done under government funding.[237] Yet other proposed solutions focus on reducing transaction costs and limiting royalty stacking by modifying liability for infringing patents subject to the Bayh–Dole Act. These include compulsory licensing;[238] greater experimental-use exemptions[239] or even a fair-use exemption;[240] resurrection of the reverse doctrine of equivalents (and continued limitation on the doctrine of equivalents);[241] more limited injunctive relief,[242] particularly where the patent holder is a non-producing entity such as a university;[243] more accurate apportionment of damages;[244] limitations on treble damages for willful infringement;[245] and government management of upstream patents,[246] among other means. Private ordering solutions may also help reduce transaction costs. Although a more detailed discussion of these various proposals is beyond the scope of this article, some of the drawbacks and costs for a few of these proposals are included here.

For example, suggestions to tighten patentability standards overlook that fact that these standards are already stricter, particularly with regard to research or other "incomplete" patents. First, the Supreme Court's recent decisions in *Association for Molecular Pathology v. Myriad Genetics, Inc.*[247] and *Mayo Collaborative Services*

236. *Id.* at 440.
237. Reynolds, *supra* note 145, at 101–12.
238. *E.g.*, Terry K. Tullis, Comment: *Application of the Government License Defense to Federally Funded Nanotechnology Research: The Case for Limited Patent Compulsory Licensing Regime*, 53 UCLA L. REV. 279, 307–311 (2005).
239. *E.g.*, Dreyfuss, *supra* note 133, at 469; Mireles, *supra* note 27; Mueller, *supra* note 138.
240. *E.g.*, Maureen A. O'Rourke, *Toward a Doctrine of Fair Use in Patent Law*, 100 COLUM. L. REV. 1177 (2000).
241. Burk & Lemley, *supra* note 73, at 1657–58; Dreyfuss, *supra* note 133, at 469.
242. Lee, *supra* note 205, at pt. IV; Mark A. Lemley, *Ten Things To Do About Patent Holdup of Standards (And One* Not *To)*, 48 B.C. L. REV. 149, 155 (2007).
243. Burk & Lemley, *supra* note 73, at 1665–68. *But see* Kieff, *supra* note 26, at 732–36 (criticizing proposals to use liability rather than property rules).
244. Lemley, *supra* note 242, at 165–66.
245. *See, e.g.*, A PATENT SYSTEM, *supra* note 100, at 108–09; Lemley, *supra* note 14, at 630; Lemley, *supra* note 242, at 164–65; Strandburg, *supra* note 115, at 113; *see also* Mireles, *supra* note 27, at 261 (discussing more robust research exemptions in the EU and Japan).
246. *See generally* Rai & Eisenberg, *supra* note 32.
247. 133 S. Ct. 2107, 2116–17 (2013) (even valuable discoveries of natural phenomena are unpatentable subject matter if not "markedly different" from nature).

v. Prometheus Laboratories, Inc.[248] have already tightened patentable subject matter restrictions, thereby increasing the likelihood that "discoveries" of naturally occurring materials or principles will be found unpatentable.[249] The courts and the PTO similarly had already tightened the utility requirement, largely in reaction to the flood of biotechnology research patent applications, by clarifying that the specific and substantial utility standards required more than recitations of general utilities common to the broad class of technology to which a claimed invention belonged.[250]

Second, the patent system also already limits patentability to a great extent by interpreting many patents in new technologies rather narrowly through the enablement requirement and—in particular—the written description requirement,[251] the latter of which has most often been applied to narrow university-held biotechnology patents.[252] On the other hand, simply narrowing patent breadth through the disclosure requirements may do little to reduce the transaction costs, as researchers may simply compensate by increasing the number of patent applications, thereby potentially exacerbating the anticommons effect.[253]

More to the point, proposals to tighten patentability standards oversimplify things a bit. Exactly how to adjust patentable subject matter, utility, non-obviousness, or the other requirements to mitigate hold-up problems is hardly clear.[254] Even those who advocate for tightening patentability requirements acknowledge that more stringent requirements may be both under- and over-inclusive.[255] On the one hand, university-created technologies often serve dual

248. 132 S. Ct. 1289, 1297 (2012) (mere recitation of scientific discoveries with directions simply to "apply it" is unpatentable subject matter).

249. Matthew Herder, *Patents & The Progress of Personalized Medicine: Biomarkers Research as Lens*, 18 ANNALS HEALTH L. 187, 203–08 nn. 92 & 94 (2009).

250. Dreyfuss, *supra* note 133, at 468–69. Heightened utility standards were first promulgated in an interim form in 1999 and later finalized in 2001. Utility Examination Guidelines, 66 Fed. Reg. 1092–02 (Jan. 5, 2001); Revised Utility Examination Guidelines, Request for Comments, 64 Fed. Reg. 71440–01 (Dec. 21, 1999); *In re* Fisher, 421 F.3d 1365 (Fed. Cir. 2005); Reynolds, *supra* note 145, at 105–07; Rai, *supra* note 188, at 840; *see also* Adelman & DeAngelis, *supra* note 140, at 1687–92 (noting that the number of biotech applications granted have decreased due to the USPTO's tightened utility requirement in its 1999 Guidelines, among other factors).

251. Rai, *supra* note 188, at 840–41.

252. ROBERT PATRICK MERGES & JOHN FITZGERALD DUFFY, PATENT LAW & POLICY: CASES AND MATERIALS 313 (6th ed. 2013); Dan L. Burk & Mark A. Lemley, *Biotechnology's Uncertainty Principle*, 54 CASE W. RES. L. REV. 691, 695–700 (2004); Burk & Lemley, *supra* note 73, at 1653–54.

253. Dreyfuss, *supra* note 133, at 469–70; Rai, *supra* note 188, at 841–43.

254. Nelson, *supra* note 43, at 466.

255. Reynolds, *supra* note 145, at 84.

roles as both "upstream" building blocks in need of further development into usable end products, but also as "completed" products already possessing direct and practical applications, sometimes as commercially marketed tools for researching other subjects.[256] Many of these inventions will therefore meet even heightened standards. On the other hand, tightening patentability standards may reduce patent incentives, as it would affect any number of researchers, not just universities and other government-funded research institutions.[257] While many upstream inventions come from government-funded basic research, others result from privately funded investments in marketable applications.[258] Some truly foundational research tools have been created by private rather than publicly funded entities.[259] Sweeping restrictions on the patentability of upstream research may therefore have unwanted effects.[260]

A possibly more tailored approach to potential hold-up problems is to reduce transaction costs rather than to reduce the number or scope of upstream patents. For example, many have proposed expanding what is now an almost non-existent experimental-use exception in modern U.S. patent law.[261] The current exemption is extremely limited,[262] and for all intents and purposes covers only research used solely for and "reasonably related to the development and submission of information under a Federal law which regulates the manufacture, use, or sale of drugs or veterinary biological products."[263] Expanding this exemption to cover experimental use of so-called research tools would allow others to use those tools for basic

256. Dreyfuss, *supra* note 133, at 468.

257. Kesan, *supra* note 37, at 2184–85.

258. Miriam Bitton, *Patenting Abstractions*, 15 N.C. J.L. & TECH. 153, 203 (2014); Eisenberg, *supra* note 134, at 1080–81.

259. Sapna Kumar & Arti Rai, *Synthetic Biology: The Intellectual Property Puzzle*, 85 TEX. L. REV. 1745, 1755 (2007).

260. Dreyfuss, *supra* note 133, at 468–69; *see generally* R. Polk Wagner, *Of Patents and Path Dependency: A Comment on Burk and Lemley*, 18 BERKELEY TECH. L.J. 1341 (2003) (distinguishing between technology-specific "micro" levers and more generally applicable "macro" levers for adjusting patentability and patent scope).

261. *E.g.*, Dreyfuss, *supra* note 133, at 469; Mireles, *supra* note 27; Mueller, *supra* note 138.

262. Lee, *supra* note 150, at 683–84 (and cases cited therein); Janice M. Mueller, *The Evanescent Experimental Use Exemption from United States Patent Infringement Liability: Implications for University and Nonprofit Research and Development*, 56 BAYLOR L. REV. 917, 918 (2004); Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WIS. L. REV. 81, 102.

263. 35 U.S.C. § 271(e)(1).

research, to develop other products, and to design around the patented tool without the cost of negotiating for a license, even if royalty-free.[264]

The main difficulty with an experimental-use exemption, however, is identifying which uses are eligible.[265] Use of a patented invention for "non-commercial" reasons—i.e., for purposes other than copying and selling the patented invention—would seem to be harmless at first. Many a patentee would nonetheless object to the use of his or her patented technologies to devise non-infringing alternatives. These alternatives would benefit the public but could harm the patentee by eroding the patent holder's market share and thereby decreasing incentives to invest in inventing in the first place.[266] Similarly, experimental use of patented research tools, even when used to create other technologies that neither infringe nor even compete with the patented technology, can harm the market for the research tool, particularly if research is the only commercially valuable use for the patented technology.[267] This latter objection to an expanded experimental-use exception is particularly salient, as industry has come to realize the value of research itself as a form of business.[268] Finding the correct breadth of an experimental-use defense therefore requires paying close attention to its potential effects on the scientific community.[269]

Alternatives similar to an experimental-use exception (but which employ a liability-rule approach instead of an all-or-nothing, property-rule approach) are compulsory licensing and damages instead of injunctive relief. Like the experimental-use exception, however, compulsory licensing and damages in lieu of injunctive relief suffer from their own uncertainties. For example, the uncertainty of a liability rule may actually aggravate transaction costs,[270] particularly if it is difficult to predict how a court, without the benefit of

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264. Dreyfuss, *supra* note 133, at 459–61; Mueller, *supra* note 138, at 4.

265. A PATENT SYSTEM, *supra* note 100, at 110–17; Eisenberg, *supra* note 16, at 224.

266. Eisenberg, *supra* note 16, at 224–25.

267. Eisenberg, *supra* note 16, at 224–25; Eisenberg, *supra* note 134, at 1074; Wolrad Prinz zu Waldeck und Pyrmont, *supra* note 148, at 416–18 (and sources cited therein).

268. Eisenberg, *supra* note 134, at 1074–75; Laura G. Pedraza-Fariña, *Patent Law and the Sociology of Innovation*, 2013 WIS. L. REV. 813, 855 (quoting and citing STEVEN SHAPIN, THE SCIENTIFIC LIFE: A MORAL HISTORY OF A LATE MODERN VOCATION 2–3, 18–19, 97–98 (2008)). The scanning tunneling microscope, for example, was the first critical step in making nanotechnology a practicable field but was created by researchers at IBM (albeit without much commercial interest on the part of IBM). Cyrus C. M. Mody, *Corporations, Universities, and Instrumental Communities: Commercializing Probe Microscopy, 1981–1996*, 47 TECH. & CULTURE 56, 60 (2006).

269. Eisenberg, *supra* note 16, at 224.

270. Kieff, *supra* note 26, at 733.

expertise in the technology, will assess an appropriate royalty rate.[271]

Similar uncertainty concerns may also be a problem for another proposed solution that is built into the Bayh–Dole Act itself: a funding government agency including exercise of the "march-in" provision under Bayh–Dole. This provision allows the agency to grant what are effectively compulsory licenses to third parties under four circumstances: where the patentee is not expected to achieve "practical application" of the patented invention within "reasonable time"; where necessary to address health and safety needs; where necessary to meet requirements for public use specified under federal law; or to ensure that any manufacturing is substantially domestic.[272] Although government agencies have been known to use the threat of march-in rights to encourage patent licensing,[273] Bayh–Dole's march-in rights have never been exercised, perhaps because of fears that such government action would have the overall effect of deterring investment in downstream development of government-funded upstream research.[274] Government agencies may also not be best situated to make informed and impartial decisions about how to best exploit a funded invention, as university faculty often have closer relationships with private industry and more familiarity with the technology at issue.[275]

Private ordering is also one way to reduce transaction costs, and is in particular an approach that can benefit from the unique position of universities within the market place. Universities and other patent holders can opt to contribute their patents to patent portfolios, patent pools, open-source pools, collective-rights organizations, or research and development consortia, all of which are ways of

271. Robert P. Merges, *Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 CAL. L. REV. 1293, 1307–16 (1996); Rai, *supra* note 188, at 843.

272. 35 U.S.C. § 203; Arno & Davis, *supra* note 21, at 647–48 & n.93; Rai & Eisenberg, *supra* note 32, at 294.

273. BNA, *supra* note 22, at 23.

274. *See, e.g.*, Burk & Lemley, *supra* note 73, at 1682. A government agency also has the right under Bayh–Dole to restrict patenting on funded research in "exceptional circumstances," where barring patenting "will better promote the policy and objectives" of Bayh–Dole. 35 U.S.C. § 202(a)(ii); *see also* Rai & Eisenberg, *supra* note 32, at 293–94; Peter Lee, *Contracting to Preserve Open Science: Consideration-Based Regulation in Patent Law*, 58 EMORY L.J. 889, 924 (2009). The elaborate administrative procedures necessary to invoke this right are prohibitive, however. Rai & Eisenberg, *supra* note 32, at 293.

275. Eisenberg, *supra* note 3, at 1700; Rai & Eisenberg, *supra* note 32, at 304–05.

making their patents more available for use.[276] For example, patents collected into patent pools and portfolios can be licensed in one lump transaction in a way more tailored than a compulsory license because the license can be informed by the patent holders' knowledge of the industry.[277] Universities may be even more likely than private firms to contribute their patents to a pool, as uncertainty as to the value of their patents may make universities less likely to behave strategically.[278] Forming and managing patent pools may incur high transaction costs, however, as it is often difficult to determine which particular patents should be included in the patent pool and how to value those patents.[279] In addition, the uncertain value of universities' often early-stage patents could further exacerbate these costs, as could the universities' divergent interests and goals.[280] Government assistance may therefore be necessary in forming patent pools,[281] but given funding agency rights under Bayh–Dole, theoretically, at least, a government agency might have an easier time coaxing university patents into pools than might be the case with privately held patents.[282] The government may nevertheless be reluctant to encourage patent pool formation, as patent pools can pose antitrust concerns.[283] Thus, where transaction costs are particularly burdensome, universities may be better off sticking to their default and dedicating their research to the public domain, a tactic that even many private firms have adopted by putting their own research into public-domain consortia.[284]

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276. *See* A PATENT SYSTEM, *supra* note 100, at 72; Lee, *supra* note 274, at 915–16; Lemley, *supra* note 14, at 623–28; Merges, *supra* note 271 *passim*; Rai, *supra* note 188, at 845–46; Shapiro, *supra* note 128, at 119.

277. Alexander Lee, *Examining the Viability of Patent Pools for the Growing Nanotechnology Patent Thicket*, 3 NANOTECH L. & BUS. 317 (2006); Merges, *supra* note 271, at 1295–96. The late Professor Richard Smalley's patents on fullerenes, carbon nanotubes, and "bucky balls" are an example of a patent portfolio. *See, e.g.*, Donald J. Featherstone et al., *Carbon Nanotubes: Survey of the Smalley Patent Portfolio*, 9 NANOTECH. L. & BUS. 35 (2012).

278. Arti K. Rai, *Proprietary Rights and Collective Action: The Case of Biotechnology Research with Low Commercial Value*, *in* INTERNATIONAL PUBLIC GOODS AND TECHNOLOGY TRANSFER OF TECHNOLOGY IN A GLOBALIZED INTELLECTUAL PROPERTY REGIME 288, 298–301 (Keith E. Maskus & Jerome H. Reichman eds., 2005).

279. Merges, *supra* note 271, at 1254–57.

280. Scott Iyama, Comment: *The USPTO's Proposal of a Biological Research Tool Patent Pool Doesn't Hold Water*, 57 STAN. L. REV. 1223, 1231–34 (2005); David W. Opderbeck, *The Penguin's Genome, or Coase and Open Source Biotechnology*, 18 HARV. J.L. & TECH. 167, 219–22 (2004); Rai, *supra* note 188, at 846–47.

281. Merges, *supra* note 271, at 1356–57.

282. *See supra* text accompanying notes 273–274 (discussing the threat power that funding government agencies can wield under Bayh–Dole's march-in provisions).

283. Rai, *supra* note 188, at 848–49.

284. Rai & Eisenberg, *supra* note 32, at 298–99. For example, the Single Nucleotide Polymorphism ("SNP") Consortium is a public-domain pool formed by the United Kingdom's

IV. UNIVERSITY PATENTING UNDER BAYH–DOLE AS (MOSTLY) IRRELEVANT

As this author has argued elsewhere, the most likely scenario is that, despite the marked rise in university patenting, most of those patents are simply not that important to downstream development, particularly in science-based technologies.[285] When we take a closer look, we can see that long development cycles, difficulties in attracting private investment, limited access to materials and equipment, high dependence on tacit knowledge, low expected commercial values, multidisciplinarity, and regulatory hurdles all pose much more significant factors than upstream patents in science-based fields such as biotechnology and nanotechnology. Science-based fields arise from university research, but—even when present—access or lack of access to upstream university research patents often take a back seat to other more salient factors that are characteristic of such technologies.

A. Science-Based Technologies Face High Technological Obstacles to Development

Science-based fields often explore new areas quite different from existing art, and patents in these fields are therefore typically complex but unpredictable and embryonic, with high failure rates and long development cycles.[286] On the other hand, imitation costs in science-based technologies are also high, creating a natural level of non-patent exclusivity; limited supplies of necessary materials and expertise can also obstruct entry by others. The technical barriers and uncertainties are thus often much more rate-limiting than patents to further research and development,[287] and may explain private industry's continued underinvestment in downstream development of university research.[288] The following is a brief listing of some of these technological barriers.

Wellcome Trust along with ten major pharmaceutical companies in 1999 to facilitate research into large-scale associations between genotypes and disease states. *Id.* at 298; *see also* Robert P. Merges, *A New Dynamism in the Public Domain*, 71 U. CHI. L. REV. 183, 189–90 (2004).

285. *See generally* Morris, *supra* note 15.

286. Merges & Nelson, *supra* note 58, at 880, 907–08; Mowery, *supra* note 46, at 44–45 (and sources cited therein); Nelson, *supra* note 43, at 457–59.

287. Adelman, *supra* note 18, at 124–25.

288. McManis & Noh, *supra* note 114, at 447.

1. *Tacit Knowledge*

Researchers often have a tacit understanding of their art that is too difficult to share or acquire without hands-on training to overcome established paradigms.[289] Tacit knowledge is common in science-based technologies,[290] where there are potentially large differences from the prior art. Tacit knowledge is critical to downstream developments as well and requires participation by the inventing researcher, thus limiting the potential for open competition among downstream developers.[291] In this way tacit knowledge provides effective exclusivity that can extend and even eclipse other types of exclusivities, including patent protection and first-mover advantages.[292] Tacit knowledge can remain tacit for only so long, however, and as understanding of a new technology matures and procedures and equipment become standardized, others will gain access to the technology. Exactly how long tacit knowledge will pose a barrier to entry varies with the technology at issue. For instance, tacit knowledge was not an issue for the widespread adoption of Columbia's patented co-transformation process for producing large volumes of high-quality proteins, as the biotechnology research community was able to master the process very quickly.[293] Nonetheless, at least one study suggests that, on average, the effective exclusivity based on tacit knowledge and access to research tools extends anywhere from ten to twenty years, depending on the discipline.[294]

As a means of sharing tacit knowledge, however, universities have created technology incubators and research and science parks to enable closer relationships between universities and private industry for joint projects, consultation, and the like.[295] University-

289. *See generally* Lee, *supra* note 13; Lee, *supra* note 139; *see also* Pedraza-Fariña, *supra* note 268, at 820 (referring to the need for "intellectual migration" from one technological paradigm and practice to another).

290. *See* Michael R. Darby & Lynne G. Zucker, *Grilichesian Breakthroughs: Inventions of Methods of Inventing and Firm Entry in Nanotechnology*, 19 (Nat'l Bureau of Econ. Research, Working Paper No. 9825, 2003), http://www.nber.org/papers/w9825; Jensen & Thursby, *supra* note 36; Rothaermel & Thursby, *supra* note 87, at 833, 846–47.

291. Thursby & Thursby, *supra* note 121, at 1052 (and sources cites therein). Estimates indicate that somewhere between 40% and 71% of licensed university research requires faculty involvement to be successfully commercialized. Rothaermel & Thursby, *supra* note 87, at 1078–79 (and sources cited therein).

292. *See generally* Darby & Zucker, *supra* note 290; Rothaermel & Thursby, *supra* note 87, at 1078–79.

293. Lowe et al., *supra* note 131, at 158.

294. Rothaermel & Thursby, *supra* note 87, at 1087–88.

295. BNA, *supra* note 22, at 266–67; Matthew M. Mars & Sherry Hoskinson, *The Organizational Workshop: A Conceptual Exploration of the Boundary Spanning Role of University Entrepreneurship and Innovation Centers*, *in* 21 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH: SPANNING BOUNDARIES AND DISCIPLINES: UNIVERSITY TECHNOLOGY COMMERCIALIZATION IN THE IDEA AGE 119 (Gary D.

based start-up companies also have become a growing phenomenon in the last thirty years or so,[296] and may be a useful conduit for transferring tacit knowledge as well as providing access to research tools and materials.[297] Faculty researchers and their graduate students are commonly active participants in university-based start-ups, as well as in private industry more generally, as research scientists now regularly move between universities, and industry and private firms host postdoctoral fellows.[298] Faculty relationships with industry are often pivotal for licensing as well, and personal relationships rather than arm's length marketing is often necessary for the commercialization of university research.[299]

2. *Limited Access to Equipment and Materials*

Evidence suggests that access to research materials, equipment, and facilities can often create greater obstacles to development of downstream applications of university research than patents do.[300] Universities are often perceived as surprisingly proprietary over their materials and instruments,[301] and materials transfer agreements often include reach-through royalty provisions or limitations on patenting the resulting research.[302] That being said, limitations on sharing research materials may be due to restrictions imposed under industry-sponsored research agreements,[303] to the need to attract such industry investment,[304] to the general increase in proprietary attitudes accompanying the increase in patenting, or to all of

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Libecap et al. eds., 2010); Rothaermel & Thursby, *supra* note 87 *passim*; Siegel & Phan, *supra* note 123 *passim*.

296. BNA, *supra* note 22, at 261. *But see* Kesan, *supra* note 37, at 2189 (finding evidence that university-based start-ups remain an infrequent form of technology transfer).

297. BNA, *supra* note 22, at 261.

298. Lee, *supra* note 139, at 47; Scott Shane, *Selling University Technology: Patterns from MIT*, 48 MGMT. SCI. 122 (2002).

299. Samuel Estreicher & Kristina A. Yost, *University IP and the Team Production Model: Why Change What's Not Broken?*, 13–14 (N.Y.U. Pub. L. & Legal Theory, Working Paper No. 489, 2014), http://lsr.nellco.org/nyu_plltwp/489; Siegel et al., *supra* note 46, at 29–30.

300. Adelman, *supra* note 28, at 986–87; Eisenberg, *supra* note 134, at 1063–75; Eisenberg, *supra* note 16, at 197–205.

301. BNA, *supra* note 22, at 215–16.

302. Mowery & Ziedonis, *supra* note 113, at 159.

303. BNA, *supra* note 22, at 241; Katherine J. Strandburg, Sharing Research Tools and Materials: Homo Scientificus and User Innovator Community Norms 14 (May 23, 2008) (unpublished manuscript) (electronic copy available at http://ssrn.com/abstract=1136606 or http://dx.doi.org/10.2139/ssrn.1136606).

304. James Flanigan, *Entrepreneurial Edge: Collaborating for Profits in Nanotechnology*, N.Y. TIMES, July 15, 2009, at B6, http://www.nytimes.com/2009/07/16/business/smallbusiness/16edge.html?_r=0.

the above.[305] The National Institutes of Health proposed standardized materials transfer agreements, at least as between similarly situated research institutions such as universities,[306] but this proposal does not seem to have gained much traction.[307]

That being said, industry-based "precompetitive" research and development consortia have also recently evolved to share research and development resources, such as research tools and materials, as well as data.[308] These precompetitive consortia are an effective means of providing public access to otherwise proprietary materials, as the consortia allow multiple downstream developers to share foundational resources. Precompetitive consortia are difficult to organize, however, and face steep transaction costs that may also require governmental intervention to overcome.[309] To the extent that university-based start-ups make use of university research tools and materials, start-ups can provide the commercial sector with at least some, albeit again limited, access to tools and materials over which the university might exert proprietary rights.[310]

3. *Long Development Cycles*

Research and development cycles in science-based technologies can take many years. Taking research-intensive technologies from laboratory proofs of concept to industrial practice, for example, often necessitates a great deal of further development to allow the invention to be reliably reproduced and used at commercial levels in a cost-efficient manner.[311] Patent terms last for twenty years, but a development cycle may take so long that patents on upstream

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305. BNA, *supra* note 22, at 429; Rebecca S. Eisenberg, *Bargaining Over the Transfer of Proprietary Research Tools: Is This Market Failing or Emerging?*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY: INNOVATION POLICY FOR THE KNOWLEDGE SOCIETY 223, 225 (Rochelle C. Dreyfuss et al. eds., 2001); Mowery & Ziedonis, *supra* note 113, at 159.

306. Uniform Biological Material Transfer Agreement: Discussion of Public Comments Received; Publication of the Final Format of the Agreement, 60 Fed. Reg. 12771–01 (Mar. 8, 1995); Lee, *supra* note 274, at 925; Rai, *supra* note 3, at 113 & nn.201–04.

307. Rai & Eisenberg, *supra* note 32, at 289, 305–06; Rai, *supra* note 3, at 113.

308. BNA, *supra* note 22, at 299; Herder, *supra* note 249, at 218–20; Liza S. Vertinsky, *Patents, Partnerships, and the Pre-Competitive Collaboration Myth in Pharmaceutical Innovation*, 48 U.C. DAVIS L. REV. 1509, 1553 (2015).

309. Herder, *supra* note 249, at 218–20.

310. *See supra* text accompanying notes 296–298 (discussing university-based start-ups).

311. Philip E. Auerswald & Lewis M. Branscomb, *Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States*, 28 J. TECH. TRANSFER 227, 229 (2003); Thomas A. Kalil, *Nanotechnology and the "Valley of Death,"* 2 NANOTECH. L. & BUS. 265, 265–66 (2005).

research inputs may expire in the meantime.[312] Foundational inventions in particular may be used through several development cycles, such that their patents expire long before their utility does.[313] In the meantime, both patentees and potential infringers may simply overlook patent rights in the name of research. In fact, lengthy time lags and long development cycles are common to many research-based fields such as physics, mathematics, and the physical sciences.[314] Long development cycles, significant technical barriers, and the consequent uncertainty inherent in development of science-based technologies can slow research and development much more than patents can.[315]

B. *Science-Based Technologies Face High Non-Technological Obstacles to Development*

Given the long development cycles common in science-based technologies, potential investors may often be nervous about when development will be complete and when they can begin to see returns on their investments. Given science-based technologies' complexity and its dependence on access to materials, equipment, and faculty expertise, investors may also be nervous that these technological hurdles will prevent development from being completed at all. All of the uncertainties inherent in the development process make these fields unattractive investment risks.[316] Even if and when development is complete, applications stemming from science-based technologies may still encounter other hurdles. Because science-based technologies often present a leap from known technologies, development in these fields may face further uncertainty about not only market appeal but also other issues, such as health and safety ramifications.[317] Whether an invention is successfully commercialized often depends not so much on the technological or other merits

312. Adelman, *supra* note 28, at 1015–16; Sichelman, *supra* note 7, at 366.

313. Adelman, *supra* note 28, at 1015–16.

314. Merges & Nelson, *supra* note 58, at 880; Mowery, *supra* note 46, at 43.

315. Adelman, *supra* note 18, at 124–25.

316. Mowery, *supra* note 46, at 42–43 (and sources cited therein); Ramirez, *supra* note 86, at 378; ChunHsien Wang et al., *A Study of Nanotechnology R&D Alliance Networking*, 2012 PROC. PICMET '12: TECH. MGMT. FOR EMERGING TECHNOLOGIES 3497 *passim*.

317. For example, well-known nanotechnology pioneer Eric Drexler opines that the possibility of regulatory restrictions and potential liability for consumer, environmental, or other harms have led to public fears and lack of enthusiasm for the field and negatively influenced private and even government funding in nanotech R&D. K. ERIC DREXLER, ENGINES OF CREATION: THE COMING ERA OF NANOTECHNOLOGY (1st ed. 1986).

of an invention but on concurrent developments, industry conditions, and the existence of complementary goods and services.[318] These additional uncertainties make investments in these areas even more unattractive—indeed, the difficulties of attracting interest and investment in science-based technologies are frequently a much more intractable problem than is the need to license upstream or complementary patents.[319] Patents and transaction costs undoubtedly exacerbate the difficulties of developing complex technologies, but what may most deter private capital from investing in science-based technologies is the complexity and uncertainty inherent in much of the downstream development in these fields. Indeed, identifying potential licensees is one of the most difficult obstacles for TTOs to overcome.[320]

Venture capitalists and other investors generally will not invest in the early stages of technologies with long R&D cycles, preferring to wait until development projects are closer to completion in order to minimize risk and maximize the time-value of their funds.[321] University inventions in particular suffer from higher failure rates,[322] with up to half of all university inventions failing during commercialization.[323] University patents are often so embryonic that the expected value of any possible commercial end products will be too low to attract private industry interest.[324] Under these circumstances, private industry, angel investors, venture capitalists, and others are understandably reluctant to invest until they have further information on the potential commercial value of developing upstream research.[325] The information gap between pri-

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318. Abramowicz, *supra* note 7, at 1071; Siegel & Phan, *supra* note 123 *passim* (noting effect of these factors on success in commercializing university inventions).

319. *Cf.* Burk & Lemley, *supra* note 73, at 1622–23 (noting that earlier patents on now-obsolete software can still hinder future development because of software's short life cycle).

320. Osenga, *supra* note 29, at 421.

321. George S. Ford et al., *A Valley of Death in the Innovation Sequence: An Economic Investigation*, 4 (Phx. Ctr. for Advanced Legal & Econ. Pub. Pol'y Studies, Discussion Paper, 2007), http://ssrn.com/abstract=1093006; Frischmann, *supra* note 31, at 172 (noting private discount rates are higher than social discount rates); Rachel Lorey Allen, *Venture Capital Investment in Nanotechnology*, JONES DAY PRACTICE PERSPECTIVES: NANOTECHNOLOGY, *available at* http://www.jonesday.com/practiceperspectives/nanotechnology/venture_capital.html (last visited Jan 5, 2016).

322. Rothaermel & Thursby, *supra* note 87, at 1078.

323. Emmanuel Dechenaux et al., *Appropriability and Commercialization: Evidence from MIT Inventions*, 54 MGMT. SCI. 893, 894 (2008).

324. Abramowicz, *supra* note 7, at 1094; Rothaermel & Thursby, *supra* note 87, at 1078.

325. *See, e.g.*, Stuart J. H. Graham & Maurizio Iacopetta, *Nanotechnology and the Emergence of a General Purpose Technology*, 115–116 ANNALS ECON. & STAT. 5, 8–9 (2014); Atul Nerkar & Scott Shane, *Determinants of Invention Commercialization: An Empirical Examination of Academically Sourced Inventions*, 28 STRATEGIC MGMT. J. 1155 *passim* (2007).

vate interests and university researchers can thus create insurmountable obstacles to downstream development, a transaction cost independent of any patent protection. Only over time, as the perceived risk attenuates, do venture capitalists and other potential investors develop the necessary comfort level to invest in fundamentally new technologies. The resulting gap in investment between upstream research and downstream end products in the meantime is often referred to as the "valley of death," a well-recognized problem for science-based technologies.[326]

For development projects that are too uncertain and risky to attract private funding, several agencies now offer government funding.[327] Enacted in 1982, the Small Business Innovation Research ("SBIR") program allows federal agencies to grant funds to small businesses for the commercialization of government-sponsored R&D.[328] The Small Business Technology Transfer ("STTR") subpart of SBIR also funds collaborations between private industry and nonprofit educational and research facilities.[329] In the late 1980s, Congress also created the Advanced Technology Program ("ATP") to provide matching funds for private investments in early-stage technological developments that face significant risk but are likely to yield significant broad-based benefits.[330] Overall, government funding steps in to provide about twenty to twenty-five percent of all funds for early-stage technology development,[331] with state governments also increasingly providing public funds for the same purposes, such as funding university start-ups.[332]

And to a lesser extent, university-based start-ups may also help bridge the valley of death. Although larger (or at least established) firms might have more expertise in commercializing and marketing generally,[333] start-ups offer their own advantages.[334] University start-ups generally are more nimble and less risk-averse than both universities and larger firms,[335] and to the extent that they are

326. Gunter Festel et al., *Importance and Best Practice of Early Stage Nanotechnology Investments*, 7 NANOTECH. L. & BUS. 50, 58 (2010); Kalil, *supra* note 311.

327. BNA, *supra* note 22, at 285–86.

328. Kalil, *supra* note 311, at 267.

329. BNA, *supra* note 22, at 285; Liza Vertinsky, *Universities as Guardians of Their Inventions*, 2012 UTAH L. REV. 1949, 2007.

330. Kalil, *supra* note 311, at 266; Charles W. Wessner, *Driving Innovations Across the Valley of Death*, 48 RES.-TECH. MGMT. 9, 9–10 (2005).

331. Auerswald & Branscomb, *supra* note 311, at 232.

332. Michael MacRae, *Commercializing University Research*, AM. SOC'Y MECH. ENG'RS (Mar. 2011), https://www.asme.org/engineering-topics/articles/high-tech-startups/commercializing-university-research.

333. BNA, *supra* note 22, at 261–62.

334. Chukumba & Jensen, *supra* note 159, at 4, 21 (and sources cited therein).

335. BNA, *supra* note 22, at 261–62; Rothaermel & Thursby, *supra* note 87, at 1087.

funded through alternatives to private investment, university start-ups also represent an intermediate step that can lessen the risk of later commercialization investments.[336] Currently only a small percentage of licensed university research is introduced through start-ups rather than through more established firms, although the numbers may be growing.[337]

Overall, the relative unimportance of patents to the likelihood of development of university research helps explain why so little of eligible university research is patented, much less licensed.[338] Moreover, to the extent that universities do opt to patent, many of those patents will probably not be worth maintaining; universities may often decide to allow their patents to fall into the public domain through failure to pay maintenance fees on the patents.[339] For example, Pennsylvania State University recently auctioned fifty-nine of its engineering patent portfolios that it had been unable to license. The auction yielded buyers for only two of its patents, but the university noted that the auction was nonetheless a useful insight into which patents the university would now consider allowing to lapse due to non-payment of maintenance fees.[340] Indeed, Professor Kimberly Moore's study of renewal rates for patents issued in 1991 suggests that early-stage patents display higher non-renewal rates where development costs are high and where private industry shows little interest.[341]

V. CONCLUSION

The question of whether the Bayh–Dole Act and the consequent rise in university patenting are worth the costs is a highly relevant

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336. Heller & Eisenberg, *supra* note 14, at 698.

337. MILLER ET AL., *supra* note 186, at 33–37; Mowery, *supra* note 46, at 53.

338. Love, *supra* note 17, at 303–04; Walsh et al., *supra* note 100, at 309.

339. *Cf.* Kimberly A. Moore, *Worthless Patents*, 20 BERKELEY TECH. L.J. 1521 (2005) (using failure to pay maintenance fees as measure of patent value). Increasing maintenance fees must be paid at 3.5 years, 7.5 years, and 11.5 years after a patent is issued; failure to pay any of these fees leads to patent expiration in six months. *Id.* at 1525.

340. Goldie Blumenstyk, *Penn State's Patent Auction Produces More Lessons Than Revenue*, CHRON. HIGHER ED., (May 1, 2014) http://chronicle.com/blogs/bottomline/penn-states-patent-auction-produces-more-lessons-than-revenue/; Neil Kane, *Patents for Sale: How to Separate the Valuable from the Worthless*, FORBES, (May 22, 2014, 10:35 PM), http://www.forbes.com/sites/neilkane/ 2014/05/22/a-modest-proposal-for-licensing-patents/. One of the reasons that Penn State sold so few patents may have been the restrictions that the university placed on the auction to prevent so-called patent trolls—non-practicing entities that use patents to extract rents from unknowing infringers—from acquiring the patents. *Id.* *Cf.* NRC, *supra* note 102, at 6 (advocating against university patent sales to patent aggregators and other non-practicing entities).

341. Moore, *supra* note 339, at 1534, 1544, 1547–48 (noting this phenomenon in biotech, pharmaceutical and chemical fields).

one, as a variety of national as well as state governments have implemented legislation similar to the Bayh–Dole Act.[342] If patenting does in fact encourage the application and commercialization of university research as intended, then the Bayh–Dole Act is perhaps worth replicating. The public may be "paying twice" for government-funded research as a result, but better that the public should pay twice and receive the benefit of that research in terms of useable applications, than to receive no such benefit because no one was willing to invest in developing those applications. If, on the other hand, university patents cause the opposite effect by creating anticommons and other obstacles to downstream development, as many critics fear, then perhaps Bayh–Dole, patent law, or both ought to be modified accordingly. It is entirely possible and perhaps probable, however, that upstream patenting is simply unimportant and does little or nothing either to facilitate or to frustrate the commercialization of government-funded research, and that other factors are more determinative of whether upstream research will be developed into marketable applications. If university and other upstream research patents have so little effect, then the various concerns about, and proposed solutions to, the perceived problems with the Bayh–Dole Act are beside the point. All the same, this rather simple summary of the issues misses a couple of crucial considerations.

First, and most importantly, university research is variable in its characteristics; in science-based fields, research tends to be very early-stage and uncertain in value, but in more applied fields, such as engineering, research may be closer to a ready-to-apply form. Likewise, downstream development of university research is highly variable and cannot be expected to follow any uniform pattern.[343] Which of the three scenarios presented above will obtain for any given downstream application will depend on a number of variables, of which university patenting under the Bayh–Dole Act is merely one of many. The effect of the Bayh–Dole Act and its related statutes are therefore hardly monolithic in their effect and will vary greatly across technologies and developmental pathways.[344]

342. Mireles, *supra* note 27, at 265; Osenga, *supra* note 29, at 417; Estreicher & Yost, *supra* note 299, at 24.

343. *Cf.* Burk & Lemley, *supra* note 73, at 1577 ("Technology is anything but uniform . . . [and] . . . demonstrates deep structural differences in how industries innovate."); Merges & Nelson, *supra* note 58, at 843, 866–67 (effect of upstream patenting varies with technology in question).

344. Burk & Lemley, *supra* note 73, at 1584–87; Frischmann, *supra* note 31, at 156–57; Merges & Nelson, *supra* note 58, at 843 ("[T]he issues at stake regarding patent scope depend on the nature of technology in an industry.").

Second, the scenarios described above are not mutually exclusive of one another. Development of one particular application may be held up by both lack of funding and lack of access to patented research tools if the downstream firm does not receive the blessing of the inventing faculty member, whereas development of a different application of that same technology may be facilitated by access to both tacit knowledge and relevant upstream patent rights if the downstream firm has an established relationship with the inventing faculty member. The effect of upstream research patenting depends greatly on the nature of the particular end product at issue, as well as the nature of the market into which that product will be introduced.[345] And, of course, the nature of the specific upstream invention to be developed into an end product will also influence its downstream path.[346] Indeed, any given development project might fall into more than one of the scenarios described above, depending on which part of the end product and its innovation cycle one focuses. Part of a product may have necessitated the coordination of multiple patents, while other parts involve significant tacit information, and yet other parts may depend on significant pre- and post-invention investments attracted by strong upstream patent rights. A few generalizations nonetheless can be made.

First, patents on upstream university research may be particularly valuable where commercialization costs are high, where neither cumulative nor complementary innovation are prevalent, and where imitation costs are particularly low.[347] The potential for patent exclusivity may also help attract private investment both in the pre-invention and post-invention stages, while the addition of some level of government funding may help reduce the risk of such investments, further incentivizing private funding.

Second, patents on "basic" or "upstream" research will not necessarily have enough preemptive breadth to create a risk of patent-induced hold-up problems.[348] Upstream patents may require a good deal of downstream development to be of commercial value, but still can be easily designed around or replaced with meaningful substitutes.[349] A patent that covers one of the few foundational or "common-method research tools," on the other hand, can have significant

345. *See generally* Graham & Iacopetta, *supra* note 325; Mossoff, *supra* note 167, at 204.
346. Nerkar & Shane, *supra* note 325, at 1163.
347. Burk & Lemley, *supra* note 73, at 1615–17; Kieff, *supra* note 26, at 747.
348. Adelman, *supra* note 28, at 1021.
349. *See* Kieff, *supra* note 26, at 730–31 (noting that the availability of market alternatives limits patent holders' power to set price).

preemptive power on a wide range of downstream developments.[350] Foundational research tools may also be the least likely to need exclusivity as a means of protecting and incentivizing further development in order to be adopted by others and commercialized.[351] Thus, if such foundational but "ready to use" research tools have been invented using government funds, the argument for intellectual property protection after the fact is particularly lacking; at the very least, broad and low-royalty licensing should be strongly encouraged.

Third, risk-aversion and the valley of death as well as other obstacles unrelated to patenting play significant roles in the development of science-based technologies. Where access to materials, tools, and tacit knowledge are more rate-limiting than patents, greater emphasis should be placed on creating depositories or consortia to provide wider access to these resources. And although the Bayh–Dole Act tried to address mismanagement of upstream research by privatizing its ownership, perhaps more government support, such as further funding to close the valley of death, rather than privatization through patenting, is the more effective solution.

350. Adelman, *supra* note 28, at 1020–21. Similarly, the cost of licensing patented diagnostic tests and other "downstream" technologies can often be prohibitive in clinical research. A PATENT SYSTEM, *supra* note 100, at 73; NRC, *supra* note 102, at 39–40.

351. Colyvas et al., *supra* note 46, at 65.