Policy Challenges of Open, Cumulative and User Innovation

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Introduction

The work of Alfred D. Chandler, Jr. has chronicled the development of the leading industrial firms such as GM and DuPont. In Chandler's telling, such modern American industrial firms in the first half of the 20th century emerged through an integrated value chain linking R&D, manufacturing and distribution.[2]

In 2003, Henry Chesbrough argued that the Chandlerian paradigm of vertical integration had become obsolete, both in theory and practice.[3] Studying companies such as IBM and Proctor & Gamble, he described an emerging "open innovation paradigm" in which firms work beyond their boundaries to obtain and commercialize innovation, a paradigm that has heavily influenced recent research in innovation. However, Chesbrough is neither the first nor only scholar to suggest that actual (or best) practice of innovation goes beyond the boundaries of the firm.

Two other broad streams of innovation research explicitly span organizational boundaries. One is the user innovation paradigm developed by Eric von Hippel, focusing on the role of informed users in improving and extending products.[4] The other stream in

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2 See, for example, Alfred D. Chandler, Jr., *The visible hand: the managerial revolution in American business,* Cambridge, Mass.: Belknap Press, 1977 and Alfred D. Chandler, Jr., *Scale and scope: the dynamics of industrial capitalism*, Cambridge, Mass.: Belknap Press, 1990.

3 Henry Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press (2003). See also the papers presented in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006) as well as the special issue introduced by Oliver Gassmann, "Opening up the innovation process: towards an agenda," R&D MANAGEMENT, 36 (3) 223-226 (June 2006).

4 Eric von Hippel, *The Sources of Innovation*. New York: Oxford University Press, 1988.

economics and sociology considers the cumulative innovation efforts across various (often competing) firms, exemplified by the work of Suzanne Scotchmer.[5]

These three critiques share an interorganizational perspective, but consider different sources of innovation outside the firm (Table 1). Here I contrast the implications of these three theories of interorganizational innovation[6] for the Chandlerian model of industrial innovation. I then suggest the potential impact of various public policies upon such interorganizational innovation and suggest opportunities for research in this area.

Contrasting Models of Interorganizational Innovation

Here I compare the three major perspectives on interorganizational innovation: the focus on user-contributed innovations, collective and cumulative innovation and open innovation.

Von Hippel: User Innovation

With his original study *The Sources of Innovation,* von Hippel argues that many firms have successfully found ideas for commercially important innovations outside the firm. While the book mentions suppliers as a possible source, the main emphasis (and application) of von Hippel's ideas has come with buyer innovation, particularly at the individual level. For example, in his 2005 book *Democratizing Innovation* the goal is

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5 Suzanne Scotchmer, *Innovation and incentives*, Cambridge, Mass.: MIT Press, 2004 provides the first complete explanation of the theoretical and practical imperatives behind policies promoting cumulative innovation, but other key work includes Nancy Gallini and Suzanne Scotchmer, "Intellectual Property: When Is It the Best Incentive System?" in Adam B. Jaffe, Joshua Lerner and Scott Stern, editors, *Innovation Policy and the Economy,* Cambridge, Mass.: MIT Press, 2003, pp. 51-77, and Fiona Murray and Siobhán O'Mahony, "Exploring the Foundations of Cumulative Innovation: Implications for Organization Science," ORGANIZATION SCIENCE 18 (6), 1006-1021 (2007).

6 When individual users are providing innovations to an organization, the modifier "extra-organizational" might be more accurate than "interorganizational" innovation. For simplicity's sake, the term "interorganizational innovation" is used herein to subsume all manifestations and extensions of the user, cumulative and open innovation frameworks.

defined as documenting that "users of products and services—both firms and individual consumers—are increasingly able to innovate for themselves".[7]

The user innovation paradigm has received the broadest application in the study of open source software, which arose in the 1980s as an alternate means of production for an information good, in which (stereotypically) the software is developed by a loosely organized federation of individual users. Such an open source project is exemplified by one of the most successful (and studied) open source projects, the Apache open source web server. Based on the university-developed NCSA server, Apache was developed by a group of webmasters beginning in 1995 to solve their own needs.[8] This illustrates how the user innovation paradigm was consonant with both the practice and the motivations of individual open source programmers, which has been captured by Raymond's oft-quoted aphorism that "Every good work of software starts by scratching a developer's personal itch."[9]

Research on user innovation in open source has examined both the benefits and origins of user-contributed innovations, as well as approaches towards facilitating user innovation through technical design choices.[10] Other researchers have extended this approach beyond software to sporting goods and music software.[11]

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7 Eric von Hippel, *Democratizing Innovation*. Cambridge, Mass.: MIT Press, 2005, page 1.

8 Brian Behlendorf, "Open Source as a Business Strategy" in OPEN SOURCES: VOICES FROM A REVOLUTION (Chris DiBona, Sam Ockman and Mark Stone, eds., O'Reilly, 1999).

9 Eric S. Raymond, *The Cathedral and the Bazaar,* O'Reilly, 1999.

10 Among the broad pool of research on user innovation in open source, the contributions are discussed in Karim R. Lakhani and von Hippel, Eric, "How open source software works: 'free' user-to-user assistance," RESEARCH POLICY, 32(6): 923-943 (2003) and also Georg von Krogh, Sebastian Spaeth and Karim R. Lakhani, "Community, joining, and specialization in open source software innovation: a case study," RESEARCH POLICY 32 (7), 1217-1241 (2003). For user innovation toolkits, see Nikolaus Franke and Eric von Hippel, "Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software,"

Nearly all of the user innovation literature has focused on the actions of autonomous individuals, acting out of their own motivations. However, Von Hippel's original studies of user innovation included business users modifying products for work-related use, as with engineers improving electronic instruments.[12] The theory has rarely been used to apply to corporate motivations for contributing innovations, which would be more consonant with the open innovation approach. As such, open innovation may be more appropriate for explaining the self-interested role of corporations in creating open source software, particularly for firms that create such software not for their own use, but to support the sale of other goods and services.[13]

Scotchmer: Cumulative Innovation

A second stream of interorganizational innovation is derived from the observation that technological progress is built upon a sequence of technical advances, both large and small.

While the innovation literature, patent system, fame and fortune are often oriented towards rewarding breakthrough innovation, most technologies are refined through a constant stream of incremental improvements. Even if a new technology starts as the

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RESEARCH POLICY, 32 (7): 1199-1215 (2003) **(as well as earlier von Hippel toolkit papers?)**

11 For sporting goods, see Nikolaus Franke and Sonali Shah, "How communities support innovative activities: an exploration of assistance and sharing among end-users," RESEARCH POLICY 32 (1), 157-178 (2003) and Christoph Hienerth, "The commercialization of user innovations: the development of the rodeo kayak industry," R&D MANAGEMENT, 36 (3) 273-294 (2006). For computer synthesized musical instruments, see Lars B. Jeppesen and Lars Frederiksen, "Why Do Users Contribute to Firm-Hosted User Communities? The Case of Computer-Controlled Music," ORGANIZATION SCIENCE, 17 (1), 45-63 (2006)

12 See von Hippel *supra* note 4.

13 For an explanation of how firms employ open innovation strategies with open source software, see Joel West and Scott Gallagher, "Challenges of open innovation: the paradox of firm investment in open-source software," R&D MANAGEMENT, 36 (3), 319-331 (2006).

product of one firm, it usually attracts a host of new and existing competitors that seek to improve upon the original breakthrough.

Thus, the cumulative innovation literature considers the role of this interdependence of producers — and the consequential flows of information — within an industry for developing and refining a new technology. Building upon the "collective invention" work of Robert Allen, this stream is most recently associated with the work of Scotchmer.[14]

This body of work considers two different manifestations of cumulative innovation. In the first, various parties successively refine a single technology until the improved technology is widely used by a range of producers. Two well-documented examples of cooperation among competitors during the English industrial revolution are the blast furnace and the Cornish mining pump.[15] This pattern also continued into the 20th century, was with the development of lasers and open source software.[16] Such shared leadership of technological progress — a diversified innovation base — means that progress does not depend on any one individual or firm. In many cases, this diversified base is essential both to the development and production of these innovations.

Cumulative innovation can also result from the combined innovation efforts of multiple users. A number of the aforementioned studies on user innovation center on the

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14 Robert C. Allen, "Collective Invention," JOURNAL OF ECONOMIC BEHAVIOR AND ORGANIZATION, 4 (1), 1-24 (1983); Suzanne Scotchmer, "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law," JOURNAL OF ECONOMIC PERSPECTIVES, 5 (1), 29-41 (1991); and Scotchmer, *supra* note 5.

15 Respectively Allen *supra* note 14 and Alessandro Nuvolari, "Collective invention during the British Industrial Revolution: the case of the Cornish pumping engine," CAMBRIDGE JOURNAL OF ECONOMICS, 28 (3), 347-363 (2004).

16 For lasers, see Scotchmer *supra* note 5; for cumulative innovation in open source software, see Murray and O'Mahony, *supra* note 5.

cumulative effects of a community of users, each building upon the other's efforts.[17] These combined efforts would then correspond to both user and cumulative innovation.

The other pattern of cumulative innovation is when firms build upon a common, ever-increasing pool of enabling science, even if their specific products are unique point products. The best-known example of this is biopharmaceutical drug discovery.[18]

In some cases, cumulative innovation is fueled by explicit cooperation between firms, while in other cases an industry's joint innovation is advanced through unintended spillovers and information flows among the firms in the industry. In the latter case, cumulative innovation happens to the degree to which it is permitted by IP policies, as firms use whatever information is available to develop their innovations — and thus, IP monopolies tend to slow the rate of innovation and progress.[19] At best, such innovation drag delays the pace of developing and diffusing an innovation.

At worst, this drag can create a negative-sum innovation standoff. An extreme example of such a standoff is given by the development of vacuum tubes in the early 20th century.[20] After the diode tube was invented and patented by Guglielmo Marconi, Lee De Forest improved the design by adding a third element to form a triode. But because the triode infringed on Marconi's patent, U.S. courts ruled that neither De Forest nor Marconi could legally sell a triode without a license from the other (which each side refused to

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17 See, for example Hienerth *supra* note 11.

18 The cumulative nature of drug discovery is discussed by Scotchmer, *supra* note 5 and Murray and O'Mahony, *supra* note 5.

19 Scotchmer, *supra* note 14.

20 Adam B. Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It*. Princeton, NJ: Princeton University Press, 2004, at page 51.

grant). Development of the U.S. broadcasting industry was blocked until the stalemate was resolved.[21]

Chesbrough: Open Innovation

As with cumulative and user innovation, open innovation builds upon the assumption of dispersed capabilities for identifying and implementing innovations.[22] However, while user innovation and cumulative innovation focus on consumer welfare, the open innovation paradigm emphasizes the opportunities for profit and competitive advantage by individual firms. These differing assumptions and emphases cause the contrasting approaches to examine the same phenomenon and reach different conclusions.

Chesbrough defines open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology."[23]

Another way to consider this is that innovation should be treated like any other input to the industrial firm — something that can be bought and sold on the open market, not just produced and used within the boundaries of the firm. Applying Oliver Williamson's

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21 Carol E. Scott, "The Radio Inventor/Entrepreneurs," BUSINESS QUEST, 2001. URL: http://www.westga.edu/~bquest/2001/radio.htm

22 Key definitions of the domain of open innovation are provided by Chesbrough, *supra* note 3 and Henry Chesbrough, "Open Innovation: A New Paradigm for Understanding Industrial Innovation," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 1-12.

23 The definition is quoted from Chesbrough *supra* note 22, page 1. The Chesbrough usage of "open innovation" is today the most common, but not only usage of the term. In some cases, the reference to "open" innovation is a generic form of openness, as in Lee Fleming and David M. Waguespack, "Brokerage, Boundary Spanning, and Leadership in Open Innovation Communities," ORGANIZATION SCIENCE, 18 (2), 165-180 (2007).

transaction cost economics framework,[24] under open innovation firms use markets to supplement — or supplant — internal hierarchies as the mechanism for both sourcing and commercializing innovations. As with other market mechanisms, using markets to source (and commercialize) innovations offers the benefits of competition and diversification of risk over the fully vertically-integrated approach.

However, in many cases the relationships are not one-time atomic transactions but a series of ongoing relationships corresponding to Powell's network form of organization.[25] In fact, the production of many complex products inherently depends on the cooperation of firms within a value network.[26] Such value networks are quite common in systems-based industries. Where once vertical integration was the norm — as represented by IBM in computers or Motorola in cellular telephones — it has been supplanted by horizontal specialization, fueled by strong economies of scale for key components.[27] The

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24 For example, Oliver E. Williamson, *The Economic Institutions of Capitalism,* New York: Free Press, 1985.

25 Walter W. Powell, "Neither Market Nor Hierarchy: Network Forms of Organization." In Barry M. Staw and Larry L. Cummings, eds., RESEARCH IN ORGANIZATIONAL BEHAVIOR 12. Greenwich, CT: JAI Press, 1990, pp. 295-336.

26 For a synthesis of prior research on value networks and its applicability to open innovation, see Wim Vanhaverbeke, "The Inter-organizational Context of Open Innovation," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 205-219. The definition of "value network" by Vanhaverbeke (and others in the same volume) seems exactly equivalent to the business "ecosystem" of Marco Iansiti and Roy Levien, *The Keystone Advantage: What The New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Boston: Harvard Business School Press, 2004 — and, in fact, they cite this ecosystem research. In contrast to the familiar Porter "value chain" (cf. Michael E. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance,* New York: Free Press, 1985, pp. 33-39), the open innovation value network differs primarily by including other paths for value creation beyond the value chain, notably companies selling goods and services that are complementary to the value created by the focal firm.

27 Joel West, "Does Appropriability Enable or Retard Open Innovation?" in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 109-133, which builds upon Andrew S. Grove, *Only the Paranoid Survive: How to Exploit the Crisis Points that Challenge Every Company and Career,* New

subdivision of labor between key members of the value network is enabled by technical modularity that enables an efficient division of labor.[28] However, innovation in such systems often requires a firm or group of firms to lead and shape the innovation occurring within a value network.[29]

Policies to Encourage Interorganizational Innovation

Even though the empirical record is still developing, researchers have provided evidence that interorganizational innovation can be faster, more efficient and more diversified than the alternative approaches for developing and commercializing innovations. Policymakers thus should be concerned about the effect various public policies would have upon the prevalence and effectiveness of interorganizational innovation.

Most of the factors affecting buy-versus-make innovation decisions remain under the purview of individual firms. However, a number of policy decisions can affect both the supply and cost of external innovations — and thus the likelihood that firms will consider and adopt such external innovations rather than developing their own (or not innovating at all).

Here I examine five policy levers: intellectual property, public funding of R&D and infrastructure, regulation of competition and taxation. I use these levers to show how both

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York: Doubleday, 1996 and Andrea Prencipe, Andrew Davies and Mike Hobday, eds., *The Business of Systems Integration,* Oxford: Oxford University Press, 2003.

28 Carliss Y. Baldwin and Kim B. Clark, *Design Rules, Vol. 1: The Power of Modularity*. Cambridge, Mass.: MIT Press, 2000; Richard N. Langlois, "Modularity in technology and organization," JOURNAL OF ECONOMIC BEHAVIOR AND ORGANIZATION, 49 (3): 19-37 (2003).

29 Markku Maula, Thomas Keil and Jukka-Pekka Salmenkaita, "Open innovation in systemic innovation contexts," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 241-257.

business strategies and policy choices are interpreted within the tenets of the three types of interorganizational innovation.

Strength of the IP Regime

The core research question for economic studies of cumulative innovation has been determining the appropriate type and strength of innovation incentives. Researchers seek to balance the need for adequate incentives to encourage investment in innovation, while trying to reduce the drag on the cumulative innovation that occurs between firms across a given industry or segment. Although Scotchmer has suggested alternative innovation incentives such as invention prizes,[30] most of the research and policy discussion has focused on the appropriate strength of the IP protection mechanisms.

Below I consider the effects on interorganizational innovation of strengthening (or weakening) two approaches for protecting intellectual property rights: patents and copyright. The three theories of interorganizational innovation focus on different consequences of changing the strength of a national IPR regime (Table 2).

Patent Regimes. The US and other developed economies have seen a wide range of proposals in the past decade for patent policy reform, many of them intended to undo prior reforms that strengthened the enforceability of patents as an incentive for small inventors.[31] Some of these reforms would be quite modest, by reducing the likelihood of

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30 Scotchmer *supra* note 5.

31 A complete review of the recent criticisms is beyond the scope of this paper. For recent economic analyses of the problems in the current U.S. patent system (including those caused by patent “reforms” of the 1980s and 1990s) and proposals for counter-reform, see Jaffe and Lerner, *supra* note 20; Nancy Gallini, “The Economics of Patents: Lessons from Recent U.S. Patent Reform,” JOURNAL OF ECONOMIC PERSPECTIVES 16 (2), 131-154 (2002); and Carl Shapiro,"Patent Reform: Aligning Reward and Contribution" (May 2007). NBER Working Paper No. W13141 Available at SSRN: http://ssrn.com/abstract=989952.

protection for trivial ideas and making it easier to overturn weak patents.[32] Other proposed changes are more dramatic.

A fundamental concern of cumulative innovation is that an excessively broad grant of intellectual property rights will shut down cumulative innovation, because a second innovator building on the efforts of the first will lack the incentive to develop the necessary extensions and improvements.[33]

Even if no individual firm has a monopoly on the IP, the collective IPR positions of a group of firms can serve as a barrier to new entrants and thus new innovation. In the European GSM mobile phone standards, the patent positions of Nokia, Ericsson, Siemens, Alcatel and Motorola meant that no outside firm could produce a mobile phone without licensing the patents of all firms. As intended by he incumbent producers, for many years this patent barrier excluded from the European market the Japanese manufacturers that were leading the world in miniaturization;[34] it also served to keep out Korea-based Samsung and LG, which rapidly grew mobile phone exports in the late 1990s. In fact, the barriers posed by GSM patents were not widely known until they were used against a British startup founded in 1999. A March 2005 patent infringement lawsuit by Ericsson against Sendo brought a counter-complaint by Sendo to the European

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32 Jaffe and Lerner, *supra* note 20; and Stuart J.H. Graham and Dietmar Harhoff, "Would the US Benefit from Patent Post-grant Reviews? Evidence from a 'Twinning' Study," (May 2006). CEPR Discussion Paper No. 5680 Available at SSRN: http://ssrn.com/abstract=921826

33 Scotchmer *supra* note 14.

34 The role of patents in the GSM standard and their role as a barrier to entry can be found in Chapter 8 of Rudi Bekkers, *Mobile telecommunications standards: GSM, UMTS, TETRA, and ERMES*. Artech House, Boston, 2001. The rapid rate of improvements in size and weight by Japanese cell phone manufacturers is documented by Jeffrey L. Funk, "Standards, dominant designs and preferential acquisition of complementary assets through slight information advantages," RESEARCH POLICY 32 (8), 1325–1341 (2003).

Commission, which was not resolved before the company went out of business three months later. Despite this protection, of the four European incumbents only Nokia remained in the handset business, while Siemens and Alcatel sold their money-losing handset divisions to smaller Asian rivals and Ericsson combined its operations in a joint venture with Tokyo-based Sony.[35]

Thus, decreasing the scope or duration of patent claims would recognize and encourage the practice of cumulative innovation within an industry. However, such changes could decrease the attractiveness of business models based on developing and licensing IP to external customers, a key strategy available within open innovation.[36] Because such licensing models are controversial, some stakeholders would view that ending such open innovation as a good thing.

Copyright. Concerns about strong IP regimes deterring interorganizational innovation are not limited to patent policy. In some ways copyright has proved to be the area of greatest policy experimentation, as right-holders have experimented by unilaterally granting additional rights within existing national policy. These rights have been designed to encourage experimentation in user or cumulative innovation.

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35 For Ericsson's patent infringement lawsuit against Sendo and Sendo's complaint to the European Commission, see Sean Jackson, "When Sendo met Ericsson," MOBILE COMMUNICATIONS INTERNATIONAL, April 2005. A post-mortem on Sendo after its sale to Motorola is given by Mike Dano, "Motorola buys Sendo's R&D, patents," RCR WIRELESS NEWS, 4 July 2005. A summary of the GSM patent situation, as well as a chronology of the exit by the three European cell phone makers, can be found in West, *supra* note 27.

36 The role of patent licensing as part of an open innovation strategy was first outlined by Chesbrough, *supra* note 3, pp. 155-176.

The initial experiments came with the creation of licenses for free and open source software.[37] The two movements share similar technical approaches but different underlying philosophies.[38] Free software is explicitly predicated on a user innovation model.[39] Open source software is designed to facilitate what would later be called open innovation — creating shared IP that could be used as a source of external innovations by for-profit entities.[40] Both approaches enable cumulative innovation, because the copyright licenses explicitly encourage sharing and thus further decentralize the innovation process. However, not all open source software strategies are open innovation or vice versa.[41]

An entire class of literary or artistic expression (typically covered by copyright) is based upon recombining, elaborating or satirizing prior art; a common example is the creation of new songs that incorporate digital samples of one or more prior songs.[42] While such recombinations have been blocked by some rights holders, others have sought to encourage such recombinations.[43] The "creative commons" licenses are intended to

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37 A complete treatment of the use of copyright and contract law in open source licenses can be found in Lawrence Rosen, *Open Source Licensing: Software Freedom and Intellectual Property Law,* Upper Saddle River, NJ: Prentice Hall PTR, 2004.

38 Jason Dedrick and Joel West, "Movement Ideology vs. User Pragmatism in the Organizational Adoption of Open Source Software," in Kenneth L. Kraemer and Margaret Elliott, eds., *Computerization Movements and Technology Diffusion: From Mainframes to Ubiquitous Computing,* Medford, NJ: Information Today, 2008, pp. 427-452.

39 Eric von Hippel, "Innovation by user communities: Learning from open-source software," SLOAN MANAGEMENT REVIEW 42 (4), 82-86 (Summer 2001).

40 Behlendorf, *supra* note 8 and Joel West and Scott Gallagher, "Patterns of Open Innovation in Open Source Software," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 82-106.

41 For an explanation of the orthogonal typologies of open source and open innovation, see West and Gallagher *supra* note 40, at 101.

42 See, for example, Lawrence Lessig, *Free culture: how big media uses technology and the law to lock down culture and control creativity,* New York: Penguin Press, 2004 (available online at http://www.free-culture.cc) and also von Hippel *supra* note 7.

43 **Law students, please help me out with a relevant sampling civil suit.**

facilitate this form of interorganizational innovation, building upon the concepts and principled developed for free and open source licenses.

As with patents, stronger copyright regimes can discourage the practice of cumulative innovation, or delay it by introducing a high degree of uncertainty to the process. On the other hand, weaker copyright regimes could shift incentives away from unique contributions towards more derivative ones. As with other weaker IP regimes, lack of effective copyright protection will particularly reduce the innovation contribution by smaller firms lacking the ability to direct commercialize their innovation.[44]

The creation of new copyright licenses (open source, free software and creative commons) show how the existing copyright law can be used to facilitate rather than deter cumulative innovation, but court tests of these mechanisms remain scarce.

<u>Funding and Managing Public R&D</u>

Another heavily debated and studied area of innovation policy over the past twenty years has been concerning government-funded innovations. The debate has focused on the level of funding and the allocation of rights, but has also considered policies related to developing, managing and diffusing such innovations.

The role of government R&D funding in fueling inter-organizational innovation comes in two major ways: through spillovers of government funded research, and through direct commercialization of innovations developed with government funding.

Research Spillovers. Innovations from government research labs, government-funded university projects and other public sources (including university funded research) were

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44 David Teece, "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. RESEARCH POLICY 15 (6), 285-305 (1986).

traditionally allowed to spillover freely to the private sector in a model Chesbrough termed an "innovation benefactor".[45] Such funding for innovation is a public good provided to promote societal welfare.[46] This approach should strongly increase cumulative innovation, since the public spillovers to a wide range of commercial actors diversify the likely supply of potential innovators who can build on that public science.

In the U.S., the role of the government as the largest innovation benefactor was cemented during World War II, when the Office of Scientific Research and Development funneled government money to fund research and development in universities and private industry. Under the direction of OSRD chairman Vannevar Bush, postwar research funding was divided into two categories: basic and applied. Broad categories of basic research were funded by the National Science Foundation, created in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense."[47] Meanwhile, the National Institutes of Health were created in 1948 to consolidate various public health research activities dating back to 1798.[48]

However, particularly for the first three decades of the postwar electronics industry, the largest source of research spillovers came from military funding of university

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45 Henry W. Chesbrough, "The Era of Open Innovation." SLOAN MANAGEMENT REVIEW, 44 (3): 35-41 (2003). For many, an "open" model of innovation (which is not necessarily "open innovation") refers to this "innovation benefactor" model of non-monetized information flows, but explicitly excludes the emphasis of Chesbrough's work (especially Chesbrough *supra* note 3) on buying and selling innovations.

46 Joel West, Wim Vanhaverbeke and Henry Chesbrough (2006) "Open Innovation: A Research Agenda," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 285-307

47 Quoted in "Historical Background of the National Science Foundation," Appendix II of *National Science Foundation: Justifications of Estimates on Appropriations. FY 1952 Budget Report,* May 23, 1951, URL: http://www.nsf.gov/pubs/1952/ See also Appendix II, "Legislative History of the NSF Act of 1950."

48 "The NIH Almanac - Historical Data," June 10, 2008, URL: http://www.nih.gov/about/almanac/historical/chronology_of_events.htm

research, leading to technological innovation and major business opportunities in semiconductors, digital computers, software, data communications and telecommunications. The government funded major research projects at elite universities, both directly and through the Joint Services Electronics Program.[49] To take but one well known example, spillovers of government funding to universities created key aspects of the US computer industry, including:

- *Univac I*. After using Army funding to building the Einiac I at the University of Pennsylvania, Prof. John Mauchly and student J. Presper Eckert quit to launch what became the Eckert-Mauchly Computer Corporation, which in 1950 built the Univac I, the first digital computer ever sold for civilian use.[50]
- *Core Memory*. Beginning in 1944, the Office of Naval Research funded MIT's Project Whirlwind computer research. Among other things, the project invented the magnetic core memory that was used commercially in IBM's 704 and 705 computers and nearly all computers for the next 25 years.[51] In one of

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49 Leo Young, "Electronics and Computing," ANNALS OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE, 502 (1), pp. 82-93 (1989).

50 A comprehensive summary of the role of the U.S. government in funding computer research from Einiac into the 1980s is presented by Kenneth Flamm, *Creating the Computer,* Washington, DC: Brookings, 1988.

51 Project Whirlwind, core memory and the SAGE air defense system are covered by The evolution of Project Whirlwind to SAGE from 1952-1958 is given by Karl L. Wildes and Nilo A. Lindgren, *A Century of Electrical Engineering and Computer Science at MIT, 1882-1982,* Cambridge, Mass.: MIT Press, 1985, pp. 296-300, and by Chapter 4 of *Funding A Revolution: Government Support for Computing Research,* Washington, DC: National Academy Press, 1999.

the rare exceptions to free university spillovers, MIT earned $22 million in patent royalties on core memory (most from IBM).[52]

- *IBM's mainframe dominance*. MIT's successor to Whirlwind was incorporated into Project SAGE, a massive air defense radar system developed by MIT, IBM and the RAND Corporation from 1952-1958. During its peak in the 1950s, 25% of IBM employees worked on the project and it accounted for half of IBM's computer revenues.[53] IBM's president later credited the project with allowing IBM to surpass Univac once and for all.[54]
- *Airline Reservation Systems*. IBM adapted the SAGE hardware to build SABRE, the American Airlines reservation system dubbed "kid's SAGE," which upon completion in 1964 was the largest ever commercial systems development project.[55]
- *Digital Equipment Corporation*. Kenneth Olsen did his 1952 MIT master's thesis on core memory and then worked at MIT Lincoln Lab monitoring IBM's manufacturing of the SAGE computers. In 1957, he left Lincoln Lab,

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[52] Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution,* New York: Touchstone, 1996, p. 403.

[53] Project SAGE is discussed by Buderi *supra* note 52 and by Wildes and Lindgren, *supra* note 53. The impact of Project SAGE upon IBM's business is recounted by Martin Campbell-Kelly, *From airline reservations to Sonic the Hedgehog: a history of the software industry*. Cambridge, Mass.: MIT Press, 2003, p. 38. as well as Thomas J. Watson, Jr., and Peter Petre, *Father, Son & Co.: my life at IBM and beyond,* Pbk. ed. New York: Bantam Books, 1991, pp. 245-249.

[54] Tom Watson Jr. later wrote: "SAGE … gave IBM the giant boost I was after. … [I]t enabled us to build highly automated factories ahead of anybody else, and to train thousands of new workers in electronics." Watson and Petre, *supra* note 53, at 249.

[55] Campbell-Kelly *supra* note 53, pp. 41-45.

started DEC and began work on the PDP-1, the first of nine minicomputer models that the firm would ship during the next two decades.[56]

- *Internet*. Defense Department funding of the ARPANET from 1968-1990 produced a military communications network robust against military attack, but also provided the infrastructure and standards later used to build the commercial Internet which in turn fueled an explosive wave of innovation during the 1990s.[57]
- *Open Source Operating Systems*. As a side-effect of government funding to develop these networking protocols, UC Berkeley developed the BSD variant of Unix, which helped diffuse the TCP/IP protocols and provided key operating system components later used by Sun Microsystems, Linux and Apple's OS X.[58]

The impact of defense spillovers on the electronics industry was not limited to computing technologies. The military funded key university research in semiconductors and integrated circuits that later became commonplace in industry, including the development of new materials, solid-state circuits, and computer-aided circuit design.[59] Meanwhile, digital communications were developed through a combination of DoD-

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[56] Wildes and Lindgren, *supra* note 51.

[57] David C. Mowery and Tim Simcoe, "Is the Internet a US invention? An economic and technological history of computer networking," RESEARCH POLICY, 31, 1369-1387 (2002).

[58] The role of the DoD-funded BSD Unix in the evolution of Unix and Linux is discussed in Joel West and Jason Dedrick, "Open Source Standardization: The Rise of Linux in the Network Era," KNOWLEDGE, TECHNOLOGY & POLICY, 14 (2), 88-112 (2001). A continuation of that discussion — linking it forward to Apple's OS X operating system — can be found in Joel West, "How Open is Open Enough? Melding Proprietary and Open Source Platform Strategies," RESEARCH POLICY 32 (7), 1259-1285 (2003).

[59] Young, *supra* note 49.

funded basic research and NASA-funded applications for deep space communications, which together enabled the creation of digital cellular phones.[60]

During the heyday years of the 1960s, the bulk of the federally funded research was tied to building complex systems for military uses and the space program, but the relative importance of such systems declined during the 1970s-1990s.[61] While government R&D funding supported the U.S. information technology sector during the 1960s and 1970s, the relative importance of federal R&D funding began a steep decline starting in 1988.[62]

Direct Commercialization. If the Internet epitomized the free spillover of university research to aid private innovation, the 1980 US Bayh-Dole Act represented the exact opposite philosophy. It assumed that the most effective path for commercializing university inventions was not through free spillovers from universities to industries, but by assuring universities of an economic incentive to see to it that those inventions were commercialized. Thus, the act encouraged universities to patent innovations developed using Federal government money and then license those innovations to private firms.[63] In

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60 Joel West, "Commercializing Open Science: Deep Space Communications as the Lead Market for Shannon Theory, 1960-1973," forthcoming at the JOURNAL OF MANAGEMENT STUDIES

61 Adam B. Jaffe, "Trends and patterns in research and development expenditures in the United States," PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, 93 (23): 12658-12663 (1996).

62 Kira R. Fabrizio and David C. Mowery, "Defense-Related R&D and the Growth of the Postwar Information Technology Industrial Complex in the United States," REVUE D'CONOMIE INDUSTRIELLE, 112: 27-44 (2005).

63 The rate of increased patenting by US universities predates the Bayh-Dole Act, and thus the Act is as much a reflection as a cause of a shift in the availability of free innovation spillovers; see David C. Mowery and Bhaven N Sampat, "University patents and patent policy debates in the USA, 1925-1980," INDUSTRIAL AND CORPORATE CHANGE 10 (3): 781-814 (2001).

open innovation terms, universities are thus transformed from innovation benefactors to innovation merchants.[64]

As with open innovation, this is predicated on an assumption that strong incentives are needed to develop and commercialize innovations — specifically, that universities will not aid technology transfer and commercialization absent limitations of drag created by patenting public science. One study concluded that attempts universities to capitalize on their innovation creation can potentially provide returns to the university, but also create innovation drag, slowing the process of cumulative innovation.[65] Others have argued that the overall empirical record is mixed and can be interpreted either support or refute the predictions that innovation drag will slow the process of interorganizational innovation.[66]

Competition Policy

While interorganizational innovation would normally be seen as promoting a diversity of innovation sources and thus be pro-competitive, under certain conditions the associated industry structure might run afoul of antitrust or other national competition policies. Here I highlight three cases: a component-based open innovation model, open standards, and explicit attempts to create cumulative innovation through R&D consortia or other efforts at R&D pooling.

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64 Chesbrough, *supra* note 45, and West et al, *supra* note 46.

65 Kira Fabrizio, "The Use of University Research in Firm Innovation," in OPEN INNOVATION: RESEARCHING A NEW PARADIGM (Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., Oxford, 2006), pp. 134-160.

66 Among the most vociferously agnostic are Charles R. McManis and Sucheol Noh, "The Impact of the Bayh-Dole Act on Genetic Research and Development: Evaluating the Arguments and Empirical Evidence to Date," working paper, Washington University School of Law, July 2007.

Horizontal Component Monopolies. As noted by Grove, an alternative to the vertical integration in the ICT industry (as with mainframe computers) is a component-integration model represented by microprocessor and operating system vendors supplying to personal computer makers.[67] Through increased volumes and market share, by supplying to a wide range of competing vendors, successful component producers enjoy a range of supply- and demand-side economies of scale that tend to create quasi-monopolies in a given product category or segment.

No matter how lawfully obtained, such successful quasi-monopolies are subject to anti-trust scrutiny — particularly in Europe, where (unlike the US) competition policy considers the impact of market power on competitors, not just consumers. The small number of high profile cases against dominant component suppliers (Microsoft, Intel, Qualcomm) make it hard to generalize thus far as to the broader impact of competition policy on future component/integration business models, but existing competition policy clearly seeks to limit the business strategies of component suppliers that achieve a dominant position in their segment. However, both case law and regulatory policy remain unsettled, in part because the economic effects of curtailing, restricting or banning horizontal monopolies remain far from certain.[68]

Meanwhile, in response to antitrust criticisms, these component suppliers have sought to enlist allies from among their customers, focusing on medium-sized and smaller buyers. These are the customers who most benefitted from the availability of components

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[67] Grove, *supra* note 27.

[68] As but one small example, two prominent industrial economists presented contradictory assessments of the 1998-1999 *US v. Microsoft* trial; see David S. Evans, Franklin M. Fisher, Daniel L. Rubinfeld and Richard L. Schmalensee, *Did Microsoft Harm Consumers? Two Opposing Views,* AEI-Brookings Joint Center for Regulatory Studies, 2000.

and thus open innovation, because they would otherwise lack the scale and innovation capabilities to compete with large vertically-integrated incumbents. The archetypal example would be Dell Computer, formed by Michael Dell in 1983 in his college dormitory: the availability of off the-shelf components allowed it to ship personal computers in competition with IBM.[69] By combining external sources of innovation with a ruthless focus on manufacturing efficiencies, within a decade Dell left the vertically integrated IBM unable to compete on cost; IBM's losses eventually drove it out of the "IBM PC" computer business in 2004.[70]

Open Standards. While there are many definitions of "open" standards, the fundamental issue is whether the standard facilitates entry and thus competition between rival suppliers.[71] Such open entry facilitates the cumulative innovation of a broad innovation base, producing related (if not directly competing) products in a given industry segment or category.

In setting competition policy for standardization efforts, regulators face conflicting imperatives based on the interests of various stakeholders. For example, if the government approves a sharing of patent rights (e.g.. by patent pool or cross-licensing) —

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69 Dell later wrote: "My Dad started. … 'Get your priorities straight What do you want to di wht your life?' 'I want to compete with IBM!' I said." Michael Dell, *Direct from Dell,* New York: HarperCollins, 1999, at 10.

70 In 1992,one analyst estimated that matching Dell's prices would have brought IBM annual losses exceeding $ 1 billion. (Andrew Kupfer, "Who's winning the PC price wars?" FORTUNE, Sept. 21, 1992). In December 2004, IBM decided to sell its PC division to China's Lenovo, after experiencing PC division losses of $965 million over the previous 3½ years (Nick Baker, "IBM's PC Business Unprofitable Since At Least 2001," Dow Jones Newswires, Dec. 31, 2004).

71 For the economic implications of open standards, see Joel West, "The Economic Realities of Open Standards: Black, White and Many Shades of Gray," in Shane Greenstein and Victor Stango, eds., *Standards and Public Policy,* Cambridge: Cambridge University Press, 2006, pp. 87-122. A proposal to operationalize definitions of open standards can be found in Ken Krechmer, "Open Standards Requirements," INTERNATIONAL JOURNAL OF IT STANDARDS & STANDARDISATION RESEARCH. 4 (1), 43-61 (2006).

and thus creating a patent cartel — it could facilitate the cooperation between the existing vendors at the expense of potential new entrants, or leverage this collusion to transfer rents from buyers to this cartel or producers.[72]

Irrespective of its regulatory role, government buyers — like other buyers — can also adopt policies favoring the production of goods based on open standards to encourage their provision, as happened in the open systems movement of the 1980s and 1990s.[73]

R&D Consortia. Another potential source of external innovations for firms is through cooperative R&D between suppliers, customers and competitors. Typically, the R&D is funded by a consortium and the consortium members share in its returns. Such *a priori* agreements on research cooperation protect later inventors from hold-up by earlier ones, thus enabling the process of cumulative innovation.[74]

However, any cooperation among competitors is fraught with antitrust implications, and thus generates many billable hours (and an occasional cancelled consortium) seeking to navigate potential minefields. In the US, R&D consortia were explicitly authorized by the National Cooperative Research Act of 1984, which reversed a policy decision of the 1890 Sherman Antitrust Act that banned such cooperation between direct competitors.[75] While NCRA-compliant consortia often include just two direct competitors (a form of cumulative innovation), in other cases the cooperation may span an open innovation

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72 See Carl Shapiro, "Antitrust limits to patent settlements," RAND JOURNAL OF ECONOMICS, 34 (2), 391-441 (2003).

73 Jim Isaak, "The Role of Individuals and Social Capital in POSIX Standardization," INTERNATIONAL JOURNAL OF IT STANDARDS & STANDARDISATION RESEARCH. 4 (1), 1-23 (2006)

74 Scotchmer, *supra* note 14.

75 William M. Evan and Paul Olk, "R&D Consortia: A New U.S. Organizational Form" SLOAN MANAGEMENT REVIEW 31 (3), pp. 37-45 (1990). The authors note that while collaborative innovation in the US required an act of Congress to eliminate antitrust concerns, such collaborative innovation was not considered illegal in Western Europe or Japan.

value network of competitors, suppliers and customers — as with the example of the Plastics Recycling Foundation, which included makers of plastics and plastic-based packaging, as well as major buyers of such packaging.[76] Presumably the direct involvement of (industrial) buyers would vitiate concerns that such collaborative R&D would be anti-competitive and hurt the interests of buyers.

Antitrust issues would presumably be less of an issue for consortia where innovation benefits spill over to participants and non-participants alike, as with open source software consortia.[77] However, the applicability of this form for shared R&D has yet to be proven beyond software production.

Promoting Public Infrastructure

The Internet is perhaps the most successful publicly-funded innovation infrastructure of the past century — an example of the role that government can play in the provision of a commons or non-rivalrous goods, particularly in cases where it would be impractical or inefficient for a private party to capture tolls for use of the infrastructure.[78] This suggests that public funding for innovative infrastructure can under some circumstances facilitate processes of interorganizational innovation by encouraging the widest possible range of innovation contributions. There are at least three mechanisms by which that innovation is facilitated.

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[76] Evan and Olk, *supra* note 75.

[77] West and Gallagher, *supra* note 13.

[78] Discussions of the role of government in providing shared infrastructure can be found in Brett M. Frischmann, "Infrastructure Commons in Economic Perspective," FIRST MONDAY, 12, 6 (June 2007) and Steven J. Jackson, Paul N. Edwards, Geoffrey C. Bowker, and Cory P. Knobel, "Understanding Infrastructure: History, Heuristics, and Cyberinfrastructure Policy" FIRST MONDAY, 12, 6 (June 2007).

First, as with other publicly-funded research, the public spillovers and lack of appropriability can fuel a virtuous cycle of adoption and enhancements. For the Internet, this encouraged entry by innovative users, suppliers, complementers, or rivals to existing firms. Such entry was reinforced by the procurement policies of the US government, which favored entry into data networking by small firms, and did not allow the technological designs of any one firm to dominate the architecture.[79]

Additionally, the process of standardizing infrastructure interfaces generally follows the best practices for multilateral standards setting organizations (SSOs).[80] As such, it benefits from well-developed policies of these SSOs, which have generally been designed to facilitate a cumulative innovation process within an industry segment across a wide range of industry participants. The most successful example of information infrastructure — the Internet — created new forms of standardization, notably the Internet Engineering Task Force, which used new processes that were in many way more open than earlier SSOs.[81]

Finally, such a process of interorganizational standardization creates alternatives to vertical integration and thus opportunities for open innovation. Well-defined interfaces enable inter-organizational modularity and thus a division of labor across organizational boundaries.[82] This could potentially create component or systems markets between providers of different pieces of the infrastructure

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79 Mowery and Simcoe, *supra* note 57.

80 Joel West "Seeking Open Infrastructure: Contrasting Open Standards, Open Source and Open Innovation," FIRST MONDAY, 12, 6 (June 2007).

81 Scott Bradner, "The Internet Engineering Task Force," in OPEN SOURCES: VOICES FROM A REVOLUTION (Chris DiBona, Sam Ockman and Mark Stone, eds., O'Reilly, 1999), pp. 47-52.

82 Langlois, *supra* note 28.

Tax Policy

Tax deductions or credits encourage firms to invest in R&D to produce innovations, but how those incentives are structured may change the relative attractiveness of internal vs. external R&D. For the typical scenario of large profitable firms buying from smaller and younger startups — as in major pharmaceutical firms buying from biotech startups — incentives that favor small firms would increase the supply of external innovations. Examples would include caps on incentive payments per firm, as well as the use of tax credits instead of deductions (the latter being less useful for small firms that pay lower tax rates or may be unprofitable).[83]

The attractiveness of external sources of innovation can also be affected by state policies, specifically the recent efforts by states to increase revenues by taxing services in addition to tangible and intangible products. A state sales tax on services assessed on contract R&D would make external innovations more expensive and thus less attractive than those traded within the firm. Conversely, a tax policy that treats royalties more favorably than contract services might allow external innovation to continue unimpeded, at least for firms that anticipate tax issues in contracting for such external innovations.

Conclusions

Interorganizational innovation is a reality of the modern industrial world. We tend to think of it as a recent phenomenon, born of the Internet technology that has enabled global virtual collaboration. However, such collaboration has been common in industrial districts for centuries, and (although records are scarce) within medieval guilds before that. That said, the combined personal computer revolution of the 1980s and the Internet

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83 **Is there a tax lawyer in the house? More suggestions are needed here!**

revolution of the 1990s have democratized such innovation, by making writing, software production, music composition, video editing and a wide array of other creative activities available to anyone with access to a PC.[84]

Whether modern or medieval, the same policy tradeoffs remain: maximizing the incentives for specific firms or individuals to innovate, while minimizing the cumulative drag on the remaining pool of potential innovators. Policy decisions need to be informed by broader and deeper empirical evidence on both sides of this tradeoff.

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84 See, for example, Jonathan Zittrain, "The Generative Internet," HARVARD LAW REVIEW 119, 1974-2040 (2006).

Tables and Figures

Table 1: Sources of innovation in contrasting theories of innovation

Theory	Key Author	Focal Firm	Suppliers	Customers	Rivals
Vertical integration	Alfred Chandler	X			
User innovation	Eric von Hippel	X	†	X	
Cumulative innovation	Suzanne Scotchmer	X			X
Open innovation	Henry Chesbrough	X	X	X	X

† Not emphasized by subsequent research

Table 2: Interorganizational innovation predictions for IP policy changes

Theory	Assumptions/Focus	Effect of Stronger IP Regime
Vertical integration	Firms gain advantage by controlling end-to-end innovation pipeline	Increasing returns for internal R&D
User innovation	Individuals contribute important innovations	May (or may not) interfere with user ability to create innovation
Cumulative innovation	Innovation comes from cooperation between firms in an industry	Reduces spillovers between firms; slows advance of science
Open innovation	Firms gain advantage through markets for innovation	Increases incentives for developing IP; creates markets for IP