Policy Challenges of Open, Cumulative and User Innovation

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Open-Source & Proprietary Models of Innovation
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Abstract: As recounted by Chandler, the rise of modern industrial capitalism in the late 19th century and early 20th century was built upon the growth of large vertically-integrated firms. These firms created innovations in their own research labs, which they commercialized through their own product development, manufacturing and marketing.

However, such an interpretation has ignored important examples of industrial cooperation, as with 19th century mining equipment (Nuvolari, 2004). In the past two decades, researchers have begun to examine the process of innovation cooperation between firms (Allen, 1983) and between users and firms (von Hippel, 1988). Most recently, the "open innovation" paradigm has been used by Chesbrough (2003a; Chesbrough et al, 2006) to describe a broader class of interorganizational cooperation for innovation.

Here I contrast the similarities and differences between open innovation, cumulative innovation and user innovation, and consider how these theories might impact public policy choices designed to encourage innovation.

Introduction

The works of Alfred D. Chandler, Jr. (1977, 1990) have 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.

In 2003, Henry Chesbrough argued that the Chandlerian paradigm of vertical integration had become obsolete, both in theory and practice. 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 (2003a) is not the only (or even first) to suggestion 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 (1988, 2005), focusing on the role of informed users in improving and extending products. The other stream in economics and sociology considers the cumulative innovation efforts across various (often competing) firms, exemplified by the work of Suzanne Scotchmer (2004).

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[1] 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.

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[1] When individual users are providing innovations to an organization, the modifier "extra-organizational," might be more accurate than "interorganizational" innovation, but for simplicity the term "interorganizational innovation" will be used to subsume all manifestations and extensions of the user, cumulative and open innovation frameworks.

Contrasting Models of Interorganizational Innovation

Here I compare the three major perspectives on interorganizational innovation: the focus on user-contributed innovations (von Hippel, 1988), collective and cumulative innovation (Allen, 1983; Scotchmer, 2004) and open innovation (Chesbrough, 2003a, 2006).

Von Hippel: User Innovation

With his original study *The Sources of Innovation,* von Hippel (1988) 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, t his 2005 *Democratizing Innovation* defines his goal as documenting that "users of products and services—both firms and individual consumers—are increasingly able to innovate for themselves" (von Hippel, 2005: 1).

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 (Behlendorf, 1999). 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 the oft-quoted saying among such programmers that "Every good work of software starts by scratching a developer's personal itch" (Raymond, 1999).

Research on user innovation in open source has examined both the benefits and origins of user-contributed innovations (Lakhani and von Hippel, 2003; von Krogh, Spaeth & Lakhani, 2003), as well as approaches towards facilitating user innovation through technical design choices (Franke and von Hippel, 2003). Other researchers have extended this approach to sporting goods (Franke and Shah, 2003; Hienerth, 2006) and music software (Jeppesen and Frederiksen, 2006).

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 (von Hippel, 1988). The theory has rarely been used to apply to corporate motivations for contributing innovations, which is more consistent 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 (West and Gallagher, 2006).

Scotchmer: Cumulative Innovation

A second stream 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 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 (1983), this stream is most recently associated with the work of Scotchmer (1991, 2004).

This body of work considers two different manifestations of cumulative innovation. In the first, competitors successively refine a single technology until the improved technology is widely used by a range of producers. Two well-documented examples from the English industrial revolution are the blast furnace (Allen, 1983) and the Cornish mining pump (Nuvolari, 2004).

This pattern also applies to 20th century examples, such as lasers (Scotchmer, 2004) and open source software (Murray and O'Mahony, 2007). Such shared leadership of technological progress — a diversified innovation base — means that progress does not depend on any one individual or firm.

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 cumulative effects of a community of users, each building upon the other's efforts (e.g. Hienerth, 2006).

The other case where cumulative innovation is important 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 (Scotchmer, 2004).

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 (Scotchmer, 1991). 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 example of such a standoff is given by the development of vacuum tubes in the early 20th century (Jaffe and Lerner, 2004: 51). 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 grant). Development of the U.S. broadcasting industry was blocked until the stalemate was resolved (Scott, 2001).

Chesbrough: Open Innovation

As with cumulative and user innovation, open innovation builds upon the assumption of dispersed capabilities for identifying and implementing innovations. 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 two approaches to examine the same phenomenon and reach different conclusions.

Chesbrough (2006:1) 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.”[2]

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. In the transaction cost economics framework of Williamson (1985), markets 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 (1990) network form of organization. In fact, the production of many complex products inherently depends on the cooperation of firms within a value network (Vanhaerbeke, 2006).[3] Such value networks are quite common in systems-based

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2 The Chesbrough (2003a) 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 Fleming and Waguespack (2007). In other cases, open innovation refers to a model of non-monetized information flows: this is consistent with Chesbrough’s (2003b) “innovation benefactor” form of nonprofit innovators, but not the primary emphasis of Chesbrough (2003a) on buying and selling innovations.

3 The definition of “value network” of Vanhaverbeke (2006) and others in Chesbrough et al (2006) seems exactly equivalent to the business “ecosystem” of Ianisiti & Levien (2004), which they cite. It differs primarily from the

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 (Grove, 1996; West, 2006). The subdivision of labor between key remembers of the value network is enabled by technical modularity that enables an efficient division of labor (Baldwin and Clark, 2000; Langlois, 2003). However, innovation in such systems often requires a firm or group of firms to lead and shape the innovation occurring within a value network (Maula et al, 2006).

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 lie within the boundaries of the firm. 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 policies: intellectual property, public funding of R&D and infrastructure, regulation of competition and taxation.

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

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more familiar Porter "value chain" 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.

or segment. Although Scotchmer (2004) has suggested alternative innovation incentives such as invention prizes, most of the research and policy discussion has focused on the appropriate strength of the IP protection mechanisms.

Here 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 faced 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. Some of these reforms would be quite modest, by reducing the likelihood of protection for trivial ideas and making it easier to overturn weak patents (Jaffe and Lerner, 2004; Graham and Harhoff, 2005). 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 (Scotchmer, 1991).

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 (cf. Chesbrough, 2003a).

Copyright. Concerns about strong IP regimes deterring cumulative (or user) innovation are not limited to patent policy. In some ways copyright has been 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.

The initial experiments came with the creation of licenses for free and open source software (Rosen, 2004). The two movements share similar technical approaches but different underlying philosophies (Dedrick and West, 2008). Free software is explicitly predicated on a user innovation model (von Hippel, 2001). Open source 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 (Behlendorf, 1999; West & Gallagher, 2006). Both approaches enable cumulative innovation, because the copyright licenses are designed to facilitate sharing of technology to enable further decentralized innovation

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 (cf. Lessig, 2004; von Hippel, 2005). The "creative commons" licenses are intended to facilitate such sharing and recombination, based on the ideas embodied in 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. 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.

Funding and Managing Public R&D

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 he level of funding and the allocation of rights, but has also consider policies related to developing, managing and diffusing such innovations.

Innovations from government research labs, government-funded university projects and other public sources (including university funded research) were traditionally allowed to spillover freely to the private sector in a model Chesbrough (2003b) terms the "innovation benefactor". In other cases, nonprofit organizations have sought to disseminate their innovations as (per Chesbrough 2003b) "innovation missionaries." In both cases, the funding or provision of innovation is a public good provided to promote societal welfare (West et al, 2006). Such an 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.

Such spillovers from government founded R&D have also been the basis of open innovation, particularly for basic science or dual use military technology. One well-known example is the Internet, which was developed using US Department of Defense funding to provide a military communications network robust against military attack, but subsequently enabled a wide range of private innovation (Mowery and Simcoe, 2002). A lesser known example is that of digital communications, where DoD-funded basic research in information theory at MIT spilled over to former PhD students who formed startup ventures during the 1960s (West, forthcoming).

However, the 1980 US Bayh-Dole Act was based on the opposite philosophy — that 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.[4] In the terms of Chesbrough (2003b), universities are transformed from innovation benefactors to innovation merchants.

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. McManis & Noh (2007) summarize the policy debate and evidence over the Bayh Dole

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4 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 (Mowery and Sampat, 2001).

Act and its effects on university biotechnology research. Fabrizio (2006) shows that attempts by 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.

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 could run afoul of antitrust or other national competition policies. Here I highlight two cases: a component-based open innovation model, and explicit attempts to create cumulative innovation through R&D consortia or other efforts at R&D pooling.

Horizontal Component Monopolies. As noted by Grove (1996), 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. 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.

Meanwhile, in response to antitrust criticisms, these 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 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 his college dormitory to ship personal computers in competition with IBM.

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 (Scotchmer, 1991).

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, reversing a policy decision of the 1890 Sherman Antitrust Act that banned such cooperation between direct competitors[5] (Evan & Olk, 1990). 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 value network of competitors, suppliers and customers — as with the Evan & Olk (1990) example of the Plastics Recycling Foundation, which included makers of plastics and plastic-based packaging, as well as major buyers of such packaging. 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 West and Gallagher (2006) observe with open source software consortia. However, the applicability of this form for shared R&D has yet to be proven beyond software production.

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[5] As Evan and Olk (1990) note, such collaborative innovation was not considered illegal in Western Europe or Japan.

Promoting Public Infrastructure

The example of the Internet 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.

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 (Mowery & Simcoe, 2002).

Additionally, the process of standardizing infrastructure interfaces generally follows the best practices for multilateral standards setting organizations (SSOs) (cf. West, 2007). 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 (Bradner, 1999).

By its nature, 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 (Langlois, 2003). This could potentially create component or systems markets between providers of different pieces of the infrastructure

Tax Policy

Tax deductions or credits encourage firms to invest in R&D to produce innovations, but allow 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).

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 was 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 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 (cf. Zittrain, 2006).

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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Tables and Figures

Table 1: Sources of innovation in contrasting theories of innovation

Theory	References	Focal Firm	Suppliers	Customers	Rivals
Vertical integration	Chandler (1977, 1990)	X			
User innovation	von Hippel (1988, 2005)	X	†	X	
Cumulative innovation	Scotchmer (2004)	X			X
Open innovation	Chesbrough (2003a, 2006)	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