Chapter 6
Does Appropriability Enable or Retard Open Innovation?

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Open Innovation reflects the ability of firms to profitably access external sources of innovations, and for the firms creating those external innovations to create a business model to capture the value from such innovations. Contrasted to the vertically integrated model, Open Innovation includes the use by firms of external sources of innovation and the ability of firms to monetize their innovations without having to build the complete solution themselves.

But as Teece (1986) noted some 20 years ago, the ability of firms to pursue this latter course (and thus create a supply of external innovation) depends on appropriability. Absent appropriability, imitators will commercialize the ideal and the innovating firm will lack the incentive (and possibly the funds) to ever innovate again.

Formal appropriability by and large depends on intellectual property laws, and certain types of Open Innovation are only possible through such I.P. protection. Thus, the remaining chapters in this section consider the relationship of IP policies (whether at the nation-state or organizational level) to the practice of Open Innovation. At the same time, from their studies of biotechnology and information technology innovations, the authors suggest cases under which too much appropriability is also bad for Open Innovation.

Implicit in these and other studies — but explicit in West (2003) — is that firms can voluntarily surrender appropriability to achieve other firm goals, such as seeking adoption in the presence of demand-side economies of scale. Appropriability decisions are thus not just those of infrequent changes in national policy, but also the ongoing strategies of individual firms for specific technologies.

In this chapter, I first review the role of IP in providing appropriability, and from that its role in enabling Open Innovation. I then discuss how strong IP can also hinder the flow of innovation, using a discussion of the remaining chapters of the section to contrast Open Innovation (as defined in Chapter 1) with three other uses of "open" in the context of innovation: open science, open standards and open source software. From this, I review a brief case study of the effect of I.P. on innovation in mobile telecommunications, and then conclude with observations and questions about Open Innovation and appropriability.

IP Enables Appropriability

Importance of Appropriability

Nearly two decades ago, David Teece wrote:

> It is quite common for innovators – those firms which are first to commercialize a new product or process in the market – to lament the fact that competitors/imitators have profited more than the firm first to commercialize it! (Teece 1986: 285)

Teece's observation anticipated a subsequent burst of research that showed that technological pioneers have as many advantages as disadvantages. Pioneer investments are highly risky due to technological, market and financial uncertainty, and their efforts to create a new market usually benefit imitators, particularly fast followers. Meanwhile, imitators have lower costs if they can wait for the pioneer to identify a winning strategy rather than having to make their own investment in technological and market experimentation (Aaker and Day, 1986; Lieberman and Montgomery, 1988; Golder and Tellis, 1993; Schnaars, 1994).

Teece's strategic recommendations were contingent upon the level of appropriability available to the firm. If the level of appropriability is high, firms would have time to develop the idea, experiment in search of a dominant design, and enjoy the fruits of any eventual success of the technology. If not, the innovative firm must vertically integrate to build a complete solution or, barring that, hope to create an enforceable contract with suppliers of complementary products and capabilities necessary to commercialize the innovation (Teece, 1986).

If firms are unable to lock up key strategic resources to assure competitive advantage, then the path to profiting from innovation is more tenuous. More recent research suggests firms must change rapidly to be able to exploit new opportunities and achieve at least temporary competitive advantage (Tushman and O'Reilly, 1986; Teece, Pisano and Shuen, 1997; Rindova and Kotha, 2001). But such dynamic or transient competitive advantage is both hard to achieve and often fleeting even if won, thus raising considerable doubt about the likely payoffs to innovators. Without returns to innovation, the temptation is for all firms to free ride on the innovation of others, with none willing to invest in creating their own innovations.

Potential Role of IP

Avoiding this problem of underinvestment in innovation is exactly the point of granting temporary monopolies[2] through intellectual property rights. As Besen and Raskind observe:

> The objective of intellectual property protection is to create incentives that maximize the difference between the value of the intellectual property that is created and used and the social cost of its creation (Besen and Raskind, 1991:5)

In the U.S., such a policy objective dates back to the Constitution (1787), which calls on Congress "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries" (Article I, Section 8). Two centuries later, responding to a fear that Europe was lagging in innovation due to its IP system, a European Commission "green paper" concluded:

> It is vital to protect the fruits of innovation. In economic terms, it has been clearly established that companies with specialized know-how which sell branded products and patented products or processes have a competitive advantage when it comes to maintaining or expanding their market share. (European Commission, 1997: 1)

Most of the discussions of strong appropriability center on one particular form of IP, the patent, because it covers the fundamental idea rather than its expression, and also blocks independent invention by potential imitators. However, industrial innovation also makes use of copyright and trade secret protections, so these two are also potentially applicable to Open Innovation.[3]

IP Enables Open Innovation

For firms seeking to gain additional revenues through Open Innovation, Chesbrough (2003a: 155) identifies two key factors. First, licensing technology depends on the firm's IP strategy, which defines the role of the IP both for the innovator and any potential licensees. Secondly, the innovator must develop a business model consistent with both the value of the IP and the innovator's position in the value network (Chesbrough and Rosenbloom, 2002).

Here I focus on innovations related to a core technology at the beginning of a complex system supported by complementary products.[4] For this model, the value network would consist of technological innovators, component suppliers, system integrators, suppliers of complementary products and end customers (Figure 6.1). The core technology may be incorporated either into a component or directly into a product. If in a component, such components are then integrated with other components into a complete system (Hobday, 2000; Prencipe et al, 2003), and firms succeed through the application of integrative competencies (Christensen, Chapter 3). The system, in turn, gains value through the provision of complementary products customized to work with the system (Teece, 1986; Shapiro and Varian, 1999).[5]

This model corresponds to complex assembled systems, such as IT and machinery products. However, other forms of cumulative innovation exist with more or fewer intermediate levels in the value chain, as well as different forms of complementary assets. For example, in the pharmaceutical industry, essential complementary assets may include manufacturing, distribution or service (Teece, 1986).

Vertical Integration vs. Open Innovation

Innovators have multiple paths to gaining an economic return from their innovation:

- they can license the innovation to downstream suppliers to incorporate in products and components, as Qualcomm has done with CDMA-related patents and Rambus attempted to do with RDRAM memory technology (West, 2002; Tansey et al, 2005).
- they can distribute them in components, which compete with other similar components, as Intel does with its microprocessors;
- they can incorporate them in complete solutions, as happened during the golden era of proprietary vertically integrated computer manufacturers such as IBM and DEC (Moschella, 1997).

Large vertically integrated firms can create a systems innovation from beginning to end, which potentially limits the scope of imitation: if only vertically integrated firms can appropriate an invention, then there’s a relatively small number of firms that have the necessary end to end capabilities. Once, the large computer makers all followed this model, but today only IBM, HP and Fujitsu can sustain it. Meanwhile, most of the computer industry is moving to the vertically dis-integrated, horizontally specialized model used by the PC industry since early 1990s (Grove, 1996; Kraemer and Dedrick, 1998), while using shared open networking standards that were developed through nonproprietary engineering committees (Simcoe, 2006). More generally, modular decomposition of a technical problem has enabled separation of production between specialist firms (Langlois, 2003b).

If an innovation is not protectable, firms may be able to combine such innovations with others that are protectable to gain indirect economic returns. For example platform vendors often bundle new applications with their systems or software to make them more attractive (as Microsoft bundled Internet Explorer with Windows 95 or Apple bundled iPhoto with OS X) and thus drive upgrade sales. However, this scenario encourages vertical integration and discourages Open Innovation because the innovation does not earn a direct return but only the indirect return through bundling; in this case, the cross subsidies discourage other (otherwise profitable) innovation and experimentation in competing with the subsidized component.

Scale Economies and Priming the Adoption Pump

The production of many types of innovations are subject to scale economies, whether in amortizing the total costs of production (such as up front R&D) or in demand-side economies of scale through positive network effects (Katz and Shapiro, 1985; Arthur, 1996). The latter are common in I.T. industries where two or more technologies compete for adopters and the provision of specialized complementary products (Teece 1986; Shapiro and Varian, 1999)

Thus, for an industry with scale economies and a need for complementary innovation, firms need to expand the total value created by the value network rather than just maximizing their share of the existing value. In reviewing open standards strategies of computer producers, West (2003) concluded:

> These various strategies reflect the essential tension of *de facto* standards creation: that between appropriability and adoption. To recoup the costs of developing a platform, its sponsor must be able to appropriate for itself some portion of the economic benefits of that platform. But to obtain any returns at all, the sponsor must get the platform adopted, which requires sharing the economic returns with buyers and other members of the value chain. In fact, openness is often used to win adoption in competition with sponsors of more proprietary standards. West (2003: 1259)

This is not to imply that value capture and value creation are mutually exclusive. Grove (1996) identifies how Intel's strategy of horizontal specialization in microprocessors — selling processors to all systems integrators — was more efficient than the vertically integrated mainframe vendors that sold processors only for their respective computers. This strategy provided supply and demand-side economies of scale, reducing costs and maximizing adoption; it also maximized the availability of complementary assets. Yet, as Kraemer and Dedrick (1998) note, Intel and fellow component vendor Microsoft capture most of the profits from the PC industry value chain during the period Grove was advocating this model.

Thus, for an industry with scale economies and a need for complementary innovation, firms need to expand the total value created by the value network rather than maximizing their share of the value captured, i.e., to worry about "growing the pie" rather than "slicing the pie." Such a strategy reduces the risks of a self-reinforcing downward spiral of declining market share and scale economies associated with losing a technology contest associated with network effects, such as the Betamax or Macintosh standards (Cusumano et al, 1992; Arthur, 1996; West 2005).

Interdependence of Business Models in the Value Network

A firm's business model depends not only its IP and value proposition — as explicitly identified by Chesbrough (2003a, Chapter 1; Chesbrough and Rosenbloom, 2002) but also implicitly on the corresponding business models of the suppliers, customers, competitors and complementors throughout its value network.

Chesbrough and Rosenbloom (2002) identify six functions of a business model: articulate a value proposition, identify a market segment and its revenue potential, define the structure of the value chain, estimate the cost and profit potential, describe the position within the value network and formulate the innovator's competitive strategy. Early stage Silicon Valley companies often refer to a "revenue model", which correspond roughly to the first two functions of the Chesbrough and Rosenbloom formulation, without the meeting the more stringent business model requirements of profitability and sustainability.

Because IP provides barriers to imitation, strong appropriability can make it easier for firms to identify the value capture (but not value creation) part of their business model. New technologies will tend to require new business models, when the technology changes the value proposition to customers, the value capture by the innovator firm, or the relationship of firms within the value network. A firm's competitive advantage thus is determined in part by its structural position relative to external organizations that play a role in its innovation (Teece et al, 1997; Simard and West, Chapter 11).

In fact, few innovators can determine their business model in isolation. The business model depends not only on the value perceived by customers, but also suppliers, competitors, customers and complementors. A firm's ability to command its desired price (and thus extract value) depends on intrasegment rivalry and its negotiating power relative to buyers and sellers (Porter, 1980), as when Microsoft and Intel used their quasi-monopolies to capture the profits in the PC value chain.

Firms that have influence over their business models thus will be concerned about entering into an Open Innovation value network where their exchange partner has strong enough IP to assure appropriation of rents. But such power will be rare: few partners — whether component suppliers or systems integrators — have the alternative of walking away from an unfavorable deal without enabling a potential competitor. One example is the failed attempt by European telephone companies to compel royalty-free licensing of GSM mobile phone patents (Bekkers, 2001:322). Another example is the monopsony buying position of U.S. cable TV companies,[6] who used that monopsony power to force commoditization by their suppliers (e.g. through cable modem standards). Given this, operators have been reluctant to procure a key component (settop boxes) from Microsoft, for fear that it would use its copyright (and trade secrets) to create supplier power in the cable TV industry comparable to that it holds in personal computers.

Conversely, Teece (1986) is concerned with the case when innovators have weak initial appropriability. In such cases, he posits that firms have a temporary window to improve their appropriability, vertically integrate, or otherwise build barriers to imitators. Teece et al (1997) later concluded that in the absence of formal appropriability barriers, firms are best able to create advantage through superior “dynamic capabilities” such as rapid learning, but such advantages would appear to be more rare and less sustainable than those provided by formal appropriability.

Another key issue is the use of cross-subsidies in business models. Such business models are increasingly common in complex systems (e.g., West and Gallagher, Chapter 5) and such models can both create vulnerabilities for business models of other firms in the value network and, in turn are vulnerable to competition from such firms. For example, a firm’s business model may be vulnerable to shifts in the business model of complementors. Netscape used a revenue model of licensing its market-leading web browser application to large corporate users that was consistent with other PC software.[7] However, this revenue model was decimated by Microsoft's decision to give away a directly competing product (Internet Explorer) as a free complement bundled with its Windows operating system. (Cusumano and Yoffie, 1998; Bresnahan and Yin, 2004).

IP and Information Search

One key issue in inbound and outbound licensing of innovations is the information exchange necessary to evaluate the innovation. Open Innovation requires significant disclosure to match buyers and sellers for transacting the exchange, as O'Connor (Chapter 4) discusses in the context of Dupont's patented materials innovations.

The two parties to the potential exchange have conflicting interests:

- the potential in-licensor wants information to evaluate, judge its value, and compare the cost of buy vs. build.
- the potential out-licensor wants to provide enough information to conclude the transaction; at the same time, it must be concerned about providing enough information to customers (or rivals) to invent around and bypass the seller.

This is consistent with Arrow's (1962) "information paradox", a limiting case that — absent property rights — a seller disclosing information for evaluation by potential buyers allows the buyer to acquire that information at no cost.

IP potentially solves this problem, because it can protect a firm's ideas while they are disseminated in search of a market: IP is thus valuable in both shopping innovations, and also allowing them to be licensed. In particular, a fundamental tradeoff in patent policy is that patenting requires disclosure of an innovation to enable subsequent cumulative innovation (Gallini, 2002).

However, not all IP mechanisms are created equal. A patent provides the best protection for this sort of information disclosure; even so, such protection is incomplete in some industries. A copyright provides protection of the expression of an idea, but does not protect against independent invention that duplicates the functionality of that idea. Information disclosure is contrary to the basic principles of trade secret law, and thus provides very limited protection for innovators seeking to license their innovations.

Having rights to IP is not the same as asserting them. Some innovators may be more interested in winning adoption than minimize potential spillovers. This is certainly more likely for organizations that are "innovation benefactors" (West, Vanhaverbeke and Chesbrough, Chapter 14). However, as Fabrizio (Chapter 7) notes, the desire to profit from basic science has caused universities to act less as benefactors (donating innovation) and more as information explorers (selling innovation).

Information search is easiest when there is no IP on the innovation: the U.S. Federal government does not hold copyright while other governments (like the U.K. with Crown Copyright) do. But giving away innovation is not a business model. With adequate resources, an innovation benefactor can persuade its stakeholders that the social benefits of giving away innovations (such as unpatented public research) exceed the cost of doing so: a common argument is that the innovation creates spillovers that increase employment and economic development. Without such a rationale, innovation benefactors (public or private) become innovation investors, forced to justify a direct return on innovation spending.

Limitations to IP-based Business Models

In addition to the challenges of market competition, the IP-based business models of firms are vulnerable to potential conflicts with other public policy goals.

For example, if IP is strong enough to have anti-competitive effects regulators may weaken or waive IP protection to implement competition policy.[8] These may be part of a general pattern of reforms to balance innovation and competition policy goals (e.g., Farrell and Shapiro, 2004). General exceptions include allowing reverse engineering exception to software copyright (West, 1995) and policies speeding generic copies of patented pharmaceuticals (CBO, 1998). IP may be weakened to address specific monopoly concerns, as with the 2004 European Commission decision to compel Microsoft to disclose server interfaces to competitors (Meller, 2004).

The IP goals of firms may also come into conflict with a country's industrial policy goals. For example, developed country innovators have found their patents voided or subject to compulsory licensing in developing countries (such as Brazil, China, and India) seeking to use local imitation as a way to bootstrap the innovation capabilities of domestic producers.

Other regulatory goals may also override IP enforceability. For example, trade secret law in Silicon Valley provides only limited protection against the interfirm mobility of knowledge due to state labor laws that restrict non-compete covenants. Gilson (1999) argue that these key differences between Silicon Valley and Route 128 can be traced to historical differences in the respective state civil codes.

In addition to regulatory conflict, a second limitation to *de jure* IP protection is that it may not provide *de facto* protection. For example, strong copyrights have not protected against unauthorized copying of information goods such as music or software, particularly in developing countries (Burke 1996). Small firms holding patents infringed by larger firms may not be able to enforce them unless they can garner sufficient resources to credibly threaten litigation; a rare example of this is Stac Electronics' 1994 landmark $120 million award against Microsoft (Graham and Mowery, Chapter 9).

If formal IP does not provide appropriability, then (as Teece 1986 predicted) firms may take other steps such as vertical integration to earn returns from their innovation, as when a firm incorporates its technology in a ready-to-use component. But even such component strategies have appropriability limits, particularly with information goods. Modular or component innovators run the risk of not getting paid by integrators, who are tempted to maximize their attractiveness to customers while minimizing their cost of inputs. This is particularly a problem with information goods, such as software utilities that are bundled with other hardware or software. Software vendors might seek to use technical means (tying their product only to use with the bundle), copy protection, or even a physical artifact such as the Windows "Certificate of Authenticity". The innovator can also modify its business model to provide components of limited utility and see profits primarily by selling an enhanced version of the innovation: the software industry refers to this as a "teaseware" or "crippleware" strategy.

Finally, a firm seeking to build a business model based on licensing IP-protected technologies and components may prove too successful, if its exit from vertical integration results in "hollowing out." In the 1960s and 1970s, RCA turned its consumer electronics emphasis from product innovation to licensing its patent portfolio to Japanese competitors — partly because such licensing produced high growth rates and profit margins, and partly because regulators compelled it to license IP free to domestic rivals (Chandler, 2001). When the company attempted to extend this model to the next-generation high definition television, the once dominant RCA was unable to produce technology competitive with rival HDTV systems (Brinkley, 1997).

Does IP Conflict with Innovation Openness?

The Open Innovation paradigm assumes firms can extract income (whether through licensing or other forms) from their innovation, which provides both the revenues and incentives to produce the innovation. However, such payments are contrary to the expectations of what many consider to be an "open" form of innovation, in which a shared (if not communal) external innovation is available without significant direct cost.[9] Conflicts between these two viewpoints have resulted in some of the most controversial IP issues of recent years related to innovation practice and policy.

The following chapters in Section II consider three key areas of conflict. In Chapter 7, Kira Fabrizio looks at the impact of universities patenting their innovation has upon the cumulative production model embodied by "open science". In Chapter 8, Tim Simcoe considers the increasing conflict between patenting and "open standards." And in Chapter 9, Stu Graham and David Mowery look at the impact of patents on the software industry at large, including open source software.

In these three areas, there are two issues. One is the effect asserting IP has upon the (potentially zero sum) allocation of returns within the value network. The second is the net effect of this income transfer — whether the incentives to innovate by technology producers outweigh the innovative drag for technology consumers, either through increased search costs, transaction costs, or duplicative investment to "invent around" innovation IP. Even under the same IP regime, there are more and less efficient solutions — as when Gallini (2002: 137) observes that increasing the appropriability of patents increases the transaction costs for producing cumulative innovation if firms are forced to separately negotiate licenses with each owner of potentially blocking patent.

Evolving University Roles in Open Science

One major source for firms seeking external innovations has been university research that is widely disseminated for firms to use as a building block in their innovation efforts. The exemplar of this policy was U.S. federal funding of university research in the post-World War II era and the role of this research in enabling industrial innovation (e.g. Henderson et al, 1998a; Cohen et al, 2002; Colyvas et al, 2002).[10] However, many have lamented a decline in free innovation spillovers in recent years, tied to declining government support and an increasing emphasis by universities on licensing their innovations.

Explaining the declining importance of U.S. government funded research is complex and controversial. During the heyday years of the 1960s, much of the federally funded research was tied to building complex systems for space exploration and military forces, and the relative importance of such systems declined during the 1970s-1990s (Jaffe, 1996). Of course, the government decisions for funding R&D depend not only on those R&D funding requests, but also the availability of resources and other demands on those resources.[11] While government R&D and procurement helped fund the development of the U.S. IT sector from the 1960s through the 1980s, the relative importance of federal R&D funding began a steep decline starting in 1988 (Fabrizio and Mowery, forthcoming B).

The issues extend beyond the U.S. context. Even as U.S. funding was declining, Pavitt (2000) called on the European Union to increase funding of university R&D to match the U.S. success at creating new innovations, which he tied to spillovers from its university research.

Taxpayer money is not the only way to pay for university research. Particularly in areas such as biotechnology, university research is increasing funded by the private sector. Of course universities and university faculty (at least in some countries) have always performed contract research for industrial firms; but overall the importance of such industry funding has been increasing over time (Jaffe, 1996). In some cases, corporate funding offers publication and open disclosure of results comparable to government funding, as with Intel's research labs located next to leading U.S. and UK universities (Chesbrough, 2003a: 123; Tennenhouse, 2003). But in other cases, the funding comes with restrictions or expectations of exclusivity.

This relates to a second trend, which is changing university attitudes towards their innovation IP. At one point, universities did not assert IP rights covering their research results, allowing that research to spillover to firms as the basis of subsequent industry innovations. For example, during the 1980s government-funded and industry-funded computer science research (at U.C. Berkeley and MIT, respectively) provided crucial technologies for Unix systems vendors of the 1990s (West and Dedrick, 2005).

Today, universities are increasingly asserting IP rights (particularly patents) over their innovations and licensing them under a royalty-bearing license. Many have attributed the rise of patenting by U.S. universities to the 1980 Bayh-Dole act, whose objectives and policies are summarized by Fabrizio (Chapter 7). However, Mowery and Sampat (2001, 2004) argue that increased university rate of patenting was discernable during the 1970s, and thus the act reflected rather than initiated the trend towards increased university patenting.

In addition to demands made by corporate sponsors, universities have also shifted away from a model of free spillovers to that of technology transfer offices, in hopes that licensing revenues would replace declining revenue from other sources of income. In fact, the policy of universities with these offices (captured in research such as Siegel, Waldman and Link, 2003 and Bercovitz and Feldman, 2003) is that any innovation not controlled by the technology transfer office constitutes a failure of the system or the individual researchers to capture the value of the innovation. This reflects a (largely unproven) assumption by these offices that university innovations will invariably lead to firm success and economic growth (cf. Miner et al, 2001).

Universities licensing technology to firms might raise the price of external innovations used by firms, but such a practice is entirely consistent with practices of Open Innovation: in the terminology of Chesbrough (2003b), universities would shift from innovation benefactors to innovation explorers. Exclusive licensing might reduce the number of firms that can benefit from a given innovation, but at the same time exclusivity provides greater incentives for licensees to invest in commercialization — a key justification cited in passing Bayh-Dole (Fabrizio, Chapter 7).

However, researchers have postulated another potential disadvantage of increased patenting. Incentives for academic research have encouraged the free flow of information through career incentives for publication. Assertion of intellectual property rights on basic research output could restrict the flows of information between basic researchers, thus slowing or impeding the process of cumulative innovation that characterize "open science" (David, 2002; 2005).[12]

Is there any evidence of such deleterious effects? This is exactly the question Fabrizio (Chapter 7) attempts to answer. From prior research, she identifies two potential negative effects of greater university patenting.

First, restrictions on access to university IP slow attempts by other researchers to build upon university research. It is straightforward to predict the effect that exclusively licensing IP to a single firm has on other firms in the same industry. But in other cases, she notes that the transaction costs of dealing with technology transfer office inefficiencies means that even IP that is available for licensing becomes less accessible. Secondly, researchers involved in commercialization of university research are more secretive in sharing their results to protect the proprietary value of such data. As Fabrizio notes, this undercuts the fundamental basis of open science collaborative innovation, in which the output of one researcher becomes the input to another.

From her own analysis of citation patterns of firms' patents, she identifies two effects consistent with prior expectations. First, as public science (unpatented prior art) became more important in a technology class, firms separated into "have" and "have nots" in their acces to public science, suggesting that some firms are doing a better job than others in their capability to access university research. Secondly, as university patenting increased, so did the lag of citations to cited prior research, suggesting a slowing down of firm exploitation of existing knowledge.

Finally, analyzing patents by biotechnology and pharmaceutical firms, she identifies two factors that explain the ability of firms to access public science. First, consistent with Cohen and Levinthal's (1990) concept of absorptive capacity, access increases with increased R&D. More interestingly, access also increases as the firm's scientists publish research co-authored with university scientists — but only up to a point. This implies that firms that always depend on university researchers do not fully develop their own internal scientific capabilities, while firms that rarely (or never) co-author have access to less cutting edge basic science. This also implies a shift by industrial researchers away from relying solely on open publication towards using university colleagues to help identify and interpret the relevant output of open science — at least for these two industries.

Open Standards

Another venue where IP potentially impairs shared innovation is in the area of product compatibility standards, particularly in the IT sector. Of course, IP has long been a central part of the proprietary *de facto* standards strategies of firms from IBM to Microsoft. As with other firms, the exclusive rights provided by IP allows firms to gain economies of scale and earn a return on their R&D investments (Morris and Ferguson, 1993; Shapiro and Varian, 1999).

Open standards implemented by multiple vendors — whether created through formal standards development organizations (SDOs) or *ad hoc* research consortia — have similarities and differences to single-firm proprietary standards. By their nature, compatibility standards enable a modular subdivision of labor and thus a decentralized production of innovation (Garud et al 2003; Langlois, 2003b). Both types provide similar incentives to third parties producing complements, as well as for end users utilizing implementations of the standards (West, 2006).

But in other key areas — the organization of innovation, ownership of intellectual property and even cultural norms — "open" and "proprietary" standards have been as distinct as "open science" and its commercial counterpart. The open standards have historically focused less on individual firm competitive advantage and more on defining rules for interoperability for a common infrastructure. Adherents of this form of standardization have emphasized openness and transparency in the standardization process and outcomes (Krechmer, 2006).

However, firms have increasingly sought to gain commercial gain within open standards, not merely through superior implementations in commercial products, but also by negotiating to have their royalty-bearing IP incorporated into the required terms of the standard. These and other business models have blurred whatever bright line might have existed between open and proprietary standards (West, 2006).

Such tactics are problematic for Open Innovation. The increasing use of licensing-based business models by specialist firms has fueled a three-way conflict between technology producers, system integrators and the eventual technology users. On the one hand, a key example of Open Innovation identified by Chesbrough has been creating business models to gain returns on innovation through outbound licensing, and so standards committees (such as W3C) that mandate royalty-free IP licensing would help users and integrators (or vertically integrated producers) while potentially eliminating the Open Innovation business models of IP-only specialists. Even without such royalty free mandates, the feasibility of such pure IP-based models can be limited by other SDO policies or weak appropriability (Tansey et al, 2005).

On the other hand, asserting IP on industrywide standards has potentially anti-competitive impacts, such as when vertically integrated firms to increase the costs and reduce competition from potential rivals (cf. Bekkers et al, 2002). Even without such market power, the holdup of IP owners can disrupt standardization activities (Simcoe, Chapter 8). And any royalty-bearing IP — whether from actual innovators or rent-seekers such as so-called "patent trolls" — increases the cost of implementing a standard and thus the net cost to consumers.

What is the net effect of this increasing role of IP in standardization? In his various empirical studies on IP and formal standardization, Simcoe concludes that Open Innovation has delayed standardization, increased implementation and coordination costs. For example, Simcoe (2006) shows that increasing assertion of patents in Internet standards has delayed standardization during the period 1993-2003.

Simcoe (Chapter 8) also considers the potential of an IP owner with blocking patents to "hold up" a standardization effort by preventing implementation of a standard without payment of a licensing fee of the innovator's choosing. Such efforts are always controversial — due to vocal objections from licensees used to cross-licensing or otherwise avoiding patent liabilities. In some cases, such licensing is an essential way for a non-integrated innovator to get compensated for its innovation, as Mock (2005) asserts is the case for Qualcomm's mobile telephone patents.

At the same time, when presented with the actual costs of innovation licensing, a standardization effort will often modify the standard to avoid infringing on a patent and thus the associated patent royalties. This is not possible if a firm tries to exploit the standardization process by not disclosing the existence or cost of IP, or if they modify patent claims after seeing the eventual standard. In Chapter 8, Simcoe interprets these as failures of IPR policies, either by standardization groups or national patent examiners.

Software and Open Source

Patents are also playing an increasing role in the software industry, and open source software in particular. Like open standards, open source software reflects collaborative production between multiple organizations (and individuals). But unlike open standards, in open source the collaboration results in a shared implementation of a technology, rather than merely its technology.

West and Gallagher (Chapter 5) classify the different business models of firms used by firms sponsoring or leveraging open source development projects. Some firms use open source as a form of Open Innovation, while others use it as a way to win adoption of their technology and attract complementary products

But fundamentally open source software — and the related "free software" movement — are about intellectual property. The IP requirements of the latter are a superset of the former, such that anything classified as "free" is also "open source," but not vice versa. Both agree that source code should be publicly disclosed and that all recipients have a right to enhance and improve that code. However, there are important philosophical and cultural differences between the two groups that are embodied in their respective IP licenses (West and Dedrick, 2001; 2005).

Open source licenses such as the Apache and BSD licenses impose few restrictions, and thus software licensed under these terms are attractive to firms to use as components in their own systems. “Free software” licenses are more restrictive: licenses such as the General Public License require modifications to GPL-licensed technology to be publicly disclosed, to prevent firms from creating proprietary derivative works that eventually supplant the free alternative (West, 2003). In fact, the restrictions of the GPL today are now used by firms to release innovations while making them less attractive for use by direct competitors (Välimäki 2003).

These two licenses thus represent two different approaches to shared innovation. The BSD-type licenses represent free spillovers that can easily serve as external innovations for firms in their own products; such commercial product may compete with the open source benchmark and could conceivably supplant it. On the other hand, the restrictions of the GPL assure that the shared innovation remains shared, while limiting the incentives for further commercial investment to develop and enhance the technology.

A second, emerging IP issue in open source software is that of software patents (cf. Nichols, 1998). While patents have already had a demonstrable impact on open standards (Bekkers et al, 2002; Simcoe, 2006), their impact on open source is far from resolved.

Many of the impacts of patents on software are not yet understood because patenting software dates only to 1981, and largely limited to the U.S. In analyzing US software patents during the period 1987-2003, Graham and Mowery (Chapter 9) subdivided the largest software innovators into two different business models: 100 software specialists whose primary business was selling software, and 12 manufacturers of electronics goods for whom software is but one component in an overall system. While the patent propensity of the former group has increased, they conclude that the latter group (dominated by IBM) has increased both its software patenting and overall share of those patents. In particular, in comparing the largest firm from each category, Graham and Mowery (2003, Chapter 9) found that IBM not only has a higher patent propensity than Microsoft — as scaled by software R&D — but has been widening the gap during the past decade.

However, Graham and Mowery conclude that (despite specific examples such as the Stac case), we don't yet know what role software patents play in the overall IP strategies of the sampled firms. For example, are these patents intended for suing rivals, defending against lawsuits by rivals, or cross-licensing with various competitors and complementors? Each suggests a different business model based on the software innovation, as well as differing implication for other (typically smaller) organizations outside this patenting population. In particular, the offensive (suing rival) alternatives has potentially severe implications for open source projects that lack a direct firm sponsor or revenue stream. Some projects have attempted to pre-empt potential problems by adopting licenses that threaten retaliation against threats of patent litigation, but such licenses have yet to be tested in court. Also, as Graham and Mowery (Chapter 9) note, there is little such license can do to address patents held by other firms not a party to creating or using the software.

Case Study: Mobile Telephone Standards

An example of how shifts in Open Innovation both affects and is affected by intellectual property policies can be seen in the increasing role of patents in mobile telephone standards across successive generations of mobile telephone standards.

Innovations in mobile telecommunications are constrained by the need for compatibility standards to provide interoperability. To be put into use, a technological innovation (such as digital encoding of radio signals) is incorporated into the formal specification of a standard; these specifications are then implemented in products (e.g. a mobile telephone or radio base station), which are then purchased and used (West, 2002, 2006). By the same token, the industry has seen an increasing emphasis of royalty-bearing patents in *de jure* telecommunications standards, reflecting both shifts in industrial organization and the associated changes in business models.

1st Generation Closed Innovation

In most countries through the first eight decades of the 20th century, a government-operated monopoly telephone company allocated equipment orders to one (or a few) domestic manufacturers; the one major exception was the U.S., where AT&T vertically integrated research, development, manufacturing and telecommunications services. In a few cases, companies with small home markets (such as Sweden's Ericsson and Canada's Northern Telecom) exported their existing designs to other countries; (Noam, 1992; West, 2000).

The rate of technological innovation in the wireline industry was slow, with capital investments in network equipment amortized over decades. With the lack of competition and monopsony buying conditions, most firms lacked incentives for patenting their innovations. And whether AT&T's vertical integration or the collaboration between government departments and their captive suppliers, few were examples of what we today call Open Innovation.

Limited scale mobile telephone systems had been deployed in major cities in the U.S. and Europe during the three decades following World War II, but their capacity was limited to hundreds of users. In the late 1970s and early 1980s, the microprocessors enabled subdividing a metropolitan area into cells, increasing the capacity of systems a thousand fold. Of the most widely adopted 1st generation analog cellular systems, those in Northern Europe and Japan were designed by operators and built by manufacturers. Vertically integrated AT&T designed and built its own system, while Motorola and other radio manufacturers built systems for competing operators. Some of these systems were exported to other countries, such as the U.K., Middle East and Latin America (West, 2000; West and Fomin, 2001).

2nd Generation: Open Innovation

To address unexpectedly large demand, during the 1980s cellular phone operators and manufacturers began investigating digital technologies to provide higher capacity and better security, among other features. These reflected a range of Open Innovation strategies: sourcing external innovation, shared innovation, licensing internal innovations and a hybrid of vertical integration and licensing.

In Japan, after the government-owned NTT DoCoMo designed its second generation PDC standard, but outsourced handset design and production to its four major suppliers. DoCoMo used buyer power and control of tacit information to both maintain control over these suppliers and gain competitive advantage over competing cellular operators (Funk, 2003).

Two more Open Innovation models were used. For the European GSM and U.S. D-AMPS (aka TDMA) standards, the technology was developed by multiple equipment manufacturers and operators through an industry standardization committee. The other major U.S. standard, eventually branded cdmaOne, was largely developed by one firm, Qualcomm, that had its standard ratified by U.S. and foreign standards committees; it earned royalties of approximately 4.5% on wholesale price of equipment using its patents, which amounted to nearly all CDMA equipment (West, 2002).[13]

By far the most successful of the 2nd generation standards was GSM (Table 6.1). It was the first to be deployed, and for most European countries marked the first significant deployment of cellular technologies (West and Fomin, 2001). Much of the technology was designed by Ericsson and Nokia, who had the most home market experience of European manufacturers. However, to win approval in the by-country voting of the GSM committee, the design was modified at the last minute to incorporate technologies from French and German manufacturers (Bekkers, 2001).

As ably documented by Iversen (1999) and Bekkers (2001, Bekkers et al 2002), a second key goal was to reduce the threat of foreign (primarily Japanese) competition in the European market, and provide domestic manufacturers an advantage when exporting the technology worldwide. One key mechanism was to mandate the use of the GSM standard across the EU — unlike Japan, U.S and China (among other countries), which allowed use of foreign technologies. The other was through GSM patent cross-licensing, which allow suppliers of key innovations incorporate in the standard to realize royalties on the equipment sales by competitors, both handsets (sold to consumers) and network infrastructure (sold to mobile phone operators). As the least integrated of the GSM IP licensees — as well as least established of selling products in Europe — Motorola in particular pursued an Open Innovation strategy that emphasized IP licensing over product sales (Bekkers, 2001:323).

The GSM standard is often held out as an exemplar of open standardization, particularly in competition with CDMA (West, 2006). Both the GSM and CDMA standards reflected a form of Open Innovation in which innovators received licensing income from the standards they created. The Qualcomm case differed from GSM in two ways. First, for CDMA only one firm (Qualcomm) paid the lowest royalty rate, versus at least five for GSM (Nokia, Ericsson, Motorola, Alcatel, Siemens). Second, for CDMA, all major makers had to pay patent royalties (and were rather vocal in their complaints) to Qualcomm at an undisclosed rate estimated at 4.5% of gross sales (West, 2002).[14] By comparison, for GSM the major European makers (plus Motorola) were believed exempt from patent royalties through cross-licensing among 15 key companies, while outsiders paid total royalties estimated at 10-13% (Loomis, 2005).

As of this writing, what was the effect of these Open Innovation strategies?

- Nokia (and, to a lesser degree, Motorola) remained active vertically integrated manufacturers, developing both new technologies and continuing to be major global suppliers of cellular handsets
- Qualcomm exited equipment manufacturing to concentrate on a successful strategy licensing CDMA IP and selling chips to implement that IP.
- In the face of stiff price competition, Ericsson, Siemens and Alcatel all exited the handset business to concentrate on selling network equipment (Table 6.2)

For the equipment makers exiting the money-losing handset business, their cost advantage in patent royalties played a key role in selling their divisions to Asian competitors (Bekkers et al, 2002; Loomis 2005).

3rd Generation: Learning the Wrong Lesson?

Not surprisingly, the success of GSM IPR licensing created an increased interest by telecommunications firms in generating and patenting licensable innovations (Bekkers et al, 2002). More than 50 companies sought to get their patents established as "essential" for implementing of WCDMA, the 3rd generation mobile phone standard created through the cooperation of the leading GSM vendors along with NTT DoCoMo. When the patents of the CDMA inventor (Qualcomm) were factored in, the high patent royalties put WCDMA at a cost disadvantage, with royalties estimated as being twice that of the leading competitor.

In response, the leading handset maker, Nokia, sought to cap total WCDMA patent royalties at 5%. But in the end, Nokia won only support for "reasonable" licenses from DoCoMo and three European manufacturers. The remaining European and Asian manufacturers — as well as leading operators — formed the competing 3G Patent Platform Partnership (3G3P). North American participants in WCDMA standardization (Qualcomm, Lucent, Motorola, Nortel, TI) joined neither camp (Tulloch, 2002; Lane, 2003; Salz, 2004). As of mid-2005, there is no reported solution to the problem, and additional patent claimants continue to be identified. Thus, the patent strategy used by the leading GSM manufacturers to profit licensing internal innovations in the 2G era are hindering their abilities to sell their main products in the 3G era.

Many of the same patents also apply to WCDMA's leading rivals, the Qualcomm-sponsored cdma2000 and China's competing TD-SCDMA, mitigating some of the competitive effects but overall likely to slow adoption of any 3G standard. As one component supplier said, "The jury is out on whether 3G will be so compelling that consumers will pay the price for 3G handsets – and IPR is part of that equation," (Salz, 2004).

The handset manufacturers face the same adoption vs. appropriation trade-offs as West (2003) identified for computer systems. In this case, there are serious problems of collective action accommodating the heterogeneous royalty (i.e. business model) preferences of more than 50 actors due to a varied mix of equipment and IP revenues. This suggests that combining two Open Innovation strategies — shared innovation and licensing internal innovations — can dramatically raise coordination costs or, at worst, create an anti-commons that fails due to the misalignment of individual and group incentives. Certainly in the trade-off space identified by Simcoe (Chapter 8), the WCDMA standardization effort has biased towards value capture over value creation.

Conclusions

Appropriability ties back to the fundamental question of who pays for innovation. Innovations can be directly subsidized by innovation benefactors, or cross-subsidized through vertical integration. Open innovation assumes the cooperation of two or more organizations — at least one generating an innovation and at least one utilizing it — with a viable business model for each.

Usually considered in the context of public policy, appropriability is what allows the innovator to capture a return from the value created by an innovation. For some classes of innovations, intellectual property law plays a key role in providing appropriability, and thus allowing some open innovators to get returns on their internal innovations and others to have a supply of external innovation.

Open Innovation can thus be affected by changes to *de jure* IP protection, whether enacted directly by legislative statute, administrative policy or judicial precedent. An example of the latter is patenting of software algorithms, as enabled by the U.S. Supreme Court in the 1981 case *Diamond v. Diehr* (Graham and Mowery, Chapter 9).

But other institutional policies can also affect IP, appropriability and thus Open Innovation. For example, an innovation benefactor can change the rights allocated for contract research, as when the U.S. government granted universities rights to contract research under the Bayh-dole Act (Fabrizio, Chapter 7). A cooperative technical organization may specify certain rules for how IP will be appropriated for the organization's joint product, as Simcoe (Chapter 8) considers for standards setting organizations. Finally, within a given appropriability regime, individual firms have broad discretion as to how much they choose to appropriate — tied to their overall value creation strategy — as illustrated by the preceding mobile phone case

Allocating the Returns of Innovation

While discussions of appropriability focus on value capture, equally important in Open Innovation is value creation. For complex ecosystems such as those illustrated by Figure 6.1, this can require complex market (and non-market) coordination among multiple firms in the value network. A crucial part of the Open Innovation strategies of technology-component suppliers (such as Intel and Qualcomm) is proactively building ecosystems to attract systems integrators and complementors.

The appropriation decisions of the focal innovator can affect other firms in the ecosystem in two ways. First, as all four chapters of this section note, the friction from the innovator appropriating the value of its innovation can hinder the process of Open Innovation if it discourages information search or cumulative innovation. Secondly, if suppliers, component producers or complementors lack their own ability to capture value, then the value network may not create enough value to win customer adoption; such systemic innovation issues are the focus of Section III, particularly Maula et al (Chapter 12).

Thus, any Open Innovation business model must consider the relationship of value creation and value capture for all the participants in the value network (Chesbrough, 2003a). This imperative is particularly important for technologies subject to network effects, where firms must trade off value appropriation against the demand-side economies of scale provided by widespread adoption (West, 2003).

Nearly a decade ago, Brandenburger and Nalebuff (1996) suggested a game theoretic framework for tradeoffs within what they call a "value net." However, research on the complex process of managing such networks has either been highly simplified (as with Brandenburger and Nalebuff, 1996) or highly particularistic (e.g., Kraemer and Dedrick, 1998). More recent research — such as Staudenmeyer et al (2000), Iansiti and Levien (2004a) and O'Mahony and West (2005) — has attempted to compare and generalize the processes of ecosystem management. But these have yet to provide a broader framework (comparable to Teece, 1986) that explains the relationship of formal appropriability and voluntary appropriability waivers in the value creation and capture within an arbitrary value network.

Unresolved Questions of Appropriability and Open Innovation

At first glance, stronger IP regimes are directly associated with more Open Innovation. Gallini (2002: 141) summarizes the predicted relationship between appropriability and innovation: first, strong patents establish as willingness to out-license; secondly, that strong patents promote vertical specialization.

Consistent with this, based on a large-scale survey of U.K. industries, Laursen and Salter (2005) conclude that Open Innovation attitudes are strongest in industries with high appropriability (such as pharmaceuticals) and weakest in industries with low appropriability (such as textiles). One might be tempted to infer that there is a direct correlation (if not causal relationship) between high appropriability and high openness.[15]

However, the case of open source software (West and Gallagher, Chapter 5) raises questions about this relationship. Open source limits how much firms can appropriate and effectively forces openness (West and Dedrick, 2005), and yet as West and Gallagher note, firms invest in open source-based Open Innovation strategies nonetheless. Does this undercut the correlation observed by Laursen and Salter, or are there problems with the generalizability (or even sustainability) of the open source business models? And if the combination of high openness, low appropriability is observable in practice, are there examples of the converse (high appropriability, low openness)? Or would we expect that in cases of high appropriability, the highly open strategy would always produce greater returns? (Figure 6.2).

The Laursen and Salter (2005) paper also raises a second issue, about the different forms of appropriability, both through government-granted IP and other means. They consider a combination of measures taken by firms to appropriate returns for their innovation, including strong formal appropriability (such as patents, trademarks, registered designs), weak formal appropriability (secrecy) and other means of securing competitive advantage (through design complexity and first mover advantage). They concluded that the six items (from an existing EU-designed survey) represented a single construct, but further research is needed to reconcile this with previous observations regarding the complementary relationship between formal and informal appropriability means.

This relates to a broader gap in the innovation (and Open Innovation) literature, which is the focus on patents as a means of appropriating value. Other researchers have observed that there are contexts where copyright and trade secrets are the most effective form of IP protection but the implications of these forms of IP upon Open Innovation have yet to be considered. If, as commonly assumed, such IP mechanisms provide less appropriability than do patents, then studying the use of these mechanisms in Open Innovation could also provide broader insights about how the nature and strength of appropriability mechanisms relate to effective Open Innovation strategies.

References

Aaker, David A. and George S. Day. 1986. "The Perils of High-growth Markets," *Strategic Management Journal,* 7/5: 409-421.

Akerlof, George A., Kenneth J. Arrow, Timothy F. Bresnahan, James M. Buchanan, Ronald H. Coase, Linda R. Cohen, Milton Friedman, Jerry R. Green, Robert W. Hahn, Thomas W. Hazlett, C. Scott Hemphill, Robert E. Litan, Roger G. Noll, Richard Schmalensee, Steven Shavell, Hal R. Varian, and Richard J. Zeckhauser. (2002). "The Copyright Term Extension Act of 1998: An Economic Analysis," Brief 02-1, AEI-Brookings Joint Center For Regulatory Studies.

Arrow, Kenneth J. (1962). "Economic Welfare and the Allocation of Resources for Invention: Economics and Social Factors" In Richard R. Nelson (Ed.), *The Rate and Direction of Inventive Activity,* Princeton: Princeton University Press, pp. 609-625.

Arthur, W. Brian. 1996. "Increasing Returns and the New World of Business," *Harvard Business Review*, 74/4: 100-109.

Bekkers, Rudi. 2001. *Mobile telecommunications standards*: GSM, UMTS, TETRA, and ERMES. Boston: Artech House.

Bekkers, Rudi, Geert Duysters and Bart Verspagen. 2002. "Intellectual property rights, strategic technology agreements and market structure: The case of GSM," *Research Policy,* 31/7: 1141-1161.

Bercovitz, Janet and Feldman, Maryann (2003) "Technology Transfer and the Academic Department: Who Participates and Why?" DRUID Summer Conference, June 2003.

Besen; Stanley M. and Leo J. Raskind. (1991). "An Introduction to the Law and Economics of Intellectual Property," *Journal of Economic Perspectives,* 5/1: 3-27.

Bozeman, Barry. (2000). "Technology transfer and public policy: a review of research and theory," *Research Policy,* 29/4-5: 627-655.

Brandenburger, Adam and Barry Nalebuff, 1996. *Co-opetition.* New York: Doubleday.

Bresnahan, Timothy F., Greenstein, Shane. 1999. "Technological competition and the structure of the computer industry," *Journal of Industrial Economics* 47/1: 1-40.

Bresnahan,Tim and Pai-Ling Yin. 2004. "Standard Setting in Browsers: Technology and (Real World) Incomplete Information," Paper presented at Standards and Public Policy conference, Federal Reserve Bank of Chicago, May 13, URL: http://www.chicagofed.org/news_and_conferences/conferences_and_events/files/bresnahan.pdf

Brinkley, Joel. 1997. *Defining Vision: The Battle for The Future of Television.* New York: Harcourt Brace

Burke, Andrew E. (1996). "How effective are international copyright conventions in the music industry?" *Journal of Cultural Economics*, 20/1: 51-66.

CBO, 1998, "How Increased Competition from Generic Drugs has Affected Prices and Returns in the Pharmaceutical Industry," Washington, DC: Congressional Budget Office.

Chandler, Alfred D., Jr. 2001. *Inventing the Electronic Century. The Epic Story of the Consumer Electronics and Computer Industries,* New York, NY: Free Press.

Chesbrough, Henry (2003a) *Open Innovation,* Boston, MA: Harvard University Press.

Chesbrough, Henry W. (2003b) The Era of Open Innovation. *Sloan Management Review*, 44/3: 35-41.

Chesbrough, Henry and Rosenbloom, Richard S. (2002) The role of the business model in capturing value form innovation: evidence from Xerox corporation's technology spin-off companies. *Industrial and Corporate Change,* 11/3: 529-555.

Cohen, Wesley M. and Levinthal, Daniel A. (1990) "Absorptive capacity: a new perspective on learning and innovation." *Administrative Science Quarterly*, 35/1: 128-152.

Cohen, Wesley M., Richard R. Nelson and John P. Walsh, 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D" *Management Science* 48/1: 1-23.

Colyvas, Jeannette, Michael Crow, Annetine Gelijns, Roberto Mazzoleni, Richard R. Nelson, Nathan Rosenberg and Bhaven N. Sampat, 2002. "How Do University Inventions Get Into Practice?" *Management Science* 48/1: 61-72.

Cusumano, Michael A., Yiorgos Mylonadis, and Richard S. Rosenbloom. 1992. "Strategic maneuvering and mass-market dynamics: The triumph of VHS over Beta," *Business History Review* 66/1:51-94.

Cusumano, Michael A. and David B. Yoffie. 1998. *Competing on Internet Time: Lessons from Netscape and Its Battle with Microsoft.* New York: Free Press

David, Paul A. 2002, "The Economic Logic of 'Open Science' and the Balance between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer," Stanford Institution for Economic Policy Research, Discussion Paper No. 02-30, Stanford University, URL: http://siepr.stanford.edu/papers/pdf/02-30.pdf

David, Paul A. 2005. "Can 'Open Science' be Protected from the Evolving Regime of IPR Protections?" Economics Working Paper Archive, working paper 0502010, Washington University in St. Louis, URL: http://ideas.repec.org/p/wpa/wuwpio/0502010.html

European Commission. 1997. "Promoting innovation through patents: Green Paper on the Community patent and the patent system in Europe," June, URL: http://europa.eu.int/comm/internal_market/en/indprop/patent/paten.pdf

Fabrizio, Kira R. and David C. Mowery (forthcoming) "Defense-Related R&D and the Growth of the Postwar Information Technology Industrial Complex in the United States," *Revue d'économie industrielle*.

Farrell, Joseph and Carl Shapiro. 2004. "Intellectual Property, Competition, and Information Technology," working paper CPC04-45, Competition Policy Center, University of California, Berkeley. URL: http://repositories.cdlib.org/iber/cpc/CPC04-045

Funk, Jeffrey L., 2003. "Standards, dominant designs and preferential acquisition of complementary assets through slight information advantages." *Research Policy*, 32/8: 1324-1341.

Gallini, Nancy T. 2002. "The Economics of Patents: Lessons from Recent U.S. Patent Reform," *Journal of Economic Perspectives,* 16/2: 131-154.

Garud, Raghu, Arun Kumaraswamy and Richard N Langlois, editors. 2003. *Managing in the modular age: architectures, networks, and organizations* Oxford: Blackwell.

Gilson, Ronald J. 1999. "The Legal Infrastructure of High Technology Industrial Districts: Silicon Valley, Route 128, And Covenants Not To Compete," *New York University Law Review,* 74/3: 575-629.

Golder, Peter N; Tellis, Gerard J. 1993. "Pioneer advantage: Marketing logic or marketing legend?" *Journal of Marketing Research*, 30/2: 158-170.

Goolsbee, Austan, 1998. "Does Government R&D Policy Mainly Benefit Scientists and Engineers?" *American Economic Review,* 88/2: 298-302

Graham, Stuart J.H. and David C. Mowery, 2003. "Intellectual Property Protection in the Software Industry," in Wesley Cohen and Steven Merrill, eds., *Patents in the Knowledge-based Economy.* Washington, DC: National Academies Press, 219-58.

Grove, Andrew S., 1996. *Only the Paranoid Survive How to Exploit the Crisis Points that Challenge Every Company and Career*, Doubleday, New York.

Henderson Rebecca; Adam B. Jaffe; Manuel Trajtenberg. 1998a. "Universities As A Source Of Commercial Technology: A Detailed Analysis Of University Patenting, 1965–1988," *Review of Economics and Statistics,* 80/1: 119-127.

Hobday, Michael (2000) "The project-based organisation: an ideal form for managing complex products and systems," *Research Policy,* 27/7-8: 871-893.

Iansiti, Marco and Roy Levien (2004a). *The keystone advantage: What the new dynamics of business ecosystems mean for strategy, innovation and sustainability*, Boston: Harvard Business School Press.

Jacobs, Irwin (2005). "My Life on the Wireless Frontier," videotaped public lecture, Computer History Museum, Mountain View, Calif., May 25, URL: http://www.computerhistory.org/events/index.php?id=1099686446

Jaffe, Adam B. 1996. "Trends and patterns in research and development expenditures in the United States," *Proceedings of the National Academy of Sciences,* 93/23: 12658-12663.

Katz, Michael L. and Carl Shapiro. (1985) "Network Externalities, Competition and Compatibility," *American Economic Review*, 75/3: 424-440.

Kraemer, Kenneth L. and Jason Dedrick. 1998. "Globalization and increasing returns: Implications for the U.S. computer industry," *Information Systems Research,* 9/4: 303-322.

Krechmer, Ken, "The Meaning of Open Standards," *International Journal of IT Standards & Standardisation Research*. 4/1: 2006.

Lane, Nick (2003) "Risk of patent poker too high a gamble for Nokia," *3G Mobile*, (January 22), 5/2: 1-2.

Langlois, Richard N. 2003b. "Modularity in technology and organization," *Journal of Economic Behavior and Organization,* 49/1: 19-37.

Laursen, Keld and Ammon Salter (2005) “The paradox of openness of knowledge for innovation,” Paper presented for the All-academy Symposium “Open Innovation: Locating and incorporating external innovations” Academy of Management Conference 2005, Honolulu, Hawaii.

Lieberman, Marvin B. and David B. Montgomery. 1988. “First-Mover Advantages,” *Strategic Management Journal*, 9 (Summer): 41-58.

Loomis, Tamara, (2005) “Cell Break,” *IP Law & Business*, July, URL: http://www.ipww.com/texts/0705/europhony0705.html

Meller, Paul (2004) “Europeans Rule Against Microsoft; Appeal Is Promised.” *New York Times*, March 25.

Miner, Anne S., Michael DeVaughn, Dale Eesley and Thekla Rua. (2001) “The magic beanstalk vision of university venture formation.” In Kay Schoonhoven and Elaine Romanell, eds., *The Entrepreneurship Dynamic*, Stanford, CA: Stanford University Press, pp. 109-146.

Mock, David, 2005. *The Qualcomm Equation.* New York: AMACOM.

Morris, Charles R. and Charles H. Ferguson. 1993. “How Architecture Wins Technology Wars,” *Harvard Business Review*71/2, pp. 86-96.

Moschella, David C. (1997) *Waves of Power*. New York: AMACOM.

Mowery, David C . and Bhaven N Sampat. 2001. “University patents and patent policy debates in the USA, 1925-1980,” *Industrial and Corporate Change* 10/3: 781-814

Mowery, David C . and Bhaven N Sampat. 2004. “Growth of U.S. University Patenting since the 1970s,” Economic History Association, San Jose, Calif., September.

Nichols, Kenneth. 1998. *Inventing software: the rise of “computer-related” patents.* Westport, Conn.: Quorum Books.

Noam, Eli (1992) *Telecommunications in Europe*. New York: Oxford University Press.

O'Mahony, Siobhán and Joel West (2005) "The Participation Architecture of Online Production Communities." Working paper, Harvard Business School.

Pavitt, Keith. 2000. "Why European Union funding of academic research should be increased: a radical proposal," *Science and Public Policy,* 27/6:455-460.

Porter, Michael E. (1980), *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, New York: The Free Press,

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

Rindova, Violina & Kotha, Suresh 2001. "Continuous morphing: Competing through dynamic capabilities, form, and function," *Academy of Management Journal,* 44/6: 1263-1280.

Salz, Peggy Anne (2004) "Pay by the Rules." *Mobile Communications International*. April, p.109.

Schnaars, Steven P., (1994) *Managing imitation strategies: how later entrants seize markets from pioneers,* New York: Free Press.

Shapiro, Carl and Hal R. Varian, *Information Rules: A Strategic Guide to the Network Economy,* Boston: Harvard Business School Press, 1999.

Siegel, Donald, David Waldman, and Albert N. Link, 2003, "Assessing the Impact of Organizational Practices on the Productivity of University Technology transfer offices: an exploratory study," *Research Policy,* 32/1: 27-48.

Simcoe, Timothy. 2006. "Delays and *de Jure* Standards: What Caused the Slowdown in Internet Standards Development?" in Shane Greenstein and Victor Stango, eds., *Standards and Public Policy,* Cambridge: Cambridge University Press.

Slaton, Joyce. (1999), "A Mickey Mouse Copyright Law?" Wired.com, Jan. 13, URL: http://www.wired.com/news/politics/0,1283,17327,00.html

Staudenmayer, Nancy., Mary Tripsas, & Christopher L. Tucci. (2000) "Development Webs: A New Paradigm for Product Development," In Rudi KF Bresser, Michael A. Hitt, Robert D. Nixon and Dieter Heuskel, eds., *Winning strategies in a Deconstructing World*, New York: Wiley & Sons.

Tansey, Richard, Neal, Mark, Carroll, Ray. 2005. " 'Get Rich, or Die Trying': Lessons from Rambus' High-Risk Predatory Litigation in the Semiconductor Industry," *Industry and Innovation,* 12/1: 93-115.

Teece, David J. (1986) "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy." *Research Policy,* 15/6: 285-305.

Teece, David J, Pisano, Gary and Shuen, Amy. 1997. "Dynamic Capabilities and Strategic Management," *Strategic Management Journal,* 18/7: 509-533.

Tennenhouse, David (2003) "Innovation breeds success at Intel." *IEE Engineering Management,* **13**, 6 44-47.

Testa, Bridget Mintz (2005) "Zander's Balancing Act." *Electronic Business*, August, pp. 31-38.

Tulloch, James, "Clear as Mud," *Mobile Communications International,* December 2002.

Tushman, Michael L. and Charles A. O'Reilly III. (1996) "The Ambidextrous Organization: Managing Evolutionary and and Revolutionary Change" *California Management Review,* 38/4: 1-23

Välimäki, Mikko (2003) "Dual Licensing in Open Source Software Industry," *Systemes d'Information et Management*, 8/1: 63-75, URL: http://opensource.mit.edu/papers/valimaki.pdf.

West, Joel, (1995) "Software Rights and Japan's Shift to an Information Society." *Asian Survey* 35/12: 1118-1139

West, Joel, (2000). "Institutional Constraints in the Initial Deployment of Cellular Telephone Service on Three Continents," in Kai Jakobs, ed., *Information Technology Standards and Standardization: A Global Perspective*, Philadelphia: Idea Group, pp. 198-221.

West, Joel, (2002) "Qualcomm 2000: CDMA Technologies." European Case Clearinghouse, Case 302-069-1.

West, Joel, (2003) "How open is open enough? Melding proprietary and open source platform strategies," *Research Policy,* 32/7: 1259-1285.

West, Joel (2005) "The fall of a Silicon Valley icon: Was Apple really Betamax redux?" in Richard A. Bettis., ed., *Strategy in Transition*, Oxford: Blackwell, pp. 274-301.

West, Joel (2006) "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.

West, Joel, and Jason Dedrick. (2001). "Open Source Standardization: The Rise of Linux in the Network Era," *Knowledge, Technology & Policy,* 14/2: 88-112.

West, Joel, and Jason Dedrick. (2005) "The Effect of Computerization Movements Upon Organizational Adoption of Open Source." Social Informatics Workshop: Extending the Contributions of Professor Rob Kling to the Analysis of Computerization Movements, UC Irvine, March, URL: http://www.crito.uci.edu/2/si/resources/westDedrick.pdf.

West, Joel and Vladislav Fomin (2001) "National Innovation Systems in the Mobile Telephone Industry, 1946-2000." Academy of Management Conference, Washington, DC.

West, Joel and Justin Tan (2002) "Qualcomm in China (B)," *Asian Case Research Journal*, 6/2: 101-128.

Iversen, Eric J. 1999. *Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology*, Aachen, Germany, September 15-17: 55-63.

Notes

[1] My thanks go to Rudi Bekkers, Henry Chesbrough, Kira Fabrizio, Tim Simcoe for engaging the work and providing many useful suggestions. The opinions (as well as all remaining errors) are mine alone.

[2] There is a trend in U.S. copyright law towards quasi-permanent monopolies for key entertainment content, epitomized by the 1996 copyright term extension act dubbed the "Mickey Mouse Copyright Law" (Slaton, 1999). The effect of such term extensions has on incentives has not been established, but one analysis concluded that "in the case of term extension for existing works, the sizable increase in cost is not balanced to any significant degree by an improvement in incentives for creating new works" (Akerlof et al, 2002: 3).

[3] In addition to patent, copyright and trade secret, Besen and Raskind (1991) list three additional mechanisms in U.S. intellectual property law: trademark law, the Semiconductor Chip Act of 1984 (a specialized form of copyright), and misappropriation (a rarely used common law doctrine regarding unfair competition). For this discussion of Open Innovation, I concentrate on the three IP mechanisms most often used to protect innovations.

[4] External innovations can be incorporated not just at the beginning of the development funnel, but at every stage from invention to final sale (Chesbrough, Chapter 1). The IP issues faced by innovators are similar for all these stages, but for simplicity's sake this discussion focuses on innovations at the beginning of the funnel.

[5] For Teece, almost any remaining portion of the value equation is a complementary asset. For the large body of standards research building upon the Katz and Shapiro "hardware-software paradigm", a complementary product has a specific meaning of a separate product that adds

value to the base innovation (e.g. Bresnahan and Greenstein, 1999; Shapiro and Varian, 1999). Unless specifically noted, I use "complement" in the latter sense here.

6 Multiple companies exist in the U.S. cable TV industry, and thus this concentration corresponds more to an oligopsony than monopsony situation. However, each firm effectively has enjoyed a monopsony in its respective geographic territory; intermodal competition is reducing but not eliminating this oligopsony power.

7 As with other Internet startups of the era, Netscape's business model relied on unproven assumptions of customer value, profitability and sustainability. Netscape was forced to exit from web browsers (West and Gallagher, Chapter 5) before those assumptions could be (dis)proven in the marketplace.

8 In the U.S., competition policy is called "antitrust" policy for historical reasons dating back to the targets of the first major competition law, the 1890 Sherman Antirust Act.

9 Even if they do not directly pay for innovations, firms may pay other costs to use external innovations — including the costs of developing absorptive capacity, search costs, technology transfer, and investments in technologies that do not yield commercial returns. For example, even when a university or government lab has a strong bureaucratic mandate to get innovations "out the door," this is not sufficient to establish that the technology is actually being used, let alone has a significant market impact (Bozeman, 2000).

10 In a dissenting view, Goolsbee (1998) argued that federal funding increased the wages of R&D workers and not the amount of research being done.

[11] As with most other requests for government spending, both industry and academic pleas for additional R&D expenditures are usually made in isolation, without identifying additional sources of revenue or opportunities to reduce expenditures in other areas.

[12] In addition to surrendering control of university IP to private firms and impairing the process of cumulative innovation, researchers looking at increased patenting also have at least implicit concern that increased private funding will be used as an excuse for reducing less restricted government research expenditures.

[13] Started without venture capital, Qualcomm used an innovative business model to fund creation of its patent portfolio. It presold licenses to its research, which was valuable to telecommunications carriers because of the (eventually realized) promise of higher capacity utilization of scarce regulated radio spectrum (Jacobs, 2005)

[14] To gain government approval for CDMA usage in China, Qualcomm cut the royalty rate dramatically for Chinese manufacturers selling to the domestic market (West and Tan, 2002)

[15] I am grateful to Henry Chesbrough for originally sharing this interpretation of the Laursen and Salter paper.

Tables and Figures

Standard	Origin	Subscribers (million)	Ratio
GSM	Europe	331.5	57.4%
CDMA	U.S.	67.1	11.6
PDC	Japan	48.2	8.3
D-AMPS	U.S.	47.8	8.3
Non-digital	various	82.8	14.3
Total		577.4	100.0

Source: Adapted from West (2002)

Table 6.1: Market share of digital cellular technologies, June 2000

Firm	Country	Market Share† 1998	2004	Fate of Handset Division
Nokia	Finland	22.5%	30%	Still owned by original parent
Motorola	U.S.	19.5%	15%	Still owned by original parent
Ericsson	Sweden	15.1%	6%	In 2001, formed Sony Ericsson, a 50/50 joint venture with Sony of Japan, which pays patent royalties to Ericsson.
Siemens	Germany	n.r.	7%	In 2005, sold division to BenQ of Taiwan
Alcatel	France	4.3%	n.r.	In 2004, formed TCL Communication, a 45/55 joint venture with TCL Corp. (China); sold joint venture to TCL in 2005

† Global share for all standards; 1998 as reported by West and Fomin (2001), 2004 as reported by Testa (2005).

Table 6.2: Performance of handset operations by key GSM patent holders

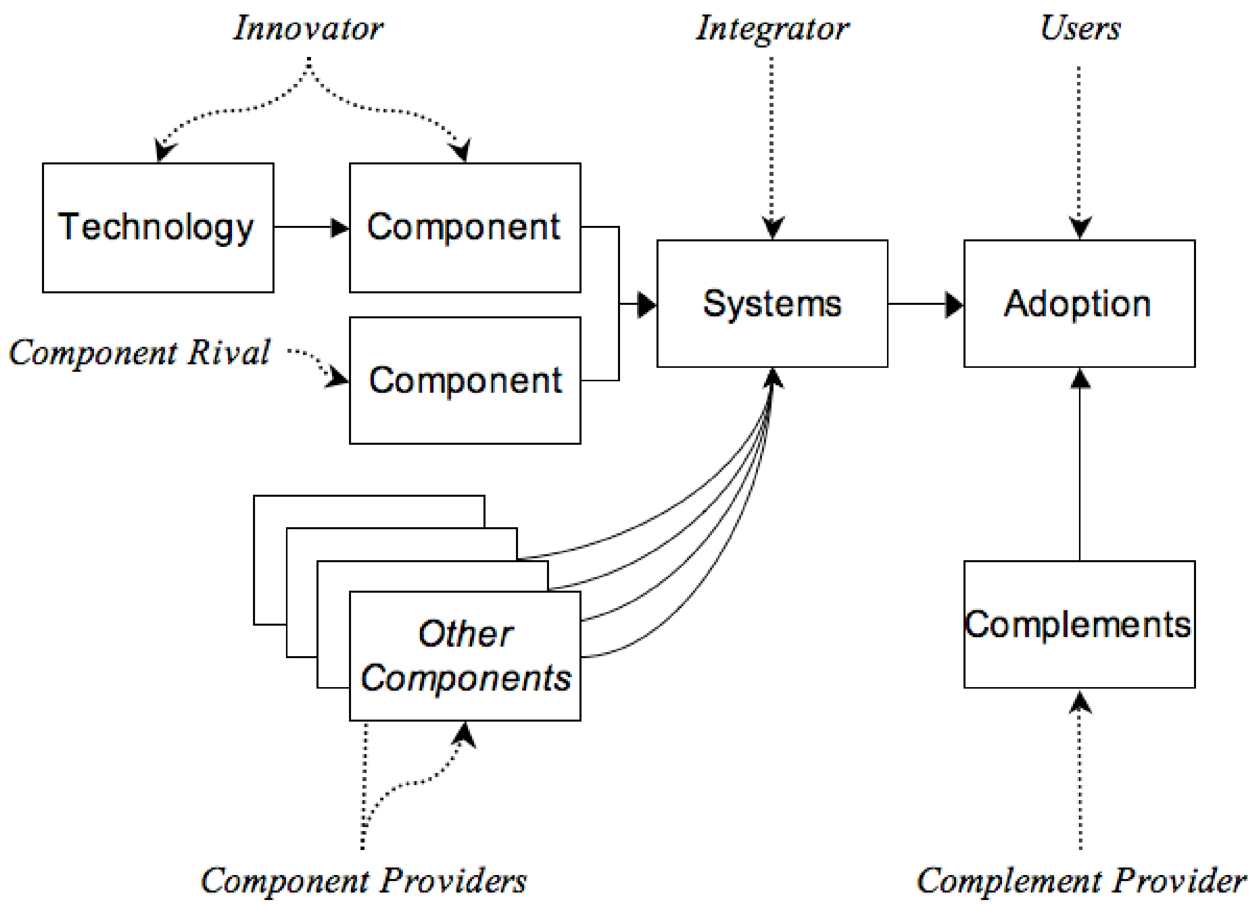

Figure 6.1: Incorporating technology innovations into complex systems

Appropriability

Openness	*High*	*Low*
High	pharmaceuticals	open source
Low	†	textiles

† Does this case exist? Is it always sub-optimal?

Figure 6.2: Does appropriability determine openness?