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How to Capture Value from Innovation: Shaping Intellectual Property and Industry Architecture

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Innnovation presents a dilemma for managers. On the one hand, innovation is proffered as an elixir for growth, profitability, and competitive advantage. One need look no further than firms such as Apple, Google, Intel, or Genentech to see examples of how innovation can drive performance. On the other hand, there are no guarantees that innovators will be rewarded for their efforts. Business history is littered with examples of innovators who failed to parlay their innovations into economic advantage. The Hydrox Cookie Company invented a chocolate cookie with a vanilla cream filling; but Nabisco followed with the Oreo cookie, and the Hydrox Cookie Company disappeared. Netscape may have been the first commercially viable web browser, but it was Microsoft's who garnered the larger market share. Search engine innovators lost market share first to Yahoo, then to Google.

Becoming "more innovative" has become a mantra of management gurus, but it is clear that this advice is not enough. The challenge is not just creating value from innovation, but *capturing* that value as well. Insufficient capture will not only hurt the enterprise, but society as well. In a private enterprise economy it is necessary for innovators (as a class) to over time earn sufficient profits to warrant further investment in research and development and related innovative activity.

Figuring out how to capture value from innovation at the enterprise level is not a new problem. Managers have long been aware of the challenge, and scholars have recognized that the substantial appropriability of returns from innovation by the innovator is uncommon. Returns from innovation can be siphoned off by imitators, customers, suppliers, and other providers of complementary products and services.[1] In practice and in scholarly research, much of the emphasis has been on how to build protective barriers around innovations in order to afford the innovator a bigger "slice" of the pie. These barriers can take the form of legal protection (such as patents, copyrights, or trade-secrets) as well as other strategies such as investing in complementary assets (such as manufacturing, distribution, brand, services, and technologies).

In making strategic decisions about how to capture value from innovation, managers often look at two critical domains—the intellectual property environment and the architecture of the industry—as beyond their control. Yet, the intellectual property environment and the architecture of the industry can have profound influences on who wins (and who does not) from innovation. Moreover, we argue, under the right circumstances, these two domains can be shaped by managers in ways that favor one firm over another. By understanding these forces, managers will be in a better position to utilize the full toolkit of available mechanisms (and strategies) to capture value from innovation. Perhaps somewhat surprisingly, we show that more IP protection and building stronger barriers around innovation are not always the best path to capturing value. Paradoxically, innovators can sometimes benefit by weakening the intellectual property environment and opening the architecture of the industry.

Profiting from Innovation

Over the past two decades, our understanding of value capture from innovation and the link to firm strategy has expanded dramatically. A stream of research with its intellectual origins in the 1980s in the work of U.C. Berkeley/Haas faculty[2] and graduate students at the time (e.g., H. Chesbrough, S. Graham, W. Mitchell, G. Pisano, D. Somaya, and S. Wakeman) stressed the importance of the architecture of the enterprise (especially the boundaries of its ownership and its control of complementary assets) in effecting the identity of the winners and losers when new technologies are commercialized. Along with enterprise capabilities and structure, the role of supporting institutions and public policy has also been highlighted in the important work of Haas colleagues David Mowery and Pablo Spiller.

Together, this body of work has come to be known as the Profiting from Innovation (PFI) framework.[3] PFI insists that "aspects of economic organization, business strategy, technology, and innovation must all be understood" if one wants to understand market outcomes when new technologies are commercialized.[4] We will not restate the framework here, except in summary form. It has recently been the topic of a special issue of *Research Policy*.[5] Rather, in this article the PFI framework is extended to consider certain factors that were previously treated (for analytical purposes) as beyond the realm of what managers could reasonably influence. In particular, we examine how the appropriability regime (the protection afforded the innovator by intellectual property and by natural barriers

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to imitation) and the architecture of the industry can be usefully shaped by managerial decisions and business strategy.

PFI addressed a puzzle that had not been well explained in the previous literature: namely, why is it that pioneers often fail to capture the economic returns from innovation? The original PFI framework[6] cites several examples (e.g., EMI in CAT scanners, Bowmar in calculators), and the phenomenon does indeed endure. The first generation PC manufacturers all but disappeared from the scene (and even IBM, while not a first-mover in PCs, recently exited the business by selling its PC business to a Chinese company, Lenova). Xerox (PARC) and Apple invented the graphical user interface, but Microsoft Windows dominates the PC market with a follow-on graphical user interface. Apple also invented the PDA (the bricklike Newton) but Palm became the dominant player (at least until convergence of mobile telephony and computing lead to "smart phones"). Netscape invented the browser, but Microsoft captured more of the market. Apple's iPod was not the first MP3 player, but it has a commanding position in the category today. Merck was a pioneer in cholesterol lowering drugs (Zocor), but Pfizer, a late entrant, secured a superior market position with Lipitor. Excite and Lycos were the first real web search engines, but they lost out to Yahoo—and Yahoo then lost out to Google.

At first glance, it is tempting to say that these examples reflect the result of Schumpeterian gales of creative destruction where winners are constantly challenged and overturned by entrants. Indeed, entrants with potentially disruptive innovations[7] are almost always waiting in the wings. However, one should note that there is ample variance in the phenomenon. There are many cases where first or early movers captured and sustained significant competitive advantage over time. Genentech was a pioneer in using biotechnology to discover and develop drugs, and 30 years later it is the second largest biotechnology firm (and the most productive firm in its use of R&D dollars). Intel invented the microprocessor and still has a leading market position more than 30 years later. Dell pioneered a new distribution system for personal computers and, despite recent challenges and many would-be imitators, remains the leader. Toyota's much studied "Toyota Production System" has provided the automaker a source of competitive advantage for decades despite numerous and sustained attempts at imitation.

The PFI framework provides an explanation as to why some innovators profit from innovation while others lose out. As Ralph Waldo Emerson pointed out more than 150 years ago, "Build a better mousetrap and the world will beat a path to your door." Emerson was partially right; one of several factors he forgot was that a better mousetrap will invite reverse engineering by would-be imitators. Even worse, suppliers and those offering complementary products will also try to get a piece of the action if they can.

The conundrum managers must confront is at least twofold. First, few innovations yield value on a stand-alone basis. To provide value to the users, every innovation requires complementary products, technologies, and services. Hardware requires software (and vice versa); operating systems require applications (and vice versa); digital music players require digital music and ways of distributing digital music (and vice versa); mobile phones need mobile phone networks (and vice versa); web browsers and web search engines require web content (and vice versa); and airlines require airports (and vice versa). In short, technology must be embedded in a system to yield value to the end user/consumer. Value capture becomes more difficult if other entities control other required elements.

Second, the delivery of product/process innovation requires the employment not just of complements, but of many inputs/components up and down the vertical chain of production. Hence, when the inventor/innovator isn't already in control of the necessary inputs/components, the economic muscle of the inventor/innovator of new technology will be considerably compromised by whatever economic muscle is possessed by owners of required inputs/components.

The unavoidable implication is that unless the inventor/innovator enjoys strong natural protection against imitation and/or strong intellectual property protection (which collectively describe its "appropriability" regime) or unless the complements and other inputs are available in competitive supply, then the providers of complements and other inputs will force the innovator to yield a large portion (possibly the greater portion) of the fruits of innovation to them. If the technology doesn't have strong natural barriers to imitation, then owning patents and trade secrets or having technology that is hard to copy are important tools for fighting back.

Perhaps the single greatest contribution of the PFI framework is that it highlights the importance to commercial success of owning critical complementary technologies and/or controlling the bottleneck asset(s) in the value chain. Otherwise the owner of the bottleneck, when not the innovator, will be in a position to extract much of the value generated by the innovation, whether or not the owner(s) of the bottleneck directly contributed to funding the creative activity that produced the innovation. The prediction of the framework is that the profits generated by a successful technological innovation tend to go to the owners of either the underlying invention (if protected by strong intellectual property of other natural barriers to innovation) or to the owners of complementary technologies and/or assets (including other components of the value chain).

The received wisdom from PFI is that management's task is thus at minimum to make sure the enterprise secures the intellectual property protection available to it and to make the right decisions with respect to building or buying the critical co-specialized complementary technologies and/or assets. Timing is of course always a critical element, as the nature of the bottleneck may change due to innovation elsewhere in the system and other market dynamics.

The Nature of Appropriability Regimes and Industry Architecture

Two environmental factors that shape the distribution of returns from innovation, and that strategy innovators should follow to enhance returns, are the *appropriability regime* and *industry architecture*.

Appropriability Regimes

The *appropriability regime* refers to the protection afford to innovators through both legal mechanisms (e.g., patents, trade secrecy, copyrights, and non-disclosure agreements) and "natural" barriers to imitation (e.g., degree of difficulty in reverse engineering, and tacitness of relevant technology). As a simple approximation, we can think of appropriability regimes spanning a continuum from "strong" to "weak."

Strong appropriability regimes reflect environments where imitation is difficult either because of very strong legal protection or very difficult to imitate technology. Software, in general, is an example of a technology that enjoys a relatively strong appropriability regime, at least in the U.S. and the European Union. Specific lines of codes and concepts can be protected by both patents and copyrights. Moreover, because it is technically possible to shield the source code from users (and competitors), imitation is extremely difficult. This is not to say software protection is perfect. No technology is completely immune from imitation. The appropriability regime concept is relative.

In contrast, for many types of mechanical technologies based on creative engineering solutions (rather than novel inventions), patenting is difficult, or the scope of available patent protection is narrow. Moreover, because such technologies can be observed (and the physical product can be literally dissected), reverse engineering can be relatively easy, allowing imitation and/or the creation of non-infringing alternatives.

Strong appropriability regimes are illustrated by environments that allow good patent protection, either through the issuance of a patent with broad scope or through the issuance of patents on a family of related inventions. Enterprises wishing to protect some patented core technology may endeavor to patent substitutes and, if successful, they may build some type of patent "fence." For example, Hounshell and Smith report that Dupont patented over 200 substitutes for nylon in an effort to protect the core invention.[8]

While strong appropriability regimes obviously favor innovators, this does not mean firms cannot capture returns from innovation in weak appropriability regimes. In fact, they do so all the time. However, they need to adapt their strategy to overcome vulnerabilities. According to the PFI framework, the character of the appropriability regime (strong, weak, or somewhere in between) should shape strategy and the choice of business model. Weak appropriability dictates reliance on other value capture mechanisms—such as developing complementary assets that would earn a return even if the innovation itself didn't. Strong appropriability gives more choices—in particular, licensing is possible if the innovation enjoys strong IP protection. For example, book writers have enjoyed relatively strong IP, so that the author Steven King has not had to own his own printing press, publication house, or book distribution to capture considerable value because the system of copyrights has worked reasonably well. Likewise, the author J.K. Rowling, creator of Harry Potter, has earned more than a billion dollars without having to become her own publisher or moviemaker. However, rock bands have not had an easy time of it recently because of Internet enabled illegal copying (piracy), causing some artists to rely more on concerts for a larger percentage of their income.

Ideally, in the PFI framework, the "first" best world is one when the innovator can enjoy a strong appropriability regime. Both scholars and practitioners often discuss appropriability regimes as if they are fully exogenous or beyond the direct influence of firms or management actions. As discussed below, however, recent history suggests that managers can re-engineer the appropriability regime in their favor, at least to some degree.

Industry Architecture

Product architecture defines the components of a system and how those components interact. In recent years, scholars and practitioners have become increasingly comfortable with the notion that industries, as systems, can also have architectures.[9] Industry architectures characterize the nature and degree of specialization of industry players (or "organizational boundaries") and the structure of the relationships between those players.

A simple example may be helpful. Historically, the computer industry had what could be called a "vertical" architecture.[10] Each computer firm designed and manufactured all the components of computer systems. For instance, IBM mainframes utilized a proprietary IBM operating system, were designed around proprietary IBM components, could generally run only IBM generated software applications, and had to be serviced by IBM. With the advent of the personal computer, the architecture of the industry began to shift toward a "horizontal" model which witnessed the entrant of firms that specialized in particular "layers" of the computer system; Microsoft specialized in operating systems and applications; Intel provided the microprocessor; other semiconductor firms provided memory and other chips; other companies specialized in components such as disk drives and displays; and others focused on distribution (e.g., Dell). Most other industry segments have gone the same way as personal computers.

Research over the past decades has shown us that there is a strong connection between the architecture of the industry and the architecture of physical products and technologies.[11] The computer industry evolved from a "vertical" to "horizontal" architecture because of the modular technological architecture of the personal computer. In general, industry architectures characterized by specialized or "networked" firms reflect product/technology architectures embodying well-specified interfaces between component technologies or high degrees of "modularity."

Industry architecture also helps shape the distribution of returns from innovation. Because modularity requires a well-established and agreed upon architecture—including standards—it is difficult for any one company to introduce a truly innovative product architecture. Instead, modularity shifts the locus of innovation to the component or subsystem level.[12] In highly modular contexts, like personal computers, opportunities for profit ("rents") from innovation at the system level are limited.

Whether profits can be captured by component-level innovators depends on the appropriability regime for specific components. In personal computers, Intel and Microsoft have managed to secure a significant portion of the rents from innovation in their respective domains because they each have been able to build strong barriers (both legal and strategic) to imitation. In contrast, while there has been a steady stream of innovation in components such as disk drives, memory, and display technology, profiting from innovation in these has proved far more difficult because of ease of imitation, weak IP protection, and low barriers to entry. Similar examples can be found in industries such as movies. Movies are an example of an industry with a modular structure. Motion picture studios are essentially assemblers of the various resources required to produce a movie: such as actors and actresses, director and other specialists, finance, technology, and distribution. Movies make money, but movie studios often do not. Why? Just as in the PC business, rents flow to the bottleneck "modules" that are in short supply, perhaps because they are well positioned to protect their "intellectual property" from imitation. In the case of movies, the star performers can command exceptional earnings. A star performer in hot demand develops a distinctive "name" and style that cannot be easily replicated.

In contrast, more integral architectures shift the locus of innovation and rent appropriation up to the level of the system. Innovation at the component level by independent firms becomes much more difficult in contexts where there are high degrees of interdependence between components or subsystems. Moreover, innovators at the component level face appropriability risks because the "owner" of the architecture has the power to set interface protocols and to decide which innovations are adopted and which ones are not. Such ex post bargaining power creates a source of quasi-rents for the system owner.

Consider the automobile industry. Cars are highly integral systems. A BMW 325ix sedan consists of a set of interdependent sub-systems (the chassis, the body panels, the suspension system, the power train, the interior) that are not "plug compatible" with those of a Toyota Camry. While car companies utilize suppliers extensively for design, the entire process is tightly coordinated. Indeed, the degree of coordination and integration across the development of these systems is a major driver of high-quality development performance. This degree of interdependence limits opportunities for independent innovation to occur within the system since any given innovation is likely to require coordinated innovation (or adaptation) from other parts of the sub-system.

Re-Engineering Appropriability Regimes

Appropriability regimes and industry architecture matter with respect to who wins and who loses from innovation. Any given appropriability regime or industry architecture is likely to favor one set of firms over another. For instance, strong IP regimes favor component innovators in a highly modular context. Integrality favors systems producers and can overcome weak IP positions. Thus, whether a firm favors a strong appropriability regime or a weak regime—or a modular architecture or integral architecture—depends on existing asset positions. Intel and Microsoft love the modular structure of the PC business; personal computer manufacturers hate it. What's great for Intel and Microsoft is often distasteful to PC manufacturers. What's great for movie stars is not always good for the movie studios.

Appropriability regimes and industry architecture are not static. They can change dramatically over time. Sometimes, this is the result of government intervention, such as antitrust action against movie studios in the 1950s or AT&T in the 1980s. Sometimes, it is the result of the evolution of technology (e.g., modularization). Sometimes, it is the result of specific strategic actions and decisions by firms themselves. Indeed, Baldwin and Clark trace the modularization of the computer industry to a series of strategic decisions made by IBM in the 1960s and 1970s.[13]

The question then becomes whether a firm can actually influence changes in the appropriability regime or industry architecture to *its advantage*. We believe so, but obviously strategic degrees of freedom are not limitless.

Weakening the Appropriability Regime

Perhaps surprisingly, the goal of re-engineering the appropriability regime is not always to make intellectual property rights stronger. One of the first to point this out was Merges, who uses the terms "property-preempting investments" (PPIs) to refer to investments by firms to weaken intellectual property for their strategic advantage.[14] He notes:

> PPIs work because of a basic feature of our system: once in the public domain, information cannot be privatized. If it is in a firm's interest to preempt an asset from being privatized, the firm will invest in the creation of that asset and then inject it into the public domain. Thus, firms employing PPS contribute to the public domain while pursuing their own private interests.[15]

Following are two illustrative examples whereby innovators may decide that they are better off weakening their (and others) appropriability regime. The first is from the field of genomics; the second is from the field of open source software.

Genomics

During the late 1980s and 1990s, there was a revolution in the field that came to be known as genomics.[16] With enormous advances in the scientific instruments used to "read" DNA code, it became possible to identify genes on a mass-production scale. Where it once might have taken a researcher 10 years of dedicated work to sequence a single gene, it became possible by 1990s to identify thousands of genes on a monthly basis. The U.S. government funded a project—the Human Genome Project—to sequence all the genes found in the human body. In addition, a competing privately funded effort was launched by a company called Celera Genomics. The potential from mass-sequencing of genes for biomedical research was immense. For the first time, researchers could begin to explore the genetic bases for a variety of diseases such as cancers, diabetes, Alzheimers, and many others. The potential economic impact was not lost on the financial community. If genes were valuable to biomedical research and drug discovery, and drug discovery was lucrative, then it stands to reason that genes had enormous economic value if they could become intellectual property. Following this logic, venture capitalists funded dozens of firms (e.g., Celera, Incyte, and Human Genome Sciences) to exploit the commercial potential of genomics through the selling of proprietary genomic databases to pharmaceutical and biotechnology firms.

The possibility that firms might take ownership of specific genes caused some consternation in public policy and legal circles. What were the implications for privately owned genes? Was this legal? Was this ethical? What impact might this have on biomedical research progress? Interestingly, equally concerned with the patenting of genes were a group of companies who are normally among the staunchest advocates of strong patent rights: pharmaceutical companies. The concern among pharmaceutical companies was that they could essentially be held hostage by another entity that claimed ownership of a key gene or genes associated with a disease where they had strong commercial interest. Take a firm like Merck. Merck had established a very strong research program in cardiovascular disease and cholesterol-lowering drugs in particular. Moreover, they had built a strong downstream assets position in the sales and marketing of such drugs. Merck's R&D and marketing capabilities in cardiovascular drugs represented strong co-specialized assets positions to use PFI terminology. If some other private firms were able to identify and claim intellectual property ownership over the genes associated with cardiovascular disease, this could potentially lead to a hold-up situation (at an extreme). If Merck could not continue to conduct certain research programs, it might not be able to leverage its existing co-specialized assets positions. The value of these assets would become severely impaired.

One strategy for a large company with existing co-specialized assets positions would be too move aggressively to secure rights to the genes that might impact its future research. This strategy was followed by a number of large pharmaceutical companies who signed expensive deals with genomics firms for access to their proprietary genetic databases. These deals were both a way to open avenues for new research, but to also protect the firm against future lock-out. Another strategy, one followed by Merck, was to attempt to alter the appropriability regime. Once something is made public, it cannot be patented. In September 1994, Merck announced plans to collaborate with Washington

University to create a database (the Merck Gene Index) of expressed human gene sequence and to put these data into the public domain.[17] Merges cites this as an example of making a property-preempting investment.[18] The stated goal of this effort, and in particular the decision to make all findings publicly available in 48 hours, was to stimulate biomedical research. This sounds highly altruistic, and we do not want to discount the potential for Merck to be engaged in a public service. However, it is also easy to see a strategic motive: by making expressed human gene sequences publicly available, Merck was essentially preventing a privatization of genes that could block its future research objectives. In essence, Merck was keeping the upstream appropriability regime "weak" in order to protect its ability to continue to leverage its downstream assets in development and commercialization.

Open Source Software

Open source refers to a movement in software development to make publicly available the source code for computer programs so that other developers can build upon on the code base. Under various open source licensing arrangements (such as the GPL), any developer can use open source code and build upon it, as long as they do not try to appropriate (i.e., claim intellectual property ownership) of the previously disclosed code. This is designed to prevent anyone from essentially privatizing the intellectual commons.[19] Well-known examples of open source development include Linux and Apache, but there have been literally tens of thousands of other lesser known (and often much less successful) efforts. Open source clearly represents a shift in the appropriability regime of software. Traditional software development followed the model we see in other industries; development was proprietary and developers did everything possible to protect the designs from imitation or un-compensated use. In software, this included using legal mechanisms (e.g., copyrights and patents) and also confidentiality or secrecy (e.g., refusing to make available source code). With open source, the opposite logic holds. Developers contribute code with an understanding that it can be used freely by others (including additional development). In essence, open source leads to the creation of a commonly shared base of technology.

Open source poses an interesting strategic challenge for firms. How do they respond? Should they embrace open source? Should they resist (if possible)? This is an issue firms such as Microsoft and Sun are dealing with today. The emergence of Linux clearly represents a threat to Microsoft's server operating system business (Windows). It represents a threat to Sun's server business, which rests on a proprietary version of Unix called Solaris. Some firms, such as IBM, have clearly embraced open source and promoted it. Figuring out how to respond depends partly on a company's co-specialized asset position. A weakening of the appropriability regime through the emergence of open source operating systems can be beneficial to companies (like IBM) with strong downstream asset positions in middleware, applications, hardware, and services while damaging firms (like Microsoft) with strong positions in operating systems. In essence, as the server operating system becomes a commodity, the locus of value capture in the innovation chain shifts downward. As Merges explains:

> IBM's anti-Microsoft strategy requires IBM to offer its operating system on a non-proprietary (or "restrictively open") basis, which preempts any attempt to claim property rights in the operating system. Thus, IBM's investment in these operating systems are PPIs as I use the term.[20]

This is another example where the weakening of an appropriability regime can be economically beneficial to some firms (while hurting others). For the firm with strong downstream complementary asset positions, it might be in their interest to proactively weaken the upstream appropriability regime (e.g., via code contributions or public announcements of support).

Strengthening Appropriability Regimes

An innovator may also find great benefit in endeavoring to strengthen the appropriability regime. One obvious way is to be a champion for strong intellectual property enforcement on a global basis. Indeed, there are indications that misappropriation of trade secrets, infringement of patents, and violation of copyrights is ubiquitous, particularly outside of a handful of the advanced economies in the world. For example, one study puts the annual loss from (global) piracy on just one industry—the U.S. Motion Picture and Theatrical Exhibition Industries—at $20.5 billion.[21]

Generalized efforts to help shore up intellectual property rights enforcement might be thought of as a public good that benefits all or most innovators. Individual firms are unlikely to find this beneficial, except through collective efforts. Indeed, there are many groups that have been assembled (e.g., the Coalition Against Counterfeiting and Piracy) to achieve precisely these goals. Lobbying for legislative action is a mechanism for cajoling government to do a better job of enforcement.

Opportunities to strengthen IP also arise in the standard-setting context. If an innovator has or expects intellectual property rights to be granted to it, and its technology is potentially relevant to emerging industry standards, then the innovator can promote its IP in the context of standard-setting bodies, possibly raising the probability that its technology will get adopted as a standard. If it is adopted as a standard, then demand is likely to be enhanced.

Today, many standard-setting bodies insist that technology providers involved in formal standard-setting activities be willing to license relevant intellectual property before they adopt a standard that requires the practice of technology that is not already in the public domain. While this is common practice, it still leaves open the question of the royalty rates that ought to be applicable in such circumstances. The typical structure is for the standard-setting body to insist on a commitment by the owner (or potential owner) of IP rights to license to all interested parties on reasonable and non-discriminatory (RAND) terms.

While no guarantee of success, the anointing of a company's technology by a standard-setting body is likely to increase the probability that the technology will be more broadly adopted. If a patented technology is recognized by a standard-setting body as being superior and desirable as an industry standard, this is likely to reduce the probability that industry participants can successfully imitate around the technology. Such outcomes are likely to be desirable not just for the innovator, but also for society. The reason is that while royalties will need to be paid, they are in the nature of transfer payments (i.e., no real resources get used), yet largely wasteful duplicative "invent around" activities become curtailed.

Recognizing that the appropriability regime and the architecture of the industry are not determined exogenously but are sometimes a function of strategic choices made by innovator and emulator alike creates an even richer menu of strategic variables for innovators (and others) to consider in industries experiencing rapid technological change. The particular actions that firms can take are in part a function of their strategic goals; but it also depends on the resources available to them. How firms act will depend on who they are and how they are positioned.

Managing Appropriability for Design Freedom

Yet another class of situations exist that is neither weakening nor strengthening appropriability; it might best be thought of as managing the appropriability regime for design freedom. By this we mean that some firms actively engage in "defensive" patenting in order to gain sufficient patents to be able to cross-license competitors, new entrants, and others. Such defensive patenting (and the possible acquisition of already issued patents) provides the firm with bargaining chips should it find that it is infringing other companies patents.

Indeed, certain scholars have argued that biomedical innovation has become susceptible to "the tragedy of the anti-commons" due to numerous property rights claims that exist in some fields and the difficulties associated with negotiating licenses.[22] We think these situations are not all that common and may have been exaggerated by some scholars and interested parties. As discussed in Somaya and Teece, we see many ways and organizational mechanisms for working around these issues.[23] Cohen reports on the work that he completed with colleagues Walsh and Arora in which he found "no evidence of breakdowns in negotiations over rights, nor firms avoiding projects due to anti-commons."[24] He concluded further that "it is too easy for academics to raise alarms when the basis for arguments are conjectural and understanding of the institutions and behaviors involved is so limited.[25]

Appropriability Regimes and Open Business Models

Open innovation is a term of art invented by our colleague Henry Chesbrough to summarize a strategy whereby companies make much greater use of external ideas and technologies in their own business, while letting their own unused ideas be used by others, typically but not only through out-licensing. As

Chesbrough notes, "open innovation offers that prospect of lower costs for innovation, faster time to market, and the chance to share risks with others."[26]

At first glance, it might seem that open innovation models and weak appropriability regimes are close cousins, but they generally are not. In many ways, strong appropriability facilitates open business models. Consider a regime of weak appropriability. Without patents, trade secrets, or other forms of IP protection, and without some degree of natural protection from imitation, the innovator has nothing to license. Potential partners can readily imitate. In this circumstance, the firm's business model is in a sense "open"; but there is unlikely to be benefit associated with the firm facilitating what is likely to happen anyway. Of course, the reverse is also true. In weak appropriability regimes, imitation strategies will be viable, at least until the generator of new technology is destroyed by free riding from the imitators.

Strong appropriability regimes allow firms the choice of a closed or open business model. In particular, the possession of a strong patent portfolio gives the innovating firm the option to simply use the technology internally, license, or both. Chesbrough offers Qualcomm, UTEK, and Intellectual Ventures as examples of IP enabled business models. He might have added Rambus and Dolby.[27] Such enterprises specialize in technological innovation and the creation of patentable inventions. If the market for know-how and IP works well, then this is a viable business model, and one that is very valuable to society, voiding the need for the innovator to enter into other segments of the value chain where it doesn't have any competitive advantage.

Strong appropriability based on strong IP thus supports open innovation. This is really nothing more than a manifestation of the principal that property rights need to be well-defined for markets to work. If property rights are nonexistent or are fuzzy, exchange will not take place, or it will be infrequent and inefficient because neither the buyer nor seller know the precise contours of that which is being bought and sold.[28] Such fuzzy boundaries around property rights are likely to lead to disagreements about value; so that transactions that might otherwise occur simply don't happen. Hence, clarity around intellectual property boundaries will both enable and encourage innovators to consider out-licensing.

Also, let us consider the role that complementary assets play in the enthusiasm with which firms should embrace open innovation and open business models. Even if the firm operates in a weak appropriability regime, the ownership of complementary assets that are likely to remain important in the future (e.g., distribution channels, brand) give the enterprise the confidence to outsource innovation and know that it will still have a means to extract value from the innovation (to the extent to which the innovation is competency enhancing and will create demand for the complementary asset). Where it is the case that the firm was both bereft of complementary assets and operating in a regime where appropriability was weak, one would expect that rapid imitation would destroy value capture opportunities, thereby undermining both open and closed innovation models.

Re-Engineering Industry Architecture

The PFI framework stressed the role that innovators should play in leveraging their existing investments in complementary assets, or in contracting out (or joint venturing) with other enterprises that own complementary assets needed to successfully bring an innovation to market. The PFI framework was self-limiting inasmuch as industry structure or industry "architecture" was taken as a given—i.e., it was assumed exogenous. Much of the time this is a good assumption. However, as pointed out by scholars such as Baldwin and Clark, Chesbrough, Iansiti and Levien, and Jacobides et al., industry architecture can be strategically shaped by industry participants.[29] Such "architectural re-engineering" can be accomplished through investments in platform technologies or through technology architecture decisions. Significant industry participants with good market positions and abundant resources can sometimes help shape the architecture of an industry through their corporate and venture capital investments, and through their co-investment activities with alliance partners and also possibly even with public institutions.

In short, innovators can sometimes help shape the investment decisions of others (such as complementors). Having a high share and financial resources to invest in venture capital and/or alliance relationships helps. This is particularly true when markets have two or more "sides," as is frequently the case with hardware and software markets, and with payment schemes (e.g., credit cards). An emerging literature on platforms illuminates these dynamics.[30]

Who Can Shape Architectures and When?

An industry architecture can emerge shaped by firms who have initial technological, organizational, or financial capabilities.[31] One or more rival platforms may exist, each with their sponsors. Over time, there can be significant switching costs associated with changing platforms. The emergence of rival platforms is by no means entirely path dependent. Legal and regulatory authorities, standard-setting bodies, and the business enterprise itself can help shape industry architecture.

Re-engineering industry architecture, such as altering the appropriability regime, is no simple feat. There are significant constraints, and managers need an understanding of the basic conditions under which such re-engineering may at least be feasible, if not desirable. It is tempting to believe that only the largest firms have the power to reshape architecture. Clearly, size can help. IBM was able to shape the architecture of the mainframe and then later the PC industry because of the clout that it had at the time.

However, one also needs to remember that when Intel and Microsoft made critical strategic decisions that helped shape the architecture of the PC business, both were much smaller firms than they are today. Firms can also shape the architecture of a business by creating alliances to invest in common platforms, as did banks in the case of creating common payment platforms for credit cards.[32] Santos and Eisenhardt note that even small entrepreneurial firms can shape the architecture of a market to their own benefit.[33]

Because industry architectures are supported by specialized assets, industry architectures display considerable inertia. Any firm that attempts to re-engineer industry architecture will face resistance. As a result, opportunities for architectural re-engineering typically only arise in new sectors and whenever a substantial technological, institutional, or demand shift takes place.[34]

When firms can shape industry architecture, the goal becomes to steer the evolution of an industrial ecosystem so that customers come to see that use of the assets owned by the firm are essential to customer satisfaction. In effect, demand for the services of the assets (and technologies) owned by the firm is not exogenous—it can be shaped by the enterprise itself. Put differently, if what the enterprise owns isn't the bottleneck, the innovating enterprise can work to shape industry architecture, without degrading the customer solution. If the latter occurs, the incumbent will be more vulnerable to another discontinuous technological innovation. The corollary, of course, is to promote competition with respect to the complements where the innovator is poorly positioned and to de-bottleneck such situations or, if possible, prevent them from emerging in the first place. This may involve putting relevant intellectual property into the public domain, as discussed earlier.

A current example of strategic re-architecting, and the element of both cooperation and conflict it involves, can be found in a technology known as WiMAX.[35] WiMAX (Worldwide Interoperability for Microwave Access) is a technology for high-speed (broadband) wireless web access. Unlike current Wi-Fi networks (that you find in airports, your home, or your local coffee shop) whose ranges are typically limited to a hundred yards or so, WiMAX permits Internet access at a range up to 30 miles and at speeds 50 times faster. In essence, WiMAX is a substitute technology for current coaxial and fiber optic lines that deliver broadband Internet access to homes and offices.

WiMAX is an excellent example of a technology embedded in a broader system of complementary technologies. Implementing WiMAX requires innovation in microprocessors, modems, wireless networks and web infrastructure, mobile handsets, data services, and other communications technologies. It is no wonder then that WiMAX is being developed as a cooperative alliance involving companies such as Intel (microprocessors), Samsung (handsets and network equipment), Motorola (handsets and network equipment), Sprint-Nextel (carrier), Clearwire (carrier and the largest holder of spectrum suitable for WiMAX), Vodafone, and over 400 other companies that form the "WiMAX Forum." Interestingly, the effort met resistance from Qualcomm, the company that owns the patents for CDMA technology (one of the digital standards used heavily in the U.S.). Phone makers using CDMA technology in their phones must pay Qualcomm a royalty. Qualcomm essentially benefits from an architecture whereby they have a significant role in the key component technology and enjoy strong IP. WiMAX potentially replaces CDMA but also, given the collaborative manner in which the technology is being developed, potentially alters the architecture in a way that is unfavorable to Qualcomm (but might favor Intel).

The Role of Standards and Modularity in Industry Architecture

With the birth of an industry, a range of architectures are possible and a set of interfaces and capabilities begin to emerge.[36] This is particularly true in the world of digital electronics. Defined architectures and interconnection protocols allow specialization and the division of labor. Recognized technical standards allow "plug and play," which in turn supports modularity. This stimulates competition on the open side(s) of the interfaces. Complementarities exist, and co-specialization is facilitated without common ownership of the producers making subsystems necessarily being required. Going back to the WiMAX example, one of the first battles Intel waged was to get the Institute of Electrical and Electronic Engineering (IEEE) to accept its standard, a battle that Intel eventually won over opposition from Qualcomm.[37]

Technological interfaces may or may not be proprietary; even if "open," they may or may not require the use of proprietary intellectual property. Efforts to shape the rules of the game can in turn lead to significant struggles and may raise regulatory and antitrust issues. On the other hand, the emergence of dominant designs can happen by virtue of strong customer demand for a particular product/system configuration, as with the early automobile industry. With the Ford Model T, the automobile became defined around the closed body, 4 wheels, with the internal combustion engine in the front.

Standards play a special role in shaping industry architecture, in part because they facilitate specialization and modularization. Modularity reduces the need for management and simplifies coordination. It also encourages scale economies, by helping to configure (standardize) demand, and also facilitating mass customization. The highly modular structure of today's personal computer industry is well known. Dell and others have been enabled by this to assemble PCs like Lego toys. Dell and others can readily access the capabilities of suppliers; suppliers can readily aggregate demand from buyers, thereby lowering prices.

Modularization also facilitates (autonomous) innovation behind interface protocols. Of course, overall systemic innovation may become more difficult. Component markets became thicker and more competitive. However, as noted elsewhere, systems integration skills are necessary to take full advantage of the economies of specialization that modularity permits. Dell Computer's ability to make its business model work by managing logistics and pre-configuring customer choices remains a critical capability.

Hence, in an extension to PFI, there are circumstances in which the innovating enterprise should endeavor to influence the rules of the game and promote competition in those complementary activities where the innovator is poorly positioned and/or needs demand drivers.

System Integration

As discussed, standards facilitate modularization and outsourcing, either domestically or offshore. However, should activity need to support innovation be outsourced, there is then a need to achieve "integration" and final assembly. The economic function of integrating knowledge, technology, and components supplied either internally or externally is always necessary, no matter the business model chosen.

Systems integration as a recognized practice developed in the military and applied successfully in the Manhattan project during the Second World War and in the development of ICBMs in the post-war period. AT&T developed a version of it to help in development and deployment of new technologies during the 1950s, 1960s, and 1970s. Systems integration is no longer just a technical and operation function; it is now strategic. The more complex and high-valued the final product, the more significant system integration becomes.[38] For instance, both Boeing and Airbus fulfill the systems integration function with respect to the development and manufacture of aircraft, an industry which today involves considerable outsourcing. Indeed, following Hobday et al., we suggest that a firm's ability to profit from innovation when there is considerable outsourcing depends importantly on whether the firm has world-class capabilities in systems integration.

Put differently, vertical disintegration sharpens the need and enhances the difficulties of systems integration, as it requires integrating the activities of parties when there is no common ownership link. Interface standards and modularity, of course, facilitate outsourcing and thereby sharpen requirements for integration. Failure at integration in turn destroys any benefits associated with outsourcing in the first place. Systemic innovation of course tends to render prior interface standards obsolete, and favors vertical integration. Possession of the systems integration capabilities gives high-tech firms outsourcing choices that were just assumed in PFI. With respect to complex systems, system integration capabilities could indeed become the bottleneck asset, in the sense discussed earlier.

Conclusion

The management of innovation for profit is a complex subject. However, emerging frameworks can assist managers in cutting to the essentials. The role of intellectual property and technology itself in shaping the appropriability regime and strategy is already recognized.

In this article, we show how the business environment itself can be managed so as to help innovators capture value from innovation. Both the appropriability regime and industry architecture at various times can be shaped by managerial action, whether emanating from large or small firms. The framework developed may allow both scholars and managers to think about technology strategy more expansively. In particular, it is sometimes beneficial for innovators to push technology into the public domain rather than keeping it proprietary. Also, it is sometimes beneficial to promote modularity, particularly if one retains competence (and control) over the systems integration function. Promoting modularity can be both beneficial and hazardous. Our understanding of how to manage these tradeoffs is still in its infancy.

Notes

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3. The core paper is Teece (1986), op. cit. The intellectual origins of the framework can be traced to Williamson (for his work on contracting), Abernathy and Utterback (for their work on the innovation life cycle), and to economic historians such as Rosenberg and Chandler (for their work on complementary technologies), to Nelson and Winter (for their work on the nature of knowledge), and Schumpeter (for his focus on value capture).
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5. *Research Policy*, 35/8 (October 2006).
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12. Baldwin and Clark, op. cit.
13. Baldwin and Clark, op. cit.
14. R. Merges, "A New Dynamism in the Public Domain," *The University of Chicago Law Review*, 71/1 (Winter 2004): 183-203.
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16. For historical background on the evolution of genomics and biotechnology, see G. Pisano, *Science Business: The Promise, the Reality, and the Future of Biotech* (Boston, MA: Harvard Business School, 2006).
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