CHAPTER 1

APPROPRIABILITY STRATEGIES TO CAPTURE VALUE FROM INNOVATION

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ABSTRACT

This chapter explores the extent to which an innovator is able to capture innovation rents. After examining the two main drivers of such rents, the strength of the appropriability regime and the ownership of specialized complementary assets, the chapter examines how their interaction is so critical in affecting imitation, commercialization options, and firm performance. After reviewing the underlying conceptual framework and empirical evidence, and using a perspective that cuts across both time and industries, the authors then discuss the implications of innovation profits for the resources to be devoted to the discovery of new or improved product and processes.

Keywords: Appropriability regime; profiting from innovation; complementary assets; intellectual property; patent protection; first mover advantage

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INTRODUCTION

Although significant science and engineering competencies are needed to invent new processes and products, the technological prowess that underlies process and product innovations is simply not enough to benefit from innovation. While invention is a necessary first step to innovation, it is not sufficient for commercial success (Teece, 1986). Innovators frequently fail to appropriate the returns to their innovations. This implies that protecting the returns to innovation is a key strategic challenge in technology-intensive industries. Commercially successful innovations create temporary monopolies, which in turn enable firms to extract transitory Schumpeterian rents. In high-technology industries, competitive advantage can be sustained only through a string of continuous innovations.[1] Thus, a firm's ability to appropriate rents from innovation determines its performance and continued survival.

Table 1 depicts several high-profile examples in which innovators lost to imitators (or second movers/fast followers), because the innovators were unable to appropriate the returns to their own innovation(s). Why does this happen so frequently? To answer this question, we focus on two factors highlighted by Teece's seminal treatise on profiting from technological

Table 1. Innovators Failing to Appropriate the Returns to Innovation.

Innovator	Innovation	Lost to Imitator/Second Mover or Fast Followers
EMI	CAT scanner	GE Medical Systems
RC Cola	Diet cola	Coca-Cola and Pepsi
Bowmar	Pocket calculator	TI, HP
DeHavilland	Commercial jet	Boeing
Ampex	Video recorder	Matsushita
MITS	PC	Apple, IBM
Xerox	GUI interface	Apple, Microsoft
Prodigy	Online service	AOL, EarthLink, other ISPs
Webcrawler, Lycos, Alta Vista	Internet search engine	Google
Apple's Newton	PDA	Palm Pilot
Book Stacks	Online bookstore	Amazon.com
TiVo	DVR Set-top-box	Cable/Satellite Providers
Friendster, MySpace	Social networking site	Facebook

innovation: the appropriability regime and the complementary assets (Abernathy & Utterback, 1978; Anderson & Tushman, 1990; Teece, 1986). Today, it is widely accepted that innovators seeking to profit from their inventions must understand the strength of the appropriability regime and the nature of the complementary assets required to commercialize their inventions.

The commercialization of the digital video recorder (DVR) set-top-box provides a recent example in which the innovator, TiVo, lost to the imitators, the pay TV cable and satellite providers. TiVo was founded in 1997 by James Barton and Michael Ramsay after working at Silicon Graphics on a centralized video-on-demand system for Time Warner which had been canceled. They believed that a better way to deliver video-on-demand to consumers would be in the form of a decentralized model that utilized a set-top-box. Their new device would combine a TV tuner connected to an external source such as cable or satellite TV service, a computer hard drive, and a user-friendly interface. TiVo's innovation would prove to be a game-changer in how consumers watched TV and consumed digital content.

In 1999, TiVo launched their set-top-box product selling direct to customers for an upfront fee for the equipment and an ongoing monthly subscription fee. Shortly after the launch they also started selling their service through cable and satellite providers. For example, their partnership with DIRECTV included TiVo providing the design for a set-top-box and DIRECTV manufacturing and distributing under a licensing agreement. While the partnerships provided TiVo with a larger install base, they generated only a fraction of the revenue that the direct-to-consumer model provided. TiVo struggled to generate profits, only achieving profitability briefly in 2005. In addition, many of their partnerships with companies such as DIRECTV started to unwind as the companies began to source DVR components and production from generic providers. While TiVo did possess some fairly strong patents, the actual design of the set-top-box was relatively easy to reverse engineer since it was comprised of coupling existing technologies. In later years, TiVo was able to be intermittently profitable due, in part, to successful patent litigation, but never had the necessary complementary assets to establish a sustainable competitive advantage and provide profits from their innovation. Cable and satellite companies, controlling access to a large installed base of users through bundling rental of the set-top-box with service contracts, were able to extract most of the profits associated with the TiVo DVR.

Another example of a company that has not yet established profits from a radical innovation can be found in Tesla Motors. Tesla manufactures and sells electric drivetrain vehicles. Their business model includes vertical integration from design to manufacture to sales and distribution. In an unusual move, their CEO Elon Musk announced in 2014 that they will open up their patent portfolio for other companies to use in good faith, without threat of litigation, possibly to help spur adoption of a de facto standard based on their technology in electric vehicles. This leaves Tesla with a relatively weak patent position. They are also racing to acquire complimentary assets in a very capital intensive and highly competitive automotive industry. It is yet to be seen whether Tesla will be able to capture profits from their innovations.

APPROPRIABILITY REGIME AND COMPLEMENTARY ASSETS: THE TEECE FRAMEWORK

TiVo's strategy neglected the two most important determinants of innovation profits: the *appropriability regime* and the *specialized complementary assets*.

The *appropriability regime* mainly depends on legal and technological factors. On one hand, the realization of rents from innovation depends on strong, or effective, intellectual property rights (IPR) protection by the legal system. On the other hand, characteristics of technology, such as degree of codification, complexity, and ease of reverse engineering, determine the height of barriers to imitation, which in turn affect the ease with which rivals can imitate the innovation. In the TiVo case, while the DVR set-top-box was a remarkable advance in how consumers watched TV, it only re-combined simple and well known technologies such as computer hard drives and TV tuners coupled with interface software. Once the idea about re-combining the different elements had become widely known, it was difficult to protect because it was easy to replicate through reverse engineering. In addition, while TiVo did possess some strong patents, they were not effectively enforced early on. As a result, the appropriability regime that TiVo faced when commercializing the DVR set-top-box scanner was weak.

The second fundamental component of appropriability is the ownership of *specialized complementary assets*. Teece (1986) highlighted the importance of complementary assets in understanding the performance implications of a new technology when he examined the reason many innovators were unable to capture the economic rents flowing from their innovations.

He argued that the commercialization of an innovation "requires that the know-how in question be utilized in conjunction with other capabilities or assets. Services such as marketing, competitive manufacturing, and after sales support are almost always needed. These services are obtained from complementary assets, which are specialized" (Teece, 1986, p. 288). The commercialization of the DVR set-top-box provides a compelling example: the innovator, TiVo, lost to the followers, the pay TV cable and satellite providers, because of a lack of specialized complementary assets.

In his conceptual framework, Teece (1986) differentiated among three different types of complementary assets: generic, specialized, and cospecialized. *Complementary assets* that are *generic* need not be adjusted to the innovation, because they can frequently be contracted for in the market on competitive terms. General purpose manufacturing equipment falls into this category. *Specialized complementary assets* must be tailored to the innovation. For example, GE Medical System's stellar reputation for quality and service in hospital equipment is considered a specialized complementary asset. Such a complementary asset can be leveraged to commercialize a variety of innovations in hospital equipment and create unilateral dependence of the innovations on the complementary assets. C*ospecialized complementary assets* are specialized complementary assets with bilateral dependence between the innovation and the complementary assets. Specialized repair facilities for Tesla Motor's innovative electric vehicles would be cospecialized complementary assets due to the bilateral dependence between the innovation and the complementary assets (both are more valuable when used in conjunction). Because the distinction between unilateral and bilateral dependence of the complementary assets and the innovation in question is not critical to our analysis, we use the term specialized complementary assets here to denote both specialized and cospecialized complementary assets.

Why are complementary assets so critical in commercializing innovation? When large-scale and high-quality manufacturing capabilities are necessary complementary assets, the owner of such assets is in a position to satisfy a large surge in customer demand, while maintaining product quality. A lack of large-scale manufacturing capabilities was the reason, for example, that innovator Immunex, a biotechnology firm, lost out to second-mover Johnson & Johnson, a healthcare conglomerate, in commercializing a biotechnology-based drug for rheumatoid arthritis. Immunex was the innovator in this market through its breakthrough development of the drug Enbrel in 1998, and sales reached quickly $750 million in 2001. Surprised by the large demand for its highly successful new drug, Immunex had not created the necessary large-scale manufacturing capabilities to satisfy such an exponential surge in demand. This strategic oversight provided Johnson & Johnson an opportunity to enter the market for biotechnology-based rheumatoid arthritis drugs with its own product (Remicade), developed by its fully owned subsidiary Centocor. Remicade has now surpassed Immunex's Enbrel sales and was one of the top-ten biotech drugs by sales in 2008 (cf. Table 3). Immunex's innovative advantage dissipated due to a lack of the necessary complementary assets in manufacturing (Hill & Jones, 2007).

Furthermore, large-scale manufacturing capabilities allow companies to ride down the experience curve faster due to learning effects and scale economies, and thus reach a low cost position that is not attainable by competitors lacking such manufacturing capabilities. This is one of the problems currently facing Tesla Motors. While it acquired manufacturing facilities and is in the process of building battery production capabilities, Tesla has yet to create a manufacturing capability necessary to produce the quantity and quality that could satisfy the potential demand for its products at a profitable cost position.

In summary, strategy scholars have highlighted the importance of ownership of specialized complementary assets in profiting from innovation. These assets are frequently built over long periods of time and thus are path dependent and idiosyncratic (Teece, Pisano, & Shuen, 1997). Their market availability is limited because firms tend to gain control over them to avoid potential bargaining problems. Overall, specialized complementary assets constitute the bulk of a firm's resources and capabilities that are valuable and difficult to imitate, and they can therefore be a source of sustainable competitive advantage (Barney, 1991).

Interaction between Appropriability Regime and Complementary Assets

In this section, we discuss whom – the innovator or imitator – is more likely to extract innovation rents. In the following section, we discuss in more detail the strategic options on which an innovator can draw when attempting to commercialize an innovation.

The interaction between the strength of the appropriability regime and the ownership of specialized complementary assets determines the degree to which firms profit from their innovations. A strong appropriability regime is typically sufficient to capture at least a positive fraction of the innovation rents. But even in such a case, a greater degree of specialization in complementary assets corresponds to greater rents for its owner. When the innovator owns such assets, it can capture almost all of the value associated with its innovation. When assets are specialized and owned by a different firm, rents have to be shared through an alliance, which in high-tech industries typically takes the form of technology licensing agreements (further discussed in this volume), such as in the pharmaceutical industry after the emergence of biotechnology (Rothaermel, 2001a, 2001b; Rothaermel & Hill, 2005). Teece's (1986) conceptual framework depicting the interaction between the appropriability regime and complementary assets is summarized in Fig. 1.

Teece (1986) analyzes the case of weak appropriability in greater detail, most likely because during the decades preceding his work courts typically provided weak protection to patent holders. Weak appropriability and generic complementary assets seem to be the unfortunate case of many entrepreneurial ventures seeking to "build a better mousetrap." Think about simple toys, for example, where entrepreneurial inventors often introduce tiny improvements from which they hope to generate quick revenues. Such simple inventions, however, are easily imitated and complementary assets (especially manufacturing-related) are easily acquired, with customers appropriating most of the value created by the innovations.

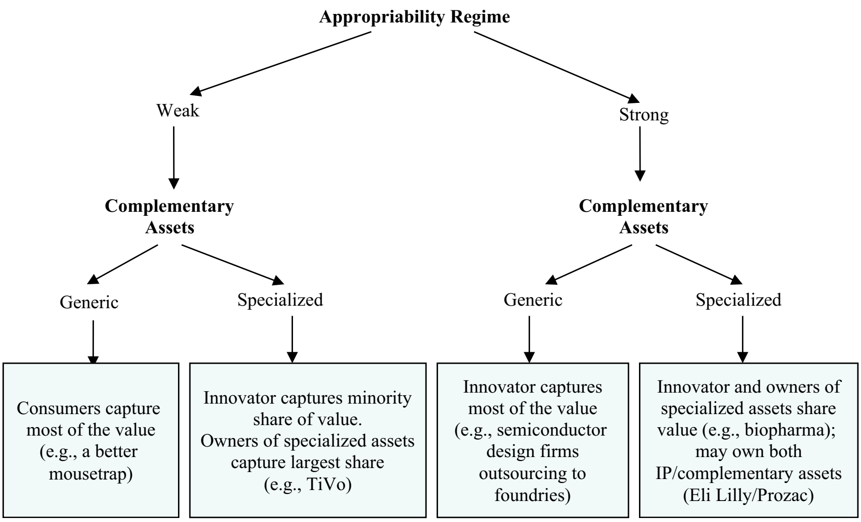

Fig. 1. The Teece Framework.

The combination of a weak appropriability regime and specialized complementary assets typically allows the owners of such assets to capture the lion's share of the value created by the innovation, as for the TiVo example discussed above.

With stronger appropriability, the innovator usually captures a greater share of the profits. It may be able to capture most of the profits if it is able to easily acquire the necessary complementary assets. When specialized assets are required, an alliance should allow the parties to earn a return commensurate with the assets they bring to the table and with their respective bargaining power. A strong appropriability regime typically safeguards the innovator, which can disclose and protect its inventions to its potential alliance partners without fear of imitation.

A strong appropriability regime does not simply happen by coincidence, but can be strategically enacted by the innovator not only through patenting, but also through following up with aggressive patent litigation. The U.S. semiconductor firm Intel is said to follow such a legal strategy (Somaya, 2003). Apple Inc., which dominates several high-end mobile device markets, is another example. In particular, Apple's domination of the tablet computer market is a well-suited example. Apple maintains its competitive advantage in this market by both maintaining a strong appropriability regime and by controlling key specialized assets. From the IPR perspective, Apple tightly controls its intangible assets in a "legendary" fashion, by aggressively maintaining and enforcing trade secrecy, patents, trademarks, and copyrights (Duhigg & Lohr, 2012; Stone & Vance, 2009). Apple also owns several specialized complementary assets: a strong cult-like brand; several complementary technologies which successfully transferred from its digital music player, the iPod; in-house digital rights management software; tacit technical capabilities that deliver a product with proverbial design; and an easy to use interface. Apple also controls key cospecialized assets such as the App and iTunes Stores; huge marketplaces owned by Apple that enhance the user experience through the online purchase of functional applications and music. Their use in conjunction with Apple's innovations is value enhancing. On the one hand, Apple benefits from the virtual stores since they encourage its consumers to remain loyal and enhance its bargaining position; on the other hand, the iPad benefits the virtual stores, since it provides developers and artists a large installed base of Apple customers. Finally, Apple aptly outsources production and assembly associated with the iPad, since these are generic complementary assets that are available in competitive markets.

Interestingly, the fact that innovators may choose, to some degree, the strength of the appropriability regime, highlights an important and somewhat counterintuitive point. Companies that possess specialized complementary assets may choose to purposefully weaken the appropriability regime (Alexys & Reitzig, 2013; Pisano & Teece, 2007), for example, in areas where standards and compatibility issues limit incentives to innovate. This is one of the reason why Elon Musk opened-up Tesla's patent portfolio (Musk, 2014), as mentioned above. Arguably, the company is attempting to profit through ownership of a key cospecialized asset such as its well-recognized, almost cult-like, brand and specialized investments in complementary assets such as electric battery R&D and manufacturing. Conversely, some argue that Apple maintained too strong IPR in the late 1980s in the PC business, neglecting opportunities for network effects and favoring the diffusion of IBM compatible PCs (Fisher & Oberholzer-Gee, 2013).

Appropriability Regime, Complementary Assets, and Commercialization Strategies

Innovations create opportunities for companies to capture first mover advantages, and thus temporary monopolies (Hill & Jones, 2007). But how should the innovator leverage its innovation toward commercial success and sustained competitive advantage? While we have focused more on theoretical descriptions by highlighting who captures the rents to innovation above, in this section we focus on the strategies available to the innovator in a more normative fashion: answering the question what an innovator *should do* given certain scenarios.

An innovator basically has three strategic options at her disposal: (1) develop and commercialize the innovation itself, if necessary, through forward vertical integration; (2) develop and commercialize the innovation jointly with a partner through strategic alliances or a joint venture; and (3) license the innovation to another company or companies, and let them develop and market the innovation in exchange for royalties. The optimal strategy to be pursued depends upon (1) the availability and the type of complementary assets; (2) the height of imitation barriers, addressing the degree of difficulty of imitating the innovation by competitors (which is determined by the appropriability regime); and (3) the number of capable competitors, which interact with the strength of the appropriability regime in determining the likelihood of imitation.

The first question the innovator must answer is whether it possesses the necessary complementary assets to commercialize the new technology. We discussed different types of complementary assets above. Assuming the innovator possesses specialized complementary assets to commercialize the innovation, the next question to consider is the height of barriers to imitation. These barriers define the degree of difficulty competitors face when attempting to imitate the innovation. Assuming the barriers to imitation are high due to a strong appropriability regime and the number of capable competitors is low, the inventor should go it alone – that is, pursue a forward vertical integration strategy. The innovator will then be in a position to leverage its complementary assets to extract monopoly rents from the innovation, and barriers to imitation will delay entry. If the number of capable competitors remains low, the innovator might be able to build a sustained competitive advantage.

More often than not, however, the innovator does not possess the required complementary assets to commercialize the innovation. If the barriers to imitation remain high (due to a strong appropriability regime) and the number of capable competitors is not too large, the innovator may profit from the innovation through joint development with the holder of complementary assets through an alliance or joint venture. While an alliance is a contractual agreement between two independent parties to share knowledge and resources and to co-develop product and processes, joint ventures are newly established third entities generally created by two parent companies to accomplish certain tasks, such as developing a new product or process. Alliances tend to be non-equity, contract-based cooperative agreements, whereas joint ventures are equity-based through setting up a third organization. As a consequence, non-equity alliances are much more frequent, although joint ventures are considered to establish stronger ties between firms. Intensive inter-firm cooperation based on alliances and joint ventures is a scenario that has played out in the pharmaceutical industry after the emergence of biotechnology; thus, one can now observe extensive cooperative relationships between the innovating biotechnology firms and the large incumbent pharmaceutical companies (Gans & Stern, 2000; Rothaermel, 2000; Teece, 1992). In this industry, thousands of alliances and joint ventures have been documented, in which the returns to innovation are shared by biotech and pharmaceutical companies (Rothaermel & Deeds, 2004). The distribution of rents, in turn, depends on the relative bargaining power of each party.

If the innovator lacks the necessary complementary assets and the barriers to imitation are low due to a weak appropriability regime, combined with a large number of capable competitors, then the innovator should license the innovation to at least capture some of the innovation rents. Not only does imitation generally cost only 40–60% of the innovation, but imitation of an innovation through reverse engineering, for example, also is frequently possible within a few short years. Given this situation, the innovator would be better off either to enter into an alliance or joint venture or to license the commercialization.

The decision between these two remaining strategic options depends on the appropriability regime. If the appropriability regime appears to be initially weak, this implies the best course of action would be to license the innovation. This is exactly the strategy Microsoft followed when faced with the question of how to commercialize its MS-DOS operating system. Microsoft opted for a non-exclusive license to IBM, which (involuntarily) aided Microsoft in making MS-DOS the first and only industry standard for operating systems in the PC industry. Microsoft was able to defend this lead for over 25 years, through continuing innovations that leverage the standard that was created through widespread adoption of MS-DOS. Microsoft's innovation strategy thus resulted in a sustainable competitive advantage.

Finding an appropriate partner to leverage the partner's complementary assets to commercialize an innovation may not always be this straightforward, because alliances often enable one partner to learn more than the other, and thus capabilities are frequently transferred. Here, the holder of complementary assets would be interested in obtaining the R&D capabilities of the innovator, while protecting its complementary assets. The innovator has the opposite motivation. The result is that learning races frequently ensue in alliances, especially in alliances initiated to commercialize innovations (Hamel, 1991). Note that often the holder of specialized complementary assets is more advantageously positioned to learn, and thus to appropriate innovation capabilities, because these firms tend to be larger and thus have more resources at their disposal, combined with an existing R&D capability. In contrast, innovators frequently lack any competence in complementary assets, especially if those assets are downstream value chain activities like large-scale manufacturing, distribution, and after-sales service. Innovative firms tend to be small research-intensive outfits that exclusively focus on discovery and early-stage development of new products and processes.

Going it alone through vertical integration may have to be achieved, absent any appropriate partners. Not infrequently, major innovations require complementary assets that are unavailable in the market, yet their nature is specialized and requires significant sunk investments to be successfully commercialized. Downstream integration frequently takes substantial time if the capabilities are to be built from scratch. In such a case, both the demand for licensing and the potential rents to be realized are very low or absent, whereas the potential commercial success could be high. The key challenge, here, is to find a partner willing to share the financial risks of developing the cospecialized assets. With weak appropriability, however, partners may well be unwilling to share such risks, which are exacerbated by the high likelihood of imitation. Downstream integration remains the only alternative left. This option should be pursued only if the investment is expected to yield positive net returns to the innovator, a principle that should always guide rational investment decisions.

PROFITING FROM INNOVATION: EMPIRICAL EVIDENCE

While we discussed theoretical decisions on how to commercialize an innovation, what does the empirical literature tell about how well these theoretical conjectures hold up? Overall, the theoretical model presented holds up pretty well. Rothaermel and Hill (2005), for example, found support for the notion that the type of complementary assets (generic versus specialized) needed to commercialize a new technology is critical in determining the industry- and firm-level performance implications of a competence-destroying technological discontinuity. Competence-destroying technological discontinuities are radical innovations that emerge exogenous to incumbent industries, and to which established firms must respond to ensure continued survival.

At the industry level, Rothaermel and Hill (2005) hypothesized, incumbent industry performance declines if the new technology can be commercialized through generic complementary assets, whereas incumbent industry performance improves if the new technology can be commercialized through specialized complementary assets. At the firm level, they posited that an incumbent firm's financial strength has a stronger positive impact on firm performance in the post-discontinuity time period if the new technology can be commercialized through generic complementary assets. They further hypothesized, however, that an incumbent firm's R&D capability has a stronger positive impact on firm performance in the post-discontinuity time period if the new technology has to be commercialized through specialized complementary assets. Drawing on multi-industry, time series, and panel data over a 26-year period to analyze pre- and post-discontinuity industry and firm performance, they found broad support for their theoretical model. Their findings are summarized in Table 2.

Further, several empirical studies find evidence for the innovation framework described on the right side of Fig. 1 (Rothaermel, 2001a, 2001b). Most of these studies have focused on the pharmaceutical industry after the emergence of biotechnology. Here, the appropriability regime is relatively strong, especially after the Supreme Court decision in 1980 that new life forms can be patented (Diamond v. Chakrabarty, 447 U.S. 303, 1980). Moreover, specialized complementary assets (in the form of large-scale manufacturing, clinical trial and regulatory management) as well as large sales forces are critical in commercializing new biotechnology drugs. Since the scientific breakthrough of genetic engineering in the mid-1970s, numerous new biotechnology entrants demand access to the market for pharmaceuticals, which is controlled by a few incumbent pharmaceutical firms. These incumbent pharmaceutical firms have developed path-dependent, firm-specific competencies with respect to certain drug and disease areas that are valuable, rare, and difficult to imitate; thus, these competencies may, according to the resource-based view of the firm, form a basis of a competitive advantage (Barney, 1991). For example, Eli Lilly enjoys a dominant position in human insulin and growth hormones, while Hoffman-La Roche has developed a strong hold in antianxiety drugs. This degree of specialization reduces the number of potential strategic alliance partners for new biotechnology firms and further accentuates the value of the incumbents' downstream, market-related value chain activities – that is, specialization enhances the value of their complementary assets.

Hence, these incumbents can benefit from the technological breakthrough in biotechnology to the extent it enables them to create and extract innovation rents based on their specialized complementary assets, through strategic alliances, joint ventures, and licensing agreements with new biotechnology firms. The emergence of a cooperative equilibrium in the biopharmaceutical industry has also been highlighted by other researchers and is exemplified in Table 3, which depicts the top-ten selling biotechnology drugs in 2008.

Note how several of the top-ten selling drugs in 2008 were not developed by the incumbent pharmaceutical companies. Some of the top selling biotech drugs are discovered and developed by biotechnology firms, leveraging their R&D competencies in the new biotechnology paradigm, and subsequently commercialized by incumbent pharmaceutical companies.

Table 2. Technological Discontinuities, Complementary Assets, and Incumbent Industry and Firm Performance (Rothaermel & Hill, 2005).

Technological Discontinuity	Industry Examples	Impact on Incumbent Upstream Technological Competencies	Type of Complementary Assets Needed to Commercialize New Technology	Impact on Downstream Complementary Assets	Effect on Incumbent Industry Performance	Stronger Effect on Incumbent Firm Performance
PC, Electric Arc Furnace	Computer, Steel	Destroying	Generic	Destroying	Decline	Financial Strength
Biotechnology, Wireless Telephony	Pharmaceutical, Telecommunications	Destroying	Specialized	Enhancing	Improvement	R&D Capability

Table 3. Top-Ten Biotechnology Drugs, 2008.

Product	Indication	2008 Sales (Millions)	Developer	Marketer
Enbrel	Rheumatoid Arthritis	5,900	Immunex	Amgen
Rituxan	B-cell non-Hodgkin's lymphoma	5,080	IDEC	Genentech
Humira	Rheumatoid arthritis, polyarticular juvenile idiopathic arthritis, psoriatic arthritis, ankylosing spondylitis, Crohn's disease	4,500	Cambridge Antibody Technology Group	Abbott
Avastin	Certain metastatic cancers	4,500	Genentech	Genentech, Roche
Remicade	Rheumatoid arthritis, Chron's disease	3,700	Centocor/New York University	Johnson & Johnson
Neulasta	Chemotherapy-induced neutropenia	3,300	Kirin-Amgen	Amgen
Aranesp	Anemia associated with chronic renal failure	3,100	Amgen	Amgen
Prevnar	Invasive pneumococcal disease	2,700	U. of Rochester/ Wyeth	Wyeth (now Pfizer)
Herceptin	Breast cancer	1,819	Genentech	Genentech
Lantus	Diabetes	992	Hoechst	Sanofi Aventis

Source: BioWorld (2009).

Cooperation may be achieved in several ways, of which the two most common are licensing and acquisitions. This empirical outcome is in line with Teece's theoretical predictions (Teece, 1986, 1992).

It is important to note, however, that more recently several more biotechnology companies were able to integrate downstream, as there are now fewer cooperative arrangements between biotechnology ventures and large pharmaceutical companies to commercialize new drugs. This can be seen in Table 3, in particular for the case of Amgen and Genentech. Rothaermel and Deeds (2004) document a new product development process based on an alliance system orchestrated by biotechnology companies, by which the biotech firms reach upstream to universities for basic knowledge, and then downstream to pharmaceutical companies to commercialize their innovations. While this integrated new product development process resonates with Teece's framework, Rothaermel and Deeds also demonstrate that the new biotechnology companies withdraw from this integrated product development process in a discriminate fashion, as the new venture accrues more resources to discover, develop, and commercialize promising projects through vertical integration. They empirically tested their model on a sample of 325 biotechnology firms that entered into 2,565 alliances over a 25-year period; and found broad support for the hypothesized product development system and the negative moderating effect of firm size. Thus, the effect of complementary assets on firm performance is likely to change over time.

This finding also resonates with the recent study of Rothaermel and Boeker (2008) who found, through studying over 32,000 dyads (i.e., pairs) between pharmaceutical and biotechnology companies over time, that a pharmaceutical company and a biotechnology firm are more likely to enter into an alliance based on complementarities when the biotechnology firm is younger. This finding echoes the theoretical conjecture above that the holder of complementary assets (e.g., a large pharmaceutical firm) is more likely to acquire the R&D skills necessary to create the innovation from the innovator (e.g., a biotech start-up) than the other way around. Evidence from litigation provides further support for this notion. For example, the first biotechnology drug to be commercialized was Humulin, a human insulin, which was discovered and developed by the biotechnology firm Genentech and commercialized by the pharmaceutical company Eli Lilly in 1982. Later, however, Genentech sued Lilly, accusing it of misusing materials provided by Genentech to commercialize recombinant human insulin. In other words, Genentech was concerned that Lilly had appropriated relevant R&D skills through their alliance to commercialize Humulin.

Recent empirical research on the software industry also provides some evidence about the idea discussed in the previous section, that firms can use a combination of a weak appropriability regime, and ownership of specialized complementary assets to foster innovation and standards. Specifically, Wen, Ceccagnoli, and Forman (2015) analyze the impact of strategic decisions taken by IBM around the mid-2000s, such as its announcement that it would not assert its patents against the open source software (OSS) community and its creation of a patent commons to support innovative activity in OSS and the diffusion of standards in operating system markets. A strategic rationale would be for IBM to profit from complementary markets, such as consulting services and Linux applications. Wen et al. present systematic empirical evidence suggesting that IBM's "open" IP strategy did stimulate new OSS product introductions by entrepreneurial firms, and that its impact is increasing in software market where litigation risks are higher. In particular, Wen et al. (2015) find that the risks that startups' infringe on patents held by other firms in the software industry tend to be higher under two conditions. The first is the cumulativeness of innovation, defined as the extent to which innovators build on prior developments and discoveries. A dense "thicket" of patents may limit further innovation, and opening up the IPR space can provide incentives to innovate. The second is the concentration of patent ownership within a software market, defined as the extent to which patents are distributed across different holders. Under concentrated patent ownership, incumbents have greater bargaining power and greater incentives to litigate their patents, thus increasing entry costs to potential innovators. In sum, by mitigating OSS startups' litigation risks, IBM open IP strategy facilitated entry of small firms based on new OSS products. To the extent that a strong appropriability regime creates a dense thicket of IPR hindering value creation, an innovator may choose to stimulate value creation by weakening the underlying IPR and capture rents through other appropriability strategies, including specialized complementary assets or lead time advantages.

Degree of Appropriability and Inter-Industry Differences: Empirical Evidence

In this section we examine evidence suggesting that the strength of different appropriability strategies varies both across industries and over time. In particular, systematic empirical evidence on the effectiveness of different appropriability strategies for the United States is available from the 1983 Yale survey, the 1994 Carnegie Mellon Survey (CMS), and the 2007 RIETI-Georgia Tech inventor survey. While the first two surveyed U.S. R&D labs (the CMS) and firms (the Yale survey) operating in the manufacturing sector, the RIETI-Georgia Tech surveyed inventors of "triadic" patents, for example patents filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO). Due to higher comparability, we first present the CMS/Yale comparison for selected manufacturing industries in Table 4 (Cohen, Nelson, & Walsh, 2000; Levin, Klevorick, Nelson, & Winter, 1987).

Table 4 suggests that the most effective mechanisms to protect product innovations according to the CMS survey across a wide number of industries is secrecy, closely followed by first mover advantages (Lieberman & Montgomery, 1988). The ownership of specialized complementary assets represents the third most effective mechanism, whereas patent protection is rated as the least effective relative to these other mechanisms.

Table 4. Comparing the 1983 Yale and 1994 CMU Appropriability Surveys: Selected High-Tech Industries.[a]

	% Firms within Industries Ranking Appropriability Strategy as First or Second Most Important																
	Number of observations		Patent protection			Secrecy			Being first to market			Comple mentary assets		
	Yale	CMU	Yale	CMU	% Change	Yale	CMU	% Change	Yale	CMU	% Change	Yale	CMU	% Change
Industrial chemicals	73	52	0.75	0.78	4%	0.59	0.98	66%	0.80	0.68	−15%	0.79	0.78	−1%
Drugs and medicines	17	47	0.94	0.80	−15%	0.53	0.91	72%	0.71	0.71	1%	0.71	0.51	−28%
General industrial machinery	32	18	0.47	0.78	66%	0.41	0.94	132%	0.78	0.89	14%	0.81	0.83	3%
Computers	21	28	0.29	0.64	125%	0.43	0.79	83%	0.86	0.89	4%	0.62	0.61	−2%
Communication equipment	17	22	0.41	0.62	50%	0.53	0.81	53%	0.88	1.00	13%	0.94	0.81	−14%
Semiconductors	10	17	0.50	0.63	25%	0.20	0.94	369%	0.90	0.94	4%	0.70	0.75	7%
Motor vehicles	24	27	0.63	0.76	22%	0.33	0.76	128%	0.71	0.92	30%	0.79	0.60	−24%
Aircraft and missiles	21	41	0.38	0.54	41%	0.48	0.95	99%	1.00	0.92	−8%	0.71	0.62	−14%
Search and navigation equipment	9	29	0.44	0.66	47%	0.67	0.97	45%	1.00	0.86	−14%	0.89	0.83	−7%
Measuring and controlling device	18	25	0.33	0.65	96%	0.28	0.87	213%	0.94	0.96	1%	0.78	0.74	−5%
Medical instruments	12	60	0.58	0.73	26%	0.50	0.83	67%	1.00	0.90	−10%	0.83	0.72	−14%
Total manufacturing	650	852	0.53	0.67	28%	0.47	0.89	91%	0.84	0.87	4%	0.80	0.73	−8%

[a]Based on own computation using original *respondent-level* Yale and CMU surveys data.

Several policy and management changes lead us to expect that the relative strength of different appropriability strategies changes over time. In particular, belief in the importance of patents and intellectual property protection in stimulating innovation is the main economic rationale underpinning the trend toward a strengthening of IP protection that has characterized the two decades between the mid-1980s and mid-2000s, particularly in the United States. In 1982, the Court of Appeals for the Federal Circuit was established to make patent protection more uniform. Indirectly, this also strengthened patent protection. Plaintiff success rates as well as damages in infringement have also risen. In the early 1980s we also witnessed an expansion of what can be patented, when the courts decided that life forms and software were both patentable. Patents have also become a growing preoccupation of management.

Given these changes that started to occur in the mid-1980s, the comparison between the earlier Yale 1983 survey and the 1994 Carnegie Mellon Survey, shown in Table 4, can be used to explore the effects of these changes in the effectiveness of different appropriability strategies for profiting from innovation.[2] The data highlight that patents are more recently perceived as significantly more important, with almost a 30% increase in the percentage of firms within industries ranking patents as the first or second most important mechanism of appropriation. Being first to market is also slightly more important, whereas ownership of complementary assets is slightly less important to protect the competitive advantage from an innovation. The sharper difference is related to the effectiveness of secrecy, with a change in the perceived effectiveness of over 90%.

Sharper differences across time characterize some industries, such as computers, machinery, and controlling devices. Such variations again suggest that the strength of appropriability has an important endogenous component: exogenous changes in the appropriability regime may have a different effect on firms' use of different strategies in different industries within the same country (Hall & Ziedonis, 2001). In particular, the increase in firms' propensity to patent, as a consequence of a stronger appropriability regime in industries such as electronics and semiconductors, has spawned patent portfolio races whose main objectives are both to discourage infringement suits and to strengthen incumbents' bargaining positions in cross-licensing negotiations.

Overall, considering that both patent protection and secrecy are knowledge−related proprietary strategies, the strength of appropriability seems to have increased over time in the United States. Teece's (1986) framework, summarized in Fig. 1, implies that we increasingly observe cases falling on the right-hand side of the tree represented in Fig. 1, where innovators capture a greater share of rents due to a strengthened appropriability regime. This is consistent with the widespread belief that innovation is increasingly the key source of competitiveness and economic growth.

Interestingly enough, changes in the appropriability regime that have taken place since the early 1980s, in particular a strengthening of software patents during the 1990s, likely have affected the evolution of the degree to which TiVo has profited from its DVR set-top-box. Indeed, TiVo started to enforce its patents in 2004 when it brought litigation against EchoStar for infringement of a patent with both hardware and software claims (U.S. Patent No. 6,233,389). Since then, they've brought suits and won settlements against such companies as AT&T, Verizon, Cisco, and Google. Despite never being able to establish a competitive advantage in the marketplace, they've been able to succeed against infringers and extract a greater fraction of rents through "stick" licensing.

The more recent RIETI-Georgia Tech survey provides results that are consistent with the earlier surveys (Nagaoka & Walsh, 2009). These data are shown in Table 5. As appropriation measures, first mover advantage in commercialization is perceived as the most important appropriability strategy. Interestingly, U.S. inventors rank patent enforcement significantly higher than possessing complementary capabilities. These data need to be used with caution, though, especially if compared to the previous surveys, due to the selected nature of the sample. Inventors of technologies that have been patented are likely to perceive patent enforcement, ex-post, as more effective.

The strengthening of patent protection discussed so far has led to an explosion of patenting and litigation during the last three decades and attracted financial investors, including so-called "patent trolls." These are non-practicing entities acquiring patents, often of questionable value, with the only objective of enforcing them against accused infringers in an attempt to collect "stick" licensing fees. Abuses of the patent system have recently led to an institutional shift suggesting that the "patent pendulum" is swinging back (Seymore, 2008). For example, since 2006 the U.S. Supreme Court has decided cases that limit the availability of injunctive relief for patent owners, make it easier to defeat a patent for obviousness, limit the ability to obtain business method patents, and make it much easier for the prevailing party in patent litigation to collect attorney's fees in "exceptional" cases. While it is too early to assess the effect of these latest changes on the strength of the appropriability regime faced by innovating companies, we conjecture that companies may have to adjust their appropriability strategy and increase use

Table 5. The Georgia Tech/RIETI 2007 Inventor Survey: Selected Technology Classes.[a]

	% Inventors within Technology Class of Triadic Patents (Granted in the United States) Ranking Appropriability Strategy as Highly Important[b]						
	NBER patent technology class[c]	Number of observations	Patents enforcement	Secrecy	First mover's advantage in commercialization	Complementary sales/ service capability	Complementary manufacturing capability
32	Surgery & Medical Instruments	123	79%	52%	81%	50%	43%
31	Drugs	101	65	43	95	24	32
33	Biotechnology	41	47	41	82	27	20
14	Organic compounds	61	44	63	47	33	53
54	Optics	43	65	29	73	20	7
53	Motors, engines & parts	56	64	29	64	52	29
43	Measuring & testing	62	58	39	72	31	34
46	Semiconductor devices	55	77	50	93	50	69
21	Communications	149	65	35	78	47	45
77	Computer software	93	51	29	63	48	24
22	Computer hardware	42	44	33	50	47	47
24	Information storage	42	38	43	94	27	33
	All technology classes	868	63%	41.5%	73%	44%	41.6%

[a]*Source*: RIETI (2009). Inventor Survey on Innovation. Retrieved from http://www.prism.gatech.edu/~jwalsh6/inventors/USJP_ind_public2009MayYN.pdf (retrieved June 22, 2016). While results are available for both the U.S. and Japan surveys, we only show results for the U.S. survey.

[b]The survey was conducted in 2007 and focused on a sample of "triadic" patents, that is, those for which a patent was granted by the US patent office and applied for at both the Japanese and European Patent offices, with 2000−2003 priority years. Survey asked whether mechanism was rated as important or very important (e.g., 4 or 5 on a Likert scale ranging from 1, not important, to 5, very important) for protecting the inventor's firm competitive advantage for the commercial product/process/service based on the invention protected by the patent.

[c]For details on the NBER patent classification, see http://www.nber.org/patents/

of alternative mechanisms such as secrecy, lead times, and "orchestration" of specialized complementary assets if the patent pendulum swings farther back. Firms may also have to change their corporate strategy.

Indeed, changes in the strength of the appropriability regime are expected to have a profound impact on corporate strategy decisions, in particular with respect to the choice of the optimal business model. Consistent with Teece's framework, Arora and Ceccagnoli (2006) provide systematic empirical evidence suggesting that firms lacking the specialized complementary assets required to commercialize innovation typically license more when patent protection is strong, in contrast to firms that have specialized complementary assets, which license less. Their work also suggests that in a world of strong IPRs, although technology buyers enjoy lower transactions costs and gain from trading technology, they also lose some bargaining power in technology alliances in favor of IP owners and therefore realize lower returns on the ownership of specialized complementary assets. This may in part explain the increasing downward pressure on the profitability of "big pharma," which seems to suffer in a world placing increasing rewards on the owners of upstream proprietary knowledge.[3] By the same token, a weakening of the appropriability regime may favor firms with specialized complementary assets.

As it should be clear now, IPR are critical for the profitability of technology startups, typically lacking specialized complementary assets. Counter to conventional wisdom, this also appears to be the case in dynamic high-tech non-manufacturing industries. For example, recent research suggests that IPR protection is critical in affecting entry of innovative startups in enterprise software markets. In particular, Huang, Ceccagnoli, Forman, and Wu (2013) show that appropriability strategies based on formal IPR, such as patents or copyrights, or the ownership of service and marketing capabilities, are critical in facilitating the entry of independent software vendors (ISV) into enterprise software markets that are complementary to a platform. Effective appropriability strategies, in this setting, are critical in ameliorating a fundamental problem in platform governance: a platform owner's inability to commit to not expropriating rents from providers of complementary products or services. Appropriability strategies are therefore critical to setting in motion a virtuous cycle of indirect network effects, since entry of innovative startups in complementary markets will enhance the platform value, increase its installed base, and stimulate the further entry of small, innovative firms with products that are compatible with the platform. In a complementary study, Ceccagnoli, Huang, Forman, and Wu (2012) find that joining a major platform owner's platform ecosystem is associated with an increase in sales of the software startups, and with a greater likelihood that these firms will issue an initial public offering.

Quantifying the Returns Provided by Patent Strategies

Assuming firms apply for patents if net benefits of doing so are positive, Arora, Ceccagnoli, and Cohen (2008) have used survey-based responses on a firm's propensity to patent (quantified as the percentage of innovations for which a firm applies for patent protection) to compute an unobservable concept, the *patent premium* – that is, the proportional increment to the value of an innovation realized by patenting. Results indicate that patents provide a positive expected premium only for a small fraction of innovations. In fact, on average, the relative magnitude of benefits and costs suggests that firms expect to lose about 50% of an innovation's value by patenting it in a broad set of manufacturing industries. Put differently, patenting the typical invention is not profitable in most industries because the opportunity costs of patenting (including the cost of information disclosure, the likelihood of inventing around, and the cost of enforcement) are substantial. The patent premium is around unity for the typical patent portfolio of the average firm in biotechnology and pharmaceuticals, meaning that a firm expects no difference, on average, between payoffs realized by patenting or not. In medical instruments, however, patenting the typical innovation is worthwhile. Only innovations for which there is a premium greater than unity are eventually patented. Indeed, the average expected premium for the innovations that firms choose to patent is about 1.5, suggesting that firms expect to earn, on average, a 50% premium over the no-patenting case. Such a premium, conditional on patenting, is about 1.6 in the health related industries and 1.4 in electronics and semiconductors (see Fig. 2).[4] Overall, these results suggest that even in those industries where patenting is not profitable *on average*, some inventions are profitable to patent and may actually provide large payoffs from doing so. This, however, does not mean that patenting is a sufficient condition to profit from innovation. Indeed, in most cases, patent strategies must be integrated with appropriate strategies to leverage or acquire complementary assets, exploit lead times, or maintain secrecy over other aspects of an innovation.

In a recent study, Ceccagnoli (2009) directly links the degree of appropriability achieved through different strategies and the way firms enforce their patents to firm performance. He finds that among the various appropriability

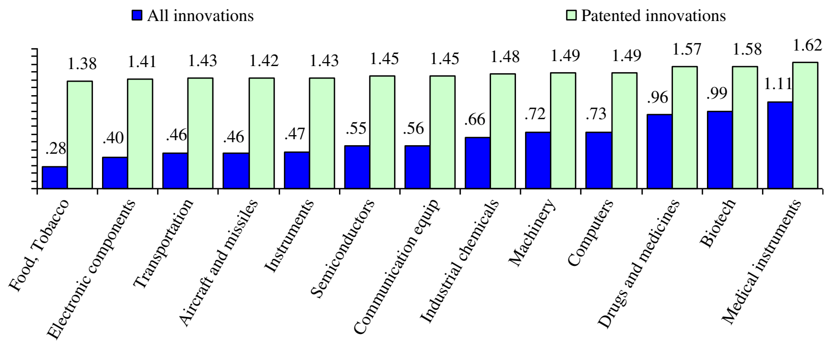

Fig. 2. The Patent Premium (Arora et al., 2008).

strategies considered in the previous section (see Table 4), the strength of a firm's patent protection strategy and the ownership of specialized complementary assets are associated with a substantial increase in the stock market valuation of a firm's R&D assets relative to tangible assets. He also finds that among the patent strategies that are increasingly and purposefully used by technology-intensive companies, *patent preemption* – defined as the patenting of substitute or complements of other innovations owned by the firm – tends to remarkably improve the rate of return to R&D investments, as valued by the stock market. Consistent with existing theories, his empirical findings also indicate that patent preemption tends to improve the profits due to a firm's R&D and firm performance, and this effect is higher for innovating incumbents with higher market power and those facing the threat of entry and it is lower when R&D competition is characterized by the discovery of drastic innovations.

THE TWO FACES OF APPROPRIABILITY: PROTECTION VERSUS INCENTIVES

The degree to which a firm captures the value created through the introduction of its innovations has a dual function. It increases an innovating firm's profits and market power, which has been the focus of much of the previous discussion, but it also affects the firm's inventive efforts. Previous empirical studies on the impact of appropriability have mostly focused on the first effect. Theoretical work, in particular economic analysis of the impact of patent protection, has instead focused on the incentive effect. The main rationale of patent protection is indeed to stimulate innovative investments, while at the same time promoting the diffusion of technological knowledge. By providing restrictions to the use of patented inventions, patent law provides the ability to recover the investment needed to introduce technological innovations, in exchange for disclosure of the technical details of the patented inventions to the public. The main social cost is the restriction in use, and thus the inefficiencies associated with monopoly protection.

The empirical works presented above, and in particular the results of Tables 4 and 5, have been interpreted as suggesting that the inducement provided by patents for innovation is small in most industries. However, these results do not imply that patents provide little incentives to invest in R&D. Indeed, the estimates of the patent premium suggest that patents could be effective for a small fraction of innovations and still provide substantial average returns. Moreover, incentive effects depend on the impact of appropriability on the marginal benefits of R&D investments. Indeed, there is still no clear empirical consensus on the idea that greater appropriability of profits due to innovation, conferred by patents or any other mechanism, actually stimulates investments in innovation. In particular, Hall and Harhoff (2012) provide a concise and accessible review of the literature on the theoretical and empirical work on patents.

To address this gap, recent economic studies have attempted to quantify the incentive effect of patents. In particular, Arora et al. (2008) provide evidence of a positive R&D incentive effect of the strength of patent protection, using firm-level data from the Carnegie Mellon Survey discussed above. They estimate an economic model in which firms' R&D decisions depend on expected returns, which are conditioned by the effectiveness of patent protection. The study further recognizes that if one firm benefits from stronger patent protection in a specific area, its competitors will also benefit from it. Their quantitative estimates suggest that a 10% increase in the strength of appropriability provided by patent protection would increase R&D investments by 7%, the firm's propensity to patent by 17%, and the number of patents applied for by each firm by 15%. Moreover, their results indicate that the incentive effect of patents varies substantially across industries, with the largest effect in pharmaceuticals, biotechnology, medical instruments, and computers. In semiconductors and communications equipment, the incentive effect of patent protection is much lower, although still positive and not negligible.

CONCLUSION

Strategies used to capture the value created by innovative investment are a fundamental source of a firm's competitive advantage. The degree to which firms profit from innovation is critically affected by the interplay of imitation-related factors, such as ownership and strength of IP and the number of capable innovators, and the ownership of specialized complementary assets required for successful product and process market introduction.

During the last three decades we have witnessed economic and legal changes, as well as evolving managerial practices related to the strength of available appropriation strategies. These changes have affected the propensity to use different appropriation strategies, firm performance, and the division of labor and profits from the value created by innovation, in a world that places increasing importance on innovation for firms' competitiveness, productivity, and economic growth.

Within this evolving competitive environment, the understanding of the relationship between appropriability and innovation investments is particularly important, not only for policy, but also for strategy and entrepreneurship. Appropriability conditions and the effective management of IP should indeed guide entrepreneurs and companies alike in their choices about allocating resources for the creation of value through technological innovations.

NOTES

1. See discussion on competitive advantage in this volume.
2. A sample of comparable firms was built using original *respondent-level* Yale and CMU survey data, that is, only using public firms operating in comparable industries. Each firm's responses on both product and process appropriability mechanisms were used to compute a dummy variable equal to one if any mechanism was rated as the first or second most effective in protecting the competitive advantage from its innovations. Table 4 shows the percentage of firms rating each mechanism as first or second most effective.
3. An increasing fraction of R&D expenses of large pharmaceutical companies includes the cost of developing drugs that are in-licensed from smaller biopharmaceutical firms, which in turn aggressively safeguard their proprietary knowledge and are able to extract a significant fraction of rents associated with their innovations.
4. Gambardella (2013) contains an excellent discussion of recent empirical research on the value of patent protection.

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