CHAPTER 1

APPROPRIATING THE RETURNS FROM INNOVATION

Marco Ceccagnoli and Frank T. Rothaermel

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.

1. INTRODUCTION

Although significant science and engineering competencies are needed to invent new processes and products, 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

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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, 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 innovation: the appropriability regime and the complementary assets (Teece, 1986; Abernathy & Utterback, 1978; Anderson & Tushman, 1990). 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 CAT scanner provides a well-known example in which the innovator, Electrical Musical Instruments (EMI), lost to the imitator, GE Medical Systems.[2] In the 1970s, EMI was a widely diversified British multinational corporation holding, for example, the rights to The Beatles records and competing in phonographic records, movies, and advanced electronics. Based on breakthrough research conducted in the 1960s by Godfrey Hounsfield, a senior research engineer at EMI (and 1976 Nobel Laureate in Medicine), EMI developed the CAT scanner, originally

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

Innovator	Innovation	Lost to Imitator
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

designed to take three-dimensional pictures of the brain, and later of the entire human body. This invention is hailed as the most significant technological breakthrough in radiology since William Conrad Röntgen (Nobel Laureate in Physics, 1901) discovered the use of X-rays for imaging in 1895. Moreover, the invention of the CAT scanner paved the way for follow-up innovations like nuclear magnetic resonance tomography.

In spring 1972, EMI launched the CAT scanner. Despite being aware that it lacked some of the requisite manufacturing and distribution assets, EMI decided to go it alone rather than to license its technology to a strong incumbent in medical devices like GE Medical Systems. Prior to market entry, the EMI management had little understanding of how effectively their patents would protect their innovation, and of the importance of complementary assets such as large-scale manufacturing and a distribution and marketing network. Still, EMI was able to create enormous excitement about its breakthrough innovation, which was first demonstrated at a medical conference.

Based on its technological lead, EMI became the market leader worldwide early on, with a strong position in the United States. Yet EMI was unable to sustain this lead because it could not satisfy the surge in demand, given its limited production capabilities, or solve the technological problems it encountered when setting up a production facility in the United States. By the mid-1970s, entrants into the CAT scanner business, like GE Medical Systems and others with strong technological and complementary assets, began to capture significant market share from EMI. It is important to recall that GE did not invent the CAT scanner, but GE soon became the market leader because it possessed the requisite complementary assets necessary to succeed in this new market – especially large-scale manufacturing and a distribution network combined with a strong technical maintenance force. On the other hand, the innovator, EMI, was unable to acquire or develop the needed complementary assets to sustain its initial lead. This deficiency eventually led EMI to exit the market. To add insult to injury, the poor-performing unit EMI Medical was acquired by GE Medical Systems.

The CAT scanner example clearly highlights the competitive race between innovators and imitators. The innovator (EMI) races to acquire complementary assets, and the imitator (GE Medical Systems) races to build the technological assets necessary to create the innovation, frequently through reverse engineering, and without infringing on the innovator's patents.

2. APPROPRIABILITY REGIME AND COMPLEMENTARY ASSETS: THE TEECE FRAMEWORK

EMI'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 EMI case, while the CAT scanner was a remarkable advance in medical technology, it only re-combined simple and well-known computing, X-ray, and imaging technologies in a new, albeit revolutionary, way. Once the idea of re-combining the different elements became widely known, it was difficult to protect because it was easy to replicate through reverse engineering. Moreover, patents were not effectively enforced by both companies and courts, partly due to fears of their anti-competitive effects and partly due to the view that patents were a cost- rather than profit-generating activity. As a result, the appropriability regime that EMI faced when commercializing the CAT 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 CAT scanner provides a compelling example: the innovator, EMI, lost to the follower, GE Medical Systems, because EMI lacked 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* exhibit unilateral dependence between the innovation and the complementary assets, and *cospecialized complementary assets* are characterized by a bilateral dependence. GE Medical System's stellar reputation for quality and service in hospital equipment is considered a specialized complementary asset, whereas specialized repair facilities for Mazda's rotary engine would be a cospecialized complementary asset. 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 its 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, which by 2002 had closed the lead held by Immunex's Enbrel. Immunex's innovative advantage dissipated due to a lack of the necessary complementary assets in manufacturing (Hill & Jones, 2007).

Moreover, a large-scale manufacturing capability allows the company 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 was precisely one of the problems EMI faced. While it built a manufacturing plant in the United States to supply the largest market for medical devices in the world, EMI was unable to create a manufacturing capability necessary to produce the quantity and quality that would satisfy demand in the United States.

This problem exacerbated another problem faced by EMI: its lack of knowledge of the U.S. market for medical equipment and the way hospitals purchase and maintain such high-ticket items. As a case in point, in the U.K., due to the nature of its socialized healthcare system, only a few regional hospitals are equipped with expensive medical devices like CAT scanners or MRI systems; thus, the market for such high-ticket items is relatively thin. This was the mental mindset of EMI's managers when entering the U.S. market. They did not realize that in the United States, competition among hospitals is decentralized, and hospitals compete with one another precisely by providing the latest advances in medical devices. Thus, most hospitals in the United States are equipped with a set of high-ticket items such as CAT scanners. Overall, the delivery of healthcare in the United States is much more capital-intensive than in Europe, where it tends to be more labor-intensive. This difference has significant implications for the demand for medical devices and explains the surge in U.S. demand for CAT scanners, which EMI had not anticipated.

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).

2.1. Interaction between Appropriability Regime and Complementary Assets

In this section, we discuss who – the innovator or imitator – is more likely to extract innovation rents. In Section 2.2, we discuss in more detail the strategic options on which an innovator can draw when attempting to commercialize its innovations.

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 (discussed in Chapter 8), 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 the complementary assets is summarized in Fig. 1.

The case of weak appropriability is analyzed by Teece 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 are easily acquired, with customers appropriating most of the value created by the innovations.

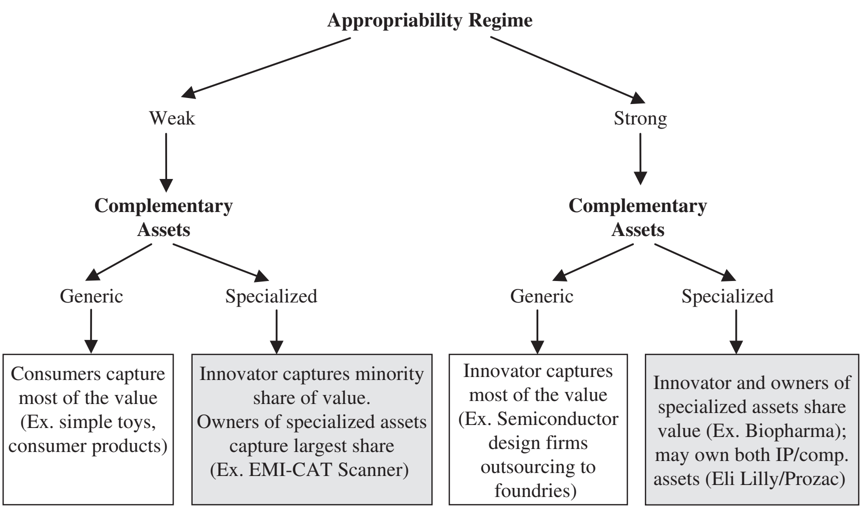

Fig. 1. The Teece Framework.

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. This is the case exemplified by the EMI/GE race.

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).

2.2. 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 towards 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 its 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 – i.e., 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 developing it jointly 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 a (temporary) cooperative equilibrium between the innovating biotechnology firms and the large incumbent pharmaceutical companies (Teece, 1992; Gans & Stern, 2000; Rothaermel, 2000). In this industry, thousands of alliances and joint ventures have been documented in which the returns to innovation are shared by biotechnology 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. While EMI held patents on its CAT scanner, the barriers to imitation were low, because GE Medical Systems (one of the first customers to purchase a CAT scanner from EMI) was able to quickly imitate the CAT scanner through reverse engineering and thus invent around EMI's thicket of patents. Thus, the barriers to imitation for the CAT scanner were low. Moreover, EMI faced a very capable and aggressive competitor in GE Medical Systems. Given this situation, EMI probably would have been better off either to enter into an alliance or joint venture or to license the commercialization of the CAT scanner directly to GE Medical Systems.

The decision between these two remaining strategic options depends on the appropriability regime, which appeared to be weak initially when the CAT scanner was first commercialized. This implies that EMI probably would have done best to license its innovation to GE Medical Systems. This is exactly the strategy Microsoft followed when faced with the question of how to commercialize its MS-DOS operation system. It 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 leveraged the standard 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 proposal, 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.

3. PROFITING FROM INNOVATION: EMPIRICAL EVIDENCE

While we discussed theoretical decision points on how to commercialize an innovation, what does the empirical literature tell us 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, 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-hand side of Fig. 1 (Rothaermel, 2001a; Rothaermel, 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 anti-anxiety 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 – i.e., 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

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, 2001.

Product	Indication	2001 Sales (millions)	Developer	Marketer
Procrit	Red blood cell enhancement	3,430	Amgen	Johnson & Johnson
Epogen	Red blood cell enhancement	2,109	Amgen	Amgen
Intron A	Hepatitis C, certain cancers	1,447	Biogen	Schering-Plough
Neupogen	Restoration of white blood cells	1,346	Amgen	Amgen
Humulin	Diabetes	1,061	Genentech	Lilly
Avonex	Multiple sclerosis	972	Biogen	Biogen
Rituxan	B-cell non-Hodgkin's lymphoma	819	IDEC	Genentech, IDEC
Enbrel	Rheumatoid arthritis	762	Immunex	AHP, Immunex
Remicade	Rheumatoid arthritis, Chron's disease	721	MedImmune	Johnson & Johnson
Cerezyme	Enzyme replacement therapy	570	Genzyme	Genzyme

Source: Standard and Poor's Biotechnology Industry Report, May 2002.

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 2001.

What is interesting to note is that none of the top-ten selling drugs was developed by the incumbent pharmaceutical companies. Thus, all new biotechnology drugs were discovered and developed by new biotechnology firms leveraging their R&D competencies in the new biotechnology paradigm. About half of these drugs were commercialized by incumbent pharmaceutical companies. 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. Rothaermel and Deeds (2004) document a new product development process based on an alliance system orchestrated by biotechnology companies, by which the biotechnology 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; they 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, Lilly was concerned that Genentech had appropriated relevant R&D skills through their alliance to commercialize Humulin.

Differences in the strength of complementary assets have also been documented across different industries. Both changes in appropriability over time and across industries are analyzed in Section 3.1.

3.1. Degree of Appropriability and Inter-Industry Differences: Empirical Evidence

Systematic empirical evidence on the effectiveness of different appropriability strategies for the U.S. manufacturing sector is available from the 1983

Yale University survey and the 1994 Carnegie Mellon University (CMU) survey, summarized for selected industries in Table 4 (Levin, Klevorick, Nelson, & Winter, 1987; Cohen, Nelson, & Walsh, 2000).

Focusing on the more recent CMU survey first, Table 4 suggests that the most effective mechanisms to protect product innovations across a wide number of industries is secrecy, closely followed by being first to market, which captures the effectiveness of 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.

Several policy and management changes lead us to expect that the relative strength of different appropriability strategies has changed since the early 1980s, about the time during which the earlier Yale survey was conducted. In particular, belief in the importance of patents and intellectual property (IP) protection in stimulating innovation is the main economic rationale underpinning the trend towards a strengthening of IP protection that has characterized the last two decades, 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. Patent coverage has been extended recently to business methods as well. Patents have also become a growing preoccupation of management.

The comparison between the earlier 1983 Yale survey and the 1994 CMU survey, shown in Table 4, confirms that substantial changes in appropriability conditions have taken place in the United States over time and across industries, as perceived by survey respondents.[3] 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 reflect the fact that the strength of appropriability has an important endogenous component: exogenous changes in the appropriability regime may have a

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			Complementary 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.

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 trade secrecy are knowledge-related proprietary strategies, the strength of the appropriability regime seems to have increased over time in the United States. Teece's (1986) framework 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 innovation 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 likely have affected the evolution of the degree to which EMI has profited from its CAT scanner itself. Indeed, EMI started to enforce its patents between the end of the 1970s and the beginning of the 1980s. Legal documents and company interviews suggest that the company, despite suffering imitation and bankruptcy of its medical device operation, was able to succeed against infringers and extract a substantial fraction of rents through 'stick' licensing.[4] In a recent interview, IP managers familiar with these matters estimated that EMI realized over $100 million in 'stick' licensing revenues related to the CAT scanner.[5]

The strengthening of patent protection is expected to have a profound impact on the way a firm profits from innovation as well. 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 IPR, 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.[6]

3.2. Quantifying the Returns Provided by Patent Strategies

Assuming firms apply for patents if net benefits of doing so are positive, Arora, Ceccagnoli, and Cohen (2007) have used survey-based responses on a firm's propensity to patent (% of innovations for which a firm applies for patent protection) to compute an unobservable concept, the *patent premium* – i.e., 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, instead, 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). Overall, these results suggest that even in

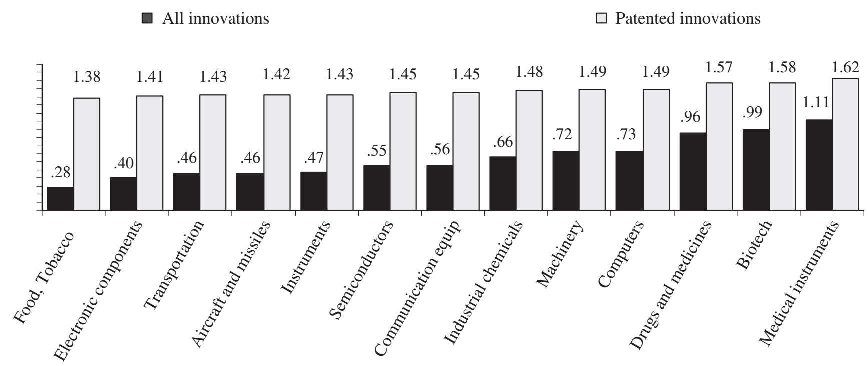

Fig. 2. The Patent Premium (Arora et al., 2007).

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 (2008) 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 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.

4. 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 its 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 work presented above, and in particular the results of Table 4, 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. To address this point, recent economic studies have attempted to quantify the incentive effect of patents.

In particular, Arora et al. (2003) provided robust evidence of a positive incentive effect of the strength of patent protection, using firm-level data from the CMU survey. 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.

5. 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 two 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 in Chapter 7.
2. See EMI and CT Scanner (A) and (B), Harvard Business Cases 9-383-194 and 383-195.
3. A sample of comparable firms was built using original *respondent-level* Yale and CMU surveys data, i.e., 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 equal to one if any mechanism was rated as the first or second most effective in protecting the competitive advantage from its innovations. Table 2 shows the percentage of firms rating each mechanism as first or second most effective.
4. In a 1983 legal document we find clear and official evidence of the 'stick' licensing activities: 'The CT manufacturing industry is a decade old. EMI, a corporation organized under the laws of England, started production of the CT scanners in the United States, in Chicago, Illinois, and made delivery of its first orders in 1973. Several years ago, it discontinued making the machines and closed its Chicago plant. It licenses others to manufacture under these patents; in all, there are approximately ten licensees in the United States, including General Electric Company, Johnson & Johnson, and Pfizer, Inc. The latter three, in contested litigation, challenged the validity of plaintiff's patents; however, those separate litigations, which extended over a two-year period, were settled before trial in return for licenses issued by EMI to the contestants.' (*EMI Limited, Plaintiff, v. Picker International, Inc., Defendant*; No. 83,Civ. 0759, U.S. District Court for the Southern District of New York; 565 F. Supp. 905, 1983).

5. Interview by Marco Ceccagnoli with Dr Stephen Potter, Commercial Director of QED (patent licensing division of EMI, subject of a management buy-out in 1996: http://www.qed-ip.com), June 1st, 2003, INSEAD (Fontainebleau, France).

6. 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.

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