Open Innovation

The New Imperative for Creating and Profiting from Technology

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The Open Innovation Paradigm

IN THIS CHAPTER, we will explore an emerging paradigm that is replacing the earlier paradigm of Closed Innovation. This new approach is based on a different knowledge landscape, with a different logic about the sources and uses of ideas. Open Innovation means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well. This approach places external ideas and external paths to market on the same level of importance as that reserved for internal ideas and paths to market during the Closed Innovation era.

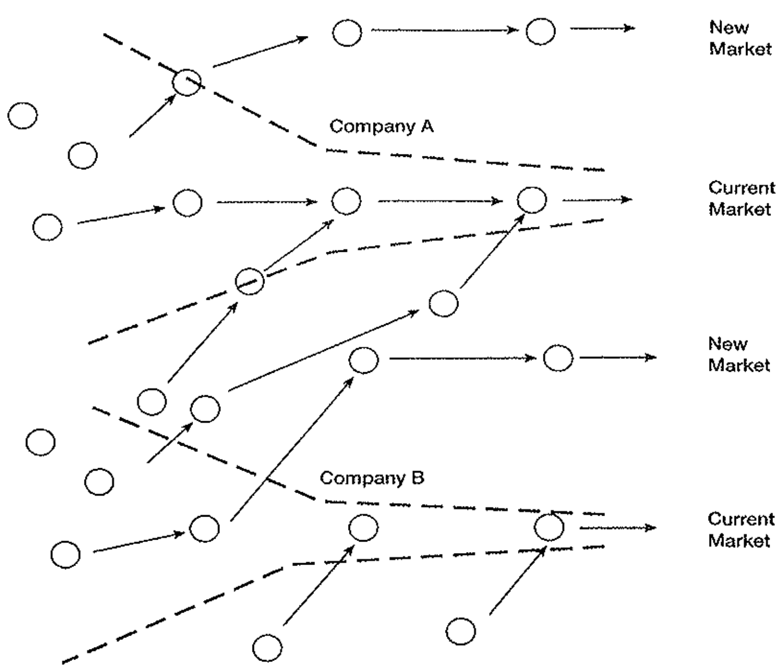
Figure 3-1 depicts the knowledge landscape that results from the flow of internal and external ideas into and out of firms A and B. Ideas abound in this environment, not only within each firm, but also outside the firms. These ideas are available to be used, and often the people who created them are similarly available for hire. The availability and quality of these external ideas change the logic that led to the formation of the centralized R&D silos of the Closed Innovation paradigm.

How to Access Useful Knowledge: The Thought Experiment One Hundred Years Later

Let's return to the thought experiment of chapter 2. What if you had become a leading company in your industry in 2000, rather than in 1900? How would you go about creating a mechanism to generate useful knowledge, to continue to advance the technologies that support your growing business? Would you choose to create an internal, central R&D organization that was responsible for investigating all the important areas of science behind the technology you plan to use?

FIGURE 3-1

The Knowledge Landscape in the Open Innovation Paradigm



The knowledge landscape in which you operate makes a big difference in how you would answer that question. Today, there is an abundance of knowledge in virtually every field around you. The proliferation of public scientific databases and online journals and articles, combined with low-cost Internet access and high transmission rates, can give you access to a wealth of knowledge that was far more expensive and time-consuming to reach as recently as the early 1990s.

The universities are full of professors with deep expertise. Better yet, these professors are surrounded by graduate students, who apprentice themselves to these professors. While the science that they do is excellent, many professors and their graduate students are clearly eager to apply that science to business problems. The norms of science and engineering have changed as well: There aren't many Henry Rowlands in university science departments anymore.

As government funding for basic scientific research declines in real terms in most scientific fields, faculty have even learned to seek out industry support for their research. Their search has helped them become more astute about the needs and problems of industry. Their future research agendas are coming to reflect important problems being confronted in industry.[1]

This abundance of knowledge is not limited to just the top handful of universities. Literally dozens of universities boast world-class research capabilities in at least a few areas (though only the top universities can maintain scientific excellence across a broad range of areas). Moreover, the demonstrable success of U.S. higher education has led to the imitation of that model in many other areas of the world. Whether it is the top technology institutes in India, the Hong Kong University of Science and Technology, the National University of Singapore, or the Technion in Israel, the quality of scientific knowledge has spread well beyond the shores of the United States to reach much of the developed world. In the world of the Internet, leading scholars from around the world contribute new papers to online archives, creating a global community of scholars.

The End of the Knowledge Monopolies

The rise of excellence in university scientific research and the increasingly diffuse distribution of that research means that the knowledge monopolies built by the centralized R&D organizations of the twentieth century have ended. Knowledge is far more widely distributed today, when compared to, say, the 1970s. And this far greater diffusion of knowledge changes the viability and desirability of a Closed Innovation approach to accessing and taking new ideas to market.

Another example of the greater distribution of knowledge in the knowledge landscape is the change in the distribution of patent awards. Patents are one outcome of a knowledge generation process, and thanks to the U.S. Patent and Trademark Office (USPTO), there are good data available on who receives U.S. patents. Table 3-1 shows which firms were the top twenty patent recipients of U.S. patents during the 1990s. Of the 153,492 patents issued by the USPTO in 1999, these top twenty companies received 17,842 patents in that year, only 11.6 percent of all awarded patents. On a related issue, the number of patents held by individuals and small firms has risen from about 5 percent in 1970 to more than 20 percent in 1992.[2]

TABLE 3-1

List of Top Twenty Organizations Holding U.S. Patents (ranked by cumulative patents held)

Company	Number of Patents Pre-1986	1986	1990	1995	1999	Total
1. International Business Machines	9,078	598	609	1,383	2,756	26,342
2. General Electric Company	14,763	714	787	758	699	25,868
3. Hitachi, Ltd.	5,957	731	908	910	1,008	19,055
4. Canon Kabushiki Kaisha	3,067	523	870	1,087	1,795	18,784
5. Toshiba Corporation	3,598	694	893	969	1,200	16,881
6. Eastman Kodak Company	5,780	229	721	772	992	16,032
7. AT&T Corp.	9,213	437	430	638	278	14,837
8. U.S. Philips Corporation	6,519	503	637	504	735	14,575
9. E. I. du Pont de Nemours and Co.	7,560	329	481	441	338	13,735
10. Motorola, Inc.	3,244	334	394	1,012	1,192	13,682
11. Mitsubishi Denki Kabushiki Kaisha	1,619	360	868	973	1,054	13,408
12. Siemens Aktiengesellschaft	6,388	410	508	419	722	13,324

Company	Number of Patents Pre-1986	1986	1990	1995	1999	Total
13. NEC Corporation	1,601	234	437	1,005	1,842	12,464
14. Bayer Aktiengesellschaft	6,541	389	499	327	341	12,189
15. Westinghouse Electric Corp.	7,896	398	436	170	11	11,970
16. Matsushita Electric Industrial Co., Ltd.	3,193	224	343	854	1,052	11,782
17. U.S. Navy	7,820	216	265	330	348	11,691
18. General Motors Corporation	6,781	294	379	282	275	11,660
19. Xerox Corporation	5,106	219	252	551	665	11,638
20. Fuji Photo Film Co., Ltd.	3,092	448	768	504	539	11,401
Total patents awarded, top 20 firms					17,842	
Total patents awarded, all firms					153,492	

Source: U.S. Patent and Trademark Office, "Technology Assessment and Forecast Report, August 1999," in *All Technologies Report January 1, 1963 to June 1, 1999* (Washington, DC: USPTO, 1999), B1–B2.

Of the 153,492 patents granted in the United States in 1999 (against 270,000 applications), foreign companies and individuals held 45 percent. Japanese individuals and firms held 20 percent of all 1999 U.S. patents issued, making them the largest single foreign owner, and Japanese firms were in eight of the twelve top spots for new U.S. patents granted to companies in 1998, receiving 10,438 that year. Worldwide, the Japanese Patent Office had the highest ratio of domestic to foreign applications, 90 percent, while both the United States and Japan had high ratios when compared with European systems (Germany had 45 percent and Britain 29 percent).

A second indicator of increased knowledge diffusion is how many U.S. patents non-U.S. companies now hold. As table 3-1 shows, 45 percent of these patents were held by companies headquartered outside the United States. Some of these foreign companies are now among the top twenty recipients of U.S. patents. This is a second indication of knowledge diffusion, a diffusion beyond the borders of the United States.

A third indicator of this diffusion is reflected in U.S. government statistics of R&D by size of enterprise within the United States. From 1981 through 1999, the share of industrial R&D has increased greatly for companies with less than one thousand employees (table 3-2). Although large-company R&D remains an important source of R&D spending, its share of overall industrial R&D spending has fallen to 41 percent. As of 1999, the majority of R&D spending in the United States is now done by companies with less than twenty-five thousand employees—a marked change since 1981, when the largest companies did more than 70 percent of industrial R&D spending. And most of this shift occurred in the last ten years depicted on the table, between 1989 and 1999. There seem to be fewer economies of scale in R&D these days.[3]

A fourth indicator of knowledge diffusion is the rise in college graduates and post-college graduates in the United States. This rise reflects the social investment in human capital, which creates the raw material to discover and develop ideas. The abundance of well-educated workers

TABLE 3-2

Percentage of U.S. Industrial R&D by Size of Enterprise

Company Size	1981	1989	1999
< 1,000 employees	4.4	9.2	22.5
1,000 – 4,999	6.1	7.6	13.6
5,000 – 9,999	5.8	5.5	9.0
10,000 – 24,999	13.1	10.0	13.6
25,000 +	70.7	67.7	41.3

Sources: National Science Foundation, Science Resource Studies, "Survey of Industrial Research Development, 1991" (Washington: National Science Foundation) and National Science Foundation, Science Resource Studies, "Research and Development in Industry: 1999," <http:www.nsf.gov/sbe/srs/nsf02312/pdf/secta.pdf> (accessed 9 October 2002).

is a great success of U.S. public policy after World War II, though one reads little about this triumph.

There is an international dimension to this diffusion of human capital as well. At Stanford University and the Massachusetts Institute of Technology, for example, more than half of the postdoctoral scientists and engineers come from outside the United States.[4]

These diffusion forces seem likely to persist. Within the United States, the pattern of high labor mobility is unlikely to return to the earlier pattern of long-term or "lifetime" employment.[5] Pension systems in the United States are increasingly portable, meaning that they travel with the worker, rather than with the job, further promoting mobility. Although VC has retreated from the heady days of the dot-com bubble, it remains a reality that will not go away, thus enabling start-up companies to exploit the diffusion of knowledge.[6]

Knowing all this, what mechanisms would you create to access this abundance of knowledge? Would these mechanisms bear any resemblance to the central R&D lab of chapter 2?

The answer is no. The central R&D lab is based on a logic of deep vertical integration, through which a single company conducts every aspect of a business internally. But this do-it-all-yourself approach only makes sense in a world of scarce external knowledge. If instead, a leading firm wishes to advance its technology in a world of abundant knowledge and competence, it will find a great deal of value on the outside. Expertise is readily available for hire and need not require extensive internal training or the inducement of lifelong employment. One can also choose ideas from a diverse menu of discoveries at a variety of universities. A wealth of capable suppliers applying their own impressive expertise across numerous businesses is another resource ready to be tapped to harness and develop these ideas. Venture capital start-ups are developing useful technology, which was sitting on the shelf of another company, or is coming out of a university.

The logic underlying the innovation process is now completely reversed. Even the expression *not invented here* (NIH), described in chapter 2 as outside technology of which a company must be wary, today has an entirely different meaning. Today NIH means that companies need not reinvent the wheel, since they can rely on external sources to do the job effectively. Indeed, internal sources may deliver wheels at lower volume and higher cost, relative to what a world-class outside vendor, serving a worldwide market, can provide. In an abundant knowledge landscape, one can now do a great deal by focusing in a particular area, without having to do everything.

If you were trying to develop mechanisms to access useful knowledge today, you would start by surveying the surrounding knowledge landscape. You would like to use as much of the surrounding knowledge as possible and fund the creation of as little new knowledge as necessary to get the knowledge you need on a timely basis. In addition to the specialized knowledge your researchers developed to enact a strategy of deep vertical integration, your researchers will also need to scan and understand a wide range of science and technology. Then they must use this understanding to envision how to integrate promising discoveries into new systems and architectures.

What would you do to access external knowledge? At the simplest level, you might employ university professors for a summer to work alongside your own people. An even cheaper idea would be to hire some graduate students of a professor to work with you. If you wanted to carry this further, you could even choose to fund external research at a nearby university. Although you could not expect to own the results of this research, you could expect to gain early access to any promising results, and perhaps get a head start on applying those results to your industry.

If you funded a number of projects, you could expect to get proposals from researchers looking for funds. This is a low-cost way to scan the opportunity horizon in the scientific and engineering fields in which you are interested. Before you spend any money, you get to review a variety of research proposals from scholars who know a great deal about the state of the art in that area.

You might scout the activities of young start-up companies working in areas of interest to you. You could learn about their efforts in a number of ways, ranging from occasional business development discussions, to strategic alliances, to giving money to interested venture capitalists to invest in areas of value for you, to investing directly yourself in promising start-up companies.

As we will explore in chapter 6, some companies such as Intel have actually conducted our thought experiment. Intel is a rather young company, founded in 1968. Despite its impressive size, it only began a truly formal advanced R&D strategy back in 1989. The company relied almost entirely on external research up to then. Today, although Intel has created an internal research capability to some degree, it plans its research efforts by assessing what is available from the outside before charting its own course inside. Intel has a very well thought-out program of funding university research projects, spending more than $100 million a year. The company also follows closely the activities of start-ups in the computer and communications industries, through a variety of means that range from informal alliances to corporate VC investment.

In the life sciences, another scientifically intensive industry, several even younger companies such as Millennium and Genzyme are thinking hard about their own innovation strategies. Yet, as chapter 8 will show, their solutions for managing innovation also depart significantly from the traditional paradigm of R&D. Even large, successful firms such as IBM and Merck, which prospered in the Closed Innovation regime, are broadening their approach to research. They are moving beyond their internal programs, toward building access mechanisms to tap into the wealth of external knowledge around them.

Toward a New Logic of Innovation

Some longtime observers note these trends and throw up their hands in despair. The research game is over, they bemoan. Where will the seed corn that fuels the next generation of discovery come from? is another concern often voiced. Even more measured published work has concluded that industrial research is "at the end of an era."[7]

The traditional paradigm that companies used to manage industrial R&D is indeed over in most industries. But that does not mean that internal R&D itself has become obsolete. What we need is a new logic of innovation to replace the logic of the earlier period. Companies must structure themselves to leverage this distributed landscape of knowledge, instead of ignoring it in the pursuit of their own internal research agendas. Companies increasingly cannot expect to warehouse their technologies, waiting until their own businesses make use of them.

The new logic will exploit this diffusion of knowledge, rather than ignore it. The new logic turns the old assumptions on their head. Instead of making money by hoarding technology for your own use, you make money by leveraging multiple paths to market for your technology. Instead of restricting the research function exclusively to inventing new knowledge, good research practice also includes accessing and integrating external knowledge. Instead of managing intellectual property (IP) as a way to exclude anyone else from using your technology, you manage IP to advance your own business model and to profit from your rivals' use. Your own R&D strategy should benefit from external start-up companies' abilities to initiate multiple organizational experiments to commercialize technologies. You might even occasionally help fund a young start-up to explore an area of potential future interest.

This is not to say that firms should discontinue all internal research activity (see box 3-1). Nevertheless, whatever research is done internally should take into account the wealth of activity outside the firm. Nor does the new logic maintain that all outputs will henceforth fit with the company's current business. Some research outputs will not be well utilized by the firm's own businesses. However, these underutilized outputs will not last long on the shelf and should be managed accordingly. The projects that sat on the shelf between the research groups and the development groups were part of "the cost of doing business" in the old paradigm. They become revenue opportunities and potential new business platforms in the new paradigm.

The factors that promote knowledge diffusion create new opportunities. Knowledge diffusion rewards focused execution: You need not invent the most new knowledge or the best new knowledge to win. Instead, you win by making the best use of internal and external knowledge in a timely way, creatively combining that knowledge in new and different ways to create new products or services.

The New Role of Research: Beyond Knowledge Generation to Connection

Open Innovation thinking changes the role of the research function. It expands the role of internal researchers to include not just knowledge generation, but also knowledge brokering. Previously, researchers simply added to the knowledge sitting in the silos. Today, they are also charged with moving knowledge into and out of the silos. In this new role, knowledge located from outside may be just as useful as knowledge created from within—and it should be similarly rewarded.

The additional role of identifying and accessing external knowledge, in addition to generating internal knowledge, changes the career paths of researchers inside R&D firms. While deep understanding remains valuable, its utility is multiplied when linked to and built on the investigations and achievements of others. With this Open Innovation approach to knowledge, research managers must evaluate researchers' performance in different ways. Managers may apply different paths of

Box 3-1 **The New Rationale for Internal R&D**

In a bountiful knowledge landscape, a company organizes its internal R&D for the following reasons:

- To identify, understand, select from, and connect to the wealth of available external knowledge
- To fill in the missing pieces of knowledge not being externally developed
- To integrate internal and external knowledge to form more complex combinations of knowledge, to create new systems and architectures
- To generate additional revenues and profits from selling research outputs to other firms for use in their own systems

The company will also need technologies that its internal research organization will not create. Research takes a long time to deliver useful outcomes, and company strategies change at a far faster rate than the rhythm of basic research. In the new paradigm, the company's businesses cannot (and should not) wait for the internal technologies to arrive; instead, they should access what they need, as soon as they need it—either from inside the company's own research labs or from the knowledge created in someone else's lab.

promotion and may give their researchers rotational assignments in areas that interact with external participants outside the company, such as business development.

One example of this new role comes from Merck, perhaps the leading pharmaceutical firm in the world in terms of doing its own research. Merck is well known for its commitment to significant internal scientific research and is proud of the research discoveries that its scientists have made in the twentieth century. But its 2000 annual report noted that "Merck accounts for about 1 percent of the biomedical research in the world. To tap into the remaining 99 percent, we must actively reach out to universities, research institutions and companies worldwide to bring the best of technology and potential products into Merck. The cascade of knowledge flowing from biotechnology and the unraveling of the human genome—to name only two recent developments—is far too complex for any one company to handle alone."[8]

Toward that end, Merck has now charged its internal scientists with a new task: to create a virtual lab in their research area. This means that Merck scientists don't just create excellent science in their own lab; rather, they identify and build connections to excellent science in other labs, wherever these labs may be. In the words of Merck's head of R&D, "Every senior scientist here running a project should think of herself or himself as being in charge of all the research in that field. Not just the 30 people working in our lab but the 3,000 people, say, in the world working in that field."[9]

This is a case where the messenger is as important as the message. Few would dispute that Merck is among the most scientifically capable pharmaceutical firms in the world. When a firm with Merck's reputation for the excellence of its own science determines that it needs to connect deeply with the external knowledge base to be successful, other firms would do well to follow Merck's lead.

A New Perspective Toward Venture Capital

Venture capital is a reality that will not go away. Although VC returns were terrible in 2001 and 2002 and the amount of VC funding has dropped by more than 70 percent from its peak in 2000, the amount of money available for investment remains at levels that were considered historic highs as recently as 1998.[10] The recent drop has wrung out some of the excesses in the VC industry and weeded out many of the marginal participants. But the leading firms have billions of dollars of capital under management and are making new investments in a number of promising areas.

Open Innovation companies accept that VC, and the myriad start-up firms it funds, will be an enduring part of the landscape for innovation. Companies caught in the Closed Innovation paradigm view the venture capitalists as pirates and parasites—people to be punished if possible and avoided if not. But Open Innovation companies have gotten beyond the negative consequences of venture capital. They have come to understand that there are some markedly positive benefits from having a vibrant VC community around them.

The same VC groups that threaten to extract key personnel and technology from within also constitute a seedbed of new organizations experimenting with new combinations of technologies. The groups often apply new technological combinations to nascent markets that are being neglected by the large companies. These start-ups function as a series of small laboratories that can guide the technological strategies and the market directions of large firms. Open Innovation firms regard companies financed by VCs as pilot fish for potential market opportunities, because these start-up firms are selling real products to real customers, who pay with real money. These pilot fish provide the most valid, most useful market research on future technologies and future market opportunities that money can buy.

These novel combinations provide learning opportunities for established companies to monitor, and potentially leverage, if and when they prove valuable. As evidence of the viability of these "lessons" emerges, Open Innovation firms may actually change their own technology strategies as a result. They learn faster and adapt their own strategies more rapidly, as a result of coexisting with an environment filled with venture capitalists and their start-up firms. Dismissing these groups as pirates and parasites forfeits important learning opportunities from observing the portfolio companies that they fund.

Some Open Innovation companies carry this logic even further. They may choose to foster the creation of useful start-up firms, investing in some of these experiments early on or partnering and allying with them later.[11] Occasionally, they may even acquire a few of the most promising start-ups. Open Innovation companies regard the VC community, and the start-ups the community funds, as mutualistic participants in a complex ecosystem of firms that create, recombine, compete, imitate, and interact with each other.[12]

Other Open Innovation firms actually utilize VC internally to catalyze their own innovation process. Chapter 7 shows how Lucent invests corporate VC to create new technology companies out of its underutilized technology within Bell Labs. The creation of these spin-offs affects Lucent's internal R&D in at least three important ways:

- It provides an outside path to market for technologies that might otherwise sit on the shelf within the labs. This brings in additional money to Lucent, creates additional options for its research staff, and frees up resources to hire new researchers.
- It forces technology to move faster out of the lab. Whenever the NVG identifies a candidate technology for spin-off, this starts a clock within the company's businesses. If the company doesn't commit to use that technology itself, then the NVG gets the opportunity

to spin it off into a new venture. This creates a forcing function to pull technologies out of the lab at a faster rate.

- Lucent's NVG ventures provide an experimental setting for the observation of Bell Labs' technologies in different uses in different markets. As a result, Lucent acquires valuable feedback not available if the technology had stayed bottled up in the lab. By getting the technology out to the market sooner, Lucent learns more quickly about customer needs, trends, and new opportunities.

Customers also have important information that can be vital to open innovation. The most advanced, most demanding customers often push your products and services to the extreme. In doing so, they themselves attempt to create new combinations with your offerings as part of the building blocks. In a real sense, they are innovators themselves, what Eric von Hippel calls lead users.[13] These experiments may again yield new knowledge. People may use your technology in ways you never expected. In the process, customers' experiments often yield new features or requirements for what you build yourself. If you respond to these required changes, then a new round of learning can begin.

This process of innovation and discovery seeks out these iterative loops of learning. Before, companies chose to wait until the technology was "ready" to ship to customers. The mind-set was "We know what they want, and they'll wait until we say it's ready." Open Innovation companies invite the customer into the innovation process as a partner and coproducer. Here, the mind-set shifts to "Here are some of our thoughts, and here's a product that features them. What can you usefully do with it? What can we do to help you do something even more useful?"

Open Innovation and Managing Intellectual Property (IP)

Many companies relegate licensing decisions and patent protection to their legal department. To the extent that IP is part of a company's technology strategy, it is usually managed so as to preserve the design freedom of the company's internal staff. Open Innovation companies regard IP as an integral part of technology strategy and insist on managing it at a strategic level within the company. Not only are these companies interested in selling IP; they are motivated and informed buyers of IP as well.

These firms accept that rarely can a company exclusively control an important technology for an extended period. The forces that diffuse

knowledge are so many and so strong, that the wiser course is to plan your technology strategy under the assumption that it will be rapidly diffused and imitated.

In a world of powerful forces that rapidly disseminates useful knowledge, the mind-set toward IP changes greatly. One implication of Open Innovation is that companies must increase the "metabolic rate" at which they access, digest, and utilize knowledge. Companies cannot treat their knowledge as static; they must treat it as fundamentally dynamic. A company cannot inventory technology advances on the shelf, for the day when they may prove valuable. Open Innovation companies use licensing extensively to create and extend markets for their technology. And the faster the technology gets out of the lab, the sooner the researchers will learn new ways to apply, leverage, and integrate that technology into new offerings.

But doesn't this run the risk of cannibalizing your own business? This fear is based on a false premise: If you don't make your products obsolete, no one else will either. While this premise may be true on occasion, it will more often be false in a world of widely distributed knowledge and competence. Competitors often find ways of inventing around a firm's IP, which allows them to enter the market very quickly, even when the firm seeks to exclude rivals from using its ideas.

The costs for moving too late are much greater than they are for moving too soon. If you err on the side of premature cannibalization, you lose some potential profit you might have been able to eke out otherwise. If you err on the side of delay, the costs are deeper and longer lasting. You lose market share among your customers and must now confront stronger competitors, who now receive additional resources from your former customers.

There is also a subtle, internal cost. Think of your researchers who worked hard to bring the technology through many difficult hurdles and got it ready to go to market. They then watch as someone on the business side squanders their efforts by holding it off the market so that current sales and margins will be maximized. How motivated will these researchers be for the next big push? Will they be willing to provide the ammunition for recapturing the terrain lost to companies that didn't delay the deployment of their new technology? If you were one of these researchers, wouldn't you be tempted to move to a company that would make active use of your ideas as soon as you had them available? Most researchers are thrilled to see their ideas in action and to learn from the use that others make of them.

Internal Competition: Increasing the Metabolism of Knowledge

As described in chapter 2, there was a mismatch between the incentives of a laboratory, operating as a cost center, and the incentives of a development group, operating as a profit center. Open Innovation companies try to overcome this mismatch by providing additional channels to market for the technology and enabling business units to source knowledge from places beyond the internal laboratory.

Subjecting the internal path to market (i.e., the business unit expecting to receive the technology) to some competition from other paths to market is an excellent way to increase one's metabolism of new knowledge. Just because your research team comes up with a better mousetrap does not mean that your sales team is the best way to sell that mousetrap. Your sales team may be distracted by selling earlier successful innovations you have made, while some other organization may be hungry to exploit your discovery in some new and interesting way.

Most companies refuse to countenance licensing to an outside company or refuse to take equity in a new start-up to pursue the technology, because of the risk of internal competition that would result. Open Innovation companies think that a little competition may not be a bad thing. They also know that their internal marketing and sales group may pay more attention and move faster toward adopting a new technology if an external group starts having success with the technology.[14]

Setting and Advancing the Architecture with Internal R&D

The Open Innovation paradigm is not simply an approach that relies on external technologies for innovation. There remains a critical role for internal R&D in this approach: the definition of an architecture to organize the many parts of a new system. An architecture, a hierarchy of connections between disparate functions within a system, joins the technologies into a useful system. In any early stage of a technology's evolution, there are many possible ways that the different component technologies might relate with one another. The greater the number of components, the greater the number of possible interconnections between them.

Utilizing internal R&D allows the firm to create a new architecture when the many possible connections within a system are not known.

Early in the life of a promising new technology, its characteristics and capabilities may be only poorly understood. The complexities of the new approach create many ambiguities about how best to incorporate it into systems. At this stage, it is difficult to specify interconnections between the new technology and the larger system.[15] There are many possible ways to partition the system to reduce its overall complexity, and there may be no obvious best way to proceed.

Complete reliance on external technologies to determine these interconnections in such uncertain, complex circumstances is doomed to failure, since the companies making these technologies will all differ on the best way to utilize their technology. In fact, each component maker will want its technology to serve as the critical technology in the system, to enable its maker to obtain more profits and more control over the system. They may even hold up the development of the overall system, to ensure their control over a key part of the system. Moving the resolution of this interconnection problem within the firm allows the firm to bypass the possible holdup tactics by outside companies who perceive that they have obtained control over a key part of the system, due to how the relationships among its parts are defined.

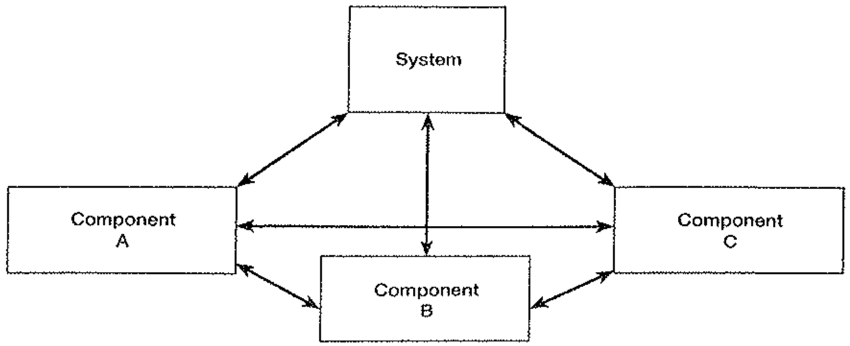
In order to coordinate the complexities and resolve the ambiguities, firms must develop deep expertise in many areas—systems-level expertise—to understand how a technology really works. In so doing, they assess what aspects of the new technology have what consequences for the larger system. The activities in one functional area influence the work of another functional area, so that there is intensive information exchange both within a function and between functions. As these influences become clearer over time, companies are able to partition tasks to resolve the earlier ambiguity they faced.

The resulting interdependencies between the parts of the system are shown in figure 3-2. In this figure, components A, B, and C constitute the system, and they all interrelate. Changing one component requires changes in all the other parts of the system, because the relationships between the parts are not clearly understood.

Developing this understanding of the relationships between the parts of a system and the system as a whole is a critical role for a company's innovation system. Technically, researchers need to experiment with many varying parameters of the technology to map out how changes in one part of the system affect the response of other parts of the system. In figure 3-2, if someone changes component A in the

FIGURE 3-2

An Interdependent Architecture



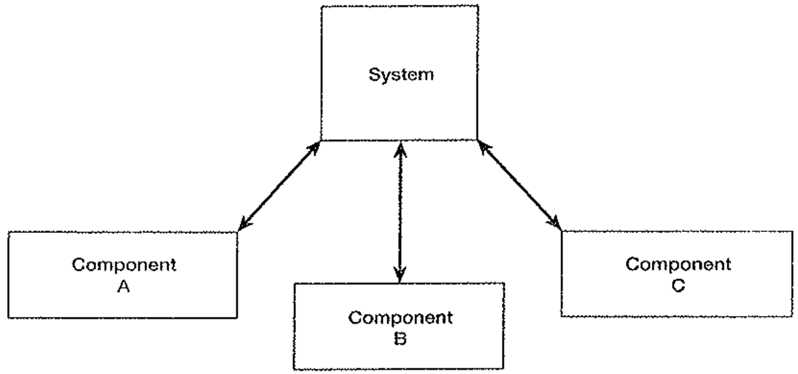
highly simplified system shown, components B and C must also change. In real systems of thousands of constituent parts, the possible interactions between the components in the system could number in the millions. Mapping out the interactions and then creating architectures to bind these interactions, without having to worry about which parts are advantaged in the struggle for profits and control, are best done through an internal R&D process.

The use of architectures to reduce interdependencies and limit complexity is only one element of the value added by internal R&D. Companies' architectures also have powerful implications for how the value chain and surrounding ecosystem will be structured. A valuable architecture not only reduces and resolves technical interdependencies, but also creates opportunities for others to contribute their expertise to the system being built. A good architecture does this even as it reserves opportunities for the firm to carve out a piece of the chain for itself to profit from the research that led to the creation of the new technology. Even very good technologies will flounder if they do not connect effectively to outside complementary technologies, while seemingly inferior ones may overtake them if they are better connected. The need for effective connections requires firms to collaborate with others in their ecosystem, as well as to compete with them.[16]

Over time, as the technology matures, interdependencies become clearer and more manageable. Companies can specify what they want,

FIGURE 3-3

A Modular Architecture



they can verify what they get, and they can add or drop vendors to reward or punish compliance. Intermediate markets can now emerge at the interfaces in the architecture, and specialist firms can enter to serve one layer within the architecture. The earlier vertical character of technological competition in the immature phase of the technology, in which internal R&D was critical to sort out the complexities, gives way to a more horizontal phase of technological competition, in which external technologies compete within the partitions of an established architecture.[17]

Figure 3-3 shows the system with the component interdependencies now well understood. In this system, components A, B, or C could change without causing any change in the other components. Firms can now compete to produce the best component A, without having to worry about the potential impact of their better product on other parts of the system. This modular mode enables companies to assemble systems more easily, since they can "plug and play" components whose interface characteristics are now well understood. In a well-established architecture, hundreds and even thousands of firms can innovate better component technologies without worrying about the possible impact of their improvements on other parts of the system.

Open Innovation firms must be adept enough to shift their approach when this transition to a modular architecture arises. Deeply vertical integration, which was vital to sorting out the intricacies of the immature technology in the earlier phase, now becomes a millstone around a company's neck. Companies must open themselves horizontally by participating in the intermediate markets within the architecture. This may involve externally buying some parts that save money, reduce development time, or provide desired features to the system. It may involve offering components externally to companies that compete at the systems level.

Crafting an Architecture for the Business

Crafting connections between technologies inside a system is necessary to manage the tremendous complexity of modern-day products and services. As challenging as that is, it is only a portion of the task of the innovating firm. It is at least as important to identify how the firm is going to create and capture value from its innovation activities. In chapter 4, we will explore the business model as a construct that creates an architecture for the business through a blend of internal and external activities. As we will see, the activities of external firms can help create significant value for a firm and its customers, while the firm's own activities are central to retaining a portion of that value for itself.