Open Innovation

The New Imperative for Creating and Profiting from Technology

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The Closed Innovation Paradigm

THE CLOSED INNOVATION PARADIGM and its associated mind-set toward organizing industrial R&D has led to many important achievements and many commercial successes. It is the mental model that Xerox's management used to run its PARC research facility. Indeed, it is the model used by most major U.S. corporations to run their labs for most of the twentieth century.

The past success of the Closed Innovation paradigm accounts for its persistence in the face of the changing landscape of knowledge. It is an approach that is fundamentally inwardly focused, which, as we shall see, fit well with the knowledge environment of the early twentieth century. However, the paradigm is increasingly at odds with the knowledge landscape at the beginning of the twenty-first century.

How to Access Useful Knowledge: A Thought Experiment

Let's begin with a thought experiment. Suppose that you are running a successful, growing company at the beginning of the twentieth century. Your products are selling well, and you have become a leading firm in your industry. Realizing that this fortunate situation will not last forever, you determine that the best way to ensure continued leadership in the industry is to create new and improved products to sell to the market in the future.[1] What is the best way for you to pursue the creation of these new products and services? Where is the useful knowledge you need, and how can you incorporate it into your business?

You might begin by assessing what the state of knowledge is for your industry outside your own firm. The state of external scientific knowledge had expanded enormously during the nineteenth century. By the early 1900s, we had learned about microbes, X-rays, the atom, electricity, and relativity. We had also learned about a more systematic way to conduct scientific research. As Alfred North Whitehead once remarked, the greatest invention of the nineteenth century was the method of invention.

Notwithstanding the scientific breakthroughs realized in the nineteenth century, for most industries around 1900, you would likely conclude that there wasn't that much external knowledge to build on to advance your industry. Although science was entering an era of enormous ferment (this is the period of Einstein, Bohr, Roentgen, Maxwell, Curie, Pasteur, and Planck), much of the science was just beginning to be understood, and its eventual commercial uses were far from apparent.

Moreover, the norms of science at that time suggested that any practical use from this science would come without much help from the scientists themselves. Emulating the norms of "pure" science held in German universities, U.S. scientists regarded the pursuit of practical knowledge as "prostituted science." Consider the bitter protest of Henry Rowland, who lamented the fame of "tinkerers" like Edison relative to men of science such as himself. Addressing the American Academy for the Advancement of Science in 1883, he proclaimed, "The proper course of one in my position is to consider what must be done to create a science of physics in this country, rather than to call telegraphs, electric lights, and such conveniences, by the name of science. . . . When the average tone of the [scientific] society is low, when the highest honors are given to the mediocre, when third-class men are held up as examples, and when trifling inventions are magnified into scientific discoveries, then the influence of such societies is prejudicial."[2]

At this time, many highly respected leaders in science argued that scientists had no place applying their talents and training to commercial problems. To do so, they believed, would imperil the value and quality of science itself. They looked on people like Thomas Edison as scientists of lesser ability, who had compromised themselves and corrupted the process of scientific discovery in so doing.

Unsurprisingly, the people who were trained as scientists in this period were mastering the tremendous intellectual breakthroughs in understanding the physical world, but were largely uninterested in applying those insights to practical problems. There was a large void between the science embodied in university classroom lectures and the beneficial use of those insights in commercial practice. Although the knowledge

being created within universities seemed to hold great promise, your growing enterprise could not rely on this knowledge being put to use in your industry on its own. Moreover, universities lacked the financial resources to underwrite and conduct significant experiments themselves.

Nor could you expect the government to be of much assistance. The overall size of government in the economy was much smaller during this period in history than it is today. And the government did not play much of a role in the research system then. It did pursue a few initiatives, such as the creation of a patent system, and provided limited funding for particular inquiries in weights and measures and in military materials such as improved gunpowders. In the United States, the government also provided some creative funding of land-grant universities for agricultural studies. And the government's antitrust actions did break up the largest monopolies. But overall, the government played a very limited role in organizing or funding science.

If universities and government were not leading the commercial application of science, what was driving these technical advances? Industry was the primary source of research funding for the commercial use of science, and industry R&D laboratories were the primary locus of this industrial research.

Weighing the costs and benefits of these challenges, you would likely conclude that pursuing the discovery and commercial development of scientific knowledge within your own firm was the only choice you could really make. You could not wait indefinitely for the external scientific community to become interested in practical applications of science. Nor could you wait for other companies to start operations to provide critical pieces of the end product you were producing. After careful consideration, you decide to create your own internal R&D organization.

As you began to enact your choice, you learned that you would have to involve your organization on a wide range of topics, from the basic materials science underlying your products, to their many applications, to the industrial processes that fabricate them, to the means of utilizing them. Your laboratory must therefore reach far down into basic materials and reach all the way up to final products. You must attract highly trained people out of the universities and offer them lifelong employment as scientists and engineers in your company. You must create an internal environment of intellectual ferment and a research community that stimulates creative thinking and excellence in conducting research.

You might look around at other leading companies and see what they were doing to advance their knowledge. You would find that industrialists in leading industries of that time—chemicals and petroleum, for example—had reached the same conclusion you did: to pursue innovation through an internal R&D organization. German chemicals firms were systematically expanding their product offerings through increasingly advanced investigations of the properties of the materials they were using to create new dyestuffs.[3] Petroleum companies were rapidly improving their yields in refining crude oil through their understanding of the properties of that oil. In the process, they were innovating additional new products out of this raw material as well.

Historian Alfred Chandler has documented the choices of many leading industrial enterprises during this period.[4] Among his important discoveries was the role of companies' internal R&D functions in creating economies of scale in their business. These R&D facilities were so successful in extracting more efficiency out of increased understanding that they created natural monopolies in many leading industries, or economies of scale. These labs also spawned the discovery of new properties in materials. The resultant new possibilities in products led to the creation of new business opportunities, or economies of scope.

The institution of the central research lab and internal product development was thus a critical element of the rise of the modern industrial corporation. Centrally organized research and development were central to companies' strategies and were regarded as critical business investments. R&D functions were a salient feature in the knowledge landscape of the economy, relatively insulated from the universities and small enterprises, relatively unconnected to the government, and largely self-contained.

One could therefore regard the knowledge landscape in the early twentieth century as a series of fortified castles located in an otherwise impoverished landscape. Within the castle walls of each company's central R&D organization were deep repositories of understanding based on thorough, detailed investigations of a wide range of phenomena.[5] Each castle was relatively self-sufficient, receiving occasional visits from outsiders, and its inhabitants ventured out occasionally into the surrounding landscape to visit universities or scientific expositions. But most of the action occurred within the castle walls, and those outside the castle could only marvel at the wonders produced from within.

Shifts in the Knowledge Landscape

One important change in this knowledge landscape was the unique relationship between the public university system and corporations that developed in the United States in the first half of the twentieth century. Unlike the higher education system in European nations, the U.S. system was highly decentralized, even among public universities. State schools were funded by state governments and thus responded to local commercial needs to a greater extent than did their peers across the Atlantic. Industries such as mining, farming, and engineering profited greatly from the focus on science and technology in the public university system. Private universities were neither accountable to a national authority nor responsible even to a state authority and were thus free to pursue their own science and technology agendas.

The earlier snobbery of Henry Rowland, imported from Germany's own attitudes toward the commercialization of science, began to be leavened by the obvious utility of that commercialization. Out of industrial R&D, tinkerers like Edison were creating blockbuster products that led to enormous commercial advantage, as Chandler's work has shown. As a result of the decentralized, local funding and focus of higher education, the rise in the number and quality of U.S. universities expanded the pool of qualified engineers and scientists from which corporations could staff their own in-house industrial research labs.

Two developments exemplify the functioning of this decentralized system. First, the federal government established a land-grant program for state universities that focused on science and technology after the Civil War. Today's "Big Ten" universities largely grew out of these land grants. Most important, these schools were start-ups, unconstrained by any history and not locked into a prior approach to their mission. They were quick to embrace the engineering disciplines as worthy of study, unlike the established universities such as Harvard and Yale, which initially adopted an attitude toward this practical application of science that was similar to Rowland's.

Second, the federal government established funding for agricultural extension initiatives with the Morrill Act of 1862 and successive acts in 1887 and 1906.[6] This legislation created a network of government-funded, locally based research offices, to disseminate new ideas in agriculture (some of which came out of these Big Ten schools!). This system increased the productivity of U.S. farms dramatically, with innovations such as hybrid seeds, crop rotation, and pest control.

Together, these research initiatives solidified the nascent links between the federal government, higher education, and industry. And these links would be strengthened substantially by the advent of World War II.

World War II: Mobilizing Scientific Knowledge in U.S. Society

World War II production efforts were a catalyst for a new emphasis on efficiency, production, and innovation in U.S. industry. President Franklin D. Roosevelt sensed that the wartime system that had successfully created the atomic bomb and the first computer could be applied to peacetime innovations as well: "New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war, we can create a fuller and more fruitful employment and a fuller and more fruitful life."[7] Near the end of the war, on November 17, 1944, with the preceding statement, Roosevelt commissioned Vannevar Bush, the director of the Office of Scientific Research and Development (which had overseen the military research programs during the war) to study the ways in which the United States could capitalize on its military and scientific advances in peacetime. Roosevelt asked Bush how the government could translate military sciences into civilian improvements, increase the number of trained U.S. scientists, and aid research activities in the public and private sector. Bush's resulting report, entitled *Science: The Endless Frontier*, became the cornerstone of U.S. postwar policy toward science and technology.

Paramount to Bush was the need for an increase in the federal funding of basic research at the university level. Although the United States had made considerable strides in applied R&D (evidenced by technologies such as the airplane, the radio, and radar), these innovations had been dependent on basic research imported from Europe. Even the atomic bomb had depended critically on the knowledge of scientists who had been trained in Europe. This dependence could no longer continue, Bush argued: "[A] nation which depends on others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill."[8]

To address this deficiency, Bush proposed the formation of a National Research Foundation, which would be responsible for coordinating efforts between the branches of government, the universities, the military, and industry. Government would distribute funding directly to universities to increase basic research initiatives; these developments would benefit both industry and the military. In turn, commerce and the military would then be able to focus primarily on applied technology.

While Bush's central coordination mechanism was resisted, the decentralized approach he advocated to using federal monies to stimulate more R&D in the universities and in industry was adopted. Table 2-1 shows both the rapid increase in government funding for R&D, and the different players in the R&D system. This system characterized the U.S. innovation system for the next forty years. Note that the amount of funding for R&D from the government exceeded that of industry for most of the postwar period until 1985. Since then, industry has provided the majority of funding for R&D.

TABLE 2-1

Sources of Funding for U.S. R&D by Sector (1992 Dollars in Millions)

Year	Government	Industry	Universities, Colleges	Other Nonprofit	Total
1930	248	1,195	210	59	1,712
1940	614	2,077	280	94	3,063
1955	17,977	12,902	453	318	31,650
1960	39,185	20,281	666	538	60,670
1970	53,559	26,944	1,099	894	82,498
1975	49,534	34,543	1,544	1,122	86,743
1980	43,070	37,084	1,810	1,273	83,237
1985	48,022	50,133	2,175	1,469	101,799
1991	63,035	95,030	3,505	3,372	164,942
1995	59,375	102,994	3,816	3,679	169,864
1998	59,083	125,469	4,342	3,717	192,611

Sources: Years 1930 and 1940: Vannevar Bush, *Science: The Endless Frontier* (Washington, DC: U.S. Government Printing Office, 1945); years 1955–1985: Richard Nelson, ed., *National Innovation Systems* (Oxford: Oxford University Press, 1993); and years 1991–1998: National Science Foundation, *National Patterns of R&D Resources* (Washington, DC: National Science Foundation, March 1999).

For this coordination to succeed, Bush recognized that the quality and the quantity of scientific personnel had to be dramatically increased. To remedy this situation, the Seventy-Eighth Congress passed Public Law 346. This law, "commonly known as the GI Bill of Rights, provides for the education of veterans of this war under certain conditions, at the expense of the Federal Government."[9] In addition, soldiers with scientific talent were eligible for new scholarships that would encourage them to pursue advanced degrees in the sciences. The GI Bill extended the federal government's role of funding academic research to funding the tuition of deserving students.

This expanded charter and increased funding enormously expanded the role of universities in the U.S. innovation system. The processes that Bush's office used during wartime led to the successful deployment of radar, the atomic bomb, timed fuses, and cryptography. These same processes now deeply influenced his proposed peacetime model of innovation. Indeed, the virtue of Bush's model wasn't simply that more money was being spent; rather, it was *how* the money was spent. Bush's vision of an "endless frontier" elevated academic science to become an equal partner with government and industry in the mission to apply science to military and societal needs. Government would fund basic scientific research, but most of that research would *not* be conducted by government labs; instead it would be housed at leading academic universities, governed by norms of scientific inquiry and publication. This arrangement greatly expanded the pool of knowledge available to society and to industry, particularly through the rising tide of college graduates and post-college graduates.

This expanded but decentralized pool of knowledge inspired industrial firms to increase the amount of resources they devoted to their own R&D. This led to the expansion of many corporate labs that had been formed before the war, such as Bell Laboratories and General Electric's and DuPont's labs. It also led to the formation of new labs, such as the T. J. Watson Laboratories at IBM, the Sarnoff Labs at RCA, and later on, HP Labs and Xerox PARC.

Some enormous commercial scientific achievements were realized as a result of these in-house industrial laboratories. Bell Labs scientists who were exploring the source of background static in microwave satellite transmissions found that the source of this static was rooted in a previously unknown phenomenon. They eventually received the Nobel Prize for the discovery of dark matter in the universe. Scientists at IBM received another Nobel Prize for their discovery of superconductivity. DuPont discovered and innovated a number of new chemical fibers and new materials. A rapidly growing young company, Xerox, exploited the discovery of using electrostatic charges to fix toner onto paper and catapulted itself into the *Fortune* 500 through its successful commercialization of xerography.

Companies that made the investments leading to these discoveries manifestly benefited from them. With a legal monopoly in telecommunications, AT&T could introduce new products that embodied applications of its science out of Bell Labs without fear of misappropriation. IBM had a near monopoly in its mainframe computer business. The company mastered the art of staging the introduction of new technological advances in ways that maximized its own profits and maximized the problems of its competitors who attempted to follow IBM's lead. Xerox similarly held a commanding share of its market with the most advanced copiers, able to copy the highest volumes and to perform the most elaborate feeding, sorting, and binding functions. These and many other successes caused companies to pursue strategies of significant investment in basic research, organized through central research laboratories.

The result was a golden age for internal R&D. Corporate R&D organizations were working at the cutting edge of scientific research. Inside their four walls, they featured the best equipment, staffed by the best people and focused on long-term R&D programs that were funded at significant levels. There seemed to be strong economies of scale in R&D as well: The largest companies in the industry were able to fund the most research and generally enjoyed the most advanced technologies as a result. These companies' lead in research and technology helped them achieve the largest profits of all the firms in the industry. And this commitment to internal R&D was viewed as a barrier to entry for their competitors: Any company that wanted to enter the industry would have to make similarly large, long-term investments in order to compete. One had to think ahead many moves to win this game of chess.

The logic underlying this approach to innovation was one of closed, centralized, internal R&D. At its root, the logic implies a need for deep vertical integration. In other words, in order to do anything, one must do everything internally, from tools and materials, to product design and manufacturing, to sales, service, and support. Outside the fortified central R&D castles, the knowledge landscape was assumed to be rather barren. Consequently, the firm should rely on itself—and not feeble outside suppliers—for its critical technologies.

This was when the term *not invented here* was first coined. The term originally had a negative meaning. If a technology was not produced inside a company (i.e., not invented here), the company could not be sure of the quality, performance, and availability of the particular technology. IBM, for example, began making its own heads and media in its disk-drive business in the 1960s, because it could not get these critical components made to its requirements from outside suppliers on a timely basis. It developed the basic components, assembled them into subsystems, designed systems out of these components, manufactured the systems at its own factories, distributed and serviced the systems themselves, and even handled the financing of the systems.[10]

Similarly, Xerox needed to make its own toner, its own copier, its own light lens, and its own feeding and sorting subsystems in order to deliver high-volume, high-quality xerography to its customers. Because Xerox was pushing mechanical and electrical systems further than anyone else in its applications, there was no available supplier base with which to work. During the early years, Xerox found that it even needed to make its own *paper*, to get the optimal paper characteristics that would feed well through its copier systems. The golden age of R&D was an age of deep vertical integration, born of necessity (since there were few capable external alternatives) and of virtue (since it was easy to capture value from one's R&D when one controlled the entire value chain of business activities, thanks to dominant positions in one's product markets).

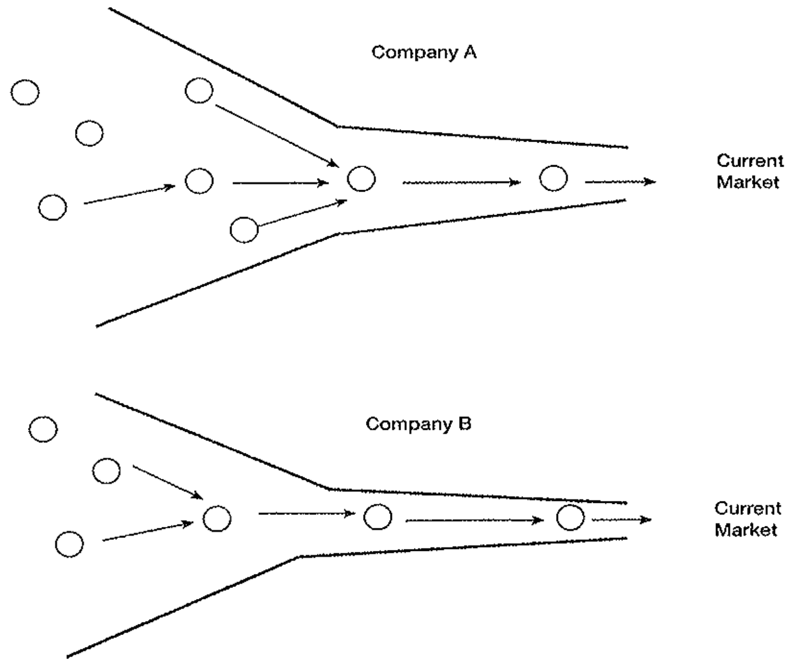
Figure 2-1 shows this Closed Innovation paradigm for managing R&D. The solid lines show the boundary of each firm, A and B. Ideas flow into each firm, on the left, and flow out to the market on the right. They are screened and filtered during the research process, and the surviving ones are transferred into development and then taken to market.

Figure 2-1 also shows the knowledge landscape that arose from the pattern of deep, vertically integrated R&D organizations such as firm A and firm B, and the impoverished landscape that surrounded them. Although there were many ideas, few of them were available outside the walls of these firms.

These concepts implicitly assume that all these activities are conducted within the firm. There is no other path for ideas to come into the firm, nor is there any other path for products and services to leave the firm. This tight coupling also assumes no leakage out of the system. Provided that the company keeps a flow of new ideas into its R&D pipeline, it will turn many of these ideas into new products and capture

FIGURE 2-1

The Knowledge Landscape in Closed Innovation



the value from these ideas. This flow will allow the company to reinvest in further research, which in turn will lead to future profitable products. Thus, the company's R&D system is sustainable over time.

The Tension Between Research and Development

This is not to say that this period of industrial innovation had no problems. One tension was the different incentives of research and of development in responding to a particular technology project. Research is fundamentally about the exploration of new frontiers, punctuated by occasional flashes of insight that lead to exciting new discoveries. These discoveries cannot be predicted in advance; nor can they be scheduled to arrive at particular dates. Nor do the people recruited into research organizations regard schedules as particularly valuable structures to aid in their discoveries. Most corporate researchers are highly trained scientists and engineers, often with Ph.D.'s in their fields. Companies recruit these individuals by offering them attractive salaries, significant discretion over the choice of projects they work on, and considerable freedom to publish their results. These researchers' skills are highly specialized to narrow domains of scientific inquiry, which makes them hard to retrain if and when business conditions changed.

These highly trained professionals are able to monitor significant research developments in their professional communities and then apply them to the company's business. They typically work on projects that have a long way to go before the results are ready to go to market. Indeed, most research organizations do not actually take their ideas all the way to market. Instead, companies restrict their research function to the discovery and early exploration of ideas, and then hand over the task of developing these into products to the development organization.

The research function is almost always structured as a cost center. Its financial goal each year is to stay within budget. Over time, the manager of the research function wants to kick out the mature, established research projects, in which most of the conceptual learning has already taken place. The manager also wants to move out the older researchers gracefully, to make room for young research talent. This turnover allows the manager to start new projects and infuses new ideas and energy into the research organization. This process of renewal makes the labs more attractive as a place to work for aspiring researchers.

Development, by contrast, takes the output of research as an input into its own process. This function is led by engineers, who are trained to solve problems within certain constraints, such as time and budget. It produces products and services that embody the research ideas so that they may be sold into the market. Such development involves a more predictable time horizon than that of the research process. Development managers seek to identify, characterize, and then minimize risks in creating new products and services. In contrast to the "blue sky" environment of research, development is fundamentally about making and hitting schedule targets and budgets, to convert discoveries into new products and services.

The development function is usually part of a business unit, which is structured as a profit center, with its own profit-and-loss (P&L) statement. Managers of development want to incorporate new inputs from research when they are as well characterized and understood as possible.

In this way, the managers can use the new research inputs with little further expense. Inputs that are not well understood require further development before they can be used in new products. This further development work is costly and hurts the business's P&L. Worse, poorly understood inputs pose a greater risk that the development group will miss the product introduction schedule. Since the development organization must integrate the new research inputs with many other technologies, the interactions of the new technology with the rest of the system make it extremely difficult to execute complex programs.[11]

The conflicting objectives of research and development create a budgetary disconnect between the two. The research cost center wants to get moving on to a new idea, whereas the development profit center wants more work done on the current research idea before taking over its further funding:

Research Organization	*Development Organization*
• Cost center	• Profit center
• Discovery: Why?	• Execution: How?
• Hard to predict	• Hit targets
• Hard to schedule	• Hit schedules
• Create possibilities	• Minimize risk
• Identify problems and how to think about them	• Solve problems within constraints

One way that many companies ended up managing this disconnect was to create a buffer that separated the two processes, so that development was not tightly coupled to research. This buffer effectively placed research ideas "on the shelf" until the development organization was ready to work on them. The research center would essentially say, "We're done with this," while the development people would reply, "We don't think it's ready yet." Thus, projects would stop receiving funding from research, while development would defer funding their further development. The projects would sit in the buffer, on the shelf, waiting for the organization to make use of them. Many organizations found that they had numerous research discoveries piled up on the shelf in this fashion.

This characterized the innovation system of many leading U.S. companies during the postwar golden age. Large companies invested in large central research labs and enjoyed significant downstream market positions that allowed them to capture a significant portion of the value they created from the technology in their labs. The companies were able to control the output of their knowledge and create value-added products with their technology. They could reinvest these returns in more research and create a virtuous cycle. This research output was managed as a knowledge bank, in which ideas were kept on the shelf until a downstream business was ready and willing to use them.

In certain industries, the golden age continues, and this internally focused approach to R&D remains well suited to managing innovation. In these industries, the protection of intellectual property is very tight, or regulatory restrictions are very high, or both; start-ups seldom arise; and VC makes little investment. The firms have the ability to store their technologies on the shelf until they are ready to take their discoveries to market, without fear of significant leakage of that technology out of the company and into a start-up or another rival company.[12]

In many other industries, though, the logic underlying the Closed Innovation paradigm has become fundamentally obsolete. Several factors have eroded this paradigm.

Erosion Factor 1: The Increasing Availability and Mobility of Skilled Workers

One erosion factor that has led to the demise of the Closed Innovation paradigm is the increasing availability and mobility of skilled workers. This factor has many causes. Among them was the explosion in college graduates and postgraduate students fostered by the GI Bill and other programs to stimulate the expansion of higher education. The supply of well-trained, knowledgeable people expanded tremendously during the postwar period. The growth of this population represented a large increase in the "raw material" able to produce useful knowledge.

Other trends in the labor market increased the mobility of these highly trained workers, diffusing the knowledge that they possessed from the fortified towers of internal R&D organizations to suppliers, customers, partners, universities, start-ups, consultants, and other third parties. With information more widespread, new companies could access useful knowledge that previously they could not. One company could profit from the training and experience of another company by hiring away some of the latter company's workers, or through hiring consultants who used to work at another company, without paying any compensation in return.

This mobility of well-trained workers created something of an auction market for highly qualified talent. Talented engineers could "surf" from company to company, selling their talents to the highest bidder. A fluid labor market permitted even start-up firms to pioneer the commercialization of promising new technological opportunities. For individual entrepreneurs, this fluid market created a powerful attraction to exit the larger firm for the opportunity to earn a significant reward. It also created strong reasons for individuals to invest in their own education, to learn as much as they could so that they might increase their value in the auction market for talent.

A particularly dramatic example of this "learning by hiring away" came in the hard-disk-drive industry. IBM for many years was the dominant innovator in the industry, earning the lion's share of the industry's profits, performing most of the long-term research driving the technology, and obtaining the majority of the patents in the industry.

Despite the company's dominance, the mobility of disk-drive engineers caused IBM's leadership to erode over time. An engineer named Al Shugart left IBM to go to Memorex, where he helped Memorex improve its hard-disk drives that plugged into IBM mainframe computers. Then he left Memorex to start a company called Shugart Associates, pursuing a new kind of hard-disk drive, the 8-inch disk drive, intended for minicomputers and workstations. Eventually, when he fell out with the financial backers of Shugart, he left to start another new company, called Seagate, which made still smaller 5¼-inch drives for personal computers.

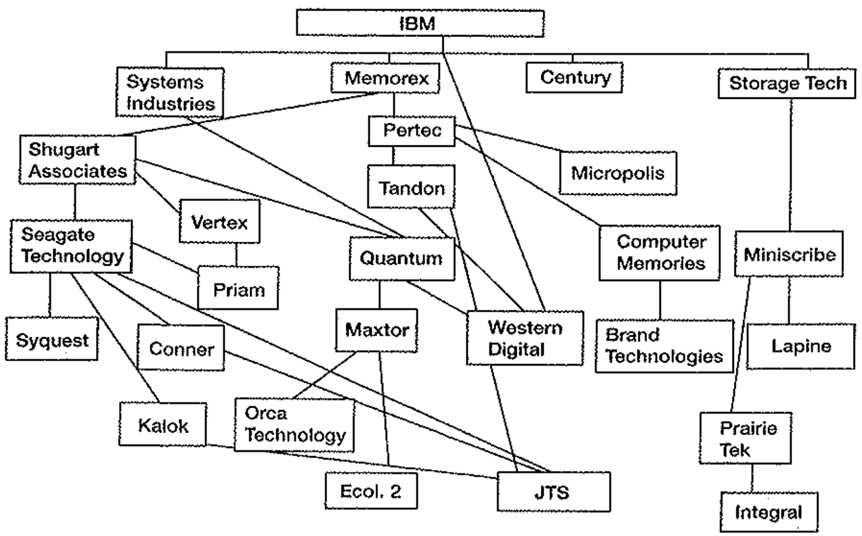
With each job change he made, Shugart took a substantial number of people with him to the new company. Each of Shugart's new start-up companies was thus able to hit the ground running, with highly experienced personnel that were trained on someone else's money. Nor is Shugart unique in this approach. Of the ninety-nine U.S.-based start-up companies that entered the disk-drive industry, twenty-one had former IBM employees on their founding teams.[13] Figure 2-2 shows a partial genealogy of hard-disk-drive firms from 1973 through 1996. It shows the diaspora of companies with former IBM personnel in their top management teams at the time they were founded. The shaded companies were still in operation in December 1996. Most of the offspring, though, have gone out of business. In 2002, IBM itself sold its hard-disk-drive business to Hitachi, culminating almost fifty years of innovation in magnetic storage.

U.S. immigration policy also played an important role in the availability of skilled professionals, drawing in talented graduate students from other countries. Though viewed as a "brain drain" by the home countries of these graduate students, the students' migration was a "brain gain" for many U.S. firms and industries. A 1998 study by the National Science Foundation found that over 50 percent of the postdoctoral students at MIT and Stanford University were not U.S. citizens and that more than 30 percent of computer professionals in Silicon Valley were born outside the United States.[14] Again, the U.S. firms paid no compensation to the home countries that educated these people, who then moved to the United States.[15]

The influx of highly talented foreigners and the high mobility of other skilled workers has been wonderful for the U.S. economy. U.S. firms get some of the best and the brightest people working on problems whose solutions create real economic value. But there are real

FIGURE 2-2

IBM and Its Offspring Hard-Disk-Drive Companies, December 1996



☐ Still making hard-disk-drives as of December 1996.

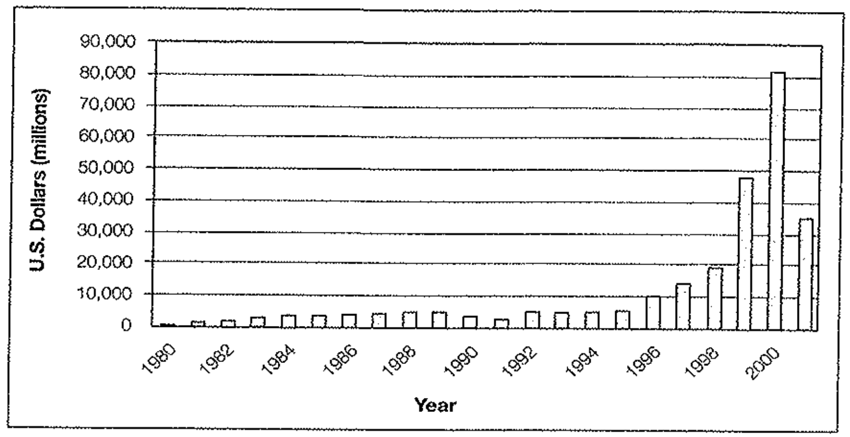
problems created by high-mobility labor markets for the firms with leading-edge R&D investments built up during the golden age of internal R&D. Rival firms can access their extensive experience and capabilities at a fraction of their true cost by simply hiring away "the best and the brightest." This creates a hazard for the previous employer, which jeopardizes that firm's ability to continue to invest in R&D.

Erosion Factor 2: The Venture Capital Market

Prior to 1980, little VC was available in the United States. Although there were start-up companies that arose from people who migrated out of large firms, these new enterprises had to struggle to find capital. The ability of companies to attract other talented staff to the new venture was also impaired by a lack of adequate capital to justify the risk of leaving a well-capitalized company for an unknown start-up company. While large companies with extensive investments in R&D weren't thrilled to see some of their employees leave, they weren't particularly concerned about how these departing employees would affect their own future business prospects.

FIGURE 2-3

Total Investment in U.S. Venture Capital, 1980–2001



Sources: Paul Gompers and Josh Lerner, *The Money of Invention* (Boston: Harvard Business School Press, 2001), 72–73; and *Venture Economics for 2001*, <http:www.ventureeconomics.com/vee/news_ve/2002VEpress/VEpress02_04_02.htm>.

As others have discussed, there has been an enormous expansion of VC since 1980.[16] About $700 million in VC was invested in the United States in 1980, and the figure rose to more than $80 billion in 2000 (figure 2-3). Although the figure dropped to more than $36 billion in 2001, it still is an enormous amount, even when compared to the dollars invested just three years earlier.

This large and growing pool of VC created real hazards for the companies that made significant commitments to internal R&D. The knowledge that they created inside their own knowledge silos and stored in their buffers between research and development was now at much greater risk. Individual personnel from their labs could be lured away by attractive risk/reward compensation packages to join new start-up firms. This attraction was exacerbated by the booming stock market during the same period. The large firms could offer world-class equipment, tremendous freedom to choose one's research initiatives, and a stimulating intellectual environment. They could not, however, hope to match the stock-option packages of these new start-up firms.

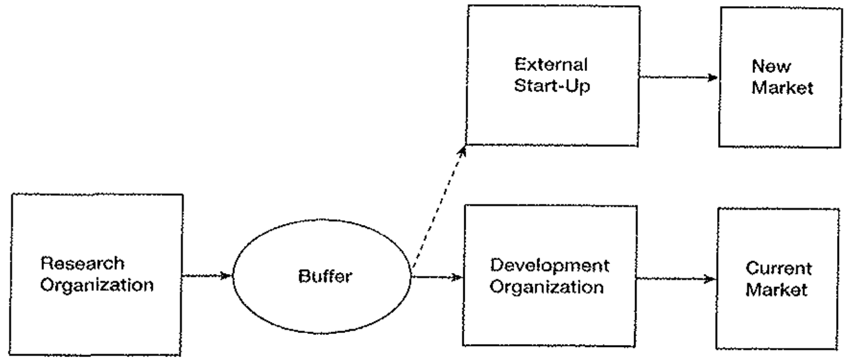
Erosion Factor 3: External Options for Ideas Sitting on the Shelf

The earlier tensions between the incentives of the research group and those of the development group gave rise to a buffer inventory of ideas sitting on the shelf. The tensions between these functions are not new, but now there is an important difference. As a result of the combination of erosion factors 1 and 2 (mobility and availability of workers, and VC) there exists a second, outside path to market for many of these ideas. If left on their own to wait until a development group works on them, these ideas might instead go outside on their own (shown as the dotted line in figure 2-4).

As product life cycles shorten and as external options grow, it becomes increasingly important for companies to increase the metabolic rate at which they process knowledge. Customers won't wait indefinitely for better products, and competitors won't make them wait for those products. If a company's internal development organization is not ready to use a new research result, it cannot blithely assume that the result will always remain on the shelf, available whenever the development group chooses to work with it. Disillusioned employees, possibly financed by VC, have other ways of commercializing their ideas. And

FIGURE 2-4

The Outside Option for Ideas on the Shelf



there may be new markets to explore with these ideas, which the established company may be poorly suited to address.

Erosion Factor 4: The Increasing Capability of External Suppliers

When companies like IBM wanted to increase the performance of their early mass-storage systems, they found that they could not rely on external suppliers to supply components of sufficient technical capability in sufficient volume with high quality. More generally, companies seeking to create new products and services in the middle of the twentieth century found that the surrounding environment lacked the requisite knowledge, production experience, and financial capital to serve as reliable partners in building the materials, components, and systems needed to serve the market.

Thanks to the confluence of many of the factors already noted, such as the expansion of universities and university enrollments, the availability of well-trained workers to companies of all sizes, and the increased presence of VC, the external supply base is much more extensively developed in most industries today than it was after World War II. These suppliers' offerings are now often of equal or superior quality to what a company can achieve internally.

The presence of capable external suppliers is a double-edged sword for large companies with extensive internal R&D investments. On the one hand, it supports the ability to apply these R&D investments in a wide variety of areas in less time than it would take if the company had to perform every function in the value chain on its own. The large companies can thus move faster and cover more potential market opportunities. On the other hand, these external suppliers are available to all comers, which places pressure on companies that have built up substantial inventories of R&D projects currently sitting on the shelf. These external suppliers let other companies move faster and serve a wider range of markets as well. This could enable the unused buffer inventory of ideas and technologies lying on the shelf between research and development to move out of the firm into the market, with or without the participation of the company that funded the original R&D.

The Erosion of the Closed Innovation Paradigm

These erosion factors have loosened the linkage between research and development in the Closed Innovation paradigm. Ideas can no longer be inventoried on the shelf, because they will leak out to the broader environment over time. A company that fails to utilize its technology may later see variants of those ideas exploited by other firms.

At the same time, these erosion factors collectively create a rich variety of possible research inputs available outside the firm. These external results could be brought into the firm and turned into new products and services. What previously was a fundamentally closed, internal environment (where the firm had to create ideas in order to use them) has transformed into an open environment (where the firm can create ideas for external and internal use, and the firm can access ideas from the outside as well as from within).

More subtly, these erosion factors have rearranged the landscape of knowledge. The distribution of knowledge has shifted away from the tall towers of central R&D facilities, toward variegated pools of knowledge distributed across the landscape. Companies can find vital knowledge in customers, suppliers, universities, national labs, consortia, consultants, and even start-up firms. Companies must structure themselves to leverage these distributed pools, instead of ignoring them in the pursuit of their internal R&D agendas. Increasingly, companies cannot expect to warehouse their technologies until their own businesses

make use of them. If a company does not use its ideas with alacrity, it may lose those ideas to outside organizations.

This shift in the knowledge landscape is disturbing to people familiar with the earlier paradigm. Isn't it problematic for ideas to start in the firm, but then leak outside? If the firm invests in research, but the results leak out to other firms, which free-ride on the investing firm's efforts, how can the original firm continue to invest in research going forward? Where will the vital discoveries and breakthroughs come from? Seen from the perspective of the Closed Innovation paradigm, these are valid, even urgent questions. Seen from the perspective of a broader knowledge landscape, though, they put the emphasis on the wrong issues and distract firms from how they might profit from a different knowledge landscape. How firms can benefit from a different innovation model will be the focus of chapter 3.