CHAPTER 2

MODELS OF INNOVATION

One question has interested management scholars for years: what type of firm is most likely to innovate? In this chapter we explore some of the models that have been advanced in an effort to better answer this question. This exploration provides some background definitions and concepts that are crucial to an understanding of the main theme of this book: recognizing the potential of an innovation, profiting from it, and protecting those profits. We first define innovation and then describe each model, pointing out its shortcomings and contributions. From these models we synthesize a framework for exploring who is likely to introduce and exploit innovation.

DEFINITION OF INNOVATION

Innovation is the use of new knowledge to offer a new product or service that customers want. It is invention + commercialization.[1] It is, according to Porter, "a new way of doing things (termed invention by some authors) that is *commercialized*. The process of innovation cannot be separated from a firm's strategic and competitive context."[2] The new knowledge[3] can be technological or market related. Technological knowledge is knowledge of components, linkages between components, methods, processes, and techniques that go into a product or service. Market knowledge is knowledge of distribution channels, product applications, and customer expectations, preferences, needs, and wants. The product or service is new in that its cost is lower, its attributes are improved, it now has new attributes it never had before, or it never existed in that market before. Often the new product or service itself is called an innovation, reflecting the fact that it is the creation of new technological or market knowledge. Thus the discovery and development of Merck's cholesterol-bursting drug Mevacor was an innovation, as were Wal-Mart's location of discount retail stores in small towns in the southwestern United States and Federal Express's one-day delivery service.

Innovation has also been defined as "the adoption of ideas that are new to the adopting organization."[4] This book is about profiting from innovation. Generating good ideas or adopting a new one, in and of itself, is only a start. To be an innovation, an idea must be converted into a product or service that customers want. Coming up with the idea or prototype—invention—is one thing. Championing it, shepherding it, and nurturing it into a product or service that customers want is another. Innovation entails both invention and commercialization.

A distinction has also been made between *technical* and *administrative* innovation.[5] Technical innovation is about improved products, services, or processes or completely new ones. This contrasts with administrative innovation, which pertains to organizational structure and administrative processes and may or may not affect technical innovation. Technical innovation may or may not require administrative innovation. A technical innovation can be a *product* or a *process*. According to Damanpour, product innovations "are new products or services introduced to meet an external and market need," whereas process innovations are "new elements introduced into an organization's production or service operations—input materials, task specifications, work and information flow mechanisms, and equipment used to produce a product or render a service."[6] Thus, to the extent that technical innovations use new technological or market knowledge to offer new products or services to customers, they fit the definition of innovation in this book.

WHO INNOVATES?

The debate over who is most likely to innovate dates back to, at least, Schumpeter, who first suggested that small entrepreneurial firms were the sources of most innovations.[7] Later he changed his view and suggested that, for several reasons, large firms with some degree of monopoly power were more likely to be the sources of technological innovation. He argued that large firms have the production and other complementary assets that are necessary to commercialize an invention; have the size to exploit the economies of scale that are prevalent in R&D; are more diversified and therefore more willing to take the kind of risk that is inherent in R&D projects; have better access to capital than smaller firms; and, as monopolists, do not have competitors ready to imitate their innovations and therefore are more likely to invest in them.[8] Empirical studies in search of support for either position have not been able to establish a clear relationship between a firm's size and market power and its innovative activity.[9] By shifting the focus to the *type* of innovation, however, some research suggests that whether incumbents or new entrants are able to introduce and exploit innovation is a function of whether the innovation is *incremental* or *radical*, that is, a function of how *new* the new knowledge and the new product (in our definition of innovation) are.[10]

STATIC MODELS

Incremental versus Radical Innovation

An innovation has two kinds of impact on a firm. In the first place, since knowledge underpins a firm's ability to offer products, a change in knowledge implies a

change in the firm's ability to offer a new product (Figure 2.1). Thus innovation can be defined in terms of the extent to which it impacts a firm's capabilities. This is what is usually referred to as the organizational view (of classifying innovations). In this view, an innovation is said to be *radical* if the technological knowledge required to exploit it is very different from existing knowledge, rendering existing knowledge obsolete. Such innovations are said to be *competence destroying.*[11] Refrigerators were a radical innovation because making them required firms to integrate knowledge of thermodynamics, coolants, and electric motors, which was very different from knowledge of harvesting and hauling ice. At the other end of the dichotomy is *incremental* innovation. In it, the knowledge required to offer a product builds on existing knowledge. It is, according to Tushman and Anderson, *competence enhancing*. For example, a "shrink" of Intel's Pentium chip to make it run at 200 MHz is an incremental innovation in the organizational sense since the knowledge required to do so builds on the firm's knowledge in microprocessor development. Most innovations are incremental.

In the second place, since innovation results in superior products (lower cost, better or new features), it can also be classified as a function of the extent to which it renders old products noncompetitive. This is the so-called economic (competitiveness) view. In this view, an innovation is said to be radical (drastic) if it results in a product that is so superior (lower cost, better attributes, or new attributes) that existing products are rendered noncompetitive. For example, the mechanical cash register could not compete with electronic point-of-sale systems (EPOSs). Thus EPOSs were a radical innovation in the economic sense. Very often, however, the innovation still allows existing products to stay competitive. In that case it is said to be incremental or nondrastic. Both diet and caffeine-free sodas are incremental in-

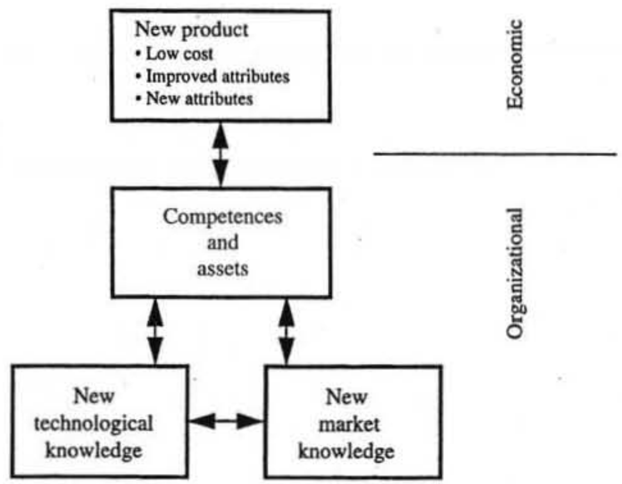

FIGURE 2.1. Innovation: Organizational and economic implications.

novations in the economic sense because their introduction allowed the standard colas to remain competitive.

These organizational and competitiveness definitions of incremental and radical innovation serve as the basis for two views of who is likely to innovate: the *strategic incentive* (to invest) and the *organizational capabilities* views.

Strategic Incentive (to Invest)

In the strategic incentive to invest view, the type of innovation—whether it is radical or incremental in the economic sense—determines what type of firm is likely to invest to be the first to innovate. Given that a radical innovation renders an incumbent's existing products noncompetitive, an incumbent with market power may be reluctant to invest in the innovation for fear of cannibalizing its existing products if, in doing so, it advances the date of introduction of the innovation.[12] New entrants, on the other hand, have less to lose. If they do not invest in the innovation, they have no products to sell in that market. On the other hand, incumbents would be more willing to invest in incremental innovations since such investments allow their existing products to stay competitive in the market.[13]

One major shortcoming of this model is that it assumes that firms have recognized the potential of the innovation, and in the case of a radical innovation, that only the fear of cannibalization prevents them from exploiting it. This is not always the case, especially with radical innovations. In any case, the model may explain why some new entrants have been the first to embrace radical innovation and incumbents have been responsible for the bulk of incremental innovations. It does not, however, explain why incumbents who invest in radical innovation may still fail. This is where the organizational capabilities view comes in.

Organizational Capabilities

If an innovation is radical in the organizational sense, incumbents have two problems in exploiting it. In the first place, since the change is competence destroying, they do not have the capabilities to exploit it.[14] In the second place, and perhaps more important, the firm's existing capabilities may not only be useless, they may actually be a handicap to the introduction and development of the innovation.[15] Firms find it difficult to break their habits, the routines and procedures they had put in place to exploit the old technology. They must unlearn the old ways of doing things. New entrants, on the other hand, do not have the burden of the old technology and can go on unencumbered to build capabilities for the innovation and exploit it.

If, on the other hand, the innovation is incremental, incumbents tend to dominate since the required knowledge builds on what they already have, but new entrants would have to build it from scratch.

Issues with the Incremental–Radical Dichotomy

One implication of these definitions is that new entrants are more likely to do well in the face of a radical innovation, whereas incumbents are more likely to fare bet-

Type of firm	Innovation: Incremental	Innovation: Radical
Incumbent	Mostek and Intel lost their industry market leadership positions in the transition from 64K to 256K DRAM	GE was successful in the transitions from X rays to CAT scans to MRI IBM successfully made the transitions from vacuum tubes to transistors to integrated circuits in mainframe computers
New entrant		

FIGURE 2.2. Counterexamples to predictions by incremental and radical models.

ter when the innovation is incremental. In many industries, however, incumbents have been the first to introduce or exploit radical innovations and, in some cases, have failed to exploit incremental innovations. Figure 2.2 gives some examples. Intel and Mostek lost their leadership positions in DRAM memory chips during the transition from the 64K to the 256K chip, an incremental innovation in the organizational sense, despite being very strong incumbents and investing heavily in the 256K DRAM. On the other hand, GE, an incumbent in the diagnostic medical equipment industry, maintained its leadership position in the transition from X rays to CAT scans to MRI, relatively radical innovations. IBM was able to maintain its dominant position in the computer industry during the radical transitions from vacuum tubes to transistors to integrated circuits.

The counterexamples illustrated in Figure 2.2 suggest that we need more than the incremental–radical model to predict the outcome of technological change. We need more models that explain why some incumbents are the first to embrace or exploit radical technological change and why they sometimes fail to exploit some incremental innovations.

Abernathy–Clark Model

The Abernathy–Clark model offers one explanation why incumbents may outperform new entrants in the face of some "radical" innovations.[16] The model suggests that there are actually two kinds of knowledge that underpin an innovation: technological and market. Thus a firm's technological capabilities could become obsolete while its market capabilities remain intact. If such market capabilities are important and difficult to acquire, an incumbent whose technological capabilities have

Market capabilities \ Technical capabilities	Preserved	Destroyed
Preserved	Regular	Revolutionary
Destroyed	Niche	Architectural

FIGURE 2.3. Abernathy–Clark terminology—role of technological and market capabilities.

been destroyed can use the market ones to its advantage over a new entrant. Focusing on the perspective of the innovating firm, the model classifies innovations according to their impact on the existing technological and market knowledge of the manufacturer (Figure 2.3). An innovation is *regular* if it conserves the manufacturer's existing technological and market capabilities, *niche* if it conserves technological capabilities but obsoletes market capabilities, *revolutionary* if it obsoletes technological capabilities but enhances market capabilities, and *architectural* if both technological and market capabilities become obsolete.

While these different categories of innovation are illuminating, the point to note in this model is that market knowledge can be just as important as technological knowledge. For example, GE's market capabilities were instrumental to its performance in the transition from one generation of technologically radical innovation to another in the medical diagnostics equipment industry.[17] It was not the first to introduce each new technology, but it successfully transitioned from X rays to CAT scans to MRI, all technologically competence-destroying innovations.

Henderson–Clark Model

Henderson and Clark were puzzled why some incumbents have so much difficulty in dealing with what appear to be "incremental" innovations—seemingly minute changes in existing technologies. Xerox stumbled for many years before finally developing a good small plain-paper copier, despite being the pioneer of the core technology of xerography.[18] RCA was never able to lead in the market for portable transistor radios despite its experience in the components (transistors, audio amplifiers, and loudspeakers) that went into the portable radio. From their research, Henderson and Clark suggested that since products are normally made up of components connected together, building them must require two kinds of knowledge: knowledge of the components and knowledge of the linkages between them, which they call *architectural* knowledge. An innovation, then, can impact either compo-

Component knowledge \ Architectural knowledge	Enhanced	Destroyed
Enhanced	Incremental	Architectural
Destroyed	Modular	Radical

FIGURE 2.4. Architectural innovation.
Source: Reprinted from "Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms" by R. Henderson and K. B. Clark, published in *Administrative Science Quarterly* 35(1). March 1990, by permission of Administrative Science Quarterly. Copyright © 1990 by Cornell University.

nent knowledge or architectural knowledge, or both, with different consequences for the firm adopting it. They went on to define four kinds of innovations, as illustrated in Figure 2.4. If the innovation enhances both component and architectural knowledge, it is *incremental;* if it destroys both component and architectural knowledge, it is *radical.* However, if only the architectural knowledge is destroyed and the component knowledge enhanced, the innovation is *architectural.* The last case, where component knowledge is destroyed but architectural knowledge enhanced, is called *modular* innovation.

With these definitions it became clear why firms had problems with what appeared to be incremental innovation. They may have mistaken architectural innovation for incremental innovation. While the component knowledge required to exploit the innovations had not changed (and therefore the semblance of incremental innovation), architectural knowledge had changed. Architectural knowledge is often tacit and embedded in the routines and procedures of an organization, making changes in it difficult to discern and respond to.

Disruptive Technological Change Model

According to the disruptive technological change model, advanced by Professor Clayton Christensen, incumbents fail to exploit disruptive technologies not so much because these firms do not "get it," as suggested by the architectural innovation model, or because the technologies are competence destroying to them, as suggested by the incremental–radical model.[19] Rather, incumbents fail because they spend too much time listening to and meeting the needs of their existing mainstream customers who, initially, have no use for products from the disruptive technology. Disruptive technologies have the following four characteristics:

1. They create new markets by introducing a new kind of product or service.
2. The new product or service from the new technology costs less than existing products or services from the old technology.
3. Initially, the products perform worse than existing products when judged by the performance metrics that mainstream existing customers value. Eventually, however, the performance catches up and addresses the needs of mainstream customers.
4. The technology should be difficult to protect using patents.

To understand the disruptive technological change model, consider a firm that has been successful in exploiting an existing technology to offer products to its mainstream customers. The firm's capabilities—what it can or cannot do—are a function of its resources, processes, and values. Its resources are assets such as product designs, brands, relationships with suppliers, customers, distribution, people, plants and equipment, technologies, and cash reserves. Its processes are the systems that the firm has put in place to transform resources into better customer value. These systems are designed to make task performance more efficient and are difficult to change, especially when they have been embedded into organizational culture. Suppose A is one of the products that the firm develops using an existing technology and that, in Year 2, more than meets the key performance attributes that the firm's mainstream customers want (B) in the product (Figure 2.5). Also suppose that in Year 2, a new product C, which costs less than A, is introduced. Initially, C's performance is inferior to that of A and does not

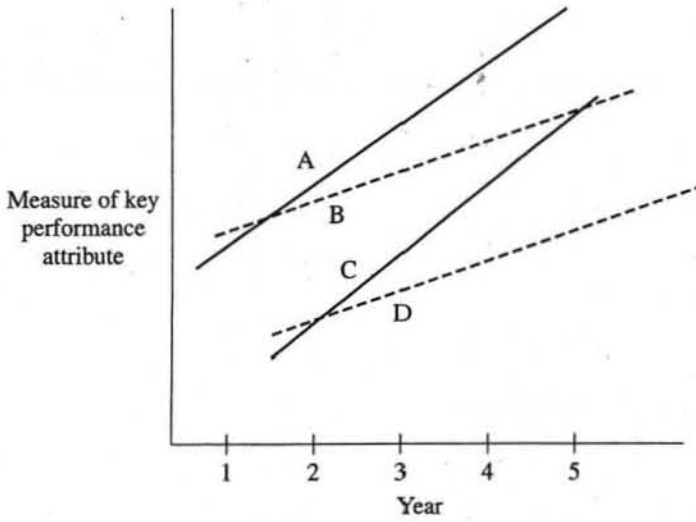

FIGURE 2.5. Disruptive technological change.

meet the performance requirements demanded by B. The firm that has produced A over the years and has been successful at doing so focuses its attention on satisfying the requirements of its key existing customers and therefore does not pay attention to developing the necessary capabilities, processes, and culture to build product C, which meets the performance attributes D that are needed by a different market. Start-ups and other entrants produce C and keep improving its performance. In Year 5, say, C's performance improves to a point where it now meets the needs of the market with demand B—the firm's mainstream customers. Because C is lower in cost than A, the firm's mainstream customers abandon it for the start-ups who offer C. At this time, it is too late for the firm and other producers of A to quickly shed their processes, values, and culture that served them so well with the old technology (in developing A) to develop C and gain a product advantage. Start-ups and other entrants take the leadership position in producing C.

Innovation Value-Added Chain

The innovation value-added chain[20] model can explain both why an incumbent can outperform new entrants at radical innovation and why it may also fail at incremental innovation. It differs from previous models in that while these other models focus on the impact of innovation on a firm's capabilities and competitiveness, it focuses on what the innovation does to the competitiveness and capabilities of a firm's suppliers, customers, and complementary innovators.[21] That is, previous models addressed the question: what does the electric car do to Ford's technological and market capabilities? But innovation also has implications for suppliers, customers, and complementary innovators, implications that can have far-reaching effects on the manufacturer.[22] Thus the electric car has implications not only for Ford's technical and market knowledge, but also for that of its suppliers (e.g., suppliers of electronic fuel injection systems), customers, and complementary innovators, such as gas station owners and oil companies. An innovation that is incremental to a manufacturer can be radical to its customers and complementary innovators and incremental to its suppliers. For example, the DSK (Dvorak simplified keyboard) keyboard arrangement that by some estimates performs 20–40 percent better than the QWERTY arrangement, which most of today's keyboards have, was competence enhancing to its innovator, Dvorak, and other typewriter manufacturers.[23] All they had to do was rearrange the position of the keys if they wanted to manufacture the DSK. But it was competence destroying to customers who had already learned how to type with the QWERTY keyboard since to use the new keyboard, they would have to relearn how to touch-type again. The various phases of this innovation at the different stages of the innovation value-added chain are shown in Figure 2.6.

Another example (also illustrated in Figure 2.6) is Cray Computer's decision in 1988 to develop and market a supercomputer that would use gallium arsenide (GaAs)[24] chips—a technology that yields very fast chips and consumes very little power, but was still relatively unproven then—instead of the proven silicon chip technology in which its suppliers had built their competences. While the super-

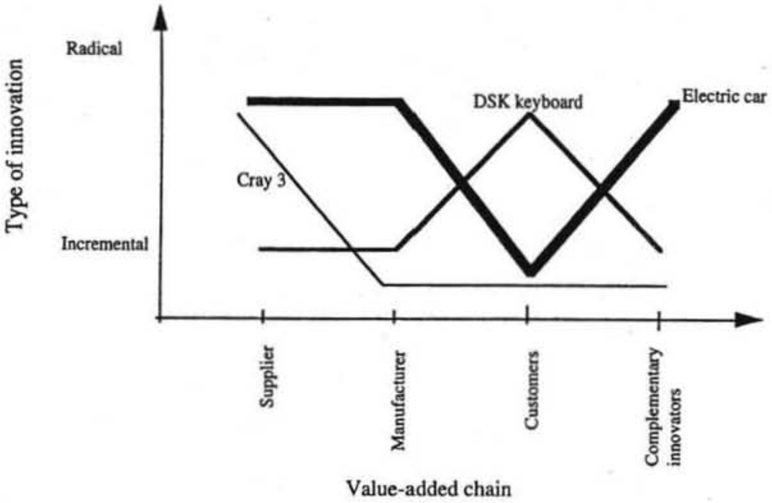

FIGURE 2.6. Innovation value-added chain. An innovation has implications not only for the firm but also for its suppliers, customers, and complementary innovators.

computer design was competence enhancing to Cray, its decision to use gallium arsenide was competence destroying to its traditional silicon chip supplier base.
In each of these examples, the innovation may have a different impact at each of the stages of the innovation value-added chain, suggesting that an innovation that is incremental to the manufacturer may not be to suppliers, customers, or complementary innovators. Thus incumbents for whom an innovation is competence destroying may still do well if the innovation is competence enhancing to their value chain, and relations with the chain are important and difficult to establish. The implications are that a firm's success in exploiting an innovation may depend as much on what the innovation does to the capabilities of the firm as on what it does to the capabilities of its innovation value-added chain of suppliers, customers, and complementary innovators (Figure 2.7).

Strategic Leadership View

The strategic leadership view argues that the strategic incentive to invest in an innovation or the failure to exploit it as a result of destroyed competence come only after a firm's top management has recognized the potential of the innovation.[25] Top management makes the decisions to invest in an innovation, or if such decisions are made by lower level managers, they still reflect the beliefs and values of top management.[26] But its incentive to invest in an innovation or its ability to embrace and exploit the innovation is a function of the extent to which the firm's top management recognizes the potential of the innovation. This ability of top management to recognize the potential of an innovation is a function of its *managerial logic,* or view of the world,[27] which, in turn, depends on management experiences, organi-

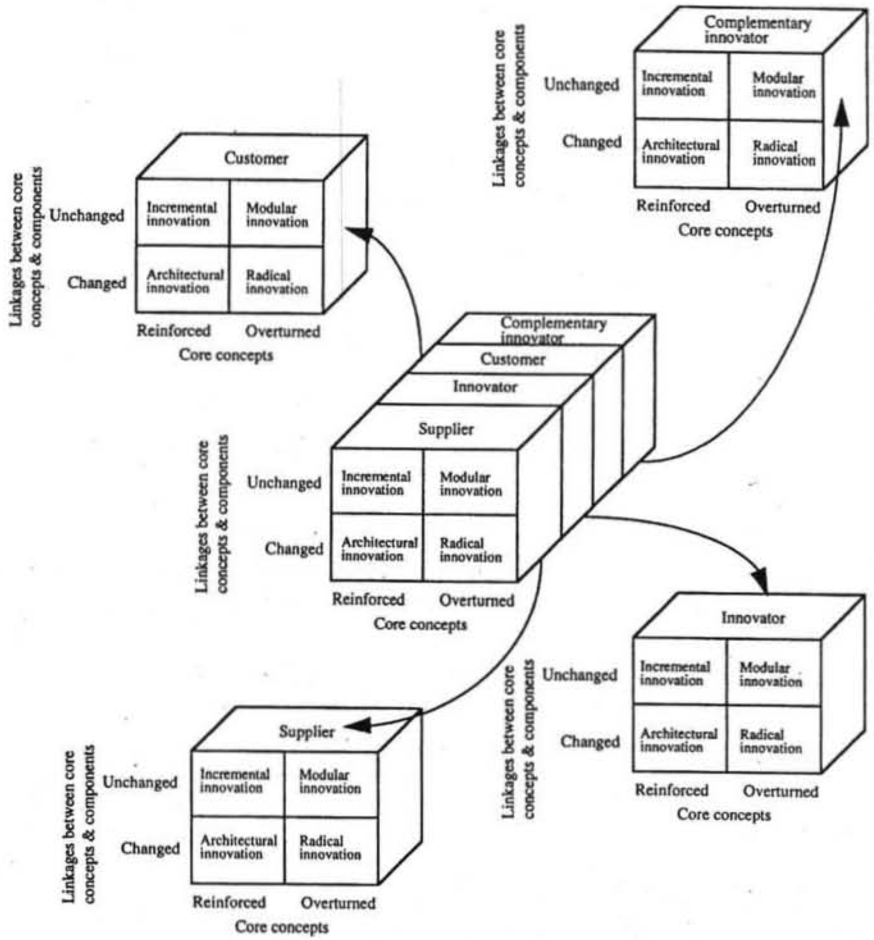

FIGURE 2.7. Impact of an innovation on an innovation value-added chain.

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zational logic, and industry logic. Thus whether a firm is a new entrant or an incumbent may not matter much. What matters is the strategic leadership's dominant logic.

Familiarity Matrix

Suppose top management has recognized the potential of an innovation and decided to adopt it. Is the firm going to be successful? It depends on the mechanism

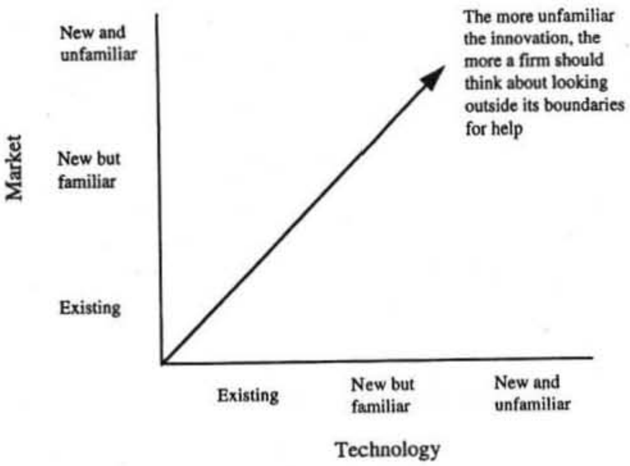

FIGURE 2.8. How to adopt an innovation, given its familiarity.

that the firm uses to adopt the innovation, Roberts and Berry argued.[28] They suggested that, in adopting an innovation, a firm can choose from seven mechanisms—internal development, acquisitions, licensing, internal ventures, joint ventures or alliances, venture capital and nurturing, and educational acquisition—depending on how familiar or unfamiliar the technology (that underpins the innovation) and the market are. That is, the appropriate mechanism depends on how radical the innovation is to the firm. The Roberts and Berry model will be discussed in much more detail in Chapter 12.

Briefly, however, if technology and market are familiar to the firm—an incremental innovation—the firm is better off developing the innovation internally since it has the capabilities to do so. If market and technology are both new and unfamiliar, the firm may be better off using venture capital, venture nurturing, and educational acquisitions to enter. As illustrated in Figure 2.8, the more radical an innovation is to a firm, the more the firm should look outside its boundaries for help.

Quantity and Quality of the New Knowledge

The incremental, radical, and architectural terminologies all describe different types of *changes* in knowledge. They describe how *new* the new knowledge is. An innovation can also be described as a function of how *much* knowledge goes into it and the *form* the knowledge takes.

Positive-Feedback Effects

Arthur groups products and services into *bulk processing* and *knowledge based*.[29] Bulk-processing products such as coal, heavy chemicals, plantains, lumber, and aniline dyes are heavy on natural resources and light on know-how. On the other

hand, knowledge-based products such as aircraft, pharmaceuticals, computers, software, telecommunications equipment, missiles, factory automation, and biotechnologicals are low on natural resources and heavy on know-how. These are so-called high-technology products, which are complicated and costly to develop, manufacture, and offer to customers. Bulk-processing products exhibit diminishing returns. For example, since the supply of plantain depends on the land on which it is grown, expanding the production of plantains means that there would eventually be less land available for plantains, thus limiting supply. Thus there is an optimum scale of operations—minimum efficient scale—beyond which costs start to increase.

Knowledge-based products exhibit increasing returns, or positive feedback.[30] Typically, the up-front costs for these products are very high, but the per-unit production costs thereafter are very low. For example, in pharmaceuticals, the cost of developing and launching a new drug can be as high as $500 million. But per-unit costs after that first unit can be as low as $0.10. These costs keep falling as more and more customers can be found. As another example, developing the first copy of a software product can cost as much as $60 million. Thereafter a copy can cost as little as $0.70 to produce.

Knowledge-based products often exhibit network effects,[31] that is, the more people who use these products, the more valuable they become. The increased value comes from two factors. First, it comes from the "sharing" effect. For example, the reader's telephone would be useless if the only person he or she could talk to were the author of this book. But the more other people there are on the telephone network, the more valuable it is to the reader since he or she can talk to more people. Second, the more people who use a product, the more complementary products can be developed. For example, the more people who use a particular computer standard, the more software is developed for that particular computer. The products may also require customers to invest in a fair amount of learning in order to use them effectively. A computer user must learn how to use the operating systems. A user of a Boeing 747 must learn how to maintain and safely operate the plane. This learning makes it difficult for a user to switch to a new system. To some extent, the customer is locked-in. Table 2.1 summarizes the differences between bulk-processing products and knowledge-based products.

The network externality and the customer lock-in properties of knowledge-based products suggest that technology B may win over competing technology A, even when A is superior to B. For example, if a user has learned how to use an operating system and bought applications software that runs on it, it may be difficult to switch to a newer operating system, even when the new one is superior in performance. The positive-feedback property also suggests that strategic actions or chance events that give a technology a lead early in its life can be amplified via positive feedback to give the technology a dominant position. Strategic actions include setting low prices (sometimes, literally giving away the product), forming alliances, and making preproduct announcements.[32] Whether or not a firm is successful with positive-feedback products is a function of the strategic actions that the firm takes early in its life, chance events, and whether or not the firm is the first to

TABLE 2.1. Differences between bulk-processing and knowledge-based products.

	Bulk processing	*Knowledge based*
Knowledge demands	Low on know-how	High on know-how
Up-front cost	Low	High
Network externalities	Low	High
Customer lock-in	Low	High
Economics	Negative feedback	Positive feedback

introduce the product. Not all products that are high on know-how require the same amount of knowledge. The amount of knowledge required is also a function of the complexity of the innovation. For example, a personal computer and a jumbo jet plane are both heavy on know-how but require different amounts of knowledge.

Tacitness of the New Knowledge

How *much* knowledge a firm has to collect and process in exploiting an innovation is one thing. The other is the form that it takes; in particular, whether it is tacit or explicit.

Knowledge is *explicit* (articulated, codified) if it is spelled out in writing, verbalized, or coded in drawings, computer programs, or other products.[33] *Tacit* knowledge is uncoded and nonverbalized. It may not even be verbalizable or articulatable. It can be acquired largely through personal experience such as learning by doing. It is often embedded in the routines of organizations or in an individual's actions and therefore very difficult to copy. Performing most activities requires both types of knowledge. Take flying a plane, for example. A student pilot can read about the different instruments and equipment in the cockpit. This is explicit knowledge. However, there are certain things about flying a plane that can only be learned by actually flying the plane and interacting with a trained pilot. The reader would probably hesitate to be flown by a pilot who learned how to fly by reading a manual but has never been in a plane before.

Thus in addition to asking how *new* the new knowledge is (that is, how radical the innovation), it is also important to ask how *much* of the new knowledge one needs and how *tacit* it is. As an example, take the two-piece aluminum can and the Boeing 777. The change from the three-piece tin-plated steel can to a two-piece aluminum can requires new knowledge.[34] So does the change from the Boeing 767 to the 777. To some functions along the value chain of each product, it is radical. The 777 with its numerous components, interfaces, and dimensions of merit and its many suppliers, customers, and regulators is more complex than the two-piece aluminum can. It requires more knowledge than the can. The final product does not have to be complex to require lots of knowledge. Most pharmaceutical drugs are very simple but require a tremendous amount of know-how.

Imitability and Complementary Assets: The Teece Model

While not explicitly categorizing innovations as radical, incremental, or otherwise, Teece proposed a model that, like the Abernathy–Clark model, helps explain why incumbents can still profit from technologically radical innovations.[35] Puzzled by such questions as why RC Cola introduced the first diet cola only to see Coca Cola and Pepsi collect most of the profits from it, or why EMI invented and first commercialized the CAT scan only to surrender its early leadership position to GE, Teece argued that two factors are instrumental to profiting from an innovation: *imitability* and *complementary assets.* Inimitability is the extent to which the technology can be imitated. Imitability may come from the intellectual property (patents, copyrights, trademarks, and trade secrets) protection of the technology, or from the fact that imitators just do not have the competences to imitate the given technology.[36] Complementary assets are all the other capabilities—apart from those that underpin the technology—that the firm needs to exploit the technology. These include manufacturing, marketing, distribution channels, service, reputation, brand name, and complementary technologies.

Figure 2.9 suggests when an innovator is likely to profit from an innovation in this model. If imitability is high in that the technology can easily be imitated, it is difficult for the innovator to make money if complementary assets are easily available or unimportant (cell I in Figure 2.9). If, however, complementary assets are tightly held and important, the owner of such assets makes money (cell II). For example, CAT scans were easy to imitate, and EMI did not have complementary assets such as distribution channels and the relations with U.S. hospitals that are critical to selling such expensive medical equipment. GE had these assets and quickly captured the leadership position by imitating the innovation. Coca Cola and Pepsi

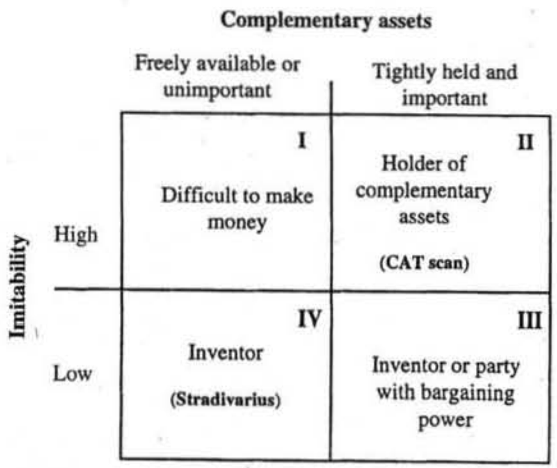

FIGURE 2.9. Who profits from innovations?

were able to profit from RC Cola's innovations because they had brand name reputation and distribution channels that RC did not, and the innovations were easy to imitate.

If imitability is low in that it is difficult to imitate the technology, the innovator stands to profit from it if complementary assets are freely available or unimportant (cell IV). For example, the owner of the Stradivarius profited enormously since no one could imitate it, and complementary assets for it were neither difficult to acquire nor important. If, as in cell III, imitability is low and complementary assets are important and difficult to acquire, whoever has both, or the more important of the two, wins. The better negotiator can also make money. Pixar is a good example. Imitability of some of its digital studio technology is low, given the copyrights it holds on its software. But offering customers movies made with that technology requires distribution channels, brand name recognition, and financing, which are tightly held by the likes of Disney and Columbia Pictures. Pixar formed an alliance with Disney to make the very successful *Toy Story*, and, so far, both firms have profited from the alliance.[37]

Local Environment

The suggestion, for example, that an innovation can be competence destroying to a firm implies that the ability of a firm to exploit the innovation may depend on something outside the firm—its environment. Indeed, several authors have argued that a firm's ability to innovate is a function of its environment. Thomas, for example, suggests that a very demanding environment can be conducive to innovation.[38] He compared the industrial policies of ten nations and found that pharmaceutical firms in the United States and the United Kingdom, where strict government regulations require proof of safety and efficacy, were more innovative than those in countries such as France, which had lenient regulation and low prices. Porter argued that the innovativenss of a firm is a function of four characteristics of its local environment, which he collectively called the "diamond."[39] These are factor conditions; demand conditions; related and supporting industries; and firm strategy, structure, and rivalry. Factor conditions, such as natural resources, skilled labor, capital, educational institutions (local universities), and private research laboratories that are repositories of scientific, technological, and market knowledge, can be sources of local advantage. It is from such repositories of knowledge that new ideas that could be nurtured into products or services often spring. It is also from them that support or nurturing for ideas from elsewhere often comes. Given that such knowledge is often tacit and therefore best transferred in person, local firms have an advantage in exploiting innovation. On the other hand, the lack of certain factors can constitute an advantage. For example, Swedish firms are leaders in prefabricated housing partly because of the short building season and the high wages of construction workers in Sweden.

The nature of local demand for products or service is also important to a local firm's ability to innovate. A firm's products tend to reflect local customer needs. One reason for this is the tacit nature of market knowledge. Customers may not be

able to articulate these preferences and expectations without repeated contact with manufacturers who can help flesh out the needs. Such contact can be very costly and difficult if both manufacturer and customer are not local. Even when customer needs are well articulated, a manufacturer may not be able to understand them without repeated physical meetings, which are easier and less costly if local. Thus if local customers are very sophisticated, their needs will be reflected in local products, allowing manufacturers to be able to serve less sophisticated customers outside the locality.

In some industries, suppliers of components and equipment are critical to generating new product or service ideas, and in supporting them through subsequent development and commercialization. The technological knowledge that underlies the use of some components and equipment may be tacit, and exploiting this knowledge requires close and frequent interaction with suppliers. Sometimes it may take a lot of input from the manufacturer to develop the component or equipment. Such frequent interaction is less costly and more probable when suppliers are local, and both parties stand to gain.

For several reasons local rivalry also improves the ability of firms to innovate. First, the rivals benefit from spillover effects. That is, by picking up knowledge from each other and building on it, everyone is better off. Second, to survive in the crowded (by rivals) environment, firms have to work harder at building their capabilities and emerge as better competitors.

Government policies also play a critical role. For example, the U.S. government provides funding for research through bodies such as the National Institutes of Health (NIH). Ward and Dranove showed that such research greatly stimulates privately funded research by local firms.[40] The role of MITI in establishing Japan as a post–World War II economic power has also been widely explored. The break of the U.S. stranglehold on commercial jet aircraft by Airbus Industry was greatly aided by the policies of some European governments.

Strategic Choice

The strategic choice view argues that if an incumbent is not the first to introduce an innovation, it may not be because it has no incentive to invest, its competence has been destroyed, it has not recognized the potential of the innovation, it does not have the complementary assets, it did not use the right adoption mechanism, or it is in an environment that is not conducive to innovation. It may be because of the firm's innovation strategy—its goals, timing, actions, and resource allocation in using new knowledge to offer new products or services. By making the right choices early, a firm can build the right competences and complementary assets, or even shape the kind of environment in which it is going to operate.[41] Freeman suggests several innovation strategies: offensive, defensive, imitative, dependent, traditional, and opportunistic.[42] A firm with an *offensive* strategy is the first to introduce new products. If its strategy is to be the first to innovate, it will invest in the innovation and build the capabilities to do so. Wal-Mart, through systematic strategic choices, has become the largest retailer in the world. In a *defensive* innovation strategy, a firm waits for a competitor with an offensive strategy to introduce a product first and resolve some of the uncertainties confronting the innovation. The defensive firm then introduces its own product, correcting any mistakes that pioneers may have made. For example, IBM let Altair and Apple establish that there was a market for personal computers before deciding to launch the PC, targeting the corporate customer. Firms pursuing a defensive strategy normally have very strong complementary assets—capabilities such as manufacturing, marketing, distribution channels, and reputation, which allow a firm to commercialize an invention—and when they decide to move, they do so very quickly. They usually have strong R&D since it takes knowledge to absorb knowledge.[43] The product is not an imitation of the pioneer's version but rather a differentiated product, often with better features and lower cost. The firm, in effect, catches up with or leapfrogs the pioneer. Thus not being the first to introduce an innovation may not be a sign of a lack of incentive to invest, competence destruction, absence of appropriate complementary assets, inappropriate adoption mechanism, or being in the wrong environment. It may be because the firm in question has a defensive strategy.

While a firm with a defensive strategy would like to differentiate its products, one with an *imitative* strategy would like to produce a clone of the pioneer's product. It has very little intention of catching up with or leapfrogging the pioneer. It usually has such low-cost capabilities as lower labor costs, access to raw materials, and strong manufacturing. In the *dependent* strategy the firm accepts a subordinate role to a stronger firm. It imitates product changes only when requested by the customer or superior. Many large Japanese firms have these satellite firms. The *traditional* strategy makes very few changes to products, only striving to offer the lowest cost possible. In the *opportunistic* strategy the firm looks for some unique needs of a market segment that are not being met—it looks for a niche market. The point in all these other strategies is that a firm's failure to introduce a product first can be due to its deliberate strategy.

Summary

The impact of an innovation on the heterogeneous capability and competitiveness of a firm as portrayed by the models of innovation discussed so far is summarized in Table 2.2. From an economic point of view, the incremental–radical dichotomy focuses on the extent to which existing products are rendered noncompetitive. From an organizational point of view, the dichotomy focuses on technological knowledge. The Abernathy–Clark model draws attention to market knowledge and helps explain why some incumbents do so well in the face of a radical innovation: their technological knowledge is destroyed but their market knowledge is intact, giving incumbents with such market capabilities an advantage over new entrants in innovations where market capabilities are important and difficult to establish. Both the incremental–radical dichotomy and the Abernathy–Clark model bundle component and architectural knowledge and therefore may see no difference between some architectural and incremental innovations. The Henderson–Clark model unbundles component and architectural knowledge, and it becomes clear that what appear to be

TABLE 2.2. Relationship between static models.

Model	*Key features*	*Value added*
Schumpeter I Schumpeter II	Entrepreneurs are the most likely to innovate. Large firms with some degree of monopoly power are the most likely to innovate.	Attempt to answer the question: who is most likely to innovate? The type of firm is what matters.
Incremental–radical dichotomy	*Strategic incentive to invest:* defines innovation as incremental if it leaves existing products competitive; radical if it renders existing products noncompetitive. *Organizational capabilities:* defines innovation as incremental if capabilities required to exploit it build on existing ones; radical if capabilities required are very different from existing ones. Focus on technological component of innovation; bundles technological and market knowledge; bundles component and architectural knowledge.	The type of innovation determines the type of firm that innovates. Incumbents are more likely to exploit incremental innovation, whereas new entrants are more likely to exploit radical innovation.
Abernathy–Clark	Unbundles technological and market knowledge. Highlights the importance of market capabilities.	Explains why incumbents may do well at radical technological innovations.
Henderson–Clark	Unbundles technological knowledge into component and architectural. Defines innovation as: incremental if both architectural and component knowledge are enhanced; architectural if component knowledge is enhanced but architectural knowledge is destroyed.	Explains why incumbents fail at what appears to be incremental innovations. These are actually architectural innovations.
Disruptive technological change	*Disruptive technologies* create new markets by introducing a new kind of product or service; the new product or service costs less than existing products or services; initially, the products perform worse than existing products when judged by the performance metrics that mainstream existing customers value; eventually, performance catches up and addresses the needs of mainstream customers; the technology should be difficult to protect using patents. Disruptive technologies require resources, processes and values that are very different from those that were acquired in exploiting the older technology. When incumbents eventually decide to adopt the new technology, it's too late.	Listening to customers too much can be a problem. Incumbents need special organizational arrangements to help them develop the new resources, processes, and values for the new technology without being encumbered by the old resources, processes, and values of the old technology.

TABLE 2.2. Continued

Model	Key features	Value added
Innovation value-added chain	Extends emphasis to the whole innovation value-added chain of suppliers, customers, and complementary innovators. The competence of a firm's ecosystem matters too.	Explains why incumbents may fail at incremental innovations and why they may succeed at radical innovations.
Strategic leadership	Explores the role of top management and argues that whether or not a firm adopts an innovation is a function of top management's dominant logic.	Explains why some incumbents are the first to embrace radical innovations.
Familiarity matrix	Suggests that success in adopting an innovation is a function of the adoption mechanism used.	It is how a firm adopts an innovation that determines its success or failure.

"incremental" innovations may actually be architectural innovations that destroy the knowledge of linkages between components. While the incremental–radical dichotomy, the Abernathy–Clark model, and the Henderson–Clark model focus on the impact of an innovation on a firm's capabilities, the innovation value-added chain model explores the impact of the innovation on the firm's local environment of suppliers, customers, and complementary innovators. It suggests that as important as a manufacturer's capabilities are in the face of an innovation, those of its suppliers, customers, and complementary innovators can be just as important.

The strategic leadership view argues that the ability of a firm to embrace and exploit an innovation is a function of the firm's top management dominant logic; of how this logic enables top management to recognize the potential of an innovation and therefore to better allocate resources for exploiting it. Roberts and Berry suggest strategies for adopting an innovation given that a firm understands the potential of the innovation and the extent to which it obsoletes existing technological and market capabilities.

The quantity and quality of new knowledge model suggests that while it is important how *new* the new knowledge is that underpins an innovation, how *much* of it there is and the *quality* of its composition are also important. Whether the innovation is bulk processing or knowledge based and how tacit that knowledge is both play a role in who is most likely to profit from it.

While not explicitly categorizing innovation, the Teece model explains why a firm can still be unable to exploit an innovation, even when it has the technological capabilities. Capabilities other than technological ones—complementary assets—matter. Advocates of the environment as a driver of innovation argue that a firm's ability to innovate is a function of its local environment. Finally, the strategic choice view suggests that a firm's innovation strategy is what determines when it introduces an innovation, and how it exploits it.

DYNAMIC MODELS

A major shortcoming of all the models we have examined so far is that they are static. Only the cross-sectional view of a firm's capabilities and the knowledge that underpins them as well as the firm's incentive to invest at a point in time are explored. For example, we say that the electric car will be a radical innovation for Ford in 2005 because in that year, the skills that Ford needs to exploit electric car technology are very different from those it uses to exploit its existing internal combustion engine technology. The models do not look at what happens with the innovation following first adoption. The only "dynamism" in them is that there is a change from the old to the new. The models that follow are dynamic in that they take a longitudinal view of innovation and explore its evolution following introduction. They view a technology as having a life of its own with radical and incremental phases, each of which may take a different type of firm to succeed.

Utterback–Abernathy Dynamic Model of Innovation

Utterback and Abernathy detailed the dynamic processes that take place within an industry and its firms during the evolution of a technology from the *fluid* phase through a *transitional* phase to the *specific* phase.[44] In the fluid phase there are a lot of technological and market uncertainties. Technology is in a state of flux, and firms have no clear idea whether, when, or where to invest in R&D. Custom designs are common, with the new product technology often crude, expensive, and unreliable, but able to meet the requirements of some market niches. These designs are in some ways but experiments in the marketplace, and they change as producers learn more about market needs and customers understand more about the potential of the evolving technology. Process innovation accounts for very little in the fluid phase. Input materials are largely off the shelf, and manufacturing equipment is mostly general purpose. The basis of competition is largely on product features.

The evolution enters the transitional phase when, as producers learn more about how to meet customer needs through producer–customer interaction and through product experimentation, some standardization of components, market needs, and product design features takes place, and a *dominant design* emerges, signaling a substantial reduction in uncertainty, experimentation, and major design changes. A dominant design is one whose major components and underlying core concepts do not vary substantially from one product model to the other, and the design commands a high percentage of the market share. Competitive emphasis shifts to meeting the needs of specific customers, which have now become more clearly understood. The rate of product innovations decreases, and emphasis shifts to process innovation. Materials and equipment become more specialized and expensive. Competition is on the basis of differentiated products.

In the specific phase, products built around the dominant design proliferate, and there is more and more emphasis on process innovation, with product innovations being largely incremental. Materials are now very specialized, and equipment is highly specialized. The basis for competition becomes low cost. Products are

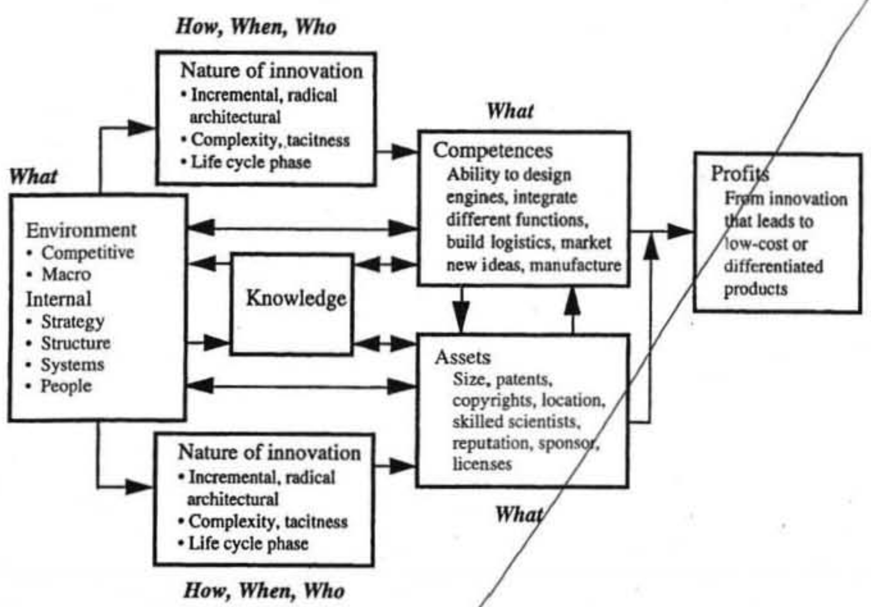

FIGURE 2.13. Integrative model for exploring how to profit from an innovation.

KEY TERMS

Administrative innovation
Appropriability regime
Architectural innovation
Boundary spanner
Champion
Competence destroying
Competence enhancing
Complementary assets
Complexity
Component knowledge
Defensive and offensive strategies
Disruptive Technology
Dominant design
Drastic innovation
Era of ferment
Era of incremental innovation
Fluid, transitional, and specific phases
Gatekeeper
Idea generation
Imitability
Incremental innovation
Innovation
Innovation value-added chain
Invention
Knowledge-based products
Positive feedback
Positive-feedback products
Process innovation
Project manager
Quality of knowledge
Quantity of knowledge
S curve
Sponsor
Strategic incentive to invest
T-skills
Tacit knowledge
Technological discontinuity

QUESTIONS AND EXERCISES

1. Can innovation be radical in the organizational sense and yet be incremental in the economic sense? How about vice versa? Give some examples.
2. What is the difference between static and dynamic models of innovation? Is this difference important?
3. What is the relationship between a firm's competitive advantage and innovation?
4. Looking at Figure 2.13, should there be an arrow from the profit box pointing back at the other boxes? Which boxes and why?
5. What is the difference between an architectural innovation and a disruptive technological change?

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