# TECHNOLOGY AND COMPETITIVE ADVANTAGE

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Technological innovations can have important strategic implications for individual companies and can greatly influence industries as a whole. Yet, not all technological change is strategically beneficial. This article focuses on ways to recognize and exploit the competitive significance of change.

Technological change is one of the principal drivers of competition. It plays a major role in industry structural change, as well as in creating new industries. It is also a great equalizer, eroding the competitive advantage of even well-entrenched firms and propelling others to the forefront. Many of today's great firms grew out of technological changes that they were able to exploit. Of all the things that can change the rules of competition, technological change is among the most prominent.

Despite its importance, however, the relationship between technological change and competition is widely misunderstood. Technological change tends to be viewed as valuable for its own sake—any technological modification a firm can pioneer is believed to be good. Competing in "high-technology" industries is widely perceived as being a ticket to profitability, while other industries that are "low-technology" are viewed with disdain. The recent success of foreign competition, much of it based on technological innovation, has encouraged companies even more to invest in technology.

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Technological change is not important for its own sake, but is important if it affects competitive advantage and industry structure. Not all technological change is strategically beneficial; it may worsen a firm's competitive position and industry attractiveness. High technology does not guarantee profitability. Indeed, many high-technology industries are much less profitable than some low-technology industries due to their unfavorable structures.

Technology, however, pervades a firm's value chain and extends beyond those technologies associated directly with the product. There is, in fact, no such thing as a low-technology industry if one takes this broader view. Viewing any industry as technologically mature often leads to strategic disaster. Moreover, many important innovations for competitive advantage are mundane and involve no scientific breakthroughs. Innovation can have important strategic implications for low-tech as well as hi-tech companies.

This article will describe some of the important links between technological change and competitive advantage as well as industry structure. It focuses not on particular technologies or on how to manage research and development, but on ways to recognize and exploit the competitive significance of technological change. The author presents a rather broad view of technology in this article because *all* the technologies embodied in a firm's value chain have potential competitive impacts.

The article begins by describing the linkage between technology and competition. What is examined is the relationship of technology to competitive advantage, growing out of technology's role in the value chain and the resulting ability of a firm to achieve low cost and/or differentiation through its value activities. How technology can shape industry structure is then shown. With this framework established, the article examines methods for selecting a technology strategy. Technology strategy must include choices about what important technologies to invest in, whether to seek technological leadership in them, and when and how to license technology. The article then describes how a firm can forecast the path of technological change as an industry evolves, crucial to the selection of technology strategy. Finally, the steps in formulating technology strategy are summarized.

## Technology and Competition

Any firm involves a large number of technologies. Everything a firm does involves technology of some sort, despite the fact that one or more technologies may appear to dominate the product or the production process. The significance of a technology for competition is not a function of its scientific merit or its prominence in the physical product. *Any* of the technologies involved in a firm can have a significant impact on competition. A technology is important for competition if it significantly affects a firm's competitive advantage or industry structure.

## Technology and the Value Chain

The basic tool for understanding the role of technology in competitive advantage is the value chain. A firm, as a collection of activities, is a collection of technologies. Technology is embodied in every value activity in a firm, and technological change can affect competition through its impact on virtually any activity. Exhibit 1 illustrates the range of technologies typically represented in a firm's value chain.

Every value activity uses some technology to combine purchased inputs and human resources to produce some output. This technology may be as mundane as a simple set of procedures for personnel and typically involves several scientific disciplines or *subtechnologies*. The materials handling technology used in logistics, for example, may involve such disciplines as industrial engineering, electronics, and materials technology. The technology of a value activity represents one combination of these subtechnologies. Technologies are also embodied in the purchased inputs used in each value activity, both in consumable inputs and in capital items. The technology inherent in purchased inputs interacts with the other subtechnologies to yield the level of performance of the activity.

Technology is embodied not only in primary activities but in support activities as well. Computer-aided design is an example of a tech-

**EXHIBIT 1**
**Product Process Technology and the Generic Strategies**

| | Illustrative Technological Policies | | | |
|---|---|---|---|---|
| | **Cost Leadership** | **Differentiation** | **Cost Focus** | **Differentiation Focus** |
| Product Technological Change | Product development to reduce product cost by lowering material content, facilitate ease of manufacture, simplify logistical requirements, etc. | Product development to enhance product quality, features, deliverability, or switching costs | Product development to design in only enough performance for the target segment's needs | Product design to meet the needs of a particular segment better than broadly targeted competitors |
| Process Technological Change | Learning curve process improvement to reduce material usage or lower labor input<br>Process development to enhance economies of scale | Process development to support high tolerances, greater quality control, more reliable scheduling, faster response time to orders, and other dimensions that raise buyer value | Process development to tune the value chain to a segment's needs in order to lower the cost of serving the segment | Process development to tune the value chain to segment needs in order to raise buyer value |

nology just coming into use in product development that is replacing traditional ways of developing new products. Various types of technologies also underlie the performance of other support activities, including those not typically viewed as technologically based. Procurement embodies procedures as well as technologies for placing orders and interacting with suppliers. Recent developments in information systems technology offer the possibility of revolutionizing procurement by changing ordering procedures and facilitating the achievement of supplier linkages. Human resource management draws on motivation research and technologies for training. Firm infrastructure involves a wide range of technologies from office equipment to legal research and strategic planning.

Information systems technology is particularly pervasive in the value chain, since every value activity creates and uses information. This is evident from Exhibit 1, which shows information systems technology in every generic category of value activity in the chain. Information systems are used in scheduling, controlling, optimizing, measuring, and otherwise accomplishing activities. Inbound logistics, for example, uses some kind of information system to control materials handling, schedule deliveries, and manage raw materials inventory. Similarly, an information system is involved in order processing, managing suppliers, and scheduling the service force. Information systems technology also has an important role in linkages among activities of all types, because the coordination and optimization of linkages requires information flow among activities. The recent, rapid technological change in information systems is having a profound impact on competition and competitive advantages because of the pervasive role of information in the value chain.

**Everything a firm does involves technology of some sort.**

Another pervasive technology in the value chain is office or administrative technology because clerical and other office functions must be performed as part of many value activities. While office technology can be subsumed under information systems technology, I have separated it because of the propensity to overlook it. Change in the way office functions can be performed is one of the most important types of technological trends occurring today for many firms, though few are devoting substantial resources to it.

The technologies in different value activities can be related, and this underlies a major source of *linkages* within the value chain. Product technology is linked to the technology for servicing a product, for example, while component technologies are related to overall product technology. Thus a technology choice in one part of the value chain can have implications for other parts of the chain. In extreme cases, changing technology in one activity can require a major reconfiguration of the value chain. Moving to ceramic engine parts, for example, eliminates the need for machining and other manufacturing steps in addition to having other impacts on the value chain. Linkages with suppliers and channels also frequently involve interdependence in the technologies used to perform activities.

A good example of the interdependence of technology in value activities is American Airline's Sabre reservations system. American leases terminals to travel agents, which allows automated reservations and ticketing. The system has been a source of differentiation for American. At the same time, however, the same system is used inside American in ticketing and issuing boarding passes as well as in route scheduling. American also sells listings on the system to other airlines.

A firm's technologies are also clearly interdependent with its buyers' technologies. The points of contact between a firm's value chain and its buyers' chains define the areas of potential interdependency of technology. A firm's product technology influences the product and process technology of the buyer and vice versa, for example, while a firm's order processing technology influences and is influenced by the buyer's procurement methods.

Technology, then, is pervasive in a firm and depends in part on both the buyers', channels', and suppliers' technology. As a result, the development of technology encompasses areas well outside the boundaries traditionally established for R&D, and inherently involves suppliers and buyers.[1] Some of the technologies embodied in the value chain are industry-specific, to varying degrees, but many are not. Office automation and transportation are just two areas where vital technologies, in large part, are not industry-

[1] Hence the label "technology development" in the generic value chain instead of the more limited phrase "research and development."

specific. Hence technology development relevant to a firm often takes place in other industries. All these characteristics of technology have implications for the role of technology in competitive advantage.

## Technology and Competitive Advantage

Technology affects competitive advantage if it has a significant role in determining relative cost position or differentiation. Since technology is embodied in every value activity and is involved in achieving linkages among activities, it can have a powerful effect on both cost and differentiation. Technology will affect cost or differentiation if it influences the cost driver or drivers of uniqueness of value activities. The technology that can be employed in a value activity can be the result of other drivers, such as scale, timing, or interrelationships. For example, scale allows high-speed automatic assembly equipment, while early timing allows some electric utilities to harness hydropower while sites are available. In these instances, technology is not the source of competitive advantage, but rather an outcome of other advantages. However, the technology employed in a value activity is frequently itself a driver when it reflects a policy choice made independently of other drivers. A firm that can discover a better technology for performing an activity than its competitors thus gains competitive advantage.

In addition to affecting cost or differentiation in its own right, technology affects competitive advantage through *changing or influencing the other drivers* of cost or uniqueness. Technological development can raise or lower scale economics, make interrelationships possible where they were not before, create the opportunity for advantages in timing, and influence nearly any of the other drivers of cost or uniqueness. Thus a firm can use technological development to alter drivers in a way that favors it, or to be the first and perhaps only firm to exploit a particular driver.

Two good examples of the role of technology in altering relative cost position are underway in the aluminum industry and illustrate these points. The dramatic rise in energy costs has made power the largest single cost in aluminum smelting and transformed a number of firms into high-cost producers because of the cost of their power. The great majority of Japanese aluminum smelters fall into this category, for example. To deal with the problem, Japanese firms have worked actively on carbothermic reduction, a breakthrough technology that dramatically lowers power consumption by converting bauxite and related ores directly into aluminum ingot without the intermediate alumina step. Here a new technology is itself a policy cost driver. Carbothermic reduction would also reduce the importance of location and institutional factors as cost drivers by reducing power consumption because location and government pricing policies for power strongly influence electricity costs.

The other example of the role of technology in cost is occurring in aluminum semifabrications, where a new process technology called continuous casting is emerging as a potential replacement for hot mills. The new process does not appear to result in lower cost at efficient scale, but it is less scale-sensitive. If the process proves successful, it could nullify the scale advantage of large semifabricators and allow plants to be located closer to buyers. This would reduce relatively high transport cost in regions previously served by products shipped from distant facilities. Here the new technology does not appear to be itself a cost driver, but is affecting other drivers (scale and location). It will influence the cost position of firms asymmetrically depending on their positions vis-à-vis drivers.

The role of technology in differentiation is illustrated by Federal Express, which reconfigured the value chain in small parcel delivery and achieved faster and more reliable delivery. The new technologies employed in Federal Express's value chain were policy choices, but also had the effect of increasing scale economies and creating a first-mover advantage. Thus as Federal Express has gained a large market share, the cost of matching its differentiation has become very high for competitors. This example also demonstrates the point that a major technological development need not involve scientific breakthroughs or even technologies that were not widely available previously. Mundane changes in the way a firm performs activities or combines available technologies often underlie competitive advantage.

Since a firm's technology is often interdependent with its buyers' technology, technological change by the buyer can affect competitive advantage just as can technological change within the firm. This is particularly true in differentiation strategies. A distributor that once differentiated itself by performing pricing and inventory control functions for its retail buyers may lose that differentiation if retailers switch to on-line point-of-sale systems. Similarly, changes in suppliers' technoogy can add to or subtract from a firm's competitive advantage if they affect the drivers of cost or uniqueness in a firm's value chain.

## Tests of a Desirable Technological Change

The link between technological change and competitive advantage suggests several tests for a desirable direction of technological change. Technological change will lead to sustainable competitive advantage under the following circumstances:

- ☐ *The technological change itself lowers cost or enhances differentiation and a technological lead is sustainable.* A technological change enhances competitive advantage if it leads to lower cost or differentiation and can be protected from imitation. The factors that determine the sustainability of a technological lead are described below.
- ☐ *The technological change shifts cost or uniqueness drivers in favor of a firm.* Changing the technology of a value activity, or changing the product in ways that affect a value activity, can influence the drivers of cost or uniqueness in that activity. Even if the technological change is imitated, it will lead to a competitive advantage for a firm if it skews drivers in the firm's favor. For example, a new assembly process that is more scale-sensitive than the previous process will benefit a large-share firm that pioneers it even if competitors eventually adopt the technology.
- ☐ *Pioneering the technological change translates into first-mover advantages besides those inherent in the technology itself.* Even if an innovator is imitated, pioneering may lead to a variety of potential first-mover advantages in cost or differentiation that remain after its technological lead is gone. First-mover advantages and disadvantages are identified below.
- ☐ *The technological change improves overall industry structure.* A technological change that improves overall industry structure is desirable even if it is easily copied.

Technological change that fails these tests will not improve a firm's competitive position though it may represent a substantial technological accomplishment. Technological change will destroy competitive advantage if it not only fails the tests but has the opposite effect contemplated in the tests—such as skewing cost or uniqueness drivers in favor of competition. A firm may also find itself in the situation where a technological change may meet one test but worsen the firm's position via another.

## Technology and Industry Structure

Technology is also an important determinant of overall industry structure if the technology employed in a value activity becomes widespread. Technological change that is diffused can potentially improve or erode industry attractiveness. Thus even if technology does not yield competitive advantage to any one firm, it may affect the profit potential of all firms. Conversely, technological change that improves a firm's competitive advantage may worsen structure as it is imitated. The potential effect of technological change on industry structure means that a firm cannot set technology strategy without considering the structural impacts.

## Technology and Entry Barriers

Technological change is a powerful determinant of entry barriers. It can raise or lower economies of scale in nearly any value activity. For example, flexible manufacturing systems often have the effect of reducing scale economics. Technological change can also raise economies of scale in the technological development function itself, by quickening the pace of new production introduction or raising the investment required for a new model. Technological change also is the basis of the learning curve. The learning curve results from improvements in such things as layout, yields, and machine speeds, all of which are types of technological change. Technological change can lead to other absolute cost advantages such as low-cost product designs. It can also alter the amount of capital required for competing in an industry. The shift from batch to continuous process technology for producing cornstarch and corn syrup has significantly increased the capital requirements in corn wet milling, for example.

Technological change also plays an important role in shaping the pattern of product differentiation in an industry. In aerosol packaging, for example, technological change has resulted in product standardization and has made the product a near commodity, all but eliminating the ability of contract packagers to differentiate themselves based on product characteristics. Technological change can also raise or lower switching costs. Technological choices by competitors determine the need for buyers to retrain personnel or to reinvest in ancillary equipment when switching suppliers. Technological change can also influence access to distribution by allowing firms to circumvent existing channels (as telemarketing is doing) or, conversely, by increasing industry dependence on channels (if more product demonstration and after-sale service is required, for example).

## Technology and Buyer Power

Technological change can shift the bargaining relationship between an industry and its buyers. The role of technological change in differentiation and switching costs is instrumental in determining buyer power. Technological change can also influence the ease of backward integration by the buyer, a key buyer bargaining lever. In the computer service industry, for example, the rapid decline in the cost of computers, driven by technological change, is having a major impact on the ability of firms such as ADP to sell timesharing, since many buyers can now afford their own machines.

## Technology and Supplier Power

Technological change can shift the bargaining relationship between an industry and its suppliers. It can eliminate the need to purchase from a powerful supplier group or, conversely, can force an industry to purchase from a new, powerful supplier. In commercial roofing, for example, the introduction of rubber-based roofing membranes has introduced powerful new resin suppliers in place of less powerful asphalt suppliers. Technological change can also allow a number of substitute inputs to be used in a firm's product, creating bargaining leverage against suppliers. For example, the can industry has benefited from fierce competition between the aluminum and steel companies to supply it, brought on by technological change in aluminum cans. Technology investments by firms can facilitate the use of multiple suppliers by creating in-house knowledge of supplier technologies. This can eliminate dependence on any one supplier.

## Technology and Substitution

Perhaps the most commonly recognized effect of technology on industry structure is its impact on substitution. Substitution is a function of the relative value to price of competing products and the switching costs associated with changing between them. Technological change creates entirely new products or product uses that substitute for others, such as fiberglass for plastic or wood, word processors for typewriters, and microwave ovens for conventional ovens. It influences both the relative value/price and switching costs of substitutes. The technological battle over relative value/price between industries producing close substitutes is at the heart of the substitution process.

## Technology and Rivalry

Technology can alter the nature and basis of rivalry among existing competitors in several ways. It can dramatically alter the cost structure and hence affect pricing decisions. For example, the shift to continuous process technology in the corn wet milling industry mentioned above has also raised fixed cost, and contributed to greater industry rivalry. A similar increase in fixed cost as a percentage of total cost has accompanied the increasing deadweight tonnage of oil tankers, made possible by improvements in shipbuilding technology. The role of technology in product differentiation and switching costs also is important to rivalry.

Another potential impact of technology on rivalry is through its effect on exit barriers. In some distribution industries, for example, automation of materials handling has raised exit barriers because the materials handling equipment is specialized to the particular goods moving through warehouses. Hence what were once general-purpose facilities have become specialized and capital-intensive facilities.

## Technological Change and Industry Boundaries

Technological change plays an important role in altering industry boundaries. The boundary of an industry is often imprecise, because distinctions between an industry's product and substitutes, incumbents and potential entrants, and incumbents and suppliers or buyers are often arbitrary. Nevertheless, regardless of where one chooses to draw industry boundaries, technological change can broaden or shrink them.

Technological change widens industry boundaries in a number of ways. It can reduce transportation or other logistical costs, thereby enlarging the geographic scope of the market. This happened in the 1960s and 1970s with the advent of large bulk cargo carriers in shipping. Technological change that reduces the cost of responding to national market differences can help globalize industries.[2] It can also enhance product perfor-

[2] See Michael E. Porter, *Competitive Strategy*, ch. 13 (Free Press, 1980); and Michael E. Porter, "Competition in Global Industries" (Cambridge Mass.: Harvard Graduate School of Business Administration, 1985).

mance, thereby bringing new customers (and competitors) into a market. Finally, the technological changes can increase interrelationships among industries. In industries such as financial services, computers, and telecommunications, technological change is blurring industry boundaries and folding whole industries together. In publishing, automated text processing and printing technologies have made shared printing operations more feasible for several different types of publications.

Technology can also narrow industry boundaries. Technological change may allow a firm to tailor the value chain to a particular segment. Thus segments can, in effect, become industries. Portable cassette players, for example, have become a full-fledged industry independent of larger cassette players and cassette players used in dictating. This has been due to technological advancements that improved their performance and widened their usage.

### Technological Change and Industry Attractiveness

While it is sometimes believed that technological change always improves industry structure, the previous discussion should make it clear that it is just as likely to worsen industry structure. If it raises entry barriers, eliminates powerful suppliers, or insulates an industry from substitutes, then technological change can improve industry profitability. However, if it leads to more buyer power or lowers entry barriers, it may destroy industry attractiveness.

The role of technological change in altering industry structure creates a potential conundrum for a firm contemplating innovation. An innovation that raises a firm's competitive advantage may eventually undermine industry structure, if and when the innovation is imitated by other competitors. Firms must recognize the dual role of technological change in shaping both competitive advantage and industry structure when selecting a technology strategy and in making technology investments.

## Technology Strategy

Technology strategy is a firm's approach to the development and use of technology. Although it encompasses the role of formal R&D organizations, it must also be broader because of the pervasive impact of technology on the value chain. Because of the power of technological change to influence industry structure and competitive advantage, a firm's technology strategy becomes an essential ingredient in its overall competitive strategy. Innovation is one of the principal ways of attacking well-entrenched competitors. However, technological strategy is only one element of overall competitive strategy, and must be consistent with and reinforced by choices in other value activities. A technological strategy designed to achieve uniqueness in product performance will lose much of its impact, for example, if a technically trained sales force is not available to explain the performance advantages to the buyer and if the manufacturing process does not contain adequate provisions for quality control.

Technology strategy must address three broad issues:

- What technologies to develop
- Whether to seek technological leadership in those technologies
- The role of technology licensing

Choices in each area must be based on how technology strategy can best enhance a firm's sustainable competitive advantage.

## The Choice of Technologies to Develop

At the core of a technology strategy is the type of competitive advantage a firm is trying to achieve. The technologies that should be developed are those that would most contribute to a firm's generic strategy, balanced against the probability of success in developing them. Technology strategy is a potentially powerful vehicle with which a firm can pursue each of the generic strategies. Depending on which generic strategy is being followed, however, the character of technology strategy will vary a great deal, as shown in Exhibit 1.

In many firms, R&D programs are driven more by scientific interests than by the competitive advantage sought. It is clear from Exhibit 1, however, that the primary focus of a firm's R&D programs should be consonant with the generic strategy that is being pursued. The R&D program of a cost leader, for example, should include a heavy dose of projects designed to lower cost in all value activities that represent a significant fraction of cost, as well as projects to reduce the cost of product design through value engineering. R&D aimed at product performance by a cost leader must be aimed at maintaining parity with competitors or the goals of R&D will be inconsistent with the firm's strategy.

Another important observation from Exhibit 1 is that both product and process technological change can have a role in supporting each of the generic strategies. Firms often incorrectly assume that process technological change is exclusively cost-oriented and product technological change is intended solely to enhance differentiation. Product technology can be critical in achieving low cost, and changes in process technology may be the key to differentiation (a favorite tactic of Japanese companies).

It is also important that a firm's technological strategy extend *beyond* product and process R&D as they are traditionally defined. Technology pervades a firm's value chain and its relative cost and differentiation are a function of the entire chain. Thus a systematic examination of all a firm's technologies will reveal areas in which to reduce cost or enhance differentiation. The information system department may have more impact on technological change in a firm today than the R&D department, for example. Other important technologies such as transportation, materials handling, communications, and office automation also deserve more than ad hoc or informal attention. Finally, development in all technological areas must be coordinated to ensure consistency and exploit interdependencies among them.

Crown Cork and Seal provides a good example of the link between technology strategy and competitive advantage. Crown focuses on select customer industries and provides cans together with highly responsive service. Crown does little or no basic research and does not pioneer new products. Rather, its R&D department is organized to solve specific customer problems on a timely basis, and to imitate successful product innovation rapidly. Crown's R&D approach, then, closely supports its focus strategy. Its technological policies are quite different from those of American Can or Continental Group, which supply broad lines of packaging in addition to cans. American and Continental invest heavily in research for basic materials and new products.

The selection of specific technologies in the value chain on which to concentrate development effort is governed by the link between technological change and competitive advantage. A firm should concentrate on those technologies that have the greatest *sustainable* impact on cost or differentiation, either directly or through meeting the other tests described earlier. These tests allow a ranking of technological changes that would yield the greatest competitive benefit. The cost of improving the technology must be balanced against the benefit, as well as the likelihood that the improvement can be achieved.

Firms often confront a choice between attempting to improve an established technology for performing a value activity or investing in a new one. In aluminum smelting, for example, a firm might concentrate on improving the Hall-Heroult process now in use, or it might attempt to develop carbothermic reduction. Technologies seem to go through a life cycle in which early major improvements give way to later incremental ones. The cost/benefit tradeoff in improving mature technologies may be less (though perhaps more certain) than that in improving newer technologies.

**Successful technological leaders pay close attention to their stock of R&D skills.**

This can be a dangerous assumption, however, that is self-fulfilling. A technology can be assumed to be mature only with great caution. Major improvements in the efficiency of the Hall-Heroult process are occurring today, for example, despite the fact that it was developed prior to 1900. Similarly, the fuel efficiency of low-speed diesel engines has risen significantly since 1974. Diesel technology is also over 80 years old and widely regarded as mature compared with gas turbines, yet diesels have actually increased their lead over turbines. In both these examples, the rapid rise in energy prices stimulated active attention to fuel efficiency. Greater attention to improving the technologies was coupled with improvements in materials technology, instrumentation, and electronics that allowed better process control, higher temperatures, and other benefits.

Most products and value activities embody not one technology but several technologies or subtechnologies. It is only *a particular combination* of subtechnologies that can be assumed to be mature, not individual subtechnologies themselves. Significant changes in any one of the subtechnologies going into a product or process may create new possibilities for combining them that produce dramatic improvements, such as those achieved in smelting and low-speed diesel engines. The advent of microelectronics, a subtechnology that can be applied to many other technologies, is having a profound effect on many industries through unlocking possibilities for new technological combinations.

Thus in choosing among technologies to invest

**EXHIBIT 2**
**Technological Strategy and Competitive Advantage**

| | Technological Leadership | Technological Followership |
|---|---|---|
| Cost Advantage | Pioneer the lowest-cost product design<br>Be the first firm down the learning curve<br>Create low-cost ways of performing value activities | Lower the cost of the product or value activities by learning from the leader's experience<br>Avoid R&D costs through imitation |
| Differentiation | Pioneer a unique product that increases buyer value<br>Innovate in other activities to increase buyer value | Adapt the product or delivery system more closely to buyer needs by learning from the leader's experience |

in, a firm must base its decisions on a thorough understanding of each important technology in its value chain and not on simple indicators such as age. Sometimes all that is necessary to produce technology improvement is effort and investment, as both examples illustrate. Efforts at improving an older technology can sometimes be futile. In such instances the best course of action is to attempt to leapfrog it. The decision by a firm to discard its own technology may be difficult, particularly if it was developed in-house, but such a choice may be essential to maintaining the firm's competitive position. In other cases, advances in subtechnologies may allow improvement in the existing technology.

The choice of technologies to develop should not be limited to those few where there are opportunities for major breakthroughs. Modest improvements in several of the technologies in the value chain, including those not related to the product or the production process, can add up to a greater benefit for competitive advantage. Moreover, cumulative improvements in many activities can be more sustainable than a breakthrough that is noticeable to competitors and becomes an easy target for imitation. The success of Japanese firms in technology is rarely due to breakthroughs, but to a large number of improvements throughout the value chain.

## Technological Leadership or Followership

The second broad issue a firm must address in technology strategy is whether to seek technological leadership. The notion of technological leadership is relatively clear—a firm seeks to be the first to introduce technological changes that support its generic strategy. Sometimes all firms that are not leaders are viewed as technological followers, including firms that disregard technological change altogether. Technological followership should be a conscious and active strategy in which a firm explicitly chooses not to be first on innovations, as that is the sense in which the strategy is examined here.

While technological leadership is often thought of in terms of product or process technology, the issue is much broader. Leadership can be established in technologies employed in any value activity. The discussion here is directed at the choice between pioneering innovation in any value activity and waiting for others to pioneer.

The decision to become a technological leader or follower can be a way of achieving either low cost or differentiation, as illustrated in Exhibit 2.

Firms tend to view technological leadership primarily as a vehicle for achieving differentiation, while acting as a follower is considered the approach to achieving low cost. If a technological leader is the first to adopt a new lower-cost process, however, the leader can become the low-cost producer. Or if a follower can learn from the leader's mistakes and alter product technology to meet the needs of buyers better, the follower can achieve differentiation. There can also be more than one technological leader in an industry because of the many technologies involved and the different types of competitive advantage sought.

The choice of whether to be a technological leader or follower in an important technology is based on three factors[3]:

- *Sustainability of the technological lead.* The degree to which a firm can sustain its lead over competitors in a technology.
- *First-mover advantages.* Gains a firm reaps from being the first to adopt a new technology.
- *First-mover disadvantages.* Losses a firm faces by moving first rather than waiting for others.

All three factors interact to determine the best choice for a particular firm. Significant disadvantages of being a first mover may eliminate the desirability of taking the leadership role even if a firm can sustain its technological lead. Conversely, first-mover advantages may translate an initial technological lead into a sustainable competitive advantage elsewhere though the technological lead itself disappears. First-mover advantages and disadvantages occur most often in the

[3] The same ideas can be generalized to evaluate pioneering of any kind, such as pioneering in marketing or in the approach to procurement.

context of technological choices, but their significance for competitive strategy formulation extends beyond technological strategy. They address the wider question of how timing translates into competitive advantage or disadvantage and into entry and mobility barriers.

## Sustainability of the Technological Lead

Technological leadership is favored if the technological lead can be sustained because (1) competitors cannot duplicate the technology, or (2) the firm innovates as fast or faster than competitors can catch up. The second condition is important because technology often diffuses, requiring a technological leader to remain a moving target. Kodak, for example, has maintained leadership in amateur photography in large part through a succession of camera systems and film chemistries, most recently the disc camera, rather than possessing a single technology competitors could not match. If a technology lead cannot be sustained, technological leadership can only be justified if the initial lead translates into first-mover advantages because of the greater cost of leadership compared with followership.

The sustainability of a technological lead is a function of four factors:

☐ *The source of technological change.* The sustainability of a technological lead depends heavily on whether technology is being developed inside the industry or is coming from outside it. An important proportion of technological change comes from external sources such as suppliers, buyers, or completely unrelated industries. In many process industries, for example, the key source of technology is construction engineering firms that design production processes and build plants.

Where important sources of technology are external to an industry, sustaining a technological lead is generally more difficult. External technology sources decouple a firm's access to technology from its technological skills and R&D spending rate, because many companies can get access to external developments. Hence external technological changes act as an equalizer among competitors. Technological leaders in industries with key external sources of technology must capture the best of those sources through coalitions or exclusive arrangements in order to sustain their lead, or have a superior ability to adapt externally developed technology to the industry.

☐ *The presence or absence of a sustainable cost or differentiation advantage in technology development spending.* A technological lead is more likely to be sustainable if a firm has a cost or differentiation advantage in performing technology development. A firm's relative cost and uniqueness in technology development activities can be analyzed. For example, scale economies or learning effects in technological development give large-share or experienced firms an R&D cost advantage. Where the costs of developing a model are largely fixed, a firm with a large share has proportionally lower R&D costs than a smaller-share firm. It may thus be able to spend more money on R&D in order to maintain its technological lead without a cost penalty. This seems to have occurred in large turbine generators, where General Electric has outspent Westinghouse in absolute terms and maintained a significant technological lead although its R&D as a percentage of sales is still lower than Westinghouse's. Rising costs of product development in an industry also work in favor of large-share firms. As the cost of bringing out a new herbicide has risen to over $30 million, for example, the advantages of the industry leaders in agricultural chemicals are widening.

A firm's relative cost or effectiveness in performing technology development can also be strongly influenced by interrelationships among related business units within the parent company. Interrelationships can allow the transference of skills or sharing of costs of R&D activity. Technological leaders often aggressively pursue technological interrelationships, entering new business with related technologies. They also create mechanisms for R&D transfer among business units, and tend to invest at the corporate level in core technologies with a potential impact on many business units.

Different parts of the innovation cycle—basic research, applied research, development—tend to offer differing opportunities for sustainable cost advantages in R&D spending. Basic product innovation is often less scale-sensitive than the subsequent rapid introduction of new product types and the incorporation of new features. This is one of the reasons Japanese firms often overtake innovative U.S. firms that fail to maintain their lead in subsequent product improvements. Many successful technological leaders do not reap all of the benefits of scale, learning, or interrelationships in R&D in the form of higher profits, but reinvest to maintain their technological lead. They also exploit any scale or learning advantages in R&D by rapid new-model introduction. Honda, for example, has reinforced its competitive advantage in motorcycles through a continual stream of new models.

☐ *Relative technological skills.* A firm with unique technological skills vis-à-vis competitors is more likely to sustain its technological lead than those with comparable R&D personnel, facilities, and management. Technological skills will influence the output from a given rate of spending on technology, regardless of scale, learning, or interrelationship effects. Technological skills are a function of many factors—management, company culture, organizational structure and systems, company reputation with scientific personnel, and others. NEC Corporation, for example, is the company most highly ranked by engineering graduates in Japan. This contributes to its ability to attract the best graduates, reinforcing its strong R&D capability.

Successful technological leaders pay close attention to their stock of R&D skills. They avoid cutting back R&D staff in industry downturns or profit squeezes. They also seek out relationships with the leading scientific centers in appropriate fields, and attempt to develop an image as the best place to work for the types of research personnel that support their technology strategy.

☐ *Rate of technology diffusion.* A final important factor in determining the sustainability of a technological lead is the rate of diffusion of the leader's technology. Superior technological skills or cost advantages in performing R&D are nullified if competitors can easily copy what a firm develops. Diffusion of technology occurs continually, though at different rates depending on the industry. Some of the mechanisms for diffusion of a leader's technology are as follows:

- Direct observation by competitors of a leader's products (reverse engineering) and methods of operating
- Technology transfer through equipment suppliers or other vendors
- Technology transfer through industry observer such as consultants and the trade press
- Technology transfer through buyers who desire another qualified source
- Personnel losses to competitors or spinoff firms
- Public statements or papers delivered by a leader's scientific personnel

The diffusion of technology is often greater for the basic product and process innovations than it is for later improvements. Product and process refinements are more likely to be kept proprietary, particularly when based on process improvements. Since Japanese firms have emphasized constant process innovations, they often develop more sustainable advantages than U.S. or European firms that pioneered the process.

The rate of technological diffusion is partly intrinsic to an industry and partly under a firm's control. Most of the technology of a mobile-home producer, for example, is readily observable by examining the product. Disposable diaper technology diffuses more slowly because much of it hinges on the way the product is manufactured on customized machines. Some factors that slow down the rate of diffusion are as follows:

- Patenting of the firm's technology and related technologies
- Secrecy
- In-house development of prototypes and production equipment
- Vertical integration into key parts that embody or give clues to the technology
- Personnel policies that retain employees

Successful technological leaders are aggressive in trying to slow down diffusion. They patent extensively where patents can be obtained, and enforce them by *always* challenging infringers. They view all contact with outsiders, even buyers, as a threat to proprietary know-how. Plant tours are a rarity, and even buyers are not told about key innovations. Technological leaders are also often vertically integrated, building or modifying equipment in-house to preserve technology, and are discrete in public disclosures. It is striking how many of the firms known to be secretive are also technological leaders. These include DuPont, Kodak, Procter & Gamble, and Michelin.

## First-Mover Advantages

Technological leadership is strategically desirable when first-mover advantages exist. These allow a leader to translate a technology gap into *other* competitive advantages that persist even if the technology gap closes. First-mover advantages rest on the role of timing in improving a firm's position vis-à-vis sustainable sources of cost advantage or differentiation. In general terms, a first mover gets the opportunity to *define the competitive rules* in a variety of areas.

The most important types of potential first-mover advantages include the following, and can also apply to moving first into a geographic area or to pioneering that which does not involve technology per se[4]:

- *Reputation.* A firm that moves first may establish a reputation as the pioneer or leader, a reputation that emulators will have difficulty overcoming. Leadership places a firm, at least temporarily, in the position of being unique, which can produce long-term image benefits not available to others. A first mover also may be first to serve buyers and thus to establish relationships where there may be loyalty. The significance of any reputation advantage from leadership will depend on the credibility of a firm and its capacity to invest in marketing. A small company may not succeed in enhancing its reputation by moving first because it lacks the resources to publicize its lead.
- *Preempting a positioning.* A first mover may preempt an attractive product or market positioning, forcing competitors to adopt less desirable ones. Stouffer's preempted the gourmet concept in frozen entrees, for example. More broadly, a first mover gets an opportunity to shape the way a product is defined or marketed in a way that favors it.
- *Switching costs.* A first mover can lock in later sales if switching costs are present. In hospital management contracts, for example, the pioneer that signed up hospitals first gained a significant edge in contract renewals because of the substantial costs to the hospital of changing management firms. Switching would result in disruption caused by a new administrator, a new computer sytem, and other changes.
- *Channel selection.* A first mover may gain unique channel access for a new product or product generation. It can pick the best brokers, distributors, or retailers, while followers must either accept the second best, establish new channels, or persuade the first mover's channels to shift or divide their loyalties.
- *Proprietary learning curve.* A first mover gains a cost or differentiation advantage if there is a proprietary learning curve in value activities that are affected by the early move. The first mover begins down the learning curve first in the new technology, and may thus establish a durable cost or differentiation advantage if it can keep its learning proprietary.
- *Favorable access to facilities, inputs, or other scarce resources.* A first mover can often enjoy at least a temporary advantage in access to purchased inputs or other resources because it contracts for them before market forces reflect the full impact of the change it is pioneering. A firm may get its pick of sites for facilities, for example, or favorable deals with raw material suppliers eager for new business. A good case in point is the airline industry, where the early no-frills carriers have acquired cheap surplus aircraft and/or low-cost terminal space, and hired out-of-work pilots. Market forces will eventually bid up the prices of these inputs as the no-frills strategy is imitated.

  Other examples come from several extractive industries. New mines and processing plants are being constructed in increasingly remote locations, raising infrastructure costs. They are also being forced to bear higher environmental costs. Early movers, then, have lower costs.
- *Definition of standards.* A first mover can define the standards for technology or for other activities, forcing later movers to adopt them. These standards, in turn, make the firm's position more sustainable. For example, RCA defined the standards in color TV which meant that competitors had to go down the learning curve RCA had already started down rather than create a new one.
- *Institutional barriers.* A first mover may enjoy institutional barriers against imitation. The first mover may secure patents, or being first into a country may give it special status with government. Institutional factors often facilitate a first mover's ability to define standards as well.
- *Early profits.* In some industries, a first mover may be in a position to enjoy temporarily high profits from its position. It may be able to contract with buyers at high prices during early scarcity of a new item, for example, or sell to buyers who value the new technology very highly.

Successful technological leaders actively pursue first-mover advantages rather than rely solely on their technological edge. They take every op-

[4] Some of these advantages also apply to other early movers besides the first.

portunity to use their technological leadership to define the competitive rules in ways that benefit them. They invest in marketing to reinforce the reputation benefits of being the leader, and price aggressively to make early sales to buyers with the highest switching costs. It is striking how many firms that were first movers have remained leaders for decades. In consumer goods, for example, such leading brands as Crisco, Ivory, Life Savers, Coca-Cola, Campbell's, Wrigley, Kodak, Lipton, and Goodyear were leaders by the 1920s.

First-mover advantages can be dissipated through aggressive spending by later entrants unless the first mover invests to capitalize on them. As happened to Bowmar in electric calculators, small pioneers are often overwhelmed by later entrants. Their lead is overcome not because first-mover advantages were not present, but because the resources were not present to exploit them. IBM in personal computers is providing a more recent example of a late mover succeeding against early movers based on resources and interrelationships with other business units.

Where the first mover does not have adequate resources, the first early mover with resources can often be the firm to gain the benefits of first-mover advantages. In minicomputers, for example, Digital Equipment did not introduce the first machine but gained many first-mover advantages because it was the first to develop the product aggressively. Digital invested heavily to exploit its advantages through expanding its product line, going down the learning curve, and increasing the size of its sales force. A similar situation occurred in video cassette recorders, where Ampex pioneered the product but Japanese firms invested heavily to improve the technology, produce units cheaply, and translate their lead into first-mover advantages.

## First-Mover Disadvantages

First movers often face disadvantages as well as advantages. First-mover disadvantages stem from two broad sources, the costs of pioneering and the risk that conditions will change.

☐ *Pioneering costs.* A first mover often bears substantial pioneering costs including the following[5]:

- Gaining regulatory approvals
- Achieving code compliance
- Educating buyers
- Developing infrastructure in areas such as service facilities and training
- Investing in the development of complementary products
- Absorbing the high costs of early inputs because of scarcity of supply or small scale of needs.

Pioneering costs vary widely depending on the type of technological innovation and can be reduced by sharing them with good competitors. However, they are often unavoidable for the first mover.

☐ *Demand uncertainty.* A first mover bears the risk of uncertainty over future demand. It must put capacity in place first, while later movers can base their decisions on more current information. Though committing before competitors has some advantages, it also has some significant risks. RCA was the first mover into color TV, for example, betting on an early takeoff of the new technology. Later movers learned from RCA's experience that demand for color sets was some years away and avoided a period of losses.

☐ *Changes in buyer needs.* A first mover is vulnerable if buyer needs change and its technology is no longer valued. A first mover's reputation advantage may also be eliminated if buyer needs change and the first mover is identified with the old generation of technology. Unless buyer needs shift radically, substantially changing the technology required to serve them, however, a first mover can maintain its lead by modifying technology over time.

☐ *Specificity of investments to early generations or factor costs.* A first mover may be at a disadvantage if early investments are specific to the current technology and cannot be easily modified for later generations. In semiconductors, for example, Philco moved early for leadership with a large automated plant. It enjoyed a period of success, but the later development of a different manufacturing process for semiconductor chips made its earlier investment obsolete. Similarly, the early mover will be disadvantaged if its process reflected factor costs or factor quality that have changed.

☐ *Technological discontinuities.* Technological discontinuities work against the first mover by making obsolete its investments in the established technology. Technological discontinuities are major shifts in technology that a first mover may be ill prepared to respond to

[5] The costs of pioneering are discussed in the context of an emerging industry in Porter, *Competitive Strategy*, ch. 10.

given its investment in the old technology. Discontinuity favors the fast follower who does not bear the high cost of pioneering. Where technology evolves along a relatively continous path, however, a first mover's head start is an advantage. It can transfer learning from the old technology to the new and stay ahead on the learning curve.

- *Low-cost imitation.* A first mover exposes itself to followers who may be able to imitate the innovation at lower cost than the cost of innovating. Followers often have to bear some costs of imitation and adaptation, however, which work to the benefit of the first mover.

## Licensing of Technology

The third broad issue in technology strategy is technology licensing, a form of coalition with other firms.[6] Firms with a unique technology are often asked for licenses, or are forced to license by government regulations. Licensing is also a way to gain access to technology. Where technology is an important source of competitive advantage, decisions on licensing are vital. Yet many firms have squandered technology-based competitive advantages through inappropriate licensing decisions.

### When Should a Firm License?

If technology is a source of competitive advantage, a firm must treat licensing other firms as a risky step that should be taken only under special conditions. Licensing fees are rarely large enough to offset a loss of competitive advantage. However, awarding licenses may be strategically desirable under a number of circumstances.

- *Inability to exploit the technology.* Awarding licenses is appropriate if a firm cannot exploit the technology itself. This may be because a firm lacks resources or skills to establish a sustainable position, or it is harvesting the business unit involved, or competitors are too entrenched to yield market position. The first motivation for licensing is at work today in biotechnology and electronics, where creative start-up firms lack the capability to commercialize innovations. Even where the firm has substantial resources, it may be unable to gain a substantial share on the basis of its new technology because competitors are too committed or because of government demands for local ownership. The former seems to be one reason why Standard Brands widely licensed its technology for high fructose corn syrup, a sugar substitute.

  Where the firm cannot exploit the market itself, failure to license will create the motivation for competitors to invent around its technology. Eventually one or more competitors may succeed, and the firm will be left with a small market position. By licensing, however, competitors gain a cheaper and less risky alternative to investing in their own technology. Thus, instead of being imitated, the firm licensing its technology may be able to set the standard and collect licensing royalties in addition to profits from its own market position.
- *Tapping unavailable markets.* Licensing may allow a firm to gain some revenue from markets otherwise unavailable to it. This includes other industries where the technology is valuable but where the firm has little possibility of entering, or other geographic markets a firm cannot or does not want to enter.
- *Rapidly standardizing the technology.* Licensing may accelerate the process by which the industry standardizes on a firm's technology. If several firms are pushing the technology, licensing not only will legitimize it but also may accelerate its development. The pioneers of the VHS and Beta formats in video cassette recorders licensed them widely to promote standardization, for example, because standardization was so critical to increasing the availability of software.
- *Poor industry structure.* Licensing can be desirable where industry structure is unattractive. In such instances, a firm may be better off collecting royalties than investing in a market position that will not yield high returns. The more bargaining power a firm has in extracting high licensing fees, the more attractive it is to license and retain only a modest position in the industry for itself.
- *Creating good competitors.* Licensing may be a vehicle for creating good competitors, which in turn can play a variety of important roles such as stimulating demand, blocking entry, and sharing the costs of pioneering. Magnavox widely licensed its video game patents, for example, reasoning correctly that it could expand the market faster through encouraging competitors to introduce a wide range of products. Entry barriers were also low enough

[6] Another possible form of coalition is joint technology development with another firm. Joint development involves many of the same issues as licensing.

that Magnavox was unlikely to be able to develop a sustainable position.

- *Quid pro quo.* A firm may award a license in return for a license of another firm's technology, as AT&T and IBM are prone to do. A firm must insure that the trade is a fair one, however.

### Choosing a Licensee

Firms should award licenses only to noncompetitors or to good competitors. Since noncompetitors can rapidly become competitors, a firm must minimize the risk of this through the terms of the license or convince itself that a noncompetitor will remain so. To insure that a potential licensee is a noncompetitor, a firm must consider not only the existing markets or segments it serves, but also markets it might want to enter in the future. Licensing buyers to make some of their needs internally can sometimes be desirable to shrink the available market for competitors or potential competition.

Where a firm licenses a competitor, it should be a good competitor and not just anyone. The same is true when a firm is compelled to license by government. A firm ideally should license noncompetitors that would be good competitors if they later decided to enter the industry. Similarly, licenses should contain renewal clauses, when possible, in order to avoid a perpetual commitment to turn over technology in the event that a licensee becomes a competitor.

### Pitfalls in Licensing

Firms often hurt rather than help their competitive position by awarding licenses. The two most common pitfalls in licensing are to create competitors unnecessarily in the process, and to give away a firm's competitive advantage for a small royalty fee. Licensing often is an easy way of increasing short-term profits, but it can result in a long-term erosion in profits as a firm's competitive advantage dissipates.

Firms often fail to perceive who their potential competitors are, and thus award licenses that come back to haunt them. They may license foreign firms that later enter their home markets. Similarly, many firms have licensed firms in other industries only to have the licensees ultimately enter their own industry. Often, the process by which a license agreement sours can be quite subtle. A firm licenses another amid talk of a long-term alliance that will strengthen both. Over time, though, the licensee learns everything possible, not only about the licensor's technology but about its other value activities. The licensee then decides it can attack the licensor successfully and becomes a serious competitor. Asian firms, which have licensed widely, have sometimes used licenses in this way.

## Technological Evolution

Since technological change has such a powerful role in competition, forecasting the path of technological evolution is extremely important to allow a firm to anticipate technological changes and thereby improve its position. Most research on how technology evolves in an industry has grown out of the product life cycle concept. According to the life cycle model, technological change early in the life cycle is focused on product innovations, while the manufacturing process remains flexible. As an industry matures, product designs begin to change more slowly and mass production techniques are introduced. Process innovation takes over from product innovation as the primary form of technological activity, with the aim of reducing the cost of an increasingly standardized product. Finally, all innovation slows down in later maturity and declines as investments in the various technologies in the industry reach the point of diminishing returns.

The product life cycle model has been refined by the work of Abernathy and Utterback.[7] Initially, in their framework, product design is fluid and substantial product variety is present. Product innovation is the dominant mode of innovation, and aims primarily at improving product performance instead of lowering cost. Successive product innovations ultimately yield a "dominant design" where the optimal product configuration is reached. As product design stabilizes, however, increasingly automated production methods are employed, and process innovation takes over as the dominant innovative mode to lower costs. Ultimately, innovation of both types begins to slow down. Recently, the concept of "dematurity" has been added to the Abernathy[8] framework to recognize the possibility that major technological changes can throw an industry back into a fluid state.

While these hypotheses about the evolution of technology in an industry are an accurate portrayal of the process in some industries, the pattern does not apply in every industry. In indus-

[7] See William J. Abernathy and James M. Utterback, "Patterns of Industrial Innovation," *Technology Review*, June-July 1978.

[8] William J. Abernathy, Kim B. Clark, and Alan M. Kantrow, *Industrial Renaissance* (New York: Basic Books, 1983).

tries with undifferentiated products (e.g., minerals, many chemicals), the sequence of product innovations culminating in a dominant design does not take place at all or takes place very quickly. In other industries (e.g., military and commercial aircraft, large turbine generators), automated mass production is never achieved and most innovation is product-oriented. Technology evolves differently in every industry, just as other industry characteristics do.[9] The pattern of technological evolution is the result of a number of characteristics of an industry and must be understood in the context of overall industry structural evolution. Innovation is both a response to incentives created by the overall industry structure and a shaper of that structure.

Technological evolution in an industry results from the interaction of a number of forces:

- *Scale change.* As firm and industry scale increase, new product and process technologies may become feasible.
- *Learning.* Firms learn about product design and how to perform various value activities over time, with resulting changes in the technology employed.
- *Uncertainty reduction and imitation.* There are natural pressures for standardization as firms learn more about what buyers want and imitate each other.
- *Technology diffusion.* Technology is diffused through a variety of mechanisms described earlier.
- *Diminishing returns to technological innovation in value activities.* Technologies may reach limits beyond which further improvement is difficult.

The product life cycle pattern of technological evolution would result if these forces interacted in the following way. Through successive product innovation and imitation, the uncertainty about appropriate product characteristics is reduced and a dominant design emerges. Growing scale makes mass production feasible, reinforced by the growing product standardization. Technological diffusion eliminates product differences and compels process innovation by firms in order to remain cost competitive. Ultimately, diminishing returns of process innovation set in, reducing innovative activity altogether.

Whether the life cycle pattern of technological innovation or some other pattern will occur in a particular industry will depend on some particular industry characteristics:

- ☐ *Intrinsic ability to physically differentiate.* A product that can be physically differentiated, such as an automobile or machine tool, allows many possible designs and features. A less differentiable product will standardize quickly and other forms of technological activity will be dominant.
- ☐ *Segmentation of buyer needs.* Where buyer needs differ substantially, competitors may introduce more and more specialized designs over time to serve different segments.
- ☐ *Scale and learning sensitivity.* The extent to which the industry technologies are scale- or learning-sensitive relative to industry size will influence the pressure for standardization. High scale economies will create pressure over time for standardization despite segmented buyer needs, while low scale economies will promote the flowering of product varieties.
- ☐ *Technological linkage among value activities.* The technologies in the product and in value activities are often linked. Changing one subtechnology in the product often requires changing others, for example, while changing the production process alters the needs in inbound and outbound logistics. Technological linkages among value activities will imply that changes in one activity will beget or be affected by technology changes in others, affecting the pattern of technological change.
- ☐ *Substitution logic.* The pressure from substitutes is an important determinant of the pattern of technological evolution. Whether substitutes are threatening based on cost or differentiation will lead to a corresponding emphasis in technological change. For example, the initial challenge for disposable diapers was to bring their cost into proximity with those of cloth diapers and diaper services. A great deal of early innovation was in manufacturing methods.
- ☐ *Technological limits.* Some technologies offer much richer possibilities for cost or performance improvement than others. In products like commercial aircraft and semiconductors, for example, diminishing returns from efforts at product innovation come relatively slowly. The technological limits in the various technologies and subtechnologies in the value chain will thus affect the path of technological change.
- ☐ *Sources of technology.* A final industry characteristic that shapes the pattern of tech-

[9] See Porter, *Competitive Strategy*, ch. 8, for a broader discussion of industry evolution and its causes.

nological change is the source of the technologies employed in the industry. The path of technological change is usually more predictable when industry-specific technologies are dominant and the impact of technologies emanating from outside the industry is small.

## Continuous vs. Discontinuous Technological Evolution

The pattern of technological evolution differs widely among industries based on whether technological change is incremental or subject to discontinuity. Where there is incremental technological change, the process is more likely to be determined by actions of industry participants or spin-offs of these participants. External sources of technology are likely to be existing suppliers to an industry.

Where there is technological discontinuity, the sources of technology are much more likely to be outside the industry. Entirely new competitors or new suppliers to the industry are more likely to have an important role. Technological discontinuity also tends to decouple the pattern of technological innovation from the state of industry maturity, because outside sources of technology are less responsive to industry circumstances than the R&D departments of industry participants.

Technological discontinuity creates the maximum opportunity for shifts in relative competitive position. It tends to nullify many first-mover advantages and mobility barriers built on the old technology. Discontinuity also may require wholesale changes in the value chain rather than changes in one activity. Hence a period of technological discontinuity makes market positions more fluid, and is a time during which market shares can fluctuate greatly.

## Forecasting Technological Evolution

A firm can use this framework to forecast the likely path of technological evolution in its industry. In commercial aircraft, for example, the product is highly differentiable. However, there are large scale economies in product design which limit the number of product varieties that are developed. The flexibility of production means that the production process is no barrier to continuous and long-lasting efforts at product innovation. Thus the aircraft industry is one where we would expect continuous product R&D. The flexibility of the production process would also allow us to expect a continuous search for new materials and components that would be much less likely in an industry with heavy automation.

With some insight into the likely pattern of technological evolution, a firm may be able to anticipate changes and move early to reap competitive advantage. However, there will always be uncertainty wherever technology is involved. Uncertainty over future technological evolution is a major reason why a firm may want to employ industry scenarios in considering its choice of strategies.

### Formulating Technological Strategy

The concepts in this article suggest a number of analytical steps in formulating technological strategy in order to turn technology into a competitive weapon rather than a scientific curiosity.

1. *Identify all the distinct technologies and subtechnologies in the value chain.* Every value activity involves one or more technologies. The starting point in formulating technological strategy is to identify all the technologies and subtechnologies, no matter how mundane, that are employed either by the firm or its competitors. In addition, a firm must gain a similar if not as deep an understanding of the technologies in its suppliers' and buyers' value chains, which often are interdependent with its own. Firms often focus on product technology or on technology in the basic manufacturing operation. They ignore technologies in other value activities and pay little attention to the technology for developing technology.
2. *Identify potentially relevant technologies in other industries or under scientific development.* Often, technologies come from outside an industry and such technologies can be a source of discontinuous change and competitive disruption in an industry. Each value activity must be examined to see if outside technologies are present that might be applicable. Information systems, new materials, and electronics should always be investigated thoroughly. All three are having a revolutionary impact in creating new technologies or allowing new technological combinations in old technologies.
3. *Determine the likely path of change of key technologies.* A firm must assess the likely direction of technological change in each value activity and in buyer and supplier value chains, including technologies whose sources

are unrelated to the industry. No technology should be assumed to be mature. Subtechnologies of it may be changing or maturity may be only a sign of little effort at technological innovation.

4. *Determine which technologies and potential technological changes are most significant for competitive advantage and industry structure.* Not all the technologies in the value chain will have significance for competition. The significant technological changes are those that meet these four tests:

   - Lower cost or raise differentiation directly and are sustainable
   - Shift cost or uniqueness drivers in favor of a firm
   - Lead to first-mover advantages
   - Improve overall industry structure

   A firm must isolate these technologies and understand how they will affect cost, differentiation, or industry structure. Supplier and buyer technologies are often among the most important in this respect. Critical technologies will be those with a major effect on cost or differentiation, and where a technological lead is sustainable.
5. *Assess a firm's relative capabilities in important technologies and the cost of making improvements.* A firm must know its relative strengths in key technologies, as well as make a realistic assessment of its ability to keep up with technological change. Considerations of pride should not obscure such an assessment or a firm will squander resources in an area in which it has little hope of contributing to its competitive advantage.
6. *Select a technology strategy encompassing all important technologies that reinforce the firm's overall competitive strategy.* Technology strategy must reinforce the competitive advantage a firm is seeking to achieve and sustain. The most important technologies for competitive advantage are those where a firm can sustain its lead, where drivers of cost or differentiation are skewed in its favor, or where the technology will translate into first-mover advantages.

   Included in a firm's technological strategy should be the following:

   - A ranking of R&D projects that reflects their significance for competitive advantage. No project should be approved without a rationale describing its effect on cost and/or differentiation.
   - Choices about technological leadership or followership in important technologies.
   - Policies toward licensing that enhance overall competitive position rather than reflect short-term profit pressure.
   - Means of obtaining needed technology externally, if necessary, through licenses or otherwise.

7. *Reinforce business unit technology strategies at the corporate level.* While technology is ultimately linked to individual business units, a diversified firm can play two key roles to strengthen its overall technological position. The first is to assist in monitoring technologies for possible business unit impacts. A corporate group can usefully invest in identifying and analyzing all streams of technology that might have wide impact, and then feed that information to business units. A corporate role in monitoring such technologies as information systems, office automation, factory automation, materials, and biotechnology is often highly desirable.

   The second key corporate role in technological strategy is in finding, exploiting, and creating technological interrelationships among business units. A business unit can gain competitive advantage if it can exploit technological interrelationships with others. The following specific actions at the corporate, section, or group level can strengthen a firm's overall technological position:

   - Identify core technologies for the corporation that impact many units.
   - Ensure that active and coordinated research efforts are under way, and that technology migrates among business units.
   - Fund corporate research in important technologies to create a critical mass of knowledge and people.
   - Use acquisitions or joint ventures to introduce new technological skills to the corporation, or to invigorate existing skills.