There are at least three perspectives on the interaction between strategy and technology. The first focuses on the effect of current technology on current strategy of the firm, the second on the effect of current strategy on future technology, and the third on the effect of current technology on future strategy. The essence of these effects are respectively: strategy capitalizes on technology, strategy cultivates technology, and technology drives cognition of strategy. As we go from the first to the third, it becomes less conventional, less oriented to economics, more development-oriented and more process and organization-oriented. Past strategy research has been dominated by the first perspective and thus has been too narrow and static. This paper tries to rectify this imbalance.

INTRODUCTION

Technology is the most fundamental of the core capabilities of a firm. It is a systematic body of knowledge about how natural and artificial things function and interact. It is a body of knowledge embodied in human brains and muscles, machines, and also in software and standard operating procedures of the organization. As such, it is inevitable that technology will become one of the central factors in deciding the firm’s strategy. Diversification strategy, for example, depends on extensible technology which the firm has accumulated (Chandler, 1962; Rumelt, 1974; Teece, 1982). Many strategists warn that technological turning points are often the times when the fortunes of many firms change dramatically (Cooper and Schendel, 1976; Foster, 1986).

Strategy, as it is used in this paper, means a dynamic design of the activities for the entire firm. It is fundamental policy which determines the basic framework of the various activities of the firm and the basic principles of its game plan in the marketplace. We do not use the term strategy as in 'technology strategy', which presumably means the basic policy the firm takes in the technology fields (Quinn, 1961; Quinn and Cavanaugh, 1964; Rosenbloom and Kantrow, 1982).

How strategy and technology interact with each other over time is the basic theme of this paper and is what we believe to be one of the fundamental themes in strategy research. We contend that, in the past, the relationship between strategy and technology has been treated in too static a way and in too narrow a sense. In most discussions, technology has been treated as a constraining factor that determines the current opportunity set for the firm. It is usually argued that the strategy that the firm wants to pursue is constrained by the technologically feasible set of actions, or the firm should invest in broadening that feasible set if it wants to take a strategy which requires
the broadened technological capability (Hofer and Schendel, 1978; Maidique and Patch, 1988; Porter, 1983, 1985). There is no denying that this is often a very sensible argument. Is it, however, the only possible argument?

In this common argument, the relationship between strategy and technology is essentially directional, and static. It is directional in the sense that a causal arrow goes only from technology to strategy, not vice versa. Said differently, technology determines strategy options. However, even when current, strategy seems to dictate the technology the firm needs, and thus the causal direction indicated is actually from technology to strategy. For the firm, a given technology determines a given strategy, and such a technological capability must first be acquired. This view is static in the sense that a contemporaneous fit must exist between strategy and technology. Current strategy has to match the firm’s current technology. No dynamic or developmental argument enters here.

When we begin to think dynamically, there are three kinds of relationships that are conceivable between strategy and technology:

1. between current strategy and current technology,
2. between current strategy and future technology,
3. between future strategy and current technology.

The first relationship is the one which is most commonly discussed as mentioned above. In the second case, it is the influence of the current strategy on the future technology of the firm that is at issue. In the third case, it is postulated that current technology can affect future strategy of the firm. We will review the kind of interaction issues in each of the three cases below. Trying to capture the essence of each interaction, we will title the three cases respectively as:

1. (Current) Strategy capitalizes on (current) technology,
2. (Current) Strategy cultivates (future) technology,
3. (Current) Technology drives cognition of (future) strategy.

STRATEGY CAPITALIZES ON TECHNOLOGY

The first perspective on the (dynamic) interaction between strategy and technology focuses on the contemporaneous match between strategy the firm wants to take and the technology it possesses. Typical questions that strategists and researchers ask in this perspective include: How should technology be used as a tool to differentiate the firm from its competition? When should a new technology be introduced to the market? What type of strategic focus is most effective given the constraints on the technology available to the firm? How should the firm cope with technological innovation introduced by the competitors or technological trends in the industry?

Technology in these discussions can act on strategy in one of the three ways: (1) as weapons that the firm can utilize in their favor (Abell, 1980; Maidique and Patch, 1988; Porter, 1983, 1985), (2) as constraints to which they must adapt (Hofer and Schendel, 1978), or (3) as threats that they have to guard against and cope with (Cooper and Schendel, 1976; Foster, 1986; Abernathy, 1978; Tushman and Anderson, 1986; Anderson and Tushman, 1990). Strategy capitalizes on technology. As a weapon, the firm presumably has some technological advantage over competition and thus can capitalize on its technology. As a constraint, strategists have to find the best way to capitalize on the constrained, extant strategy. As a threat, technology forces the firm to match competition and the industry trend and, to do so, the firm once again has to make the best use of technological possibilities it possesses or can develop. Either the firm can or has to, i.e., active or passive, the strategy the firm develops capitalizes on technology that the firm has or tries to have.

In all three cases, a basic premise is that current strategy should make the best use of current technology of the firm and, often implicitly, should be within the technological limit of the firm. In this sense, contemporaneous matching between strategy and technology is advocated. Most of the past research on strategy and technology has been devoted to clarifying the logical structure of this contemporaneous matching (see, for example, Maidique and Patch (1988)).

Examples are too many to list exhaustively.
This seems to be the orthodoxy in strategy research and with good reason. This static matching or framing of strategy by technology is difficult enough to practice and it is the first order of business that the firm has to cope with. Even when research focuses on what type of technological development should be undertaken to fill certain strategic needs in the marketplace, it deals with contemporaneous matching of strategy and technology. This line of research may not treat the technological possibility of the firm as something fixed, but technology is still made to fit strategy contemporaneously.

In this sense, technology frames strategy. Technology determines or limits strategy as its environmental factor, either as weapons, constraints or threats, or strategy asks for certain technological developments because they frame the feasibility of strategy under consideration. Behind this type of reasoning lies an implicit assumption of independence between strategy and technology. As far as their respective internal logic is concerned, strategy and technology can remain intrinsically independent of each other, but have to be matched within the firm consciously so that they synchronize with each other to produce the best performance. Interaction appears in this perspective only in this sense of synchronic matching. Matching is done by adjusting two independent variables, strategy and technology (see, for example, Hayes and Wheelwright, 1979).

When observed over time, a series of efforts for synchronic matching may appear quite ‘dynamic’, but this is not dynamic interaction, only a dynamic sequence of static matching (see Figure 1). Of course, the way strategy is matched to technology may change over time. At some times, technology may give the firm competitive advantage (as their weapon) and later on it may become a threat (when the competitor changes the basic rule of technology games). Both strategy and technology change over time, but, within this perspective, current strategy does not affect future technology directly, nor does current technology affect future strategy in any explicit way. They are not truly interactive.

In reality, however, they are interactive. For example, the product portfolio that the firm currently has influences the kind of technology that the firm tries to maintain or develop and thus affects the firm’s future technological base available to the firm, for its next strategic moves. We now turn to more subtle, but truly dynamic, interactions in which current strategy affects future technology or current technology affects future strategy.

**STRATEGY CULTIVATES TECHNOLOGY**

Quite often, current strategic decisions have long-term implications for technology accumulation. For example, a decision to enter or strengthen a certain business, a typical strategic decision, forces the firm to invest in technology development to be competitive in that business. This is actually a requirement from contemporaneous matching that we mentioned in the previous section. This technology development effort can bring to the firm not only a set of competitive weapons effective in that business, but also a deeper technological base applicable in other businesses too. Technology is often extensible.

Casio, once a small Japanese calculator maker has extended its technology from digital watches and electronic musical instruments to office information machines. It has done this through its development of LSI (large scale integrated circuit) design capability necessary to its remaining competitive in the calculator business. By succeeding in this technological accumulation, Casio not only became very competitive in calculators, but gained a very important technological base to extend its product portfolio into other businesses. Its current competitive strategy in calculators affected its future technology in LSI design. Many other calculator manufacturers decided to buy standard LSI chips and thus decided not to invest in LSI technology accumulation. This decision not only affected their competitiveness in calculators but also their future growth potentials.

This is a very good example of strategy

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1 Needless to say, we do not imply that technology would independently evolve without any external influence, like government funding of R&D or a major discovery in science. Independence here means independence from strategy.

2 For a more detailed description, see Itami (1987).
cultivating technology. It is not, however, limited to the cases of R&D efforts in the lab required for a certain current strategy. More mundane-looking accumulations of technological bases can occur during the implementation process of current strategy. A good example is the case of Toyota establishing a lean production system. Toyota’s just-in time system was needed to cope with the difficult production planning requirements it encountered when it had to produce a variety of vehicles from trucks to passenger cars, all in small quantities, using limited production facilities. To remain viable in the Japanese automobile industry after World War II, Toyota did not have much choice other than to go after a wide product line with small market volumes for each product. To implement this strategy with efficiency, it had to devise a new production system, which later became one of the bases of its international competitiveness. Building an internationally competitive production base was not Toyota’s original intention, but it helped Toyota’s later strategy immensely.3

In essence, pursuit of contemporaneous fit between technology and current strategy can lead to technology accumulation with much greater future potentials than necessary to meet current needs. This can occur either through a particular technological development project, such as Casio’s, or from a day-to-day implementation of current strategy, as in Toyota. Either way, the essence is that strategy implementation processes affect technology accumulation processes (see Figure 2).

We can summarize these cases as ‘current strategy cultivating future technology’. It can

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3 For a more detailed description of the historical development of Toyota’s strategy and production system, see Cusumano (1985) and Itami et al. (1988).
occur when: (1) contemporaneous matching between strategy and technology is pursued in earnest, but at the same time (2) the technology being accumulated is greater in its potential than current short-term needs. The catch here is if strategists are aware of this logic, a somewhat counterintuitive strategy recommendation may prove valuable, like 'try to enter into some business in which the firm may not have a competitive advantage now'. It is logical only when this strategic decision can lead to efforts to cultivate valuable technology for the future, within reasonable cost.

**Origin of research**

The origin of research on dynamic interaction of current strategy on future technology goes back to Penrose (1959) and Chandler (1962), or even to the findings of the learning curve by the U.S. Air Force production workshops in the 1920s (see Wright, 1936). Penrose argued that a firm accumulates various unutilized resources (often unintentionally) as it grows and these resources bring further potential for growth. Chandler also pointed out that resources accumulated from past business activities become driving forces behind a firm's diversification strategy. Learning curve phenomena, in which skills of workers improve by repeated performance of similar tasks, can also be considered as a way in which valuable resources accumulate from current or past business activities within the firm.

Research in the 1950s and 60s stressed the fact that daily corporate activities not only consume resources but also create some. Later on some
researchers began to argue further that strategy should utilize this resource creation aspect of the business activity more purposefully. They maintained that the grand design of business activity from now to the future, i.e., strategy, should be constructed with resource accumulation for the future as one of its goals. We will review some of this research.

Experience curve

One of the first in this line of research was the experience curve strategy developed by the Boston Consulting Group (1968). They generalized learning curve phenomena which had been reported in manufacturing processes in such industries as aircraft assembling and contended that similar accumulation and sharing of experiences was possible in engineering, marketing, accounting and so forth. They renamed the concept experience curve theory to emphasize its broad applicability.

The strategic implications of experience curve theory are relatively straightforward and well-known. Doing more production and selling than one’s competitors, i.e., generating more business volume and greater market share, leads to greater accumulation of experience, which in turn may give the firm competitive advantage in terms of reduced cost. Pricing of a product should not be based strictly on the current level of product cost, but should consider the effect of price on volume and market share so that the firm can accumulate greater experience for the future. Despite some warnings against too much reliance on the experience effect, this concept has had wide influence both on practitioners and researchers (Abernathy and Wayne, 1974; Hayes and Wheelwright, 1984). In fact, in the semiconductor industry, this concept has been widely used and Texas Instruments and Japanese manufacturers have gained dominant positions partly by following the pricing strategy from the experience curve.

Of course, the experience effect does not materialize automatically. Careful efforts by management for accelerating learning and organizing to utilize the accumulated experience are necessary. In strategy formulation, organizational capability for learning becomes an important variable since ‘experience’ is not only limited to better skills by the individual worker but is broadened to capability enrichment for the organization as a whole through experiences from many daily activities. Thus, designing new production processes, better product design which makes production easier, and better communication between R&D and production, all become important beneficiaries or drivers of organizational learning (Adler and Clark, 1991). Looking back from this vantage point, the experience effect concept and the organizational learning behind it is one of the predecessors of recent interests in strong overlap between R&D and production (Imai, Nonaka, and Takeuchi, 1985; Clark and Fujimoto, 1991).

Invisible assets and core competence

Research on the experience effect later became the basis of the growth/share matrix and the product portfolio management (PPM), for strategic management of a diversified firm (Henderson, 1970; Abell and Hammond, 1979). Use of the growth/share matrix and PPM became fashionable in the late 70s and the early 80s. The main lesson that PPM brought from the experience curve concept is that a greater market share or competitive strength in one business is the basis of greater cash flow from that business. The firm should try, PPM says, to have a dynamic balance of cash flows from various businesses, some contributing current cash flow and others capitalizing on this cash flow for investment for the future. The main focus is cash flow interaction among businesses. The original experience effect concept, however, contained a wider discussion than mere cash flow. It had some arguments on noncash synergistic effects among businesses, such as shared experience and shared technology. It was only in the mid 80s that research appeared centered around diverse resource accumulation chains and intertemporal synergistic effects among different businesses. Some of them offered a more comprehensive strategic logic which argued that the current strategy of a firm should be formulated with resource accumulation for the future as one of

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4 Retrospective evaluation of PPM and other portfolio management techniques are abundant in text books such as those by Hatten and Hatten (1987) and McNamee (1985). For criticisms on the analytical tools of strategic management, see Peters and Waterman (1982) and Prahalad and Hamel (1990).
Interaction Between Strategy and Technology

its basic goals. This was advocated even though the current strategy may not be a winner in the short-term competitive game (Itami, 1983, 1984, 1987; Hamel and Prahalad, 1989; Prahalad and Hamel, 1990). One of the most fundamental resources to accumulate, of course, is technology.

Itami (1983, 1984, 1987) emphasized the importance of information-based invisible assets, like technology, reputation, organizational culture, and so forth, as crucial to strategy. These invisible assets, which are true sources of competitive advantage and a driving force behind growth, not only support the firm’s strategy, but accumulate through strategy implementation. Including technology, these invisible assets can be produced as a result of learning by people in and around the firm through daily business activities. Their accumulation, in other words, is done not only through direct efforts for such accumulation (like R&D projects), but also as a byproduct of daily business activities through learning by doing. Thus, unlike depreciating physical resources which are only consumed by strategy, invisible assets have the dual nature of being both a necessary input to and an accumulating output produced from a strategy (or business activities implementing the strategy). Furthermore, invisible assets are extensible, i.e., usable in other businesses than in the original business in which they are created. Actually, cash is another resource that has this dual nature. That is the reason why PPM had to consider the intertemporal dynamics of cash flow, and the dynamic interaction between strategy and cash flow. In a similar vein, Itami argued the intertemporal dynamics of invisible assets and dynamic interactions between strategy and invisible assets. Technology is one of the most important elements in that dynamic interaction.

One of the paradoxical strategy prescriptions in this line of argument is overextension. Itami argued that current strategy of the firm should be destabilizing and unbalanced against the firm’s current level of technology. The firm should overextend itself beyond the current technological limit in some part of their businesses. This misfit can provide, first of all, the opportunities for learning by doing, and secondly, generate creative tension among the organization’s members by focusing their attention on the area of weakness. Tension and focusing will stimulate learning by doing, which accelerates accumulation of important technology for future strategic uses. Clearly, current strategy can cultivate future technology purposefully. It is worth noting that, in this context, not only the organization’s learning ability, but also the psychological side of tension and motivation is built into strategy formulation. In other words, various human and organizational aspects are important, not only as constraints or tools for strategy implementation, but also as one of the target variables in strategy formulation.

Prahalad and Hamel (1990) and Hamel and Prahalad (1989) later emphasized similar points by arguing that the most important element in strategy formulation is not end products, but core competencies. They say:

In the long run, competitiveness derives from an ability to build, at lower cost and more speedily than competitors, the core competencies that spawn unanticipated products. The real sources of advantage are to be found in management’s ability to consolidate corporate-wide technologies and production skills into competencies that empower individual businesses to adapt quickly to changing opportunities (Prahalad and Hamel, 1990: 81).

They warn against the potential misuses of ideas based on strategic business unit analysis which might make the accumulation of core competencies difficult, or the integration of core competencies distributed and dissipated across various units tenuous. They also emphasize strategic intent which deliberately sets ambitious goals for the organization to accumulate future core competencies. These intents are hard to come by within the framework of traditional competitive analysis and strategic planning tools because these tools are overly concerned with contemporaneous fit between strategy and resources.

All of this research, which emphasizes resource creation and organizational capability development, is becoming more common and is sometimes grouped under the name of ‘resource-based view of the firm’ (Wernerfelt, 1984).

Economies of evolution and economies of multiple projects

Another recent development in research, which emphasizes the effect of current strategy for
future technological capability, is the research on economies of evolution or economies of multiple projects strategy (Numagami, 1991, 1992a; Clark, Fujimoto and Aoshima, 1991; Nobeoka, 1992). One of their main messages is that the strategy of coexistence of multiple projects with different stages of technological evolution not only encourages technological transfer between projects, but also creates new knowledge, which would be hard to generate without this coexistence. For example, a product with an old technology may coexist with a similar product with a much more advanced technology, and a technological interactive effect between products may often ensue.

A case in point is a technological advantage for a liquid-crystal-display (LCD) manufacturer to have both LCDs for watches with old technology and LCDs for TV and computer display with more advanced technology. By having two technologies in the different evolutionary stages for the same product category at the same time, technological development for the advanced product is speeded up and cost reduction for the less advanced product is reinforced. Numagami (1991) named this the 'economies of evolution'.

This economy arises from the combination of the evolutionary nature of technology and retrospective learning by those engaged in technological development. To reach the higher more challenging level of technology in the evolutionary path in a particular technology (e.g., LCD technology), solid accumulation of earlier technology is necessary. What a firm can develop is at least partly determined by what the firm has learned in the past (Pavitt, 1990; Cohen and Levinthal, 1990). At the same time, however, what the firm learns today depends on what it is aiming at. There are two aspects of today's learning here. First, the challenge of the higher goal influences what it tries to learn in the advanced technology. Secondly, the knowledge gained in the advanced level often helps people retrospectively systematize their knowledge in the less advanced technology in a fresh way. Thus, the old technology becomes the basis of the new technology, and the new technology stimulates the deepening of the old technology.

Of course, for this to actually happen, suitable organizational arrangements are necessary so that people in charge of two different stages of the technologies can really interact.

An interesting strategy prescription from economies of evolution is again a bit paradoxical. To deepen today's technology, like cost reducing innovation for the current product, the firm may have to go after the technology for its future product in full steam even if the current technological level may not look sufficient. By trying to incorporate today's strategy in a future product whose market is expected only far in the future, the firm stretches itself beyond an obvious limit of today's technology. By this stretching and learning, and channeling the knowledge gained to the old product, the firm can benefit in the form of sharper competitive weapons for the coming battle in the old product area. Here again, misfit between the current level of technology and the firm's current strategy is proposed, because such strategy can cultivate or deepen the technology of the firm.

TECHNOLOGY DRIVES COGNITION OF STRATEGY

The third perspective in conceptualizing the dynamic interaction between strategy and technology is concerned with the effects of current technology on future strategy of the firm. Technology that the firm possesses now and/or the firm's current commitment to technological development affect human cognitive processes for strategy formation within the firm. Of course, any factor can have two opposite effects on human cognitive processes. It can help stimulate appropriate cognitive processes, or it can hinder them. Here, we emphasize the positive side, and claim that current technology can drive cognition of future strategy of the firm (see Figure 3). This is a new perspective that should be pursued more in strategy process research.

In the past, the negative side of the cognitive effect of technology on strategy seems to have been more prominently emphasized. For example, in the research on the effect of technology on corporate culture, technology is often to blame because excessive psychological commitment to the old technology may hinder emergence of new strategic thinking. In reality, however, there

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5 For retrospective aspects of learning and concept creation process in general, see Schutz (1970) and Weick (1979).
are many cases in which strong commitment to a particular technology lets the firm see a strategy that other firms fail to imagine. Let us cite the case of Sharp who, despite its history as an also-ran in Japanese consumer electronics, is now becoming a firm with a clear strategic direction as an opt-electronics leader emphasizing its liquid-crystal-display technology. Its strategic product-market domain is electronics products with opt-related unique electronic devices and its strategic focus is to use LCD technology as the major differentiating weapon in many of its products. This strategy emerged over the years mainly because of its commitment to LCD technology. Here, it is interesting to note the time-sequence of the events. It is not that the grand strategic decisions on the domain and its focus were made in the beginning and then this decision dictated massive development efforts in LCD. Rather, initial commitment to LCD was made first to help Sharp win its competition in the calculator war and then this technology began to permeate other product areas naturally. After this spontaneous process continued for some time, and concomitant technological efforts in LCD deepened the organization’s knowledge reservoir on this technology, company-wide recognition emerged that the strategy of opt-electronics domain and LCD focus was suitable for Sharp. Only then the firm began massive acceleration in its commitment to LCD technology. In a sense, technology drove the cognition of the strategic direction that Sharp is taking now.\(^6\)

\(^6\) For a more detailed description of the historical development of Sharp’s strategy, see Numagami, Nonaka, and Otsubo (1991).
Current technology can affect individual and organizational cognitive processes behind the emergence of an organization-wide strategy in two steps. First, deep knowledge in a particular technological area shared by many people in the organization stimulates those people to generate elementary ideas of various new products or new competitive weapons that may become feasible with that technology. This idea generation may, in the beginning, be quite fragmentary and autonomous, rather than very systematic and well-coordinated. Implementation of these ideas in bits and pieces will follow, and then the efforts to integrate various initiatives into an organization-wide strategic direction can emerge, often under the leadership of top management. Sharing of technology helps at this integration stage too. For the emerging strategic direction to be widely understood and accepted by many members of the organization, it is helpful for them to share a common frame of understanding and communication. Sharing of deep technological bases can build that understanding and communication.

Thus, technology drives cognition of a particular strategy because (1) it channels and activates idea generation processes, and (2) it helps integrate these fragmentary ideas. In fact, the future is not only uncertain, but often unknowable. To try to imagine its future by the collective efforts of the members of the organization, the firm needs some common lens which is shared by many members. Technology works as such a lens. In this sense, current technology serves as a cognitive driver for future strategy.

Origin of research

There is much research which points out that technology tends to create a particular mind-set, or that technology is a set of knowledge with strong cognitive influence. Deal and Kennedy (1982), for example, assert that technology (or task characteristics, to be more precise) is an important determinant of corporate culture. Dosi (1982) contends that technology often becomes a paradigm which guides its own evolutionary path. This research, however, did not go far enough into technology's contribution in making the invisible future visible, or in promoting the emergence of a new strategy.

Rosenberg (1976) is perhaps the first to refer to the strategy-generating function of technology. He pointed out that internal logic in technology works as a focusing device to show the direction of new product innovation. Technology, according to Rosenberg, is a system of interdependent component elements which perform a set of functions as the final technology, like interdependent component parts comprise a system that performs as the final product. When a certain component technology advances alone, it disturbs the previous equilibrium among the component technologies. One component stands out, but the performance of the entire system does not advance because the stagnant parts become bottlenecks. This technical imbalance clearly shows a direction of further innovation by making clear where improvement is needed. Imbalance thus works as a focusing device for a new direction, i.e., a new strategy to come up with a new product which solves this bottleneck. In other words, by following the internal logic of interdependence of technology, a firm can find a bottleneck, and thus can decide which product to innovate and which direction to allocate its resources. Technology lets the firm recognize which strategy it should take. This argument, albeit its rather passive tone for strategic cognition, alludes to the causal link from current technology to future strategy.

Technology as a cognitive driver

We stress a more active role of technology driving a strategy cognition process, sometimes as its main engine. Since past research is almost nonexistent, let us present our own view of why technology can function as a cognitive driver for strategy.

The keys to this view lie in the very nature of technology. Technology is a systematic body of knowledge based on the principles of how natural things behave as they do and how they interact
with artificial things. It is a logical system which combines this body of knowledge. The purpose of technology is to produce artificial things to satisfy basic human needs. Note, in this definition, that technology (1) is a logical system, and (2) aims at satisfying basic human needs.

As Thompson (1967) said, technology is a set of knowledge and beliefs on causal relations and thus a system of logic. When the entire logic becomes a closed system, technology becomes complete as an instrument. Technology encompasses not only articulated knowledge, but also tacit knowledge. Technology evolves as a system by incorporating new variables of which people are unaware but become cognizant through production and use experiences (Burgelman and Rosenbloom, 1989; Jaikumar and Bohn, 1986; Rosenberg, 1982; Habermeier, 1990). As such, technology is a logical system which has its own tendency toward perfection and systematization. It is, however, different from science in the sense that, although science can remain in the abstract world, technology cannot and has to produce things to be used by people. The output of science is information, but the output of technology has to be information to be embodied in products and services made available to society (Allen, 1977). Scientists care about contributions to knowledge per se, but technologists care about contribution to human life and markets (Bailyn, 1980). Thus, technology is very fundamentally oriented toward basic human needs.

These twin properties of technology, a system of logic and orientation toward human needs, serve as the basis of a cognitive driver for strategy. When the firm has a deep commitment to a particular technology, technology first activates idea generation processes for strategy formation. Second, technology channels these idea generation processes in a common direction and thus makes the appearance of strategic domain direction and common strategic focus easier. Third, technology makes it easier to persuade members of the organization to accept a strategy.

As the first contribution to strategy cognition, a strong knowledge base provided by the commitment to a particular technology will activate idea generation. The human needs orientation of technology makes people think about what type of needs their technology can satisfy. These ideas naturally relate to markets. Deep commitment accelerates this thinking. Furthermore, because they have deeper knowledge than their competitors, they are the first to think about ideas in this particular direction. The logical nature of technology will also make idea generation easier because logic makes points to be attacked clear. Rosenbergs' concept of 'focusing devices' emphasizes this aspect of technology.

Secondly, strong commitment to a particular technology by the firm often implies that a common base of deep knowledge in that area is widely shared by many people in the organization. Because of this commonality, ideas that people generate and experiment with independently will, even though they are fragmentary, tend to cluster around this common base of knowledge. Thus, a direction for common attractive domain or common strategic focus among various product ideas would be easier to attain. Not only would clustering in a common direction appear, but various ideas would be more understandable by others and tend to stimulate others' thinking because of this twin nature of technology. An orientation towards basic human needs helps this understanding by stimulating others in the organization. This reinforces the tendency for a common direction to appear among the strategic ideas to be generated. This common direction would become a natural candidate for an organization-wide strategy.

Thirdly, once various ideas are integrated into an explicit strategy, the fact that the strategy is backed by a strong technological base makes the acceptance of the strategy by the organization easier. Since technology is a system of logic, persuasion by this logic would be easier. This is particularly important in a large organization where some bureaucratic tendencies emerge inevitably. Logic often survives bureaucracy better. Basic human needs orientation will lend more credibility to the selected strategy. In all, technology makes the persuasion of average people easier.

Although deep technological commitment and a strong knowledge base have these benefits for strategy cognition, any technology will not do. Appropriate technology seems to be one with a reasonable degree of immaturity and heterogeneity. Immaturity means that the technology is still a developing one and heterogeneity means that the technology in question is reasonably,
but not greatly, different from the past technology set that the firm has employed. A very mature technology in which new developments seldom happen is not very exciting and thus will activate little idea generation. A technology too heterogeneous and in which the members of the firm have little familiarity will not be able to stimulate thinking because only a handful of people can relate to it. Even when very heterogeneous technology succeeds in strategic idea generation, strategic directions based on these ideas will have difficulty in obtaining the organization's acceptance. The same would be the case for very new and immature technology. On the other hand, very mature and homogeneous technology may have a better chance of integration for strategic direction, but the integrated direction will not be very different from the past strategic path of the firm.

In short, the technology which is likely to drive cognition of attractive strategy is neither too mature and homogeneous, nor too new and heterogeneous. The firm needs to commit itself to the very process of developing a reasonably heterogeneous and immature technology into a more mature and homogenized one. Perhaps, one of the reasons why many established firms cannot have a clear and attractive strategic direction, or cannot 'see' its strategy well is that they lack, in their technology portfolio, this type of reasonably immature technology at a developing stage. What they have tends to be either too mature or two new.

HOW THREE PERSPECTIVES ARE DIFFERENT

The three perspectives on dynamic interaction between strategy and technology are different on several key dimensions. Obviously, they differ in terms of the assumptions on the degree of independence between strategy and technology (see Figure 4). In the first perspective, technology is rather independent and develops with its own dynamics. In the second perspective, technology that accumulates is dependent on the strategy chosen. In the third perspective, strategy is dependent on the technology committed.

Behind this basic difference, there are three dimensions along which we can summarize different images of strategy and technology among the three perspectives: (1) distinction between content and process of strategy, (2) importance of learning and human cognitive process, and (3) importance of technology. On each of these dimensions, the second perspective, strategy cultivating technology, is positioned in the middle between the other two perspectives.

First of all, in the third perspective, where technology drives cognition of strategy, distinction between strategy content determination and strategy implementation process is unclear. It shows in the image of strategy and who decides it. In the third perspective, strategy is emergent (Mintzberg and McHugh, 1985). No one decides and commands strategy as one unit of decision. It emerges from the evolutionary process of technological commitment and strategic idea generation involving many people in the organization. Strategy content determination cannot be separated very clearly from the strategy implementation process. On the other hand, in the first perspective, the distinction can be very clear. The strategist decides on strategy to capitalize on technology and then commands the organization to implement it. Whether people in the organization accept or commit to the commanded strategy is a matter of the implementation process. It should be addressed, for example, by incentive systems and other organizational arrangements. In fact, this is the most conventional distinction between content and process, just as the first perspective is by far the most conventional concept on the relationship between strategy and technology. In the second perspective, it is the strategy implementation process that cultivates technology for the future. Thus, when strategy content is decided, it has to take into account the process with which the strategy will be carried out, because this process will influence future technology. In this way, content and process are intertwined, although they are not inseparable as in the third perspective.

Secondly, the three perspectives are different in terms of the degree of importance attached to the learning and cognitive processes by people in the organization. In the first perspective, these aspects are not considered explicitly at all. In that sense, this perspective attaches no importance to human learning and cognitive processes induced by or associated with strategy. Just the opposite, they are at the center of the stage in the third
perspective. Strategy is inseparable from learning and cognitive processes induced by technology. These processes are the actual determinant of strategy. In the second perspective, learning by doing is the basis of the interactive effect that strategy has on technology and thus is very important. It is, however, fair to say that the presence of learning and cognitive processes is not as pervasive in the causal link between strategy and technology as in the third perspective.

The third dimension is the degree of importance of technology implied in each of the three perspectives. In the third perspective, technology is all important. It not only constrains what the firm can do technically, but frames and drives the way people think. Even strategy emerges from technology, to be a bit extreme. In the first perspective, technology is something to utilize. It is certainly one of the essential ingredients for the corporate activity, but still just a tool and not something the firm’s identity depends on in a fundamental way. If the firm needs technology, it can even buy technology from outside. In the second perspective, technology is a very important endogenous variable of the firm that needs to be developed by appropriate strategy. Market procurement mentality for technology is much less conspicuous and developmental mentality is much more pronounced than in the first perspective.

RESEARCH AGENDA AND CONCLUDING REMARKS

Research agenda

Many research questions remain to be asked in each of the three perspectives. Some questions are obvious from our discussions and from our framework, especially for the second and the third perspective. For example, when is overextension beneficial and when is it not? What is the logic behind technology-driven cognition of strategy? What type of technology would cause strategy to accumulate or be likely to influence the cognitive process for strategy formation? We will not repeat them here. The following is a sample of interesting questions which may not be so obvious from our framework.

First of all, we need to test whether our framework is helpful in understanding the
relationship between strategy and technology. We suspect that the world automobile industry may be an intriguing industry to investigate to learn how these three perspectives have interacted with one another in the real world. It may be that GM under Sloan, who created the full-line policy with annual model change, emphasized the first perspective. In sharp contrast with Sloan, Ford, who involved himself deeply in technology, at last ‘saw’ the new strategy, ‘to democratize the automobile’. Toyota may have emphasized the second perspective. Toyota had to manufacture a variety of car models in small volumes during the 1940s and 50s. Toyota's strategy of a wide product line with small production volume finally generated a valuable production technology. It may be that Honda followed both the second and the third perspectives at the same time. Honda's founder, Soichiro Honda, was a fanatic and genius engineer like Ford. But unlike Ford, he did not run a one-man business. He left much of the managerial work to an outstanding strategist, Takeo Fujisawa. Honda's history suggests that even though these three perspectives may not coexist in one person, they can be balanced by the composition of the managerial team.

Within each perspective, we can suggest many interesting questions. Even in the first perspective which has been most researched, we know little about which aspects of technology affect which aspects of strategy most. It may be, for example, that the type of competitive strategy the firm should select depends not only on the stage of technological evolution, but also on the technological difference of the firm with its competitors. Furthermore, dynamic sequencing of this static matching may have some pattern depending on the competitive situation and the nature of technology.

Within the second perspective, much research is needed to identify how much and what type of misfits between (current) strategy and (current) technology are necessary for a firm to accumulate valuable technology and at the same time survive in current competition. Some precautions necessary for consciously creating these misfits need to be known.

Since the third perspective is such an underdeveloped area, there are many questions to be asked. For example, it seems promising to examine the technology portfolios of established firms in order to understand the reasons why some established firms are successful in self-renewal (i.e., integrating a new strategy) and others are not. It is also interesting to know the balance of the positive cognitive effect of technology on strategy with the negative cognitive effects like mind-set fixation.

Interactions of the three perspectives would also be an interesting area of research. First, for example, it is important to understand how these three perspectives interact in real business settings. It seems that some balance among these perspectives is necessary for a firm to survive over the long haul. If any one perspective prevails and drives out the other two, the firm may suffer either from low profitability, or poor growth potential. Dynamic balance may be attained over time through one perspective being dominant only to be succeeded by the another cyclically. Contemporaneous balance among them could be reached by some composition of the management team. We also need to conceptualize how management integrates the three perspectives in one strategy process for a firm. In reality, all three interactions occur at the same time.

In many of the research questions above, we are still at a hypothesis generating stage, not hypothesis testing stage. Some caution seems to be in order regarding the research methodology researchers should use. In short, we should not be too preoccupied with the rigor of hypothesis testing techniques when we do not know which hypothesis is interesting enough to be tested in the first place. At such a stage, we would like to emphasize the importance of in-depth case analysis and what we would call ‘logical compound synthesis.’

Solid research methodology is necessary when one wants to persuade others that one’s statements are valid or correct. There seem to be four types of methodology of persuasion in strategy research which have been variously used in different proportions. The first methodology is mathematical model analysis, in which plausible assumptions and correct operations of mathematics ensure the plausibility of the conclusion. A basic appeal of this methodology is a long chain of logic contained in mathematical analysis. Logic persuades people.

The second research methodology is statistical data analysis. This approach utilizes the statistics of a large amount of data selected from some
population and relies on the theory of probability in interpreting and drawing inferences from these statistics. The plausibility of one's statements largely depends on the construct validity of the measurements. The basic appeal of this methodology arises from large samples. If large samples point toward the same tendency, it must be rather universally true. Data are persuasive.

The third methodology is in-depth case analysis, among which history and ethnography are most familiar. People are convinced by the in-depth case analysis of disparate evidence. This is another form of massive data gathering, albeit often qualitative. The fourth methodology, which is often used in many conceptual arguments, but has never been named, is what we dub logical compound synthesis. Just like chemists synthesize various materials into some chemical compounds that are new to the world, researchers of this approach pick up various theoretical concepts and empirical findings as materials and synthesize them into a plausible logical story. This approach derives its plausibility from the robust coherence among its component stories and reveals logical connections among conceptual constructs. In this approach, one says: there are many bits and pieces of evidence here and there, all of which can be explained logically by a particular theoretical framework. Then, such a theory must have rather wide validity. The basic appeal of this methodology is again logic, although not mathematical.

It is rather obvious that we need different research methodologies depending on the research question we are asking. For the interaction questions between strategy and technology, too much reliance on the first two methodologies seems to be counterproductive given the stage of research now.  

CONCLUDING REMARKS

As we go from the first perspective, strategy capitalizing on technology, to the third, technology as a cognitive driver, it becomes less conventional for strategic analysis, and more internal-oriented, more development-oriented, and more human psychology-oriented. In a sense, interaction between strategy and technology becomes more dynamic. In terms of the basic mode of argument, we go from economics to organizational behavior. There seems to be a clear trend. And then, among the three perspectives, the first perspective has been most dominant, perhaps too much so. Why?

Clearly the dominance is justified. It is the most basic requirement for strategy to capitalize on technology, because technology is the most fundamental weapon for competition and determines physical feasibility of alternative actions. So the real question should be, why neglect the other two perspectives to the extent that past research has done?

Perhaps the reason for this lies partially in the influence of economic thinking on strategy analysis, particularly in the U.S. In a fundamental way, the existing orthodoxy in economics is still struggling with technology and by default treats technology largely as something given exogenously. Another reason could be the reinforcement effect from the way many corporate organizations are structured and manned. The strategist, as the top management, decides strategy and the technologist, vice president in charge of the R&D organization, must supply necessary technology or even provide an inventory of technologies from which the strategist can select. Top management with technology backgrounds is something of an anomaly in the U.S. This image of organization reinforces independence between strategy and technology and thus makes the first perspective very natural and dominant. This dominance further justifies the organizational structure and so the self-fulfilling cycle of the first perspective repeats. Whatever the reasons, we need to rectify the balance and pay more attention to the more

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9 This may not be limited to strategy–technology interaction. In many fields of strategy research, too much reliance on 'hard' data gathering might have been obstacles rather than helpful in advancing meaningful theories.

10 For a more detailed analysis on the orthodoxy's treatment of technology, see Rosenberg (1976, 1982), Nelson and Winter (1982) and Dosi (1982).

11 Whether this dominance persists may also depend on the relative status of technology specialists within the organizational hierarchy. If they are removed from the strategic decisions of the firm, it would be an additional reason to treat technology as a rather independent exogenous variable in strategy formation.
dynamic interaction patterns in the second and third perspective.\(^{12}\)

This is a fundamental theme in 'process-oriented' strategy research that we think vitally important as it relates to technology. Note, however, that it is actually the content of strategy that is really under query in all three perspectives. Because the content is influenced by the process and these two are intertwined and sometimes inseparable, the process-side of the story comes to the fore. Process and content are and have to be truly interactive. Sharp distinction between process and content research will do more harm than good.

**REFERENCES**


\(^{12}\) Although we have given many examples from Japanese firms in explaining the second and the third perspectives, we do not think that these two perspectives are in any sense unique to the Japanese. They are universally plausible.
Interaction Between Strategy and Technology


