The International Center for Research on the Management of Technology

The Dynamic "Diamond": A Technological Innovation Perspective

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November 1995 WP # 138-95

Sloan WP # 3872

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ABSTRACT

A firm's proximate environment, defined as its factor conditions, demand conditions, suppliers, related and supporting industries; and firms' strategy, structure and rivalry can constitute a source of national or regional competitive advantage. How do supportive proximate environments come about, and how can they be lost? What are their origins and migration paths? In this paper we argue that a firm's proximate environment is a function of the process of technological evolution. It is a function of how initial and prevailing conditions, together with chance events, influence the processes of uncertainty resolution, capabilities building and survivor selection that are characteristic of technological evolution. We also argue that a region can lose its advantage when a dominant design emerges or when a technological discontinuity makes obsolete the localized technological capabilities of not only manufacturers, but also of their suppliers, customers and related industries. The environment is not static, but dynamic, as firms and nations, in response to their performances, also influence it by changing their strategies or altering some of the initial conditions. In addition to discussing these questions implications for strategy and policy makers are outlined.

1 INTRODUCTION

Why do some regions or nations have a competitive advantage in some industries? A firm's proximate environment, defined as its factor conditions, demand conditions, suppliers, related and supporting industries; and firms' strategy, structure and rivalry can constitute a source of national or regional competitive advantage. This immediately raises a simple but important question: if some environments are better sources of competitive advantage than others, how do such environments come about? In other words, what are the origins and evolution of environments that are conducive to competitive firms? Just as important is why and when such a competitive advantage can be lost. The answers to these questions are critical to firm strategy and public policy formulation, and have been the subject of considerable research (Thomas, 1989; Porter, 1990). Porter suggests that the environment often starts with an advantage in one of three determinants—factors of production, related and supporting industries, and demand conditions—and sets a process in motion in which other determinants assume greater roles, signaling the beginnings of a winning environment. Over time, the determinants reinforce each other, cumulating in an environment that is the source of competitive advantage. Porter concludes that Sweden's specialty in the steel industry grew initially out of deposits of low phosphorus content iron ore in Sweden. Later, an industry supplying special trains and other equipment for deep mining grew up around the iron mines. Today this industry, located around Ludvika, supplies the mining industry worldwide even though its importance in Sweden is much diminished.

This paper explores the questions both of the creation and of the loss of such industries by focusing on the evolution of the technologies that underlie a firm's cost reduction and product differentiation. The thesis of the paper is that the proximate environment that is the source of national or regional competitive advantage is the result of the process of technological evolution driven by some initial and prevailing conditions. The type of environment that emerges is a function of how these initial conditions, chance events and the reaction (by firms and regional policy makers) to firms' performances influence the processes of uncertainty resolution, capabilities building and survivor selection that are characteristic of technological evolution. Building on the Utterback and Abernathy dynamic model of innovation (Utterback and Abernathy, 1975; Abernathy and Utterback, 1978; Abernathy, 1978; Utterback, 1994) we develop a framework that can be used to explore how competitive environments evolve and the consequences for firm competitive advantage. We also argue that a region can lose its competitive advantage when a dominant design emerges during the evolution of the technology or especially when a technological discontinuity makes obsolete the localized technological capabilities of not only the manufacturer but also of existing suppliers, customers and related industries.

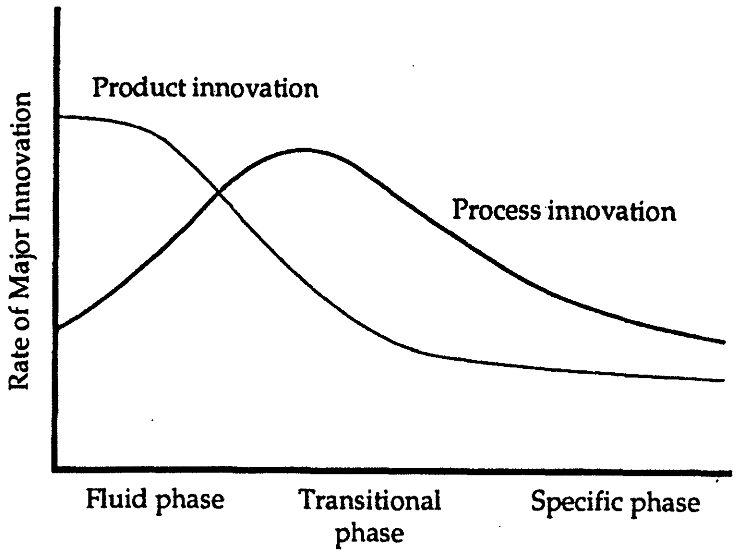
The paper is organized as follows: In the next section we lay the foundation for the framework that follows by drawing on the Utterback and Abernathy dynamic model of innovation to explore the process of uncertainty resolution, capabilities building and survival selection that takes place during the evolution of localized technological change and the impact of this evolution on firm proximate environment. In Section 3, we develop a framework for exploring how conditions at the beginning of or during the evolution of a technology can determine the nature of the proximate environment. In Section 4 we explore how the emergence of a dominant design or the arrival of a technological discontinuity can end a regional advantage. In the conclusions of Section 5, we discuss some issues about the model, and suggest areas for future research.

2 BACKGROUND

Technological Evolution and a firm's Proximate Environment

Given its tacit nature, the technological and market knowledge that underlies innovation is localized[1] and therefore learnt by doing, using, and interacting with customers, suppliers and related industries (Antonelli, 1995; Bell and Pavitt, 1993; Rosenberg, 1982; Nelson and Winter, 1982; von Hippel, 1994). Consequently, at the onset of an innovation, it may not be clear to producers exactly what type of knowledge, components or related technologies they need, what customers want, and the markets that the product will address (Clark, 1985). Utterback and Abernathy (1975) formalized the process of experimentation, error, correction, learning and interaction with the proximate environment of suppliers, and customers that takes place during the life cycle of a technology. The co-evolution of product, competition, suppliers and customers, which we now briefly explore, is summarized in Figure 1.

[1] See Antonelli (1995) for the definition of localized technological knowledge.



Product	From high variety, to dominant design, to incremental innovation on standardized products
Process	Manufacturing progresses from heavy reliance on skilled labor and general-purpose equipment to specialized equipment tended by low-skilled labor
Organization	From entrepreneurial *organic* firm to hierarchical *mechanistic* firm with defined tasks and procedures and few rewards for radical innovation
Market	From fragmented and unstable with diverse products and rapid feedback to commodity-like with largely undifferentiated products
Competition	From many small firms with unique products to an oligopoly of firms with similar products

Figure 1: Key elements of the dynamic process of innovation (Utterback, 1994)

Uncertainty resolution, capabilities building and survival selection

According to Utterback and Abernathy (1975), there is a lot of product and market uncertainty early in the life of a technology. As the technology is in a state of flux, firms have no clear idea where to place their R&D bets. This is exacerbated by the fact that it is not quite clear what the target market is or what product features will best serve the market's interests. Custom designs are common with the new product technology often crude, expensive and unreliable; but able to fill a function in a way that is desirable in some niche market. These designs are in some ways but experiments in the market place (Clark, 1985). The case of the Personal Computer illustrates some of these points. The first personal computer makers like Altair or MITS did not know just what the attributes of the personal computer should be and were not quite sure about the market they were going to address. Some of those first personal computers were nothing more than a box with a microprocessor in it that was sold largely to hobbyists (Langlois, 1992). As producers learn more about how to meet customer needs through producer-customer interaction and product experimentation, some standardization of components, market needs and product design features takes place. Eventually, a dominant design emerges, signaling a substantial reduction in uncertainty, experimentation and major design changes. A dominant design is one whose major components and underlying core concepts don't vary substantially from one product model to the other, and the design commands a high percentage of the market share (Utterback and Suárez, 1993; Utterback and Abernathy, 1975; Henderson and Clark, 1990; Anderson and Tushman, 1990). Emphasis changes from major product innovation to process innovation, and incremental product innovations. At the same time scale can increase greatly as a consequence of standardization, process innovation, reductions in costs and prices and rapidly rising volume of demand. As firms gain more experience in the dominant design, products become more highly defined with differences between competitor's products often fewer than similarities. In the case of the personal computer, the dominant design emerged in 1981 when IBM introduced its version of the personal computer. It quickly became the dominant design as the firms that entered the market tended to use the IBM design. Emphasis has since been on incremental product innovations and some process innovations. The emergence of the "Windows" operating system has further consolidated convergence in this market.

Competition, industry structure and rivalry

Utterback and Abernathy (1975) and Utterback (1994) suggest that competition in an industry is a reflection of the changes in products and processes stemming from technological evolution. Thus, early in the life of the technology when product and market requirements are still ambiguous, there is expected to be rapid entry of firms with very few failures. The basis of competition is on product features. A most important aspect of the period of experimentation preceding the synthesis of a dominant design is the acquisition of tacit knowledge about user needs and performance requirements. Following the emergence of a dominant design, those firms that were not "winners" of the dominant design are likely to exit. There are very few or no entries with designs that deviate substantially from the dominant design. In the personal computer example, there were very few or no entries that used a different design from the IBM one. Competitive emphasis shifts in favor of those firms with greater skill in process innovation and process integration, and with more highly developed internal technical and engineering skills focused on the dominant design. Many firms will be unable to compete effectively and will fail. Others may possess special capabilities and thus merge successfully with the ultimately dominant firms, whereas weaker firms may merge and still fail. Eventually, the market reaches a point of stability in which there are only a few firms producing standardized or slightly differentiated products, and stable sales and market shares. The basis for competition becomes primarily low cost.

Mueller and Tilton (1969) present similar arguments. Empirical evidence also supports this pattern (Gort and Klepper, 1982; Klepper and Graddy 1990; Klepper and Simons, 1993; Utterback and Suárez , 1993; Utterback, 1994, Suárez and Utterback, 1995).

Suppliers

Early in the evolution of the technology when product innovation prevails, input materials are largely off-the-shelf and manufacturing equipment mostly general purpose. The labor used in manufacturing is largely very skilled. This allows for process flexibility since process changes may be frequent. Following the emergence of the dominant design, the rate of product innovations decreases and emphasis shifts to process innovation. Materials become more specialized and equipment more specialized and expensive. The labor used becomes largely unskilled. Turning to the personal computer example again, early versions of personal computers by the likes of MITS, Apple and Altair were assembled in garages or warehouses using different microprocessors and standard off-the-shelf microchips. Following the emergence of the dominant design, the Intel microprocessor became the microprocessor to be used in personal computers. Eventually, makers of personal computers have had to rely on automated low cost manufacturing and high quality products to perform well.

Customers

Early in the life of the technology, customers may not know which of their needs the product can satisfy (Clark, 1985). They may not even know if they have such needs. Brand names may not account for much at this point since producers are probably still unknown quantities. As time goes on, manufacturer's and customers learn more about customer needs and expectations. Back in the late 1970s, most of today's personal computer users did not know that they needed one, let alone know what attributes it should have. But through interaction with computer makers, customers now know what some of their needs are.

Arrival of a technological discontinuity

The pattern described above repeats itself when a new technology or other source of disruption having the potential to render the old one non-competitive is introduced resulting in a technological discontinuity (Tushman and Anderson, 1986) that starts the cycle all over again (Utterback and Kim, 1986; Utterback, 1994; Tushman and Rosenkopf, 1992). Emphasis shifts from major process and incremental product innovation back to major product innovation. Product and market uncertainty again become rife. Eventually another dominant design emerges and emphasis shifts again from major product innovation to major process innovation and incremental product innovation. The frequency and concurrence of these product cycles may vary from product to product, and from industry to industry (Tushman and Rosenkopf, 1992).

Impact of discontinuities on a firm's proximate environment

The technological discontinuity that ushers in a new cycle may render the existing localized technological knowledge and skills of a firm useless (Tushman and Anderson, 1986). They can also have more far-reaching consequences: they can render the technological knowledge of existing suppliers, customers and related industries useless (Afuah and Bahram, 1995). For example, the electric car which requires knowledge and skills in the electric motor, battery, motor control unit and of the linkages between them not only renders the technological knowledge of the internal combustion engine automobile (engine, drive train and transmission) useless, it also renders that of suppliers of components and gasoline stations (complementary innovators) useless.

3 DETERMINANTS OF PROXIMATE ENVIRONMENTS

With the groundwork in place, we now turn to the first question: what determines the environment that gives a region a competitive advantage? In this section, we argue that this environment is a function of the impact of three factors—initial and prevailing conditions, chance events, and the reaction by firms and policy makers to firm performance—on three important characteristics of technological evolution: uncertainty resolution, capabilities building, and survivor selection. We explore how conditions such as a guaranteed market for outputs, very demanding customers, well articulated product quality levels, firm strategy and policies that force weak appropriability of technology or make venture capital easily available,[2] help determine what kind of environment emerges. These conditions do so in the way they help resolve technological and market uncertainty, select survivors, and build firm and related industry capabilities through the trial, error, correction and experimentation processes that take place during the evolution of localized technological innovation. The elements of these relationships are shown in Figure 2 and the role of each condition in shaping the type of proximate environment that emerges is detailed below.

[2]This list of initial conditions is not intended to be exhausive but rather to serve as examples of those factors that help resolve uncertainty, build capabilities, and select surviving firms during technological evolution).

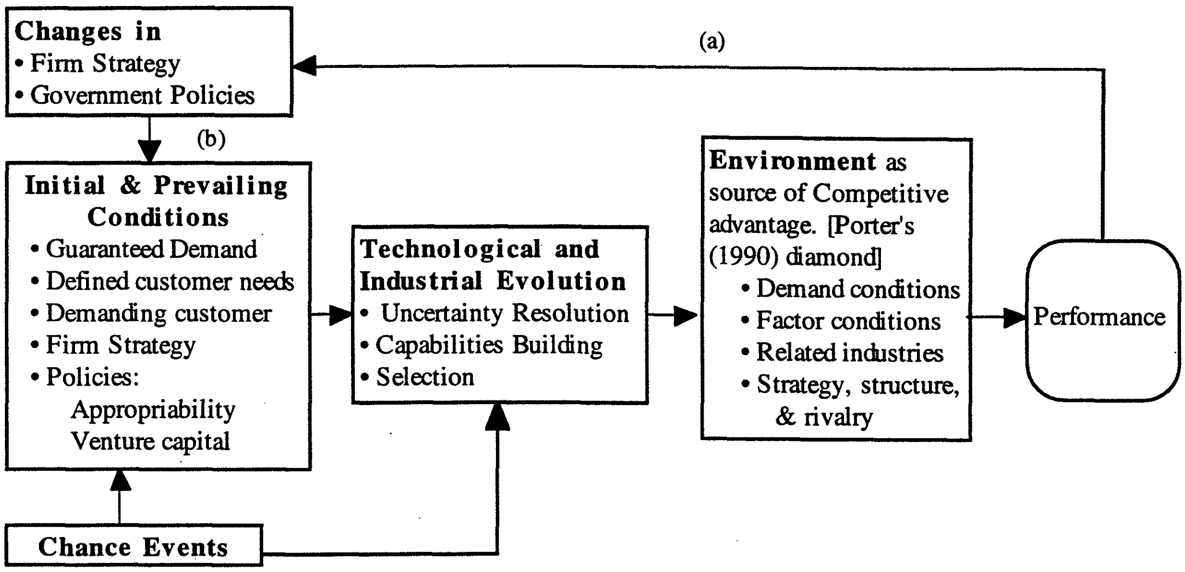


Figure 2: Determinants of proximate environments.

Role of Initial and Prevailing Conditions in Shaping Proximate Environment

Guaranteed Demand

Early in the life of an innovation, firms may know very little about customer needs, the type of product to offer, and what kind of demand there is going to be for the product since the technological and market knowledge that underlies the innovation is localized (Antonelli, 1995; Freeman, 1982; Utterback and Abernathy, 1975). Firms may have to resort to experimentation, trial, error, correction and learning to resolve such uncertainties (Clark, 1985; Nelson, 1994). A guaranteed market for products reduces some of the market uncertainty. Such a reduction has several ramifications for an innovation. In the first place, more firms are likely to enter the market than would otherwise. Once in the market, they can concentrate on resolving technological uncertainties, determining customer needs and translating the needs into the appropriate product design rather than worrying about where the next order will come from. The more firms that enter, the higher the rate of competition and product innovation (Baldwin and Scott, 1988; Scherer, 1980; Porter, 1990). The larger the pool of entering firms the greater the chances that surviving firms will be more competent.

In the second place, guaranteed demand for manufacturers' products means that they are, in turn, more likely to assure suppliers (of components and equipment) of demand for their own products. Moreover, a reduction in product uncertainty may also mean a reduction in market uncertainty for suppliers. That is, more firms will enter related industries accelerating the rate of innovation for components, equipment and complementary products, and increasing the chances of having more competent surviving firms in related industries. This is particularly important in the latter part of the innovation cycle when emphasis shifts to process innovation and manufacturers need specialized materials and equipment. Borrus (1988), Wilson et al (1981) and Utterback and Murray (1977) suggest that US government guarantees to buy the output from US semiconductor start-up firms had an influence on the types of competitors, suppliers and customers that emerged.

Well-defined customer needs and expectations, as was the case with the US Defense Department's detailed functionality and reliability standards for semiconductors, reduce both technological and market uncertainty (Utterback and Murray, 1977). With customer needs articulated, manufacturers can concentrate on translating those needs into product features. There are likely to be fewer design types and a dominant design is likely to emerge faster. There is also likely to be more competition and more innovation as is the case with a guaranteed market.

Very demanding customers—Quality and Quantity

A customer can be demanding in two ways: in the level of attributes of the products it expects (form, fit, function and reliability), and the quantity of parts that are needed. To satisfy each type of demand requires a different kind of capability. Meeting very high product attribute levels implies more product innovation than process. In the early part of the innovation cycle, such demand is likely to increase competition and result in an industry with surviving firms that are more competent at product innovation.

Instead of emphasizing product attributes, the demanding customer may want large volumes delivered on time at low cost. Such demands would force the manufacturer to emphasize process innovation, paying more attention to relations with suppliers of both materials and equipment who are often the sources or catalyst of process innovations. Over many product cycles, surviving manufacturers are likely to be more competent at process innovation than at product innovations. Suppliers of materials and manufacturing equipment are likely to emerge stronger than in environments where emphasis is on product innovation.

Policies: Weaker technological appropriability and availability of Venture Capital

Firm's are less likely to invest in an innovation if they know that they will not be able to appropriate the rents from the innovation (Tirole, 1988). But once the invention[3] has taken place, weaker appropriability has two key effects, both of which lead to a higher rate of incremental and process innovation, and more competent firms. In the first place, it invites more entry and competition. More competition means a higher rate of innovation and more competitive surviving firms (Scherer, 1980; Thomas, 1989; Porter, 1990). In the second place, it allows entrepreneurs and technical gurus to move around more easily and either start other firms or join more established ones. In either case, since technological knowledge is best transferred by moving people (Allen, 1984; Roberts, 1979), the rate of innovation, learning and quality of surviving firms is likely to increase. Availability of venture capital funds increases both the rate of entry and an entrant's chances of survival.

Weak appropriability and availability of venture capital funds also has an impact on suppliers and related industries in two ways. First, some of the same funds are going to be available to suppliers of materials and equipment as well as to suppliers of complementary products from related industries. For example, venture capital made available to personal computer makers would also be available to makers of personal computer components as well as to software developers. Second, the competitive pressures put on producers may be passed on to suppliers as they co-evolve resulting in surviving suppliers who are more competent.

Firm Strategy

A firm's strategy can have an impact on the evolution of its proximate environment. Consider Sun Microsystems, a maker of computer workstations whose strategy has been, since its founding in 1982, to maintain open standards. That is, it has used standard components and technologies that are available to anyone in designing its workstations. When a new microprocessor technology called RISC (Reduced Instruction Set Computer) came along, Sun designed its own version of the technology and promptly licensed it to any chip or workstation maker who wanted it, instead of maintaining a proprietary hold on it as had DEC with its Alpha chip. This had two consequences. First, many chip makers opted to manufacture the chip which meant more opportunities to learn about the complicated microprocessor and to supply Sun with chips. Second, many workstation makers also opted to clone Sun's workstations, helping forge a large coalition for the competition for a standard in RISC workstation technology. This coalition assured customers of a large network and installed base of workstations giving Sun an advantage (Garud, 1993; Khazam and Mowery, 1992). So far, Sun's RISC technology has maintained the

[3] Freeman (1982) defines innovation as invention plus commercialization.

highest market share of the competing technologies even though the Alpha chip seems technologically superior.

Combined effect of conditions

So far, for expository reasons, we have considered each of these conditions, demand, customers, policies and strategy, singly. However, their combined effect may be more effective in influencing the proximate environment than each alone. For example, if intellectual property protection is weak, allowing employees to move around easily without any legal repercussions, venture capital is easily available, and customers emphasize product features rather than large quantities, there is likely to emerge an environment in which product innovation thrives. Related industries such as product design tools and services are likely to thrive too. If, on the other hand, customers demand large quantities delivered on time and without defects, survivors in such an environment are likely to excel at process innovation. Related process innovation industries such as suppliers of equipment and materials are also likely to thrive.

Chance Events

Chance events and dynamic returns to scale play a significant role in explaining the outcome of competition between different technologies and the resulting competitive environment (David, 1985; Arthur, 1989). They can influence the proximate environment directly or indirectly via initial conditions. For example, Shockley founded Shockley Transistor and decided to stay in the Silicon Valley, because his mother in-law was sick and needed the valley's milder weather. Many Silicon Valley microchip companies (including Intel and National Semiconductor) can trace some of their roots to Shockley Transistor. His decision to stay in the valley may have had an impact on the localization of semiconductors in the Valley.

Feedback Effects: Reaction to firm performance

Upon realizing the significance of their proximate environment on their performance, firms and nations are likely to take some measures to influence it. They can, for example, alter the prevailing conditions (Figure 2, feedback loop "b"). For example, Sematech was formed by US firms with the help of the US government to develop more manufacturing technologies for US semiconductor makers, their customers and suppliers of equipment (ICE, 1995). Firms can also change their strategies in response to low performance (Figure 2, feedback loop "a"). For example, Intel decided to exit the DRAM (Dynamic Random Access Memory) and SRAM (Static Random Access Memory) business to concentrate on microprocessors where it now thrives (Burgelman, 1994). These examples suggest that the proximate environment is not static but dynamic as firms and nations, in response to their performances also influence the environment by changing strategies or altering some of the initial conditions.

In summary, a firm's proximate environment is the result of technological evolution. Producers learn more about what to build and how to build it by interacting with each other and their proximate environment of suppliers, customers and related industries. As the product that must be offered also evolves, those firms that do not posses the capabilities to offer it are forced to exit. Members of the proximate environment (suppliers and related industries) that cannot support the product are also forced to exit. The firms that survive and the nature of their competencies are a function of conditions during the period of uncertainty resolution, capabilities building and survivor selection. It is a dynamic process as firm strategies and government policies can be changed in response to perceived performance.

4 LOSING THE ADVANTAGE

Now we turn to the second question: why do regions lose their competitive advantage. We argue that a region can lose its advantage during the evolution of the technology when a dominant design emerges or at the arrival of a technological discontinuity when the discontinuity makes obsolete the localized technological capabilities of not only manufacturer's but also of suppliers, customers and related industries.

Dominant Design and Advantage

As an innovation evolves, the proximate environment that is conducive to superior performance also varies. Drawing on the Utterback and Abernathy model, we use Porter's (1990) "diamond" to summarize the elements of desirable environments before and after the emergence of a dominant design as shown in Table 1. Prior to the arrival of a dominant design, emphasis is on product innovation. This favors an environment with a large pool of skilled labor and whose research institutions emphasize product R&D. Demand conditions that emphasize product features and the presence of a significant number of lead users can also be valuable. Such lead users play a significant role in the experimentation to resolve market uncertainties (von Hippel, 1986). The presence of industries that provide design tools such as Computer Aided Design (CAD) Software as well as a broad scope of complementary products can also nurture product innovation. Finally, access to technological knowledge, availability of venture capital funds, and free movement of employees between firms allow new firms to exploit new product ideas from incumbents or universities.

	Before the emergence of a dominant design	**After** the emergence of a dominant design
Factor Conditions	• Universities and other R&D institutions that emphasize product R&D • Large pool of skilled labor • Easy movement of employees	• Industry research that emphasize manufacturing and process R&D • Pool of low cost labor
Demand Conditions	• Demand that emphasizes product features • Presence of many lead users	• Demand that emphasizes low cost and high quality • Large number of followers
Related and Supplier Industries	• Presence of design tools and services • Broad scope of complementary products	• Presence of suppliers of specialized materials and equipment for process innovations
Firm, Strategy, Structure and Rivalry	• Easy to start new firms • Inexpensive access to technological knowledge • Availability of venture capital	• Difficult to start new firms

Table 1: A firm's proximate environment as a source of advantage—before and after the emergence of a dominant design

Following the emergence of a dominant design, emphasis shifts to process innovation and incremental product innovation. Such innovations would thrive where universities and other R&D institutions emphasize manufacturing R&D and transfers and use of knowledge and where there is a large pool of low cost labor. Demand conditions that emphasize low cost and large number of customers who tend to be followers also favor the post-dominant design period. The presence of suppliers of special materials and equipment needed for the increased emphasis on process innovation can also be valuable. If the region is such that it is difficult to start new firms, incumbents would tend to dominate, and given their tendency not to initiate new major product innovation, one can expect product innovation to be less frequent.

Thus an environment that is conducive to pre-dominant design firm performance may not be for post-dominant design, and a region whose proximate environment is conducive to product innovation may lose that advantage following the emergence of a dominant design. Alternatively, an industry may fully evolve in a region where it had its origins, but then fail to renew its base when threatened by a new technology.

Discontinuities and proximate environment

The emergence of a dominant design is not the only way a region can loose its competitive advantage. If the technological discontinuity that ushers a new cycle makes obsolete not only the localized capabilities of manufacturers, but also those of its suppliers, customers and related industries, then a region that previously had competitive advantage may lose it. Why? Well, a primary reason why a firm can derive an advantage from its proximate environment is the relationships that it can forge with suppliers, customers and related industries that its competitors outside the region cannot (Porter, 1990). If the competencies that allowed these parties to participate in the relationship are made obsolete by a technological discontinuity, the relationships themselves may not be worth as much. Take Japanese automobile makers and their suppliers. It has been estimated that an important part of their advantage in product development and manufacturing comes from their relationships with suppliers (Clark, 1989; Clark and Fujimoto, 1991; Helper, 1987). The electric car is a technological discontinuity and destroys the competencies of both automobile makers and their suppliers. This is because the components for the internal combustion automobile (engine, transmission, fuel injection and drive train), their underlying concepts and the linkages between them are radically different from those for the electric car (with components: electric motor, battery, and electric motor control). In adopting the electric car, these auto makers would have two choices: stay with the old manufacturer's or switch to other suppliers. Staying with the old suppliers means using inferior components since the supplier's existing localized technological knowledge on internal combustion engine automobiles has been rendered obsolete by the electric car. Switching suppliers means having to build relationships from scratch and incurring switching costs. Similar arguments can be made for the case when customer localized knowledge (from learning by using) or those in related industries have been rendered obsolete. Thus if the discontinuity renders localized technological knowledge of members of the proximate environment obsolete—the core to the relationships that formed the basis for a regions advantage—the region is likely to encounter difficulties sustaining its advantage.

5 SUMMARY AND CONCLUSIONS

Our goal was to explore two questions from a technological evolution perspective. How does a proximate environment that gives a region a competitive advantage arise? What might end such an advantage? In exploring the first question, we argued that such environments are the result of the process of technological evolution, in which conditions such as a guaranteed market for outputs, policies that force weak appropriability of technology and make available venture capital, very demanding customers, and well articulated product quality levels, together with chance events help influence the processes of uncertainty resolution, capabilities building and survivor selection that are characteristic of technological evolution. The environment is not static, but dynamic, as firms and nations, in response to their performances, also influence it by changing their strategies and policies.

In response to the second question, we argued that a region can lose its advantage during the evolution of the technology when a dominant design emerges or at the arrival of a technological discontinuity when such a discontinuity renders the localized technological capabilities of not only manufacturer's but also of suppliers, customers and related industries obsolete.

This technological perspective to exploring the dynamics of firm proximate environments provides a framework for exploring other questions. For example, nine semiconductor products with estimated 1995 sales of $23 billion were all invented by US firms. The US lost its leadership position in seven of these products once a dominant design emerged. Might the above framework be used to corroborate or complement prior explanations for the US slide in leadership in semiconductors?

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