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Preface

The research project on *Systems Analysis of Technological and Economic Dynamics* at IIASA is concerned with modeling technological and organisational change; the broader economic developments that are associated with technological change, both as cause and effect; the processes by which economic agents – first of all, business firms – acquire and develop the capabilities to generate, imitate and adopt technological and organisational innovations; and the aggregate dynamics – at the levels of single industries and whole economies – engendered by the interactions among agents which are heterogeneous in their innovative abilities, behavioural rules and expectations. The central purpose is to develop stronger theory and better modeling techniques. However, the basic philosophy is that such theoretical and modeling work is most fruitful when attention is paid to the known empirical details of the phenomena the work aims to address: therefore, a considerable effort is put into a better understanding of the 'stylized facts' concerning corporate organisation routines and strategy; industrial evolution and the 'demography' of firms; patterns of macroeconomic growth and trade.

From a modeling perspective, over the last decade considerable progress has been made on various techniques of dynamic modeling. Some of this work has employed ordinary differential and difference equations, and some of it stochastic equations. A number of efforts have taken advantage of the growing power of simulation techniques. Others have employed more traditional mathematics. As a result of this theoretical work, the toolkit for modeling technological and economic dynamics is significantly richer than it was a decade ago.

During the same period, there have been major advances in the empirical understanding. There are now many more detailed technological histories available. Much more is known about the similarities and differences of technical advance in different fields and industries and there is some understanding of the key variables that lie behind those differences. A number of studies have provided rich information about how industry structure co-evolves with technology. In addition to empirical work at the technology or sector level, the last decade has also seen a great deal of empirical research on productivity growth and measured technical advance at the level of whole economies. A considerable body of empirical research now exists on the facts that seem associated with different rates of productivity growth across the range of nations, with the dynamics of convergence and divergence in the levels and rates of growth of income, with the diverse national institutional arrangements in which technological change is embedded.

As a result of this recent empirical work, the questions that successful theory and useful modeling techniques ought to address now are much more clearly defined. The theoretical work has often been undertaken in appreciation of certain stylized facts that needed to be explained. The list of these 'facts' is indeed very long, ranging from the microeconomic evidence concerning for example dynamic increasing returns in learning activities or the persistence of particular sets of problem-solving routines within business firms; the industry-level evidence on entry, exit and size-distributions – approximately log-normal – all the way to the evidence regarding the time-series properties of major economic aggregates. However, the connection between the theoretical work and the empirical phenomena has so far not been very close. The philosophy of this project is that the chances of developing powerful new theory and useful new analytical techniques can be greatly enhanced by performing the work in an environment where scholars who understand the empirical phenomena provide questions and challenges for the theorists and their work.

In particular, the project is meant to pursue an 'evolutionary' interpretation of technological and economic dynamics modeling, first, the processes by which individual agents and organisations learn, search, adapt; second, the economic analogues of 'natural selection' by which interactive environments – often markets – winnow out a population whose members have different attributes and behavioural traits; and, third, the collective emergence of statistical patterns, regularities and higher-level structures as the aggregate outcomes of the two former processes.

Together with a group of researchers located permanently at IIASA, the project coordinates multiple research efforts undertaken in several institutions around the world, organises workshops and provides a venue of scientific discussion among scholars working on evolutionary modeling, computer simulation and non-linear dynamical systems.

The research focuses upon the following three major areas:

1. Learning Processes and Organisational Competence.
2. Technological and Industrial Dynamics
3. Innovation, Competition and Macrodynamics

Responding to Structural Industry Changes: A Technological Evolution Perspective

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ABSTRACT

We argue that the search for a dynamic theory of strategy and for a link between the product-market and resource-based views may be incomplete without an exploration of the evolution of the technology that underlies products and heterogeneous firm capability. As technology evolves, so do industry characteristics, products, and critical success factors. Firms without the right capabilities are forced to exit. Thus an industry's structure, attractiveness and the kinds of capabilities that it needs to succeed, may vary over time suggesting different strategies for each phase.

(Key words: Resource-based, product-market position, Competences, technological evolution, dominant design, dynamic competitive analysis, dynamic industry structure)

1. Introduction

Two streams of research have been useful in explaining the sources of competitive advantage. The first, the product-market position view, holds that a firm's profitability depends on the attractiveness of the industry in which the firm competes and its positioning in the industry as well as its local environment (Porter, 1980, 1990, 1991). The second, the resource-based perspective, maintains that a firm makes profits from having competences and firm-specific assets[1] that are scarce and difficult to replicate (Rumelt, 1984; Teece, 1984; Wenerfelt, 1984; Cool and Schendel, 1988; Prahalad and Hamel, 1990; Barney, 1991; Quinn, 1992; Henderson, 1994). Both perspectives are static. They explain what it takes to be profitable at any point and time. But industry structures are not static. Barriers to entry, the nature and sources of substitutes, the number and kinds of rivals, suppliers and customers often change making what is an attractive industry and product-market position today not so attractive tomorrow. Competences that once were useful in exploiting certain markets may be rendered obsolete by structural changes such as deregulation or technological discontinuities (Tushman and Anderson, 1986; Henderson and Clark, 1990). Irreversible investments in assets such as plants can also be rendered obsolete.

We argue that the search for a dynamic theory of strategy and for a link between the product-market and resource-based views may be incomplete without an exploration of the evolution of the technology that underlies products and heterogeneous firm capability. Our argument rests on the Utterback and Abernathy (1975) dynamic model of innovation, the Utterback & Kim (1986) hypotheses on discontinuous change in a product, and the Utterback and Suarez (1993) model on the dynamics of innovation among multiple productive units. The models suggest that technology evolves as the firms exploiting it interact with their environments. As the technology evolves, so do

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[1] There is some confusion in the strategy literature when it comes to the definition of capabilities, resources, firm-specific assets, and competences. In this paper, the words *resources* and *capabilities* are used interchangeably. Competences + firm-specific assets = capabilities or resources.

industry structure, attractiveness and critical success factors. The evolution determines what kinds of products (low cost, niche or differentiated) can be offered at each of the stages of evolution. To offer any of these products (and therefore survive), a firm needs certain kinds of strategies and capabilities. The firms that don't have these capabilities and therefore cannot offer the specific products of the particular stage, are forced to exit. Thus, an industry's attractiveness and the kinds of capabilities that a firm needs to succeed also vary from one stage of the evolution to the other, suggesting different strategies for each stage. A firm's heterogeneous capability in the latter part of the evolution, and therefore its strategy, can be expected to depend on its strategies, capabilities and market positioning early in the life of the technology.

The paper is organized as follows: In the next section, we review several models of innovation as well as the product market-position and resource-based static models to lay the groundwork for the dynamic competitive model that follows. In Section 3, we present the model. At each phase of the technological evolution cycle, we explore the pressures exerted by Porter's (1980) five forces and suggest strategies that anticipate the needs of that phase and the phase(s) that follow. We also explore the competences that are required to offer the products of each phase and the extent to which each firm's unique capabilities allow it to offer those products. In Section 4, we summarize our arguments and discuss some issues for further research.

2. *Background Material*

Technological Evolution and Industry Structure

The Utterback and Abernathy dynamic model of innovation (Utterback and Abernathy, 1975; Abernathy, 1978; Abernathy and Utterback, 1978; and Utterback, 1994) details the dynamic processes that take place within an industry and within member firms during the evolution of a technology. According to the model, at the onset of an innovation, in the *fluid phase*, there is a lot of product and market uncertainty. Manufacturers are not quite sure of what should go into the product. Customers may not know what they want in the product either. There is competition between the new and old technologies as well as between different designs using the new technology. Manufacturers interact with their local environment of suppliers, customers, complementary innovators and competitors to resolve both technological and market uncertainties.

The evolution enters the *transitional* phase when some standardization of components, market needs and product design features takes place, and a dominant design emerges signaling a substantial reduction in uncertainty, experimentation and major design changes. A dominant design is one whose major components and underlying core concepts don't vary substantially from one product model to the other, and the design commands a high percentage of the market share. The rate of major product innovations decreases and emphasis shifts to process innovation and incremental innovation. Competition is based largely on differentiated products.

In the *specific phase* products built around the dominant design proliferate, and there is more and more emphasis on process innovation with product innovations being largely incremental. Products are highly defined with differences between competitors' products often fewer than similarities. The pattern described above repeats itself when a new technology with the potential to render the old one non-competitive is introduced, often by a competitor from outside the established industry. This results in a *discontinuity*, plunging the innovation cycle back to the fluid phase with another wave of entering firms.

Tushman and Rosenkopt (1992) present a similar technology life cycle model, emphasizing the role that a product's complexity plays in determining the extent to which non-technical factors influence the evolution of the technology. The more complexity, the more influential non-technical factors—e.g., complementary assets and organizations in the local environment—are likely to be in determining the course of an innovation's evolution and the less likely the selection process reflects economic efficiency. That is, the best technology is more likely to win in simple products like glass than it is in complex ones like computers.

This dynamic process described by both models has a direct effect on industry structure. Utterback (1994) suggests that competition in an industry is a reflection of the changes in products and processes stemming from technological evolution. Thus, in the fluid state where product and market requirements are still ambiguous, there is expected to be rapid entry of firms with very few or no failures. Following the emergence of a dominant design, the rate of exits increases, rapidly decreasing the number of competitors. If the standard is open, however, the number of entries may actually rise, increasing the total number of competitors. For example, when IBM entered the PC market and its PC quickly emerged as the dominant design, many firms entered since the company made the design open. Eventually, the market reaches a point of stability, corresponding to the specific state, in which there are only a few firms, having standardized or slightly differentiated products, and relatively stable sales and market shares.

Figure 1 shows how the structure of an industry changes over the life of the underlying technology. It illustrates the case of the supercomputer industry where until the 1980s, Cray Research, and Control Data Corporation (CDC) dominated the market. In the early 1980s, new entrants entered using minisupercomputer technology. In the mid-1980s, others entered with massively parallel processor technology. In the 1990s more firms are failing, signaling some semblance of the emergence of a dominant design. Utterback and Suarez provide evidence of these changes in industry structure for typewriter, automobile, television, picture tube, transistor, calculator, and integrated circuit industries. Klepper and Simons (1993) provide similar evidence for automobiles, tires, televisions and penicillin.

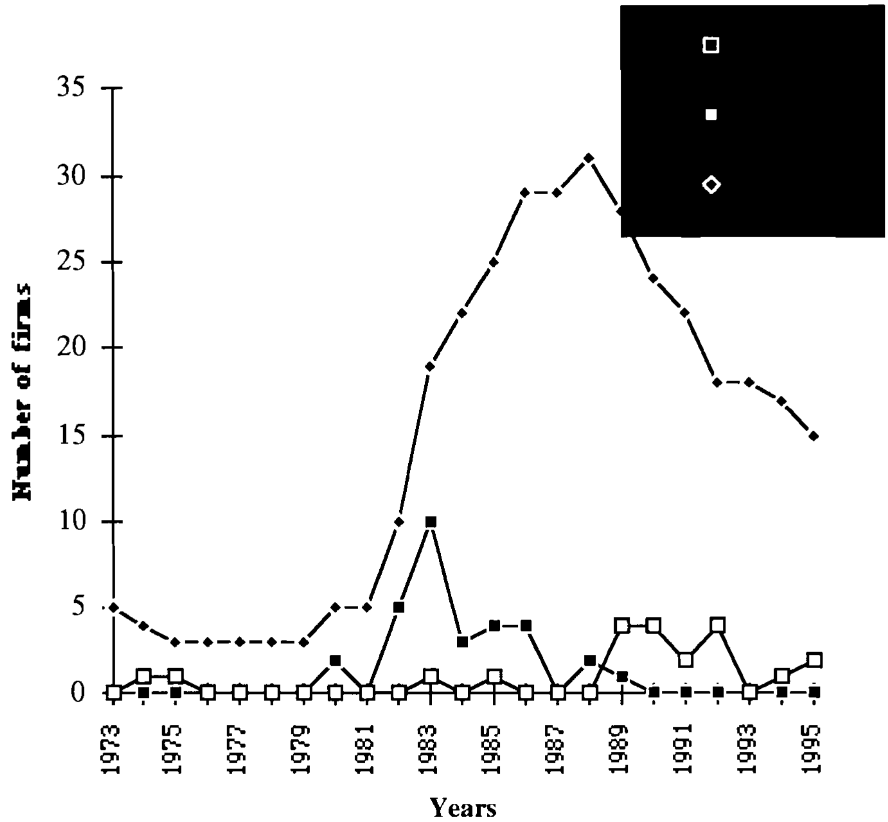

Figure 1: Number of firms participating in the supercomputer industry

Current Models

Product Market Position. The evolution of industry structure and the changes in critical success factors suggest that each phase of the industrial innovation cycle requires a different strategy and that success at any phase is a function of present and previous strategies. However, dominant industry strategy models have been static (Teece, Pisano, and Shuen, 1994). According to Porter (1980, 1990, 1991) the success of a firm is deeply rooted in the structure of the industry in which it operates, its position in the industry, and its local environment. Competition varies from industry to industry, and so do the opportunities for sustained profitability. It also varies from nation to nation, and sometimes from region to region as a function of the local environment (Porter, 1990). For each industry, five competitive forces combine to erode the long term profitability of any industry or segment of it: the threat of new entrants, the threat of substitute products or services, the bargaining power of suppliers, the bargaining power of buyers and the rivalry among existing competitors. The stronger these forces in an industry, the lower the profitability of the industry. New entrants increase competition and therefore drive down profit margins. Availability of close substitutes makes it more difficult for the manufacturer to raise its prices without driving customers to waiting substitutes. Powerful suppliers can increase cost while powerful customers can bargain away profit margins. Rivalry among competitors results in erosion of profit margins in the form of lower prices for customers and increased cost of sales. The strength of each of the five forces is a function of industry structure. For example, the threat of entry is a function of entry barriers such as the history of retaliation of incumbents, brand loyalty, or economies of scale. Some industries, by their nature, offer more attractive opportunities for sustainable profits than others.

Resource-based view. In the "resource-based" view (Rumelt, 1984; Teece, 1984; Wenerfelt, 1984; Cool and Schendel, 1988; Prahalad and Hamel, 1990; Quinn, 1992; Henderson, 1994), the focus is on the firm, in particular, on its unique resources or capabilities. Success comes not from being well-positioned in an attractive industry but from having firm-specific assets and competences that are difficult to imitate, replicate or substitute. Firm-specific assets include reputation, patents, trademarks, specialized production facilities and computer installed base. A firm's competence is its ability to integrate different skills and knowledge among individuals, groups and organizations to deliver high perceived customer value (Prahalad and Hamel, 1990).

3. A Dynamic Competitive Analysis Model

From the models just reviewed, it is evident that industry structure, the types of products that can be offered, as well as the nature of competences and firm-specific assets that a firm needs to be profitable, vary from one phase of the industrial innovation cycle to the other. The attractiveness of an industry to a firm is therefore a function, not only of the forces being exerted in the present phase, but of the competences of the firm and the actions it took in the previous phase(s). First, at each of the four phases of the industrial innovation cycle, the firm analyzes the pressures being exerted by Porter's (1980) five forces to determine the industry's attractiveness. This is illustrated in Figure 2. Second, the firm evaluates the extent to which its competences and firm-specific assets meet the levels and quality needed to be successful at each phase. Finally, at each phase, the firm takes strategic steps that anticipate the nature of the next phase(s).

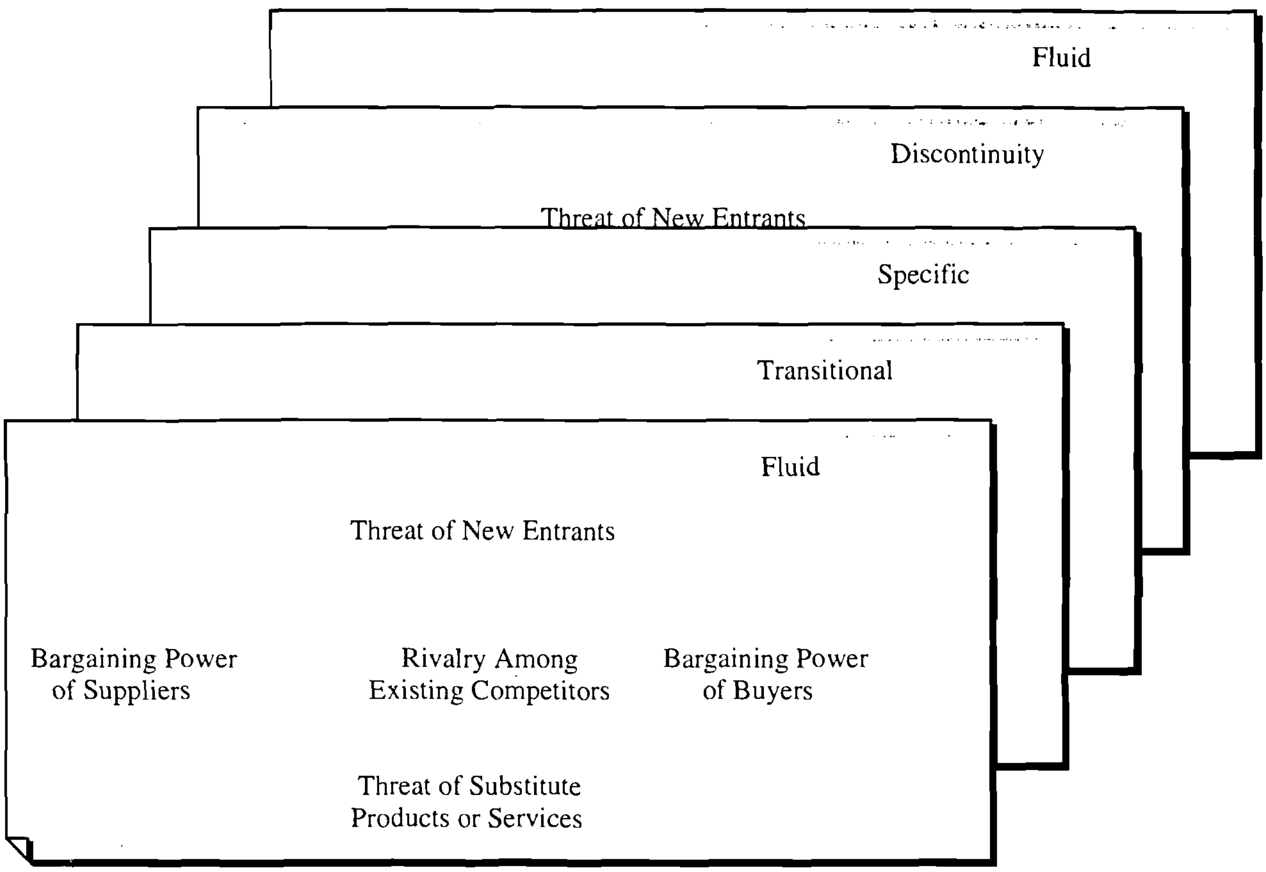

Figure 2: Industry attractiveness over the phases of the technology life cycle

Industry Attractiveness–Five Forces

As discussed above, the five forces exert different pressures at the different phases of the technological evolution cycle. In this section, we explore the role of each of these forces at each phase and the kinds of strategies that can give a firm a competitive advantage.

Fluid Phase. Since early phase products are highly differentiated and serve niche markets, *rivalry among existing competitors* is not expected to be as high as in later phases. As more new entrants enter, however, even the niches may become crowded increasing rivalry. If the technological discontinuity that ushered the fluid phase destroys the competences and firm-specific assets that incumbents had accumulated in the specific phase, the *threat of new entrants* is very high. Given early stage technological and market uncertainties, incumbents cannot take some of the measures that they would take in more stable conditions to keep out new entrants. For example, making irreversible commitments in capacity or staking out product-market positions is more difficult since uncertainty about what markets to serve or products to develop still looms large. The *bargaining power of suppliers* is low since materials and equipment are general-purpose. The *bargaining power of customers* is also moderately high since the products they buy are highly differentiated and many customers may be lead users. The *threat of substitutes* comes largely from the old technology that is being replaced by the new. As Utterback and Kim (1986) have shown, some of the best innovations in the older technology may come when the threat of the invading technology is becoming a reality. The effects of the five forces on the manufacturer are summarized in Table 1.

Strategies. To some extent, the type of strategy pursued is a function of whether the firm is a leader, follower, or fast second.[2] In anticipation of the transitional phase in which a dominant design or standard may be expected to emerge, a leader can invest in helping its own design emerge as the dominant design (Hariharan and Prahalad, 1994). Such

[2] Our thanks to an anonymous reviewer for this suggestion and several others. Leader here would be equivalent to a firm with an offensive strategy using Freeman's (1982) terminology.

efforts are particularly useful for products for which network externalities are important; in fact, so useful that the firm still stands to benefit even if its product does not become the standard (Garud and Kumaraswamy, 1993). For example, Sun Microsystems' easy licensing of its SPARC technology to anyone who wanted it may have helped its position in the RISC workstation business (Khazan and Mowery, 1992). Rather than compete to win the dominant design, a follower or fast second may concentrate on building its complementary assets to take advantage of the dominant design when it eventually emerges.

Force	Pressure in the fluid phase
Rivalry among existing competitors	• Low since products are highly differentiated and often unique • May be increased by campaigns to win the dominant design of the transitional phase
Threat of new entrants	• High. Given high market and technological uncertainty, it is difficult to erect barriers to entry. • Threats from alternate technologies with comparable price/performance
Bargaining power of suppliers	• Low since materials and equipment used are usually of general-purpose
Bargaining power of customers	• High since products are still unique and most users are lead users
Threat of substitutes	• High, especially from old products that are still viable substitutes in many applications
Some strategies	• Focus on niche products • Build complementary assets • Invest to try and influence the dominant design of the transitional phase

Table 1: Industry attractiveness at the fluid phase

Transitional Phase. With the emergence of a dominant design, many of the product and market uncertainties of the fluid phase are reduced. This results in more *rivalry among existing competitors* as the "winners" of the dominant design scramble to win new customers with a product that is less differentiated than at the fluid phase. With product innovation giving way to process innovation, firms scramble to invest in capacity in research and development, in advertising and other measures designed to signal commitment to specific market positions in preparation for entering the specific phases with concomitant higher volumes of production. The *threat of new entrants* depends on whether the dominant design is proprietary or open. It is high if the design is open, and low if proprietary since product and market uncertainties have been reduced with the emergence of a dominant design and better defined markets. The *bargaining power of suppliers* increases (compared to the fluid phase) since the equipment and materials are now more specialized. Since the emergence of a dominant design allows for differentiated but not unique products, the *bargaining power of customers* increases. An open design also increases the bargaining power of suppliers and customers. The *threat of substitutes* becomes higher since the products being sold are less niche oriented than earlier. These effects are summarized in Table 2.

Force	Pressure in the transitional phase
Rivalry among existing competitors	• Low but the emergence of a dominant design increases rivalry leading to an industry "shake out"
Threat of new entrants	• Differentiated products assure some level of protection from new entrants but threat increases with the emergence of standard or dominant design. • Low if "winners" of dominant design keep technology proprietary • High if "winners" of dominant design license technology generously
Bargaining power of suppliers	• Higher than in the fluid phase since materials and equipment become more specialized
Bargaining power of customers	• Higher than in the fluid phase since products are no longer unique
Threat of substitutes	• Higher than at the fluid phase as products become more standard

Some strategies	• Focus on differentiated products • Make irreversible investments in capacity, brand advertising, process and product R&D in preparation for specific phase. • Contract with suppliers for equipment or specialized materials that will be needed in the specific phase.

Table 2: Industry attractiveness at the transitional phase

Strategies. Strategic alliances or licensing policies could help the firm win or consolidate the dominant design. The firm can start preparing for providing low cost products in the specific state by making irreversible investments in capacity, process R&D, and advertising to establish brand name recognition. It can also locate and acquire intellectual property rights or enter special contracts with suppliers for key factors of production.

Specific Phase. In the specific phase, competition is oligopolistic with a few firms that produce commodity products from a dominant design. The forces exerted on a firm in an industry are shown in Table 3. *Rivalry* among these firms is high given the commodity nature of the products they sell. It is even higher if the design is open. Competition uses such tools as incremental product or process innovations. For example, some automobile makers have used such incremental product innovations as electronic fuel injection, anti-lock brakes, all-wheel-drive and air bags to try to gain an advantage. The rate of such innovations, and therefore of the amount of rivalry, is also a function of such environmental factors as how demanding customers or government regulators are (Porter, 1990, Thomas, 1989). An incumbent can also stake out a product-market position by making non-reversible investments in capacity or advertising thus signaling to rivals that any entry into its product-market space will be met with retaliation (Schmalensee, 1983; Ghemawat, 1991). For example, a computer memory chipmaker who invests $1.3 billion to build a manufacturing facility signals to its competitors that it will be in that market for computer memory chips for the long haul.

Several factors reduce the *threat of new entrants* who want to use the prevailing technology to enter (Oster, 1994). In the first place, incumbents may have certain advantages over new entrants. For example, they may have licenses and patents that give them exclusive access to complementary technologies, supplies or special distribution channels. They may also be further along the technology learning curve, or have established brand names and reputations through prior advertising and performance. In the second place, incumbents may exhibit certain characteristics that signal new entrants that they will fight entry by, say lowering their prices. For example, incumbents with high irreversible investments in firm-specific assets, excess capacity, or a reputation for retaliating against new entrants are likely to keep out new entrants from entering their market. If an incumbent has high exit costs, it is also more likely to fight to stay in the industry than one without. The biggest threat, therefore, comes from new entrants that are using an invading technology that can render incumbent competences and firm- or technology-specific assets obsolete. For example, electronic cash registers rendered NCR's competences, and irreversible investments in capacity and service centers obsolete. This allowed Singer to use electronic cash registers to invade the electromechanical cash register market.

Force	Pressure in the specific phase
Rivalry among existing competitors	• High because of the commodity nature of products • May be reduced by such things as tacit collusion
Threat of new entrants	• Low because of measures such as: irreversible investments in capacity, brand name, patents, special licenses or contracts and distribution channels; reputation for retaliating. • There may also be a threat from alternate technologies with better price/performance potentials.
Bargaining power of suppliers	• High for major suppliers of specialized materials and equipment who are also sources of innovations, especially process innovation.
Bargaining power of customers	• Higher since product is more or less a commodity
Threat of substitutes	• High especially from invading technologies.

Some strategies	• Focus on low cost • Emphasize quality • Signal commitments by advertising, investing in capacity and R&D.

Table 3: Industry attractiveness at the specific phase.

The *threat of substitutes* is mostly from new technologies although in some cases it may be from so-called generics when, for example, an incumbent's patent has expired. On the other hand, the *bargaining power of suppliers* is high since they supply specialized equipment and materials, and are a major source of innovations. So is the *bargaining power of customers* since products are more or less a commodity. In both cases, the bargaining power may be reduced by collusion on the part of rivals.

Strategies. A firm can pursue several strategies. For the specific phase, the firm could maintain a low cost strategy given that the products being sold are largely undifferentiated commodities and most innovations are process innovations earmarked for cost reduction. Some product differentiation is possible but more a matter of positioning. For example, Honda's positioning the Acura brand cars in a more luxury bracket than the Honda brand. Mass customization can also give a firm an advantage (Pine, 1993). The firm can also make irreversible investments in capacity or build a reputation for retaliation to signal to rivals and new entrants alike to stay out of its product-market positions. Since the biggest threat is that of an invading technology that will take the industry into a more turbulent period, the firm can scan sibling technologies to better detect the arrival and potential of a viable discontinuity (Afuah, 1996).

Discontinuities. A technological discontinuity sometimes renders the old technology non-competitive, and many of the barriers that firms have erected around them in the specific phase may become useless. Irreversible investments in plant capacity and R&D, special licenses, contracts for special materials or services may become obsolete. For example, the arrival of electronic cash registers destroyed a lot of the barriers to entry such as specialized plants, excellent service networks, investments in R&D for electromechanics, patents, and other intellectual property that NCR had accumulated in exploiting electromechanical cash registers. Technological discontinuities normally level the playing ground since incumbent existing capabilities may be rendered obsolete (Foster, 1986; Utterback, 1994).

The impact of a discontinuity on industry attractiveness is summarized in Table 4. The *threat of new entrants* is high since the playing ground has been leveled and incumbent existing capabilities may not only be useless, they may actually become a handicap. The *threat of substitutes*, from the new technology is now very high. *Rivalry* among incumbents gets higher as the new technology invades the old and incumbents who have not switched to the new technology are increasingly squeezed. As manufacturers leave specialized materials and equipment of the specific state to turn to the general-purpose equipment of the emergent fluid phase, the *bargaining power of suppliers* drops. The impending discontinuity further increases the bargaining power of customers.

Force	Pressure in the discontinuity phase
Rivalry among existing competitors	• Low or high depending on the reaction of incumbents
Threat of new entrants	• High since new entrants can use the new technology to enter
Bargaining power of suppliers	• Low since their specialized materials and equipment may be replaced soon by general purpose materials and equipment.
Bargaining power of customers	• High since discontinuity leads to fluid phase with its unique products
Threat of substitutes	• High
Some strategies	• Ensure compatibility with old technology if technology exhibits network externalities. • Take necessary steps to identify lead users

Table 4: Industry attractiveness at the discontinuity phase

Strategies. Depending on their innovation strategies, leaders may want to cannibalize their own products and quickly embrace the new technology. However, this behavior is seldom observed. They may also retrench to attempt to prolong the viability of their established positions for as long as possible. Where network externalities are important, a manufacturer may want to insure that he new product is compatible with the older ones. For example, in developing its user-friendly Windows operating system, Microsoft made sure that it was compatible to the character-based DOS operating system. A firm can also identify lead users that will be helpful in the product development of the fluid phase and try to work out joint developments.

Competences and Firm-Specific Assets

The capabilities that a firm needs to be successful also vary from one phase to the other. Since firms within an industry have different capabilities that allow them to earn different levels of economic rents (Cool and Schendel, 1988; Barney, 1991; Nelson, 1991), an industry's attractiveness to a firm is also a function of the extent to which the firm's competences and firm-specific assets match the levels that are needed to be successful in the industry. The strategy process, then, consists of (following the determination of industry attractiveness as outlined above): 1) determining what kinds of competences and firm-specific assets are necessary to stake out a profitable market position (low cost or product differentiation) for that particular industry at each phase of the industrial innovation cycle, 2) examining the firm's own competences and firm-specific assets to see to what extent they can allow the firm to compete in the industry at the phase in question, 3) establishing strategies at each phase to build competences and firm-specific assets for that phase and the next one(s).

Fluid Phase. Given the high technological and market uncertainty of the fluid state, a firm needs the ability to make some sense out of chaos, communicate well with customers to help them identify their needs, and work with lead users. Since the fluid phase is often ushered in by a competence-destroying technological change that requires completely new knowledge (Utterback and Abernathy, 1975; Tushman and Anderson, 1986), there may be some problems unique to incumbents. An incumbent's history—especially the competences and firm-specific assets acquired in the specific phase of the previous technology—play a vital role in where it searches for the new technological information and the kinds of decisions that it takes (1986; Henderson and Clark, 1990; Bettis and Prahalad, 1995). Thus an incumbent's perception of the attractiveness of an industry may be greatly biased by its history. For example, NCR saw the invading cash registers as only a faster way of adding numbers. It did not see them as a new tool for its customers to better manage their inventories and supplier-relations (Afuah, 1996). Incumbents may have to unlearn most of what made them so successful in the specific state of the previous technology (Bettis and Prahalad, 1995).

Sample competences	Ability to: • Manage projects • patent • unlearn old competences and acquire new ones • make sense out of chaos • work with suppliers to modify general purpose equipment to meet unique needs • decipher customer needs and translate to products • make sense out of customer feedback • communicate with complementary innovators to understand how they can provide complementary products
Strategies	• Focus on key customers, especially lead users, and their needs • Build technical competences, project management skills and endowments such as patents.

Table 5: Competences and firm-specific assets needed to succeed in the fluid phase

Examples of the types of competences required to perform well at the fluid phase are shown in Table 5. The ability to decipher customer needs and translate them into products, for example, is a good competence while skilled personnel and good relationships with suppliers and lead users are valuable firm-specific assets.

Strategies. For the leader, the focus is in building the capabilities that will enable it to win the dominant design. These can include building a stock of patents to use as a bargaining chip in establishing alliances. For the follower or fast second, the focus could be on building the absorptive capacity (Cohen and Levinthal, 1991) so that it can quickly imitate the dominant design when it emerges.

Transitional. The emergence of a dominant design greatly reduces both product and market uncertainties and suggests the need for competences that are different from those of the fluid phase. Whereas, in the fluid phase, the focus was on those capabilities that allow one to determine what features to include in the product, in the transitional phase, attention shifts to how to improve the values of those features. There is a shift from major product innovations to process innovations and a corresponding shift in skills. As materials and equipment become more specialized the need for supplier-focused competences also increases. As products are no longer niche but differentiated, the need for customer-focused competences also increases.

A strong reputation in related technologies or products, and strategic alliances can help win the dominant design. For example, IBM's reputation in mainframes and minicomputers was instrumental in making its PC the standard. Examples of the types of competences and firm-specific assets that a firm must have to perform well at the transitional phase are shown in Table 6.

Strategies. Prior to the emergence of the dominant design, strategic maneuvering such as detailed by Cusumano, Mylonadis and Rosenbloom (1992) in the case of VHS emerging as the standard for video tape recording can take advantage of existing capabilities. Building of customer-and supplier-focused competences may also be valuable given the switch from using generic supplies to using more specialized ones.

Sample competences	Ability to: • design products that meet customer needs • know where to make irreversible investments • negotiate contracts for specialized materials and equipment that are needed in the specific phase • synthesize emerging customer needs • develop installed base, distribution and service networks • build network of complementary innovators
Strategies	• Focus on skills for product differentiation • Focus more attention on marketing than in the fluid phase • In preparation for specific phase, advertise to establish brand recognition

Table 6: Competences and firm-specific assets needed to succeed in the transitional phase

Specific Phase. Since products are largely commodity in the specific phase, emphasis is on those competences and firm-specific assets that allow a firm to produce at low cost and profit from it Low costs are attained largely through process and incremental product innovations. Special licenses or patents that give a firm unique access to low cost processes can give a firm a competitive advantage. The source of process innovations is often major suppliers of specialized equipment who, in this phase, have high bargaining power. Special contracts, unique supplier-relations or special skills in dealing with such suppliers can be important. Close supplier relations that allow for co-development of components or close monitoring of incremental innovations from suppliers can be assets in the specific phase. Low cost and some product differentiation can also come from incremental product innovations. Such incremental innovations, by definition, require skills that build on existing competences and firm-specific assets. This gives incumbents an advantage since they already have the competences and firm-specific assets to build on for incremental innovations. Some innovations which masquerade as being incremental, however, may actually be architectural and can present firms that view them as incremental with problems (Henderson and Clark, 1990).

Sample competences	Ability to: • Design for manufacturability • Reduce cycle times • Effect process and incremental innovation expertise • integrate innovations from supplier to own processes • sell • create new distribution channels • co-ordinate innovations with complementary innovators
Strategies	• Focus on competencies that assure low cost and profitability from it • Boost process innovation and incremental product innovation skills • Scan and prepare for invading technologies

Table 7: Competences and firm-specific assets needed to succeed in the specific phase

Given that the bargaining power of customers and rivalry among existing competitors are high, a firm's customer-focused competences and firm-specific assets can be particularly valuable. For example, a firm's brand names, reputation for high quality products, networks of service centers, distribution channels, user networks, and ability to synthesize customer needs into product attributes and a language that product developers can implement technologically are invaluable. Examples of the types of competences required to perform well at the specific phase are shown in Table 7.

Strategies. As we show shortly, all these acquired competences and firm-specific assets can become a handicap in the face of a competence-destroying technological discontinuity. Thus the biggest challenge to a firm in the specific phase is balancing the act of exploiting the old technology while getting ready for the inevitable arrival of the new one (Tyre and Hauptman, 1992). Strategies in this phase are focused on preparing for the discontinuity and fluid states.

Discontinuities. It usually takes a discontinuity to move from the specific phase of one technological evolution cycle to the fluid phase of the next cycle. A technological discontinuity can be competence-enhancing if the capabilities required to exploit it build on those used to exploit the previous technology (Tushman and Anderson, 1986). Such a discontinuity would tend to perpetuate the oligopolies of the specific state. If, however, the technology is competence-destroying in that the capabilities required to exploit it are significantly different from existing ones, then a firm's accumulated competences and firm-specific assets may not only useless, they may actually constitute a handicap for the firm (Henderson and Clark, 1990). In any case, the first step in coping with or taking advantage of a technological discontinuity is to recognize the potential or threat that the new technology poses early enough to take appropriate action (Afuah, 1996).

A competence-destroying technological innovation usually levels the playing field but incumbents (from the oligopoly of the specific phase) may be shackled by the competences and firm-specific assets that had been a source of competitive advantage in the specific phase (Leonard-Barton, 1992). The technological change may not obsolete all of an incumbent's capabilities to exploit it. For example, if a discontinuity obsoletes only product-focused competences and firm-specific assets, leaving market competences and market-specific assets intact, then incumbents have an advantage (Mitchell, 1989). Similarly, if supplier-focused capabilities are left intact in industries where supplier relations are important, incumbents may also have an advantage. Thus a firm's ability to recognize just which of its capabilities will be obsoleted by the arrival of a technological discontinuity and to build those capabilities while taking advantage of those capabilities that are not impacted by the technology can also be an asset. An understanding of, and better relationships with value networks can make the task of dealing with discontinuities easier to handle (Christensen and Roosenbloom, 1995).

Strategy. It is important to focus on recognizing the potential of the threats and opportunities that the discontinuity presents. Additionally for incumbents, the primary focus is on unlearning the old knowledge so that it may not be a handicap in exploiting the new (Bettis and Prahalad, 1995). In anticipation of the fluid state, a firm may also start acquiring the skills that it needs to cope with the rapid rate of product innovations of the fluid phase. Quinn (1992) suggest that in this state, a firm should look at its portfolio of competences to see which ones best fit the new technology.

Sample competences	Ability to: • recognize the threats and potential of new technologies early • recognize supplier-originated innovations • make discontinuities transparent to customers • recognize customer-originated technological discontinuities • make discontinuities transparent to complementary innovators
Strategies	• Focus on recognizing the potential threats and opportunities of the discontinuity • Unlearning of old skills by incumbents is critical

Table 8: Competences and firm-specific assets needed to succeed in the discontinuity phase

4. *Summary and Conclusions*

We proposed a dynamic strategy model based on a technological evolution perspective which suggests a link between the product-market position and the resource-based views of competitive advantage. Drawing on various dynamic models of innovation, we argued that the technologies which underlie low cost, product differentiation, and firm heterogeneous capabilities evolve over time as the firms exploiting them interact with their environments and resolve uncertainties. As technology evolves, so do industry characteristics and critical success factors. The evolution determines what kinds of products (niche, differentiated or low cost) can be offered at each of the phases. Firms that do not have the capabilities to offer these products may be forced to exit. Thus an industry's attractiveness and the kinds of capabilities that a firm needs to succeed, may also vary from phase to phase suggesting different strategies for each phase. A firm's strategies and heterogeneous capability in one phase, depend on its strategy, and capabilities in the previous phase(s).

With this background information, we proposed a dynamic competitive model. In the model, we argued that since industry structure and critical success factors change as the underlying technology evolves from phase to phase, the competitive pressures exerted on a firm necessarily vary. Moreover, since only certain products can be offered at each phase and firm capabilities are unique, an industry that is attractive to one firm may not be to another. Based on these arguments, we proposed a three-step process for competitive analysis: First, at each of the four phases of the industrial innovation cycle, the firm analyzes the pressures being exerted by Porter's (1980) five forces to determine the industry's attractiveness. Second, the firm evaluates the extent to which its competences and firm-specific assets meet the levels and quality needed to successful offer products at each phase. Finally, at each phase, the firm takes strategic steps that also anticipate the nature of the next phase(s).

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