Planning for dominance: a strategic perspective on the emergence of a dominant design

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Abstract

Researchers in technology and innovation, organization research, and product standardization in economics have noted that innovations may become the dominant designs in their product classes for reasons that may have little to do with design. The emergence process for dominant designs has typically been viewed as a black box process involving a sophisticated interaction of technological and non-technological factors. This paper shifts the discussion to a strategic perspective. It argues that firms can frame the emergence process and can systematically manage elements of it in the pursuit of competitive advantage from innovation. An analytical framework is developed and discussed, with particular emphasis on the roles of certain external conditions, non-technological forces, and complementary assets, as well as the implications for R&D strategists and for future research. Four distinctive examples illustrate different aspects of the framework's utility.

I. INTRODUCTION

The emergence of a dominant design, which refers to a single architecture that establishes dominance in a product class (Anderson and Tushman, 1990:613), has received researchers' attention in the area of technology and innovation (Abernathy & Clark, 1985; Pavitt, 1989; Teece, 1986; Utterback & Abernathy, 1975; Utterback & Suarez, 1992), as well as organization research (Anderson & Tushman, 1990; Tushman & Anderson, 1986) and the area of product standardization in economics (Farrell & Saloner, 1987; Gabel, 1987; Hergert, 1987; Katz & Shapiro, 1985; Link, 1983). An interesting, often-noted issue is that the reasons why an innovation becomes the dominant design may have very little to do with design itself and that, as a consequence, the dominant design is not necessarily the technologically superior one (e.g. Anderson & Tushman, 1990, p. 616).

A famous case in point is the VHS format as the dominant design in the area of videocassette recorders, despite technological weaknesses relative to the competing Sony Beta format. The marketing perspective, with its emphasis on consumer preferences, might suggest Beta's simpler design and noticeably superior performance would have thrived, while an economic perspective might explore issues of first-mover factors, price, and market maturation. However, neither approach is fully explanatory. A complementary yet more integrative understanding is needed. In particular, we are concerned with the impact of factors such as network externalities and appropriability, which may profoundly moderate product commercialization but appear by and large neglected in the marketing perspective.

This unpredictable course in the evolution of technology brings substantial uncertainty to the firm's strategic decision-making in general, and research and development planning in particular. Indeed, it is by understanding why, and how, an innovation

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becomes dominant that a firm can strategically plan its resource allocation and make the type of informed decisions that will allow maximum opportunity to benefit from its own innovation (for example, by allowing the firm to capitalize on first-mover advantages). That is, the ability to foresee the processes of emergence will partly determine competitive winners, particularly in fast-paced technological environments.

Much of the earlier research analyzing technological change or innovation focused on the differences between pre- and post-dominant-design eras (Abernathy & Clark, 1985; Marquis, 1969; Pavitt, 1986; Utterback & Abernathy, 1975). The emergence process itself was essentially relegated to a 'black box' — an outcome of a sophisticated process driven by technological and non-technological factors (Rosenberg, 1982). Although several more recent studies (Anderson & Tushman, 1990; Hariharan & Prahalad, 1991; Tushman & Rosenkopf, 1992) attempt to uncover reasons underlying the emergence of a dominant design, an integrated framework for systematically analyzing this problem is still lacking.

Recognizing the strategic importance for a firm in understanding the dynamics of the emergence process, this paper suggests an analytical framework for uncovering this black-box process. While we note above the insufficiency of the marketing and economic perspectives in explaining the emergence of a dominant design when there are competing designs, these perspectives are encompassed in this framework. By integrating various research disciplines into the framework, we propose a strategic perspective on exploring the dynamics of the emergence process. We argue that only through understanding certain external conditions and the interactions between technological and non-technological factors can a firm strategically define and manage key complementary assets (Teece, 1986) or strategic infrastructure (Hariharan & Prahalad, 1991), and hence seek advantage through market dominance.

It is not the ultimate concern of this framework to predict the winning design *ex ante*, but to suggest an important pathway for firms to pursue advantages through the technology planning process, a pathway which also creates heterogeneity among potential competitors. The ability of such a framework to spur analysis as a 'catalyst for dialog' is highly valuable (Carroll, Pandian, & Thomas, 1993).

After briefly reviewing existing thought about the emergence of dominant designs, we propose a framework for analyzing emergence from a strategic perspective and expand discussion of the role of *non*-technological forces. In order to illustrate the framework's applicability, we offer three distinctive examples of the emergence of a dominant design (computer tomography scanners, universal credit cards, and distance measurement for agricultural equipment). A fourth illustration, automotive power, shows how the framework may be used to analyze future prospects. Finally, we discuss implications for strategy and issues for future research.

II. THE EMERGENCE OF A DOMINANT DESIGN

Influence of dominant designs

Technology literature characterizes the dominant design as the key event in the evolution of an innovation, marking the transition from a fluid to a specific state (Utterback and Abernathy, 1975). It represents the end of the technical variation and selection cycle, and initiates an era of more incremental technological development (Anderson and Tushman, 1990 : 613).

The emergence of a dominant design has a significant impact on both supply- and demand-side economics. First, it reduces product-class confusion and permits producers to explore greater scale economies through learning-by-doing effects (Arrow, 1962). Such benefits normally can be expanded to both up-stream (e.g. standard and interchangeable parts) and down-stream markets (e.g. after-sales market), as well as markets for complementary inputs and peripheral devices (Farrell and Saloner, 1987). Second, a dominant design can reduce the risk associated with choosing between competing systems, for both producers and consumers. The degree of risk depends upon the extent of potential switching costs. Third, a dominant design has direct competitive effects, because when most of the competing

products are compatible, competition may be more on price than on design (Farrell and Saloner, 1987), and R&D emphasis more on process improvement than on product innovation (Abernathy and Utterback 1985). These effects, coupled with the reduction of consumption risk, lead dominant designs to spark demand and elevate product-class sales (Anderson and Tushman, 1990). However, the post-emergence period is also the beginning of a shake-out (Utterback & Suarez, 1992) since firms incapable of adjusting to the new competitive context will exit or fail. Finally, by reducing the number of issues for debate, a dominant design may facilitate cooperative behavior among oligopolists in the same industry (Hergert, 1987). A dominant design also may raise or lower entry barriers — essentially, it changes the basic nature of competition and entry barriers.

Emergence of a dominant design

The process of emergence of a dominant design has been described as a black box (Rosenberg, 1982), within which many diverse factors and conditions act to support and constrain the likelihood of any particular design becoming the accepted standard. The emergence process can be triggered internally if either buyer or seller has absolute selling or buying power (volume), or through external agreements with other manufacturers (Farrell and Saloner, 1987). A dominant design can also be precipitated by industry committee, government regulation, or even international standardization commissions.

Nevertheless, identification of alternative routes to the emergence of a dominant design does not indicate the determinants of the outcome. Research from multiple disciplines provides valuable insights to this black-box puzzle. Previous literature uses various levels of analysis and emphasis but generates the coherent suggestion that non-technological factors may dominate the emergence process (Arthur, 1989; Anderson & Tushman, 1990; Teece, 1986; Tushman & Rosenkopf, 1992).

Technology and innovation literature highlights the critical role of the user in influencing the adoption of a new design (Abernathy & Clark, 1985; Marquis, 1969; Pavitt, 1986; von Hippel, 1986). Anderson & Tushman (1990) address emergence from social and organizational perspectives, asserting that the emergence of dominant designs is an evolutionary outcome of the interactions among individuals, the organization, and networks of organizations. Tushman & Rosenkopf (1992) extend this view by arguing that the technological change within a organizational community is a result of the interaction among technological complexity as well as organizational and socio-political processes. Beyond these non-technological factors, historical events may strongly influence the adoption of technology since these sometimes unpredictable events could lock technology suppliers and users into a particular design due to the existence of increasing returns to scale, and hence prevent them from adopting other late-coming, competing technologies (Arthur, 1989).

Such research provides rich insights to the emergence of a dominant design, but its concern is generally more from a broader industry point of view than from a firm standpoint. It doesn't explicitly involve the possibility of firm heterogeneity. However, building on this broad view, Teece (1986) moves to the firm level of analysis to explore the puzzle of why innovators may lose in technological competition. His contingent solution proposes the strategic importance of complementary assets, which include firm capabilities other than technical knowledge and which, combined with appropriability, can significantly influence the distribution among firms of the profits from an innovation. In a similar vein, Hariharan & Prahalad (1991) argue that a heterogeneous firm can catch strategic opportunities by preempting others during a 'strategic window' in the emergence of a dominant design.

This research reminds us that the search for competitive advantage during the emergence of a dominant design may be an important source of heterogeneity and hence uneven distribution of economic rents. Especially because the dominant design is difficult to anticipate (Arthur, 1989) and can have profound implications for firm performance, it should be treated as a strategic issue, which previous research fails to do. Starting from this deficiency, our research attempts to elaborate a strategic approach by integrating economic, technological, organizational, and socio-political driving forces into an analytical framework.

III. DOMINANT DESIGN: THE STRATEGIC PERSPECTIVE

A dominant design is not a product, but a way of doing things which is manifested in a product. Neither is it a brand but, rather, the design underlying that brand. For the purpose of this analysis, we define a dominant design in a broader perspective as *the distinctive way of providing a generic service or function that has achieved and maintained the highest level of market acceptance for a significant amount of time.* A dominant design indicates the importance of gaining and keeping notable acceptance in the market through the varying pace of technological change. In addition, it encompasses both demand and supply side concepts since 'dominant' is a function of demand while 'design' is a function of supply.

From innovation to economic success and dominance

According to previous literature, the emergence of a dominant design can be structured as an interface between innovation and economic success. This interface, which previous research characterized as 'black-box', represents impediments to the diffusion of superior technology and frictions to the adoption of innovations which might have led the firm to market dominance. Before we start to explore the 'black-box', we need to briefly elaborate the concept of innovation and technological feasibility.

An *innovation* is knowledge in the form of an idea, or embodied in a method or device, that differs from existing knowledge or practice. Innovations may thus be 'soft' (ideas or methods) or 'hard' (tangible items). They need not be better than current practice, merely different. Given the development of an innovation, there is a necessary condition for an innovation to become economically successful or dominant, that is *technological feasibility.*

Technological feasibility of an innovation is a combination of *functionality, reproducibility, and superiority (or parity).* First, an innovation is feasible only if it actually works and can be created more than once. 'One-of-a-kind' innovations aside, most innovations are expected to be reproduced in some quantity. Second, a customer has little incentive to use (buy) the innovation unless it is perceived as superior, or at least equal, in value to the product, process, or service that it is intended to replace or substitute. We will note the cost aspect of value later in this analysis; the technological aspect means that the innovation must, on the whole, be as good as or better than the technology it would replace, at accomplishing a task or fulfilling a need. The exception is the innovation which creates its own task or need to be filled, and is itself the benchmark of performance.

Just as building a better mousetrap does not guarantee success, technological feasibility is a necessary but insufficient condition for an innovation or design to become economically successful or dominant. For example, the Japanese firms whose biotechnology research led to innovative catalytic enzymes for corn syrup production were unable to commercialize it, yet American firms built a multi-billion dollar business based on the process (Gamota and Frieman, 1988, p. 138).

Our research suggests that the underlying factors and forces influencing the emergence of a dominant design from a technologically feasible innovation are those outlined in Figure 1 below: certain 'external' conditions, a set of technological and non-technological 'driving forces', and the concept of assets which are complementary to the commercial viability of a design.

As suggested in the introduction to this paper, an understanding of these factors and forces is necessary if a firm is to reap the most from its R&D efforts, not only in the fundamental choice of research areas, but in the analysis of commercialization options as well.

The variety of factors that may influence the emergence of a dominant design precludes the use of simple heuristics for predictive purposes. For all practical purposes, we might well consider each situation unique. In fact, even designs that appear technologically similar may be remarkably

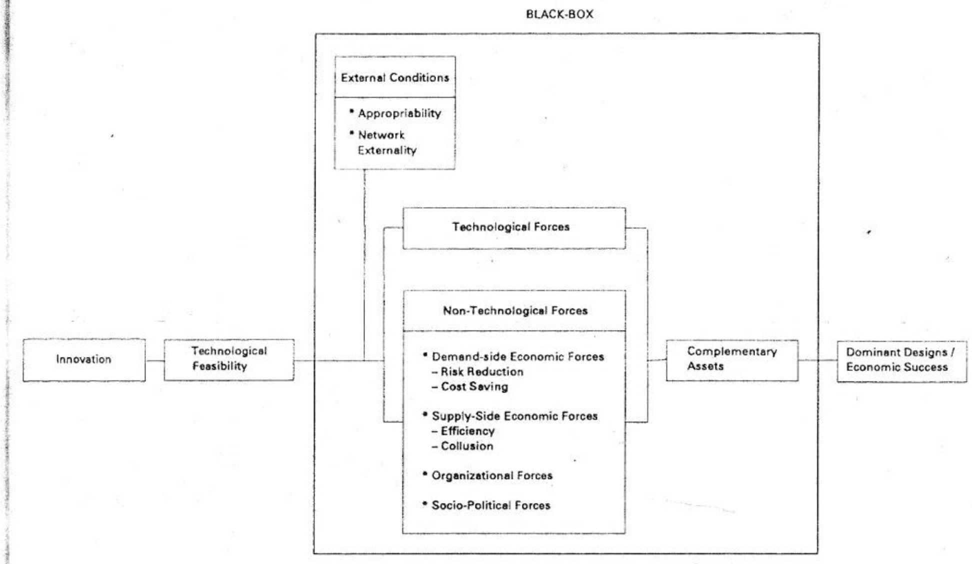

Figure 1 A Framework for the Emergence of a Dominant Design

dissimilar in the manner and forces by which they emerge. For example, Sun Microsystems emerged as the dominant firm in computer workstations, primarily due to first-mover advantages. MS-DOS, on the other hand, became the dominant PC operating system due to its adoption by IBM, which was a follower in the personal computer field. Therefore, rather than just a formula, it seems necessary to develop a transferable framework for systematic analysis. No obvious or easy answers result from using a framework rather than a formula, but we can be reasonably assured that many of the right questions will have been considered, and the range of possible actions narrowed down to those most likely to succeed.

This framework outlines driving elements in the emergence process, but it does not suggest that the process is necessarily linear or sequential. Like all models, it is a parsimonious description. Clearly, some elements are simultaneous and feedback loops can occur, but these characteristics are readily accommodated within the present model.

External conditions: appropriability and network externalities

The first major element inside our black-box framework is external conditions, including appropriability and network externalities.

Appropriability, the ability of a firm to protect an innovation from imitation by competitors, is partly a function of secure R&D and production environments and partly of patent, copyright, or trademark. A high degree of appropriability — slowing the diffusion or use of proprietary information — can have a major influence on an innovation's or a firm's success. It means that the firm does not have to compete, for a while at least, on the innovation itself. The stronger the firm's hold on the innovation, the greater the firm's degree of strategic choice. For example, it can shift resources into other R&D, cost reduction, or the development and strengthening of complementary assets (an issue to which we will return).

There are, however, two sides to appropriability. Encouraging imitation is a way of encouraging market development, as well as adoption of a particular design. The choice of an 'open architecture' for the IBM personal computer is a graphic example of this strategy and its results, which include both the stimulation of demand (a positive) and strong competitive pressure (perhaps a negative). Neither high nor low appropriability is desirable per se — it depends on the circumstances in which technological and strategic choices must be made.

Network externalities exist when a consumer's valuation of a good increases as a function of its adoption by other consumers. They represent for users a concept similar to minimum efficient scale for suppliers in that there is a 'minimum efficient demand' from the consumer's point of view. The presence of network externalities affects both the cost and benefit of a good, in turn influencing the utility provided by a good and thus its valuation by a consumer.

Network externalities may come from several sources. They can be generated through the direct physical effect of the number of purchasers on the quality of the product — phones have greater consumption utility as more users join the network (Katz and Shapiro, 1985). They can also come from the indirect effects of using a product — the utility of software support or repair service for cars depends on the number of other users in the same user-group or 'network', since in these cases the unit costs and variety of these complementary products are highly related to the number of other users (Chou and Shy, 1990).

The scope of the network that gives rise to the consumption externalities will vary across markets. However, the higher the dependence on network externalities, the greater the need for some form of compatibility among competing designs and the more likely that the emergence of formal or de facto product standards will strongly influence which design becomes dominant. This suggests that in the case, for example, of an innovation with significant network externalities, the firm faces an obvious choice between encouraging imitation of the design or trying to set the standard while keeping its hold on the design.

Of course, appropriability and network externalities may not be significant factors in the commercialization planning of all innovations, but they merit evaluation beginning at the earliest stages of the R&D planning process.

Driving forces

The second major element inside the black box of Figure 1 consists of a taxonomy of driving forces, those related essentially to technology and those classifiable as non-technological — organizational, socio-political, and economic forces on both the demand and supply sides.

Technological forces

Various technological forces and factors influence the emergence process.

The *rate of technological change* clearly affects the number of design alternatives available. The attendant pace or possibility of obsolescence (not all change makes previous technology obsolete) affects the propensity of suppliers and buyers to invest in a design. The rate of change or evolution within the context of a specific design also affects the desirability of committing to that design.

The *type of change* — radical or incremental (Abernathy and Utterback, 1988) — influences the pace of obsolescence and thus the propensity to invest, as does the *degree of fit* with existing technology, both on the supply side (i.e., with production-related technologies) and on the demand side (i.e., with other technologies currently used by consumers). Note that radical change does not necessarily imply a misfit with existing technologies.

These forces — rate of change, type of change, and degree of fit — all affect the emergence process and the R&D and commercialization choices a firm must make. Sets of non-technological forces, however, provide further complications to strategic choice, as suggested below.

Non-technological forces

Organizational Forces of two kinds influence the emergence of a dominant design — forces within an individual organization and those between and/or among organizations.

Intra-organizational forces concern how an organization reacts to technological change. Uncertainty brings disagreement and conflict among different power groups inside an organization over the direction and format of research, development, and commercialization, and continued R&D. These forces play out in ways not entirely dissimilar from a market, for example the ability to sell visions of new products, or 'expeditionary' marketing in the words of Hamel and Prahalad (1991). Organizations tend to specialize both in technologies and in the way they develop and organize research. Further development based on that existing competence may lead to competency traps (Levitt and March, 1988) if those technologies are, in the larger arena, being supplanted (although older technologies often retain profitable markets). The chances of competency traps are sensitive to learning rates. The faster a competing technology or method of organization can be learned by an individual organization, the higher the probability it will mesh with or supplant the existing technological routine. Success and failure reinforce the learning of new recipes (Brown, 1991).

On the other hand, the *interactive learning between organizations* also is important. Organizations sometimes follow the leads of others and, clearly, the adoption of a competing technology by organizations may pressure another, interdependent, organization to mimic them. This imitation may, for example, be the result of explicit demands by customers or suppliers, or the result of observing others' successes or failures.

Socio-political forces are perhaps the least predictable, quantifiable, or controllable.

Many players besides the firm have important stakes in the outcome of the innovation process and may take active influential roles. Their motivations need not be primarily economic, but may relate to political power, social issues, culture, or values and beliefs (see the institutional forces of Dimaggio and Powell (1983)). Customers, suppliers, and governments — national, regional, and local — may have substantial interests in, and preferences for, particular designs. They may also have reasons to support or oppose the general move to standardization. Standards may be influenced by dominant producers, powerful users or groups of users, industries, and governments (Anderson and Tushman, 1990). The many forms of government research, industry, and trade policies and actions can greatly affect innovation, development, and commercialization through their impact on resources and the cost and rules of doing business.

Economic Forces or incentives are of two sorts — one belonging to the demand side (i.e. buyers), and the other relating to the supply side (i.e. suppliers) — which influence the commercial acceptance and dominance of a design.

Demand-side forces include *cost-saving* and *risk-reduction.* The emergence of standard or dominant designs is induced in part by the desire of buyers to increase purchasing efficiency, by lowering search costs, and to reduce risk, by lowering switching costs (Hergert, 1987). Search costs arise primarily from information asymmetry between buyers and sellers about the product, and are exacerbated where a wide variety of product choices are available. Risk-avoidance influences potential buyers to wait for the emergence of an industry standard before purchasing. From the customer's perspective, therefore, dominant designs reduce product-class confusion and the possibility of switching costs. Returning to the idea of value, we can see that search and switching costs are inescapably part of the cost component of the buyer's estimation of value.

Supply-side forces include *efficiency and collusion.* The emergence of a dominant design offers the opportunity to improve a producer's efficiency through scale economies, by limiting the variety of systems offered, and by simplifying the technical information needed for efficient production. Marketing costs also can be significantly reduced through simplified customer communication, lower inventory requirements, and a smaller variety of systems to service.

The existence of a dominant design also may facilitate oligopolistic coordination by eliminating competitive versions of the underlying technology. Tacit collusion may be easier with lower degrees of product diversity.

Complementary assets

The third major element inside the black box of Figure 1 consists of complementary assets: particular capabilities or resources which, in addition to technological knowledge, are essential to the commercial success of a project (e.g., marketing, distribution, service, or manufacturing capabilities). Possessing them is one reason that imitators sometimes outperform innovators (Teece, 1986).

Complementary assets are partly a function of the innovation, and partly a function of strategic choice. They depend upon the innovation itself, not the firm, and upon the factors underlying the emergence process, including the set of implementation choices available to the firm. Different commercialization strategies may require different complementary assets, but not all strategies are feasible, so some commercialization efforts may be stymied. Some assets or resources may be bought on the open market (Barney, 1988), but others are inimitable and tend to accumulate over time (Dierickx and Cool, 1989).

Here, again, even if the complementary assets necessary to support its design's success are not within the firm's control, awareness of that limitation is essential to the decision of whether to pursue the project, and how, and to what degree.

IV. ILLUSTRATIONS OF THE FRAMEWORK

As argued above, the essence of the emergence of a dominant design is the dynamic relationship among external conditions, driving forces, and the (organization of) complementary assets. Although these relationships are difficult to generalize, analysis based on this framework can help strategic planners through this 'mysterious jungle' and on to economic success. To demonstrate this, we utilize four 'real-world' cases which illustrate the applicability of this framework in strategic planning for the success of an innovation. Instead of elaborating every detail of each case, we intend to draw readers' attention to the underlying factors that were critical to the emergence of the dominant design in each particular situation. In this manner we suggest the critical role played by complementary assets, given the key forces that were specific to each case.

The first three examples will illustrate the use of the framework in examining, *ex post*, the circumstances surrounding the emergence of a dominant designs. The fourth example will show how the framework can be used, *ex ante*, to help anticipate which forces will likely be crucial to the emergence of a dominant design.

EMI in the CT scanner market, the first case, is a classic example of the failure of an innovator to remain the dominant firm in its area of innovation.

In 1970 EMI (Electric and Musical Industries, Ltd.), whose technological innovation over the years had resulted in the automatic record changer, stereophonic records, magnetic recording tape, the pioneer commercial TV system adopted by the BBC in 1937, and airborne radar, began seeking ways to reduce its overwhelming dependence on the music industry. In the early 1970s, internal research resulted in the development of computerized tomography (CT), which creates a three-dimensional image of an object by taking multiple X-rays from different angles and then using a computer to construct a picture. After patents and successful clinical trials, EMI introduced the CT scanner into the U.S., and was successful for the first few years. However, as other (late but highly-competitive) entrants like GE and Technicare appeared, EMI soon lost its market leadership, and eventually left the market altogether.

EMI's scanners failed because the firm could not gain certain necessary complementary assets, nor could it appropriate the technology. First, the CT scanner is a sophisticated, complex piece of equipment. As a consequence, highly-qualified training and maintenance support is important to hospitals, but EMI lacked these resources when it entered the market. Second, although CT technology was a conceptual breakthrough, it basically combined three existing technologies: X-ray, data processing, and cathode ray tube display. Therefore, it was not difficult for competitors to reverse-engineer and invent around. The threat worsens in a system of imperfect legal protection. If the incumbent firm cannot control the key and tacit technology to prevent competitive entry, then the erosion of incumbent advantage, hence profitability, is inevitable.

While the EMI case reveals the interplay between appropriability and complementary assets on the success of an innovation, the second case, *universal credit cards*, depicts the dynamic relationships among network externalities, economic driving forces and complementary assets.

The idea of credit cards was introduced into daily life almost a century ago. So-called 'plastic money' has evolved from the initial retail cards to the dominance today of universal cards. However, since the early days there are two distinct operating ideas behind universal credit cards — that of T&E (travel and entertainment) cards and of Bank Credit Cards. While both cards provide cardholders the privilege to charge their purchases from thousands of participating merchants, they are different in, among other things, type of issuer, payment method, and service charges to the merchants. For T&E cards (e.g., American Express and Diners Club), the operating company issues the cards, extends credit to cardholders (which has to be paid in full before next billing cycle), and receives services fees in return from both cardholders and participating merchants. However, for Bank Credit Cards (e.g., Visa, MasterCard, and Discover), financial institutions become the card-issuing units and cardholders can not only choose to pay their debts in monthly instalment with interest but also borrow money from the card issuers. For these card issuers, interest becomes the major source of revenue; service fees to both cardholders and participating merchants are normally low.

These two operating systems have developed in parallel since the 1950s and still coexist. Market share analysis reveals clear dominance by Visa with over half of worldwide charge volume, while American Express has about 15% (Spiro, 1992). In fact, in 1988 there were around ten times as many bank cardholders as T&E cardholders. Why did Bank Cards become the dominant system? To answer this question, we have to look at the nature of network effect and its impact on both demand- and supply-side incentive in adopting a system.

For the operation of a universal credit card, the installed base, both quantity and quality, of merchants and cardholders will directly determine the acceptance of that particular card by both parties. Prospective cardholders want a widely-usable credit card, while potential affiliated merchants expect more of their target customers to be the cardholders. Card issuers must resolve this chicken-and-egg problem before they can successfully promote their specific card system. Hence, the acceptance of merchants, especially large chain merchants, becomes the crucial complementary asset in the development of a credit card system. J.C. Penney's acceptance of Visa in 1979, which allowed bank cards to promote their affiliation with nearly half of the country's major retailers, is a typical example.

The need of a credit card network has a profound effect on the incentives of accepting a particular credit card for cardholders and affiliated merchants on the demand side, as well as card issuers on the supply side. The basic incentive for consumers to have a credit card may be to get maximum credit for minimum cost; for merchants joining a card network, maximizing sales and minimizing service charges is the key. Since a person can hold more than one card, the net cost-benefit becomes the major concern for both cardholders and affiliated merchants. Bank Cards raise cardholder benefits through low annual fees, low service charges, and credit availability, in addition to more recent innovations like cash-back bonuses, extended warranties, etc.

On the supply side, multiple credit providers (banks) within the Bank Card system do enhance the scale and network effect. In fact, until 1966 most US Bank Cards operated independently of each other, as did T&E cards. However, in 1966 Bank of America announced that it would license the operation of its BankAmericard (now Visa) across the US to enable the cardholders to use a card purchasing goods in areas served by other banks, and this operational idea soon made local cards nationalized. Following the same idea, several large banks formed Interbank Card Association, and were renamed as the Master Charge card (now MasterCard) in 1969. Eventually, the Visa/MasterCard method became today's dominant Bank Card system. Given the nature of network externality, BankAmericard's strategy of licensing proved to be a successful service design since participating banks own their limited customer accounts yet enjoy a network of affiliated merchants on a national basis.

The credit card example indicates the critical role of network externalities in the emergence process. The third case, *distance measurement of agricultural equipment*, highlights the importance of economic forces in the emergence of a new technology.

For many years mechanized agricultural equipment, such as tractors and harvesters (combines), measured distance travelled by means of an odometer, driven from the vehicle's power transmission, in a manner similar to automobiles and trucks. Operating in the field, any vehicle experiences some degree of wheel slippage, which varies depending on soil conditions, weight, and speed. The accuracy of odometer readings was, therefore, a function of wheel slippage, which is normally in the 7 to 15% range, but can easily run 25%, or higher.

In the 1970s, as grain-belt farmers expanded operations to obtain economies of scale, accurate measurement of field operations became essential to the management of seed, chemical, and fuel costs, and, even more important, time. In 1975 a new distance-measuring device was introduced for field use. This radar sensor, mounted on the vehicle and aimed at the ground, compared the time and intensity of sound waves transmitted and received, to calculate distance travelled, thus completely eliminating the effects of wheel slippage.

Although extensively tested over a period of years, adoption by the customers (farmers) was painfully slow, in spite of the enthusiastic endorsement of early-adopters. Word-of-mouth reports fed a gradual diffusion of information until the agricultural original equipment manufacturers (OEMs) began to realize the potential of this dramatic improvement in measurement accuracy. They then provided the impetus to wider use — their endorsement — by offering radar first as an option, and then as factory-installed standard equipment.

This example illustrates the key role played by economic considerations in the emergence of a new technology. The demand considerations were primarily economic — a search for operating efficiency in the field — but not until purchase risk was minimized by availability from trusted sources were potential users willing to adopt it. The supplier's key considerations were economic, too — the technology appeared superior and potentially profitable, but not worth risking reputation and customer loyalty for until proven in field use. So, although this innovation was obviously superior to previous technology, demand-side and supply-side economic forces became barriers to its emergence as the dominant design. Ultimately, the innovator was able to overcome supply-side resistance by field-proving the design's value and, once the OEM put his stamp of approval on the design by offering it on his equipment, the customer's demand-side risk concerns were also overcome.

As previously mentioned, these first three examples illuminate how the strategic framework for the emergence of a dominant design can be applied to the analysis of various historical situations. In the fourth example, *automobile power*, we shift our discussion to planning for the future, and begin by noting a common challenge of the first three cases, that of formulating strategies for controlling critical complementary assets.

To use the strategic framework to help anticipate the likely keys to the success of an innovation, picture a firm willing to invest in developing electric power for cars, given a reasonable chance of earning an adequate return. To achieve this, management should first formulate a strategic plan to maximize the possibilities of their design emerging as a significant competitive force in automotive propulsion. An understanding of how the current dominant design emerged becomes necessary.

The gasoline, internal combustion piston engine is the dominant form of power for most automotive uses, yet battery-powered electric motors were an early alternative, as were diesel and steam engines. All of these save for electric motors were based on the existing concept of piston engines. At one level, the electric motor lost out for technological reasons (weak power and the inability to carry much energy) and for complementary asset reasons (the battery and motor industries, and the electrical infrastructure, were in their infancy). Also, electricity was costly, but gasoline was a nuisance by-product of the petroleum industry and could be added onto an existing distribution network. Network externalities were not a significant issue for users, but it is important to note that the number of users is directly tied to suppliers' incentives to provide a delivery system.

Economic incentives played a very strong role. On the supply side, moving to a dominant technology brought scale economies, allowed incremental technological improvement, reduced risk by building on strong companion industries, and reduced the risk of obsolescence of large, technology-specific capital investments.

On the demand side, an unsophisticated market benefited from reduced searching costs (product choices now consisted of variety within a standard design), a comprehensible product (which batteries and electric motors arguably were not), scale economies in service, and lower risk (easier re-sale reduced switching costs).

Changes since the early days of automotive power act both for and against the continued dominance of the current system. Battery/electric motor technology is increasingly close to commercial feasibility, but its cost and power lag those of combustion technology. A form of network externality has emerged for current engines in that consumers have benefited from the continuing improvement facilitated by large demand. Regarding appropriability, batteries and electric motors can be taken apart, but it remains to be seen whether production technology would be sufficiently complex to hinder imitation.

However, perhaps the most obvious changes are the strengthening of the salient factors that supported internal combustion engines. Petroleum is now a world-wide, distribution-intensive, capital industry complementary asset and, although electricity is widespread, the problem for electric cars seems to be more how cars might fit into the power grid format, not vice versa. The economic incentives discussed above also continue in great part.

There is no obvious answer as to what our hypothetical entrepreneurial decision-maker should do. However, the above analysis does suggest several issues for consideration. First, since there is now a broad distribution network for electricity, the complementary asset issues that constrained electrical cars in the past are now less significant. A major constraint now seems to be the motor/battery technology itself. Second, in addition to considering complementary assets and economic incentives, he might focus attention on other factors, such as legal and socio-political forces, that might drive the adoption of battery-powered cars. Finally, it suggests that, once technologically feasible, the technology may be competitive only in niches. For example, hybrid designs, combinations of combustion and electric power, might be able to capitalize on the economic forces relating to combustion engines.

V. STRATEGIC IMPLICATIONS

We have demonstrated a conceptual framework describing the process leading from an innovation to the emergence of a dominant design. Although the pattern of emergence varies from one design to another, a number of general strategic implications and research avenues can be drawn from this framework.

First, the framework conveys a strong message about the *dynamic characteristics of the process that make the emergence of a dominant design much more than competition between the technological characteristics of innovations*. The path from innovation to commercial success is so littered with potholes, detours, and roadblocks, that the attainment of technological superiority may have little to do with which firm's design evolves as the standard. Firms need to understand the importance of *non-technological factors* in the process of commercializing innovations in order to formulate and pursue profitable strategies.

Second, it offers a *systematic sequence for analysis of the forces that can influence or impede a particular innovation, and which must therefore be strategic considerations.* Analysis from a strategic perspective is crucial to the corporate overview that is necessary to neutralize the blind-spots and separate agendas that so often influence decision-making at the functional or sub-unit levels, particularly in the promotion of an innovation. The framework provides practical guidance for researchers and practitioners alike on how to analyze the emergence of dominant designs, as well as periodic consideration of changes in such areas as external conditions, underlying forces, and complementary assets. *For example, the analysis can start from asking what is the basic unit of analysis — what is the generic service or* *function provided by this product or technology type? That generic service or function can be described in terms of its 'life cycle' by exploring how the demand for and basic nature of the service or function have changed over time and what may be expected in the future. By looking at designs, which are distinctive alternative ways to fulfill the generic service or function, we can describe the broad set or sequence of technological steps that have been or can be pursued, which designs have been dominant, what designs are achievable by the firm, and who else outside the set of existing suppliers of alternative designs could provide this service or function based on present or anticipated technology?*

Third, the framework *focuses particular attention on the economic considerations*, both for the demand-side and supply-side, that become primary driving forces in the emergence process, and which can have significant influence on which complementary assets may play crucial roles. While Teece (1986) focuses on ownership of complementary assets, *we offer a strategic approach to the identification of the criticality of such assets. Assets are complementary only in relation to a strategy and to the forces and factors identified in our framework.* While complementary assets can be catalysts to the emergence process, they can also present barriers to entry. This framework therefore, also suggests that competitive strategies based on product standardization may offer important competitive advantages.

Standardization relates to how a design is implemented in competition, suggesting that complementary assets are a function not only of conditions, but of implementation as well. They are not a question of formulation or of a 'correct' ex ante setting up of a resource mix. A firm needs early awareness of possible complementary assets, but *complementary assets cannot be defined or predicted without looking at availability and at implementation choices*.

Fourth, the framework suggests further research. It highlights the need for research on links between the various forces and factors. *For example, how are complementary assets related to network externalities?* What sorts of complementary assets are needed to address an externality, and what does the externality imply, if anything, for complementary assets the firm has for other reasons? Once a firm understands the possibly complementary nature of certain assets, should it acquire them, create them, or devise an alternative strategy which bypasses them?

Finally, beyond the suggestion that additional systematic exploration is needed of the nature and determinants of the elements identified in this framework, there remain fundamental questions about the significance of dominant industry designs from a firm's point of view. Under what conditions is the existence of, or participation in, a dominant design desirable or undesirable for the firm? How can a firm benefit from a dominant industry design and, conversely, what strategic choices and advantages does the firm possess in the absence of one?

VI. CONCLUSIONS

Although the literature on technology, innovation, and organization research has extensively discussed how dominant designs ultimately emerge from among competing innovations, it has offered little practical assistance to strategic planners in explaining how to improve a firm's chances of capitalizing on its own or others' innovations. This paper attempts to fill that void by offering a strategic framework that allows R&D planners to systematically analyze the *non-technological forces* that may prevent even the most technologically superior innovation from becoming commercially successful.

The variety of non-technological factors that may influence the emergence process, coupled with the heterogeneity of firms, precludes the use of simple heuristics or formulas to predict or analyze emergence. Although our framework does not offer easy answers, it does give reasonable assurance that the most critical issues will have been considered, and the right questions asked. It reminds us to evaluate the possible influences of external conditions, non-technological forces, and the complementary assets that may be essential to successful commercialization.

The effectiveness of a corporate strategy

hinges on thoughtful formulation, which requires analysis of industry forces, forces in the broader environment, and the firm's internal strengths (distinctive competences) and weaknesses. But no matter how well-formulated a strategy, effective implementation is essential to its ultimate success. Since the strategies of organizations are both formulated for and dependent on commercial success of specific products and services, it stands to reason that formulation and implementation of individual product/service strategies can help maximize not only their individual successes but, cumulatively, the success of the overall corporate strategy.

The strategic framework offered here can be useful in guiding both the formulation and implementation of a strategy for the successful development of an innovation. Inventing and introducing new designs without understanding what can happen to them in the 'black box' of the emergence process is akin to flying at night without instruments — with luck you may get where you are going, but with the ability to foresee obstacles likely to block your path you can substantially increase the probability of a successful arrival.

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