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Battles for technological dominance: an integrative framework

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Abstract

This paper proposes an integrative framework for understanding the process by which a technology achieves dominance when "battling" against other technological designs. We focus on describing the different stages of a dominance battle and propose five battle milestones that in turn define five key phases in the process. We review the literature from several disciplines to identify the key firm- and environment-level factors that affect the outcome of a technology battle and posit that the relative importance of each factor will vary depending on the phase considered. Our framework complements and extends existing literature and has implications both for theory and for management practice.

Keywords: Dominant design; Standards; Platform; Technology battles; Technological change

1. Introduction

During the last two decades, the business press has stressed the occurrence of several "battles for dominance" between two or more rival technologies, often involving well-known firms operating in highly visible industries. Stories such as those of the high definition television (HDTV), PC operating systems, VCRs, modems, Internet browsers and—more recently and still ongoing—web services and third generation wireless systems, have attracted significant attention from the business press and the academic community. The outcome of these technological battles often determines not only the fate of the winning and losing technologies and their sponsoring firms, but also whether a whole array of complementary goods and services offered around each of the competing alternatives prospers or decays.

Under labels that include: "dominant designs" (Utterback and Abernathy, 1975; Anderson and Tushman, 1990; Utterback and Suarez, 1993), "technological trajectories" (Dosi, 1982; Sahal, 1982) and, more recently, "platforms" (Meyer and Lehnerd, 1997; Cusumano and Gawer, 2002), management scholars have been studying technology battles for several decades. Economists have assumed actors' rational behavior to study similar phenomena under the labels of "standards" in network industries (Katz and Shapiro, 1985; David and Greenstein, 1990); and "technology diffusion" (Reinganum, 1981). The Internet boom of the late 1990s contributed to the popularity of "standards wars" and network effects (Arthur, 1998)—although some of their claims have since been disputed (Liebowitz, 2002). Regardless of the label used, we argue that these different bodies of literature address different facets of the same phenomenon: the emergence of a dominant technological trajectory among several competing ones. We use the broader notion of a technology's "dominance" to refer to this concept.

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This paper proposes an integrative framework for understanding the process by which a technology achieves dominance when competing with alternative technologies designed to achieve the same objective. Although important progress in this direction has recently been made (Gallagher and Park, 2002; Schilling, 1998; Shapiro and Varian, 1999), no framework has, so far, linked the ideas and conclusions coming from the different studies and streams of literature dealing with the topic in a way that it is helpful both to researchers and to practitioners. To date most of the effort has been focused on identifying the different factors that affect the final outcome of a technology battle—e.g. technological superiority, firm resources, institutions' role, etc. (Suarez and Utterback, 1995; Schilling, 1998; Shapiro and Varian, 1999; Scott, 1994; Scherer, 1992)—but has provided insufficient insight as to how these factors play out in different situations, and particularly how their effect varies over time. A few studies provide in-depth insights into the process by which a technology achieves dominance, but these have typically been based on one or a few case histories (e.g. Khazam and Mowery, 1994; Garud et al., 2002; Gawer and Cusumano, 2002), and it is therefore hard to generalize from their results. There remains a need for further integrative effort—based on a meta-analysis of the empirical, theoretical and case-based literature to date—if we are to improve our understanding of the process by which a technology achieves dominance and the various strategic options available to firms at different stages.

By focusing on the process of dominance and proposing five battle milestones that in turn define five key phases, we are able to shed light on the different stages of a dominance battle. We posit that the relative importance of the different factors of dominance will vary depending on the stage considered. Our framework complements and expands existing literature, integrating the various perspectives into a more consistent and comprehensive approach. We argue that most of the "value-added" to management practice—and theory—resides in the very process of achieving dominance. Firms involved in technology dominance battles—sponsor firms and producers of complementary products—still lack an integrative framework within which to make sense of their own actions and those of other actors. The literature on standards and dominant designs has sometimes been criticized, rightly so in most cases, for being "ex-post" in nature, which limits its usefulness and utilization in management life (Tushman and Anderson, 1986). We believe a more interesting and useful theory on the subject will derive from a better understanding of the "ex-ante" dynamics—i.e. the process of dominant design and standard formation. Our framework applies mostly to battles that develop within the broad set of industries typically defined as information and telecommunication technologies—which have been the focus of much of the research on this topic so far. Although we believe that many of the concepts and stages proposed here may well apply to other contexts—e.g. biosciences—further research is needed on these contexts before the framework can be extended to include them.

2. Theoretical streams on technological dominance

Technology management scholars were among the first to study the technology dominance phenomenon systematically. The work of Utterback and Abernathy (1975)—who coined the term "dominant design" to signify the emergence of a dominant technology in an industry—gave rise to a whole stream of literature that continues to date (Gallagher and Park, 2002). A technology—broadly defined as a set of pieces of knowledge, some of which are embodied in physical devices and equipment—becomes dominant as the result of a complex process by which several competing alternatives and versions are de-selected until a preferred technological "hierarchy" becomes evident; a particular design then emerges (Clark, 1985). This notion of hierarchies or "trajectories" is also present in other technology management articles (e.g. Sahal, 1982; Dosi, 1982) and economics-based studies of innovation (Nelson and Winter, 1982). Indeed, the whole notion of technological dominance is related to studies on the sociology of science and technology, which postulates that both science and technology evolve through extensive periods of incremental change, punctuated once in a while by revolutionary breakthroughs (Kuhn, 1970).

A series of empirical studies corroborated the existence of dominant designs and tested for some of the concept's strategic implications. Anderson and Tushman (1990), using data from three different industries, build on the early literature by testing eight hypotheses about the emergence of dominant designs. Suarez and Utterback (1995) research the effect of entry timing—entry pre- or post-dominant design—on the survival of firms. Christensen et al. (1998) provide a detailed definition of dominant designs and identify, for the disk drive industry, the specific technological elements that comprise the resulting dominant design. Tegarden et al. (1999) use the PC industry to test whether decisions, with respect to a particular design or technological trajectory, made by firms at entry are "reversible"—that is, whether firms can switch effectively to a different technology after entering with the "wrong" one; these authors find that, in the PC industry, firms are not necessarily "doomed from the start". Klepper and Simons (2000) show how previous experience in radio influenced entry, firm performance, and technological dominance in the US TV industry. Finally, a more qualitative cluster of research has focused on single-firm or single-industry case studies. Cusumano, Mylonadis, and Rosenbloom (1992) describe the strategic choices that led to the emergence of a dominant technology in the VCR industry, stressing the importance of pioneer R&D efforts on a firm's ability to compete successfully. Willard and Cooper (1985) describe the evolution of the US color television industry; Tripsas (1997) describes the evolution of technology in the typesetter industry; and Khazam and Mowery (1994) describe the battle between RISC and CISC microprocessor architectures. Overall, the technology management literature stream has stressed the specific elements that comprise a dominant architecture, emphasized the importance of adopting these elements and examined the implications of entry timing on the final outcome of a technology battle.

A related stream of literature, centered on the idea of technological platforms or product "families" (Sanderson and Uzumeri, 1997), originated from efforts to improve firms' new product development processes by shortening lead times and reducing costs (e.g. Meyer et al., 1997). Some authors then used the platform management concept to explain the emergence of dominant technological platforms in entire industries. For instance, Cusumano and Gawer (2002), study the impact of firms' strategies on the race for a dominant technological platform in the semiconductor industry. The Cusumano and Gawer study borrows from new product development literature the attention to issues such as the organizational structure of development teams (Clark and Wheelwright, 1992) or the make versus buy decision (Richardson, 1993; Cusumano and Nobeoka, 1998). However, its main contribution is in the detailed exploration of the actions—entailing a delicate balance between collaboration and competition—undertaken by firms to secure and manage a healthy pool of producers of complementary goods for their systems, so as to make them more attractive to customers.

The complexities of accumulating support for a technology led several authors to approach the issue from an institutional theory perspective. Building on earlier research focused on the roles involved in shaping emerging institutions (DiMaggio, 1988), several authors have looked at the processes of "institutional entrepreneurship" in the setting of technology standards—that is, the actions by which actors define, legitimize, combat, or co-opt rivals in order to succeed in their institutional projects (Scott, 1994). Garud et al. (2002) use this approach to analyze the case of Java; Garud and Kumaraswamy (1993) explore similar issues around Sun's open systems strategy in the workstation market; and Wade (1995)—borrowing from population ecology—describes how the main microprocessor producers built up organizational communities to support their technological designs. Tushman and Rosenkopf (1992) suggest that dominant designs arise as a result of community level socio-political processes that adjudicate among feasible options, i.e. "a negotiated logic enlivened by actors with interests in competing technical regimes" (p. 322). These papers highlight the challenges and dilemmas faced when trying to gather support for technological designs: on the one hand, some actors have—at least partially—to give away their technology in order to gather support; on the other hand, such behavior tends to constrain the choices both of the sponsoring actors and of those who decide whether or not to support a given technology. This stream of research additionally sheds light on the boundary to be considered in studies of communities formed around a particular technology; more specifically, a "technological field" is defined as "a pattern of relationships among objects and humans related to a product-market domain" (Garud et al., 2002).

A final major scholarly perspective on technological dominance is that of industrial economics—in particular, the stream known as "network economics". Researchers in this stream of literature have developed formal models—based mainly on game theory—to understand the implications and dynamics of standard setting. A standard is understood as a set of technical specifications adhered to by a producer, either tacitly or by formal agreement (see for instance, David and Greenstein, 1990 for a review). The hallmark of these models is that network effects are built into the demand function, i.e. products represent a particular technological network and the benefits derived by users—which influences the level of demand—depend not only on each product's specific attributes, but also on the relative size of the installed base of that network compared to competing networks (Katz and Shapiro, 1985). Some models concentrate on the demand side—e.g. customers' expectations—while others focus on the supply side—e.g. firms' strategic behavior.

Although the wide variety of models available means it is not feasible to incorporate a complete review of the literature within the scope of this paper, some key aspects of the models' structures and implications can be highlighted. Most models consider a world comprising two firms, each representing a particular technology and a particular network: the "old" and the "new". Customers typically buy just one product, and there are network externalities in the demand function. From then on different assumptions allow for the exploration of different issues. Farrell and Saloner (1986), for instance, explore the private and social incentives for adoption. They show that when there are delays in building a network—i.e. when a network is built over time—inefficiencies may arise in the form of "excess inertia" or "excess momentum". Katz and Shapiro (1992) provide conditions under which, instead of excess inertia, the equilibrium involves "insufficient friction"; that is, a tendency to rush to adopt the new, incompatible technology. Significant attention has been devoted to the conditions by which the industry will either be "locked in" to a particular technology or will allow different technologies to coexist—"multiple equilibria" (Arthur, 1989). There is no integrative model that pulls all the findings from the different models together, but the modeling literature has added to our understanding of battles for technological dominance by highlighting at least the following issues: (a) the role of firms' installed base and "excess inertia"—a bias towards the technology with the largest installed base (e.g. Farrell and Saloner, 1986); (b) the role of consumer expectations, shaped by brand image, pre-announcements and information availability (e.g. Arthur, 1989; David, 1987; Farrell and Saloner, 1985); and (c) the importance of dynamic elements of firms' strategies, such as pricing and licensing policies (e.g. Farrell and Saloner, 1986).

3. Factors associated with technology dominance

Technological dominance occurs at different levels of analysis. For instance, the literature on technology management has long conceptualized technological artifacts as composed of subsystems that are linked together and has distinguished between simple products and complex products comprising many subsystems (Clark, 1985). A well-accepted classification is that of non-assembled products, simple assembled products and complex systems (Utterback, 1994; Tushman and Rosenkopf, 1992). Non-assembled products have no separable components (e.g. light emitting polymers); simple assembled products are made up of a few components or subsystems (e.g. disk drives); and complex systems are made up of a set of technological subsystems that link together through specific interfaces (e.g. computer). The literature on standards employs a different set of classification criteria, differentiating between quality standards and compatibility standards: quality standards simply indicate that a product conforms to specific characteristics, while compatibility standards indicate that a product can be used with other specified products (David and Greenstein, 1990). Furthermore, compatibility standards can either be non-sponsored or sponsored, the latter being the case where one or more actors holds a direct or indirect proprietary interest in a particular technology and actively seeks to persuade others to adopt it.

For the purpose of this paper, we will focus on sponsored technologies used in non-assembled, assembled, or complex products; this allows us to embrace the most interesting cases of dominance battles—those that put different actors in active competition against each other. We claim that the nature of the dominance process remains the same when going from simple non-assembled technological artifacts to complex systems; in all cases, different technological trajectories or designs, sponsored by different actors, compete for dominance through a process where economic, technological, and socio-political factors are intertwined (Tushman and Rosenkopf, 1992). No technology works in isolation; at each level, some coordination and compatibility with other products or systems is required. What changes is the complexity of that process: the more complex the product, the greater is the number of actors needing to be aligned for a technological design to achieve dominance and thus the more complicated the sponsoring role becomes. For a simple assembled product a sponsoring firm may only have to deal with one key interface and one key group of complementary products or users, while a complex system may require paying attention to many different interfaces and negotiating with several different types of users and producers of complementary products. The level of complexity to be managed will increase non-linearly with the numbers of actors involved or, in other words, the boundary of the technological field (Garud et al., 2002) expands as we move from simpler technological artifacts to more complex ones.

Irrespective of the size of the technological field, two broad groups of factors influence the outcome of a technology battle: firm-level factors and environmental factors—see Fig. 1. This broad distinction is consistent with the existing schools of thought in management that stress the importance of firm-level capabilities and resources (Dierickx and Cool, 1989) and environmental factors (Dess and Beard, 1984; Hannan and Freeman, 1977; Porter, 1985) on the performance of different firms in an industry. However, technology battles have very special dynamics and it is therefore important to identify the specific factors that play a role in the process. Note that, from a methodological point of view, the environmental factors cannot only directly influence the outcome of a technological battle—e.g. via a regulation that mandates the use of a

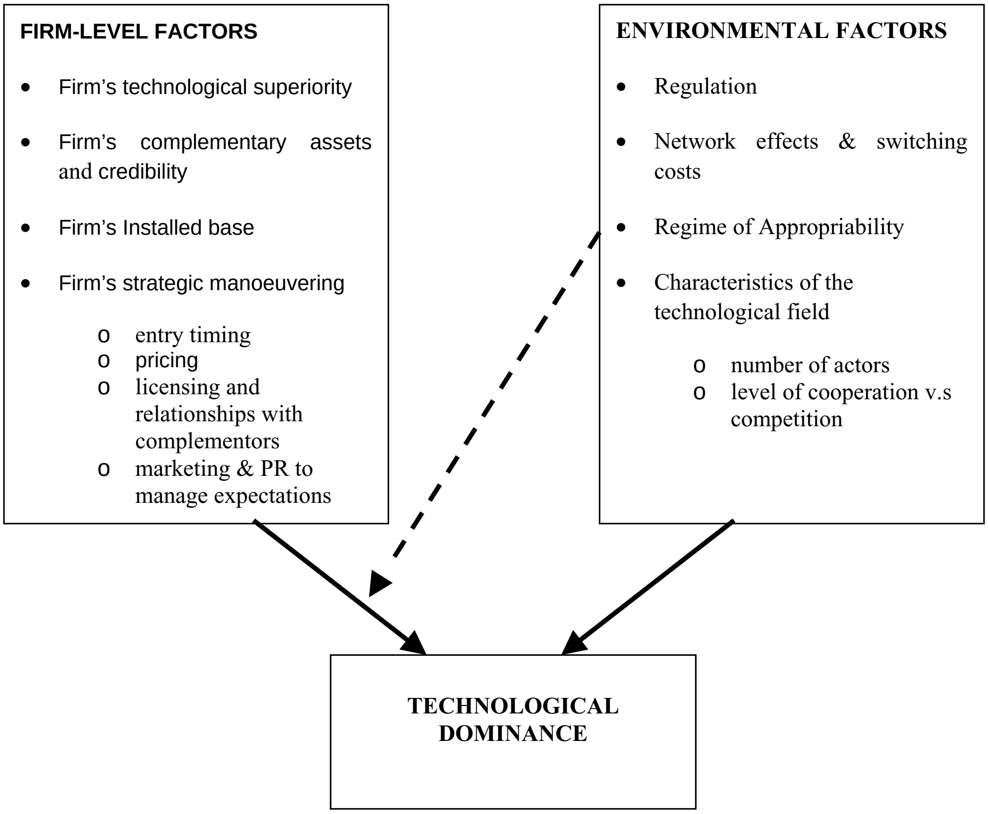

Fig. 1. Firm- and environment-level factors influencing the outcome of technology battles.

particular technology—but can also act as moderators of some firm-level variables—e.g. the appropriability regime moderates the effect of technological superiority: a clear advantage in technological performance is most useful to a sponsor firm if it can be protected from imitators. The potential for environmental factors to act as moderators is depicted as a dotted line from the environment box to the firm-level box in Fig. 1.

Typically, no single factor of dominance is strong enough to tilt the balance in favor of a particular technology; the final outcome is always the result of the interplay of several firm- and environmental-level variables. Firm-level variables have received most of the attention in the management literature to date, partly because they represent those variables that managers can influence more directly.

3.1. *Technological superiority*

This term captures the pure effect of technology, e.g. how well a given technology performs vis a vis competing alternatives. Other things being equal, the better a technology performs with respect to competing technologies, the higher the likelihood that it will become dominant. However, empirical research has found that technological superiority does not always play a significant role in dominance battles. For instance, Rosenbloom and Cusumano (1987) find that technological superiority did not help Sony in promoting Betamax over JVC's VHS in the VCR industry. In general, it is reasonable to expect that technological superiority will play a greater role when there are large performance differences between a technology and its competing alternatives; for example, the large performance difference observed in the case of Sony's Trinitron technology for TVs versus RCA's shadow mask, as opposed to the minor performance differences that existed between Betamax and VHS in the VCR industry.

3.2. *Complementary assets and credibility*

The work of Teece (1986) highlighted the importance of complementary assets—e.g. reputation and manufacturing capabilities—on the ability of a given firm to benefit from technological innovation. As in the well-known case of IBM and the Apple Macintosh, these assets may be crucial when battling for dominance. Klepper and Simons (2000) demonstrate that prior experience and reputation in radio production gave firms an advantage over new entrants in the emerging TV industry and ensured them certain "dominance by birthright". Similarly, Gallagher and Park (2002) highlight the importance of Sony's reputation and credibility in the company's ability to overcome Nintendo's leadership position in the game console industry after launching Playstation 1 in September 1995. Motorola's greater support and financial backing for its C-Quam AM stereo technology has also been identified as key in the company's ability to overtake the head start of Kahn and other smaller competitors' technologies (Grindley, 1995). In general, a better set of complementary assets will be associated with a higher likelihood of dominance, other things being equal.

3.3. *Firm's strategic maneuvering*

This captures the key elements of strategy open to a firm that engages in a technology dominance battle. From the existing theoretical and empirical literature it is possible to identify four elements of particular importance: the timing of entry to the industry; the specific pricing strategy; the type of licensing policy followed by the firm or—more generally—the way a firm manages the relationship with complementary goods and services; and the form and intensity of a firm's marketing and public relations efforts aimed at managing customers' expectations.

Researchers in strategy, marketing, and economics have extensively studied the effects of entry timing into new markets (see Lieberman and Montgomery, 1998 for a review). For the particular context of technology battles, entry timing has been associated both with market entry—i.e. the launch of a product in the market—and with R&D pioneering—e.g. the start of systematic R&D activities (Klepper, 1996; Rosenbloom and Cusumano, 1987). These studies often find an important association between entry timing—in both market and R&D—and a firm's ability to impose its design as dominant in the industry. An early market entry has several important effects in a technology battle; for instance, it helps to build a larger installed base and creates reputation effects (Carpenter and Nakamoto, 1990). An early entry in systematic R&D activities creates important learning effects and gives firms more time to experiment with different technological alternatives (Rosenbloom and Cusumano, 1987). Early entry does, however, have some potentially negative consequences: it can lock firms into particular technological trajectories (Dosi, 1982) that are not consistent with the resulting dominant technological design. Christensen et al. (1998) argue that in fast-paced industries, very early entry does not lead firms to maximize their survival chances; these are maximized when firms enter the industry in the few years just prior to the emergence of a dominant technology.

Pricing has always been a key variable in the demand function of any product, but it has particular importance in the case of technology battles for dominance. Theoretical research on standards has shown that early aggressive pricing in the presence of network effects can lead to a larger installed base that in turn makes it more likely a firm's technology will become dominant (Katz and Shapiro, 1985). Such instances of penetration pricing are observed frequently in situations where alternative technologies compete; for instance, Microsoft launched xBox in November 2001 with a price point 30% lower than that of competing Playstation 2 from Sony (US$ 199 versus US$ 299)—after resisting for a little while, Sony had to follow suit.

In addition to price, a firm's licensing policy has also been identified as a key driver in managing the relationship with producers of complementary goods. In the most extreme case, a firm may decide to make its technology completely available for free—an "open standard"—as did IBM when it entered the PC market. An open architecture is always an attractive characteristic for other actors in the technological field. Khazam and Mowery (1994) describe how Sun Microsystems' "liberal licensing policy" of its SPARC chip architecture contributed to the establishment of Sun's architecture as the dominant design in the workstation market. Of course liberal licensing often comes at the price of increased competition (from licensees) and a certain lost of control over the development path of the technology. IBM found this with the PC and Sun later faced a similar problem when trying to promote its Java technology. As Garud et al. (2002) recount, Sun allowed third-party developers to download Java for free through the Internet: the strategy brought many new licensees for Sun, but soon one of them—Microsoft—began adding proprietary extensions to Java that had the potential to fragment the technology into several incompatible versions. The issue led Sun to tighten control over Java, and to a well-publicized battle against Microsoft—only this time in the courts.

A final firm-level factor that affects the outcome of a dominance battle is the way a firm uses its marketing and public relations resources. Theoretical models of standard formation have long placed emphasis on the role of customers' expectations in the final outcome (Katz and Shapiro, 1985). For instance, these models highlight the part played by product pre-announcements that can create positive expectations about a company's upcoming models while at the same time cause customer "hold-up" with respect to competitor products in the market (Farrell and Saloner, 1986). Sony, for instance, followed this strategy when it pre-announced the Playstation 2, one week after Sega had launched its new 128-bit Dreamcast console—and a full year ahead of the actual launch of Playstation 2. Microsoft has followed a similar buzz-creating strategy several times, most recently with its .NET technology and its Stinger operating system for mobile devices. Not all firms follow this same pattern, though. Some firms prefer a clean, stick-to-the-facts approach when dealing with the media and customers as is the case for Symbian, the joint venture between Psion, Nokia, Sony–Ericsson, Motorola and other handset manufacturers aimed at producing the dominant operating system for the emerging "smartphones". As Symbian's head of PR described: "we have a responsibility as a company not to create hype over something that has not been delivered yet—they [Microsoft with Stinger] are attacking the market with hype which they're good at, but we say 'ship the product"'.[1]

3.4. Size of a firm's installed base

A final firm-level element that can affect the outcome of a technology dominance battle is that of a firm's installed base of users. Even though this can be considered the outcome of a firm's relative positioning in the other variables that affect dominance, research in industrial economics has pointed out that the installed

[1] Alex Sloley, "The Race to Own the Phone", *Infoconomist*, December 2000.

base by itself has can have an effect on customers' demand, if network effects are present in the industry (Katz and Shapiro, 1985). A larger installed base will be associated with higher rates of adoption for a specific technology. In other words, on top of the effect of the previous variables, the size of the installed base provides an "extra push" to the chances of dominance for a specific technology. Moreover, the size of the installed base can partially be the result of a firm's specific strategy; in particular, a firm can design its products to be compatible with a customer base that already exists on the basis of a previous technology (in the modeling literature, this implies making compatibility endogenous to the model—see, for instance, Berg, 1988). Atari is a good example of this strategy: the company tried to stop the rapid market inroad of Nintendo's NES 8-bit system by making sure their 8-bit Atari 7800 was compatible with the large installed base of earlier Atari VCS videogames. However, the value of compatibility with an earlier installed base depends on the performance difference between the old and the new technology—for instance, the installed based of older videogames was of little benefit for Atari: graphics quality had improved so much that it made the old games look obsolete.

As Fig. 1 illustrates, several environmental variables also come into play to affect—directly or indirectly as moderators of other variables—the final outcome of a technology battle.

3.5. Regulation and institutional intervention

Sometimes a government will intervene directly to mandate the use of a particular technology, as in the well-known case of the US standard for color TV. Here, the Federal Communications Commission's approval of the RCA television broadcast standard allowed RCA to establish its design as dominant for the television industry. More recent examples involve the selection of wireless technologies in Europe. GSM was mandated as the European standard for second generation wireless—despite the fact that competing technologies, such as CDMA which made more efficient use of the spectrum, had technical advantages over GSM. WCDMA has been mandated as the third generation wireless standard by European regulators. The role of governments in the emergence of a dominant technology is not restricted to regulation: for example, government purchases of a product in the early stages may tilt the balance in favor of the firm or firms producing it, and make this product more likely to become dominant in the industry. Sometimes, private institutions such as industry associations or standards making bodies—such as the American National Standards Institute (ANSI)—can influence which technology enters the industry first or even which technology dominates. For instance, the Telecommunications Industry Association (TIA)—a non-profit trade association accredited by ANSI—gave TDMA a head start in second generation wireless in the US, by approving it in April 1992—more than a year before their next 2G approval (CDMA was not approved by TIA until July 1993). Even though the TIA approval did not receive a mandate from the US regulator, it was an important element considered by the network operators when deciding which technology to buy.

3.6. Network effects and switching costs

Network effects arise in firms' environments as a result of consumption complementarities where the utility derived by a consumer is affected by the total number of consumers subscribed to the same network. In other words, the demand curve shifts upward with increases in the number of users in the network. The literature distinguishes between direct and indirect network effects (Katz and Shapiro, 1985). Direct network effects arise from mere fact that when the *n*th customer joins a network a new network connection is created for all existing customers. Indirect network effects arise as a result of increased demand for complementary products or services: e.g. specialized training; after-sales support; compatible software, etc. It is clear that the existence of network effects in a firm's environment will have important implications for the value of the firm's installed base of users as a competitive weapon in the battle for dominance (the moderator role mentioned earlier). Indeed, the strength of network effects in the environment may also affect some of the other firm-level strategic maneuvers described above: for instance, weak network externalities may make early entry less crucial to the final outcome.

The existence of switching costs can also have an effect on a firm's ability to attract customers and build or retain its installed base. Switching cost may arise from network effects but they may also arise in the absence of them. For instance, most observers agree that network effects for end users of wireless technologies are weak: users of any network can call users in other networks seamlessly because the network operators have made all networks inter-operable. However, once they have joined a network, users may be reluctant to switch to a different one if, for instance, switching networks involves changing their telephone number (in many countries, number portability is not mandated by the regulator). It follows that the higher the switching costs, the more difficult it is for a firm to steal customers away from rivals and the more "loyal" is its own customer base. The presence of switching costs may affect a firm's strategic maneuvering perhaps prompting them to enter the industry early and apply penetration prices.

3.7. Regime of appropriability

The regime of appropriability has been defined with respect to the aspects of the commercial environment, excluding firm and market structure, that govern a firm's ability to capture the rents associated with an innovation (Teece, 1986). Different business environments will present different degrees of appropriability, and this in turn may have strong implications for the different technologies competing for dominance. The effect of technological superiority on the outcome of a dominance battle is likely to be mediated by the appropriability regime in place. For instance, a strong appropriability regime will favor firms with a superior technology, as it will prevent or at least limit the effectiveness of competitor's efforts to woo customers to their camp. This is well illustrated by the example of Polaroid's technology for instant photography: Polaroid was protected by a whole array of patents that the company defended very aggressively against any rival that would challenge them—e.g. Polaroid successfully took Kodak to the courts when the latter tried to invent around Polaroid's patent. In another example, Sun filed a lawsuit against Microsoft charging the latter with infringing the Java licensing agreement.

3.8. Characteristics of the technological field

A final environmental factor relates to the structure and dynamics of the market and technological field. As Garud et al. (2002) point out, "within technological fields, the meaning of artifacts and patterns of interaction among actors emerge through a negotiated process" (p. 197). Within a new technological field, alternative technological trajectories compete for dominance. It follows that the ability of a firm to reach agreement with other actors in the technological field—e.g. producers of complementary products or services and customers—will depend in part on the structure and dynamics of the technological field itself, i.e. the number and relative power of each actor and the level of cooperation versus competition. This goes beyond the impact of firms' complementary assets described above; technological fields are populated by communities of researchers in particular disciplines and also by firms that operate along the whole value system into which the new product is to be inserted. Research communities have been shown to respond to specific dynamics, rules of engagement and information-sharing practices which cut across the organizations in which the researchers work (Garud and Rappa, 1995); for example, there is a significant support for "open standards" within the software developer community. In addition to the characteristics of the research community, the structure of the industry's value system can have implications for the ability of the different sponsor firms to push for their technology alternatives. Research in industrial economics has shown that initial market structure along the value system can affect the success of firms' standardization efforts (David and Greenstein, 1990). For example, firms sponsoring alternative designs of a new brake technology for the automobile industry will face a concentrated demand where a few potential users hold significant power—a situation that is likely to influence the effect of firm-level factors such as strategic maneuvering and complementary assets.

4. The dominance process

Consider a technological field in which two or more alternative technological trajectories compete for dominance. We posit that the technology dominance process can be described in terms of a few key milestones. Each milestone marks the start of a new phase in the dominance battle, and each phase is characterized by different dynamics that in turn make some of the factors associated with dominance more relevant than others.

The beginning of the technological field can be traced back to the moment when a pioneer firm or research group starts doing applied R&D aimed at producing a new commercial product. For instance, Japan's NHK started research in HDTV in 1968 while Sony is reputed to have been the first firm to do applied research in digital photography. Sometimes the pioneering applied research is done at universities (Roberts, 1991). Pioneer applied research efforts are soon followed by other researchers and organizations that set up similar research programs, and the technological field is gradually populated by several actors competing with alternative technological designs that often represent totally different technological trajectories. In the theoretical literature on standards this situation has sometimes been labeled an "R&D race" (McCardle, 1987).

A second milestone is marked by the appearance of the first working prototype of the new product. The first working prototype sends a powerful signal to all firms in the race that at least one of the technological trajectories is feasible and has been developed to such a level that there will soon be a product in the market. A working prototype often acts as a signal for competing firms to review the feasibility of their research programs. A case in point was when NHK demonstrated a working HDTV system at the SMPTE conference in 1979 and the US government reacted by setting up a task force to study HDTV options from American firms. Similarly, Ampex demonstrated their "transverse scanner" VTR technology in the US in 1956, and were shortly followed by Toshiba's working prototype of a "helical scanner" VTR technology; both events stimulated widespread interest in the market and prompted rival firms to assess carefully their own VTR research programs (Rosenbloom and Cusumano, 1987).

A third milestone in the dominance process is the launching of the first commercial product, which for the first time, directly connects a technology coming out of the lab to customers. Typically, the first product in the market is too expensive for the mass market and is therefore aimed at the "aficionados" or at the high-end of the market. This is often the commercial or corporate market and was the case when, in the early 1980s, NHK and Sony were offering their HDTV systems to movie studios several years before the first HDTV sets for home use appeared on the market (in Japan). The introduction by Ampex of the first VCR machines was also targeted at high-end of the market. In all cases, the first launch of a commercial product acts as a "last-minute call" for the remaining firms to speed up their research efforts if they do not want to risk being left behind. When Texas Instruments introduced the first transistor-based radio to the market, researchers at the young Sony redoubled their efforts to produce a "pocketable radio" and worked feverishly to bring their design to the market as quickly as possible.

The early market, although typically a relatively small one when compared to the mass market, helps a particular design become an early "forerunner"; this happened with Ampex's design that dominated the emerging VCR industry for almost 10 years (Rosenbloom and Cusumano, 1987), and with Apple Computers that dominated the emerging personal computer industry for several years after the introduction of the Apple I in 1976. The presence of a clear front-runner marks the fourth milestone in the dominance battle. Indeed, the front-runner has a chance of winning the battle, as its larger installed base tends to create some "excess inertia"—a bias towards the technology with the largest market share. The final outcome will depend on how fast the competitors improve on their own designs and how fast the market grows. The work of Katz and Shapiro (1985, 1986) shows that when there is rapid market growth, initial excess inertia can be overcome by competing firms finding enough of a market to grow their own installed bases quickly, particularly if their product is superior to the front-runner's.

Finally, at some stage, a specific technological trajectory achieves dominance and marks the last milestone in the dominance process. Different authors have determined the dominance point differently. Anderson and Tushman (1990) classify as dominant a design that acquires more than 50% market share while Christensen et al. (1998) follow specific innovations in hard disk drives to claim that four of these became the key elements of the industry's dominant design; they consider the dominance date as the first year in which a model that contained the four key innovations was introduced. The modeling literature on standards looks at agents' purchasing decisions in relation to alternative technologies and implies that market share is the measure of "dominance" (Katz and Shapiro, 1985). The problem with the existing operationalizations of dominance is that they are for the most part blind to the competitive dynamics behind each battle; for instance, an early front-runner could achieve more than 50% market share for a few years but that would not signal dominance, as other competitors may be following closely behind and closing the market share gap with the early leader. For the purpose of this paper, a specific technological design achieves dominance when, during stage IV of the process described below, one or both of the following two events occur: (a) there is a clear sign that the most closely competing alternative design has abandoned the active battle, thus acknowledging defeat directly or indirectly; (b) a design has achieved a clear market share advantage over alternative designs and recent market trends unanimously suggest that this advantage is increasing. An example of a type (a) event was when in 1988—after 12 years of active battle in the market—Sony acknowledged defeat by starting production of VHS-based VCRs; a (b) type event is exemplified by the fact that, by the mid 1990s, all the data suggested that the IBM PC design had irrefutably prevailed over the Mac design, even though Apple was still fighting hard—and continue to do so even today. Once dominance has set in, the dominant technological design stays unchallenged until a discontinuous technology shakes the market at some point in the future; a technological discontinuity opens the door for new entry and a new dominance process begins (Anderson and Tushman, 1990).

Fig. 2 illustrates the timeline suggested by the different milestones in the technology dominance process, where:

- t_0 denotes the beginning of a technological field with an organization pioneering applied R&D;
- t_P denotes the time when the first working prototype emerges;
- t_L denotes the time of the first launching of a commercial product;
- t_F denotes the time when a clear early front-runner appears; and
- t_D denotes the time when one of the alternative designs becomes dominant.

The different milestones shed light on the process that unfolds in an industry whereby one particular technological trajectory becomes dominant. We posit that the role and strength of the different firm- and environmental-level factors associated with dominance vary depending on the stage of the battle. Note that this is not to say that some factors will only be relevant for a particular phase of the process; clearly all factors are present in most of the phases and do play some kind of a role. However, the existing theoretical literature and empirical evidence allows some degree of fine-tuning with respect to when is each factor more likely to be important. We summarize these ideas below.

4.1. Phase I—R&D buildup ($t_0 - t_P$)

This early phase determines the key characteristics of the technological field. Typically, a mix of large firms with expertise in a related technology (e.g. radio producers entering TV technology), a set of new firm entrants, and groups doing applied research in universities or similar institutions comprise a technological field. The nature, size, and market power of the actors entering the field will determine the level of competition and collaboration that will exist among them. In this phase, the different technological trajectories are being developed and thus the emphasis is on technology and technological talent. In attracting

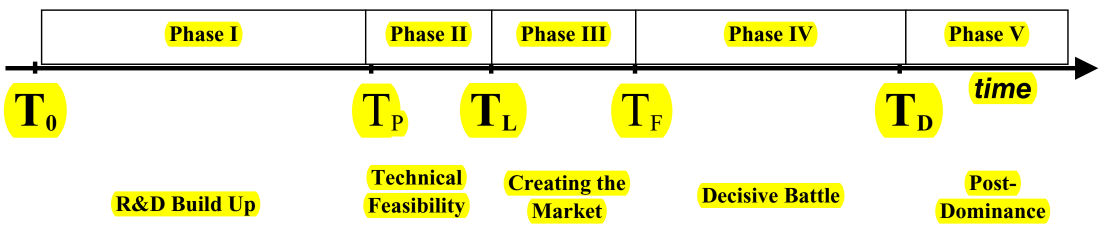

Fig. 2. Five milestones in the process of technological dominance.

technological talent, a firm-level factor—credibility and complementary assets—plays an important role, as large and visible firms with generous research budgets will attract good researchers. New entrants will typically compensate for this through generous stock-option packages to attract key technological talents. The ability of any firm to progress faster than competitors along a specific technological trajectory is seen as a key element to focus on in this phase: the battle as such has not yet started but firms are busy amassing their munitions. Attracting key technical talent is key during this first phase of the battle, as there is still high technological risk. Together with the characteristics of the technological field, another environmental factor—the regime of appropriability—also plays an important role in this phase, as it determines whether or not firms with important innovations can pursue their technological trajectories unchallenged by imitators.

4.2. Phase II—technical feasibility ($t_P - t_L$)

The demonstration of technical feasibility (working prototype) by one of the actors creates a powerful set of new dynamics in the dominance process. It prompts all firms to evaluate their research programs and assess whether or not they are in a position to fight the upcoming battle independently. It is in this phase that a firm-level factor, technological superiority, has its strongest effect on the final outcome and may sometimes lead to the early emergence of a winning technology. For instance, many firms with different technological trajectories and designs populated the technological field for CD technology; in 1979 Philips, after demonstrating the feasibility of its design, approached Sony with the proposal to form an alliance before launching a product in the market and, in a rather unusual decision, Sony accepted the proposal. The alliance brought together the two technological designs considered by experts as the most advanced at the time: Philips had the best overall CD architecture and Sony had an excellent error–correction system. The two firms launched the CD in 1982 and shortly thereafter more than 30 firms had signed licensing agreements to use the Philips/Sony technology (Grindley, 1995).

Phase II is sometimes also affected by an environmental factor—an active regulator role. It is typically at this point, when the leading technological trajectories have proved their feasibility but have not yet or only just reached the market that regulators intervene. This was the situation when GSM was mandated as the second generation wireless technology for European operators. A regulator's action directly affects the outcome of the battle, either by favoring a particular technology (as in the case of 2G in Europe) or by narrowing the range of possible alternatives. The latter was the case for HDTV in the US, when the FCC issued a ruling indicating that the HDTV standards to be issued should be compatible with the existing NTSC service, and confined to the existing VHF and UHF frequency bands. This ruling automatically excluded some of the competing technologies, particularly those from Japanese firms.

4.3. Phase III—creating the market ($t_L - t_F$)

The launch of the first commercial product marks an irreversible change of emphasis from technology to market factors, making any technological differences between the alternatives become increasingly less important as time goes by. It is in this phase that a firm-level factor, strategic maneuvering, has the highest impact on the final outcome. By securing a first-mover market position, a firm may gain important reputation advantages and be able to pre-empt later entrants' access to key resources (Lieberman and Montgomery, 1998). It is also in this phase that penetration pricing has the strongest effect because, when no firm has yet achieved the advantage of a large installed base, customers' decisions are likely to be strongly influenced by price. Similarly, as the market starts to unfold, customers are likely to have only limited information as to the real potential and benefits of each technology, thus paving the way for firms' marketing and PR efforts to shape customer expectations. Finally, it is at this stage that competing actors need to secure support for their specific trajectories in the form of complementary goods or services. Even though firms typically start wooing support for their technologies in the previous phase, producers of complementary goods often wait for the technology to be on the market before giving it their full commitment and support.

4.4. Phase IV—the decisive battle ($t_F - t_D$)

In Phase III, several competitors start to accumulate a sizable installed based of users. In Phase IV, these increasingly large customer bases begin to have an important effect on customers' decisions—which is consistent with recent empirical findings suggesting that the benefits a technology can only be observed after a certain critical mass of users has been achieved (Roller and Waverman, 2001). The strength of the installed base effect—a firm-level factor—is in turn determined by the strength of network effects in the environment.

In addition, the firm-level factor complementary assets and credibility often play an important role in Phase IV. As the experiences of IBM in PC hardware and Microsoft in PC software show, a firm with strong assets and credibility can have important advantages in the final stretch to dominance. This is explained by the characteristics of the users who decide to enter the market at different times. The work of Moore (1999) illustrates that the early market (Phase III) comprises technology "enthusiasts" and "visionaries" who place emphasis on technological novelty and performance when deciding which technology to buy. However, mainstream market consumers—those that comprise the bulk of the market in Phase IV—show a more conservative approach and are less impressed by technological performance alone: they tend to prefer products produced by established firms that they consider trustworthy.

4.5. Phase V—post-dominance (t_D onwards)

In Phase V, a clear dominant technology has emerged in the market. Its large installed base acts as a strong defense against potential challengers, particularly in situations of environments with strong network effects and high switching costs. Competition in this post-dominance phase is often an intense "within-standard" competition (Gallagher and Park, 2002) between several firms that have licensed production rights based on the dominant technology. It is therefore often based on production capabilities and process innovation (Utterback and Abernathy, 1975; Utterback and Suarez, 1993)—as the success of Dell Computers illustrates. As stated earlier, this phase of within-standard competition can last for a long time, until a discontinuous technology starts a new dominance cycle.

5. Final remarks

As the above discussion has shown, the five milestones in a dominance process define phases that have different characteristics. In particular, success in each phase seems to respond to a different mix of firm- and environmental-level factors. Fig. 3 summarizes the main propositions emanating from our discussion; in the figure, each phase has been associated with the factors that tend to have the strongest effect. Of course,

Factor Type	Dominance Factor	Phase I	Phase II	Phase III	Phase IV	Phase V
Firm-level	Technological superiority		***			
	Credibility/complementary Assets	***			***	
	Installed base				***	***
	Strategic manoeuvering			***		
Environ-mental level	Regulation		***			
	Network effects and switching costs				***	***
	Regime of Appropriability	***				
	Characteristics of the technological field	***				

Fig. 3. Key factors of success at each stage of the dominance process.

we do not claim that each situation will conform precisely to the pattern described in our five phases: some factors may also have an effect in adjacent phases to the ones suggested in Fig. 3. However, we believe the proposed pattern captures the main elements behind the story of many of the battles for dominance that we have observed in the past few decades and can therefore shed additional light on the complex issues and decisions surrounding these situations.

Arthur (1989) suggested that the standard-setting process might be "path-dependent" in the sense that network effects can make the outcome dependent on the particular historical pattern of adoption. Although Arthur's model was developed for non-sponsored technologies, several authors have reflected on its intriguing proposition that the resulting equilibrium is especially sensitive to chance events early in the adoption path (e.g. Schilling, 1998). As our framework highlights, a careful look at the dominance process suggests that "chance" events may not be pure chance but, instead, the result of actions on specific factors that have a particular importance in a given phase of the process. Chance is simply what we cannot explain for lack of better theory; frameworks such as the one proposed here should complement and expand the modeling literature. For instance, our framework suggests that the dominance process begins before the first product is launched on the market—that is, before network effects even take off. By concentrating on the specific factors that are important in the pre-market phases, firms may be able to secure a leading position in the market phase, as the example of the Philips/Sony alliance for CD suggests.

Our framework has also clear implications for managers, particularly in firms sponsoring one of the competing technologies. On the one hand, the framework spells out the different factors that affect the final outcome, separating those that firms can act upon directly from the environmental factors that are mostly beyond a firm's control. A comprehensive spelling out of the different factors at play in a dominance battle is by itself helpful, as different streams of literature have tended to place the emphasis on various sub-sets. On the other hand, our framework enables managers to watch for five key milestones and five key phases in the process, each with its own dynamics and sets of factors that are more likely to prevail. In particular, the framework suggests that the interplay of firm- and environmental-level dynamics in a dominance battle provides key areas in each phase that managers need to stress. For example, since technological superiority is key in Phase II, managers may want to follow their firms' R&D efforts more closely in order to assess how their technologies compare with those of competitors, and then plan their strategic actions—e.g. the formation of alliances—based on this analysis. Moreover, a correct understanding of the ways in which environmental factors constrain managerial action—e.g. through regulation or network effects—can help managers to time their "strategic maneuvering" efforts better. In Phase III, the outcome seems to be particularly affected by managers' strategic actions and a proper understanding of this "window of opportunity" for strategic maneuvering is key to the effectiveness of different firm-level actions. Thus, Apple's late effort to licensing its technology was of little benefit to the company because it happened in Phase IV of the dominance process. As in other areas of management and strategy, the final outcome of technology battles is the result of a complex interrelation between managerial decisions and environmental factors that together influence customer choice. A better understanding of which levers to pull and which factors to act upon at each stage of the process is a key capability that firms have to develop when dealing with battles for technological dominance.

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References

Anderson, P., Tushman, M., 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. Administrative Science Quarterly 35 (4), 604–635.

Arthur, B., 1989. Competing technologies, increasing returns, and lock-in by historical events. Economic Journal 99, 116–131.

Arthur, B., 1998. Increasing returns and the new world of business. Harvard Business Review 74, 100–110.

Berg, S., 1988. Duopoly compatibility standards with partial cooperation and standards leadership. Information Economics and Policy 3, 35–53.

Carpenter, G., Nakamoto, K., 1990. Competitive strategies for late entry into a market with a dominant brand. Management Science 36, 1268–1278.

Christensen, C.M., Suarez, F.F., Utterback, J., 1998. Strategies for survival in fast-changing industries. Management Science 44 (12), 207–220.

Clark, K.B., 1985. The interaction of design hierarchies and market concepts in technological evolution. Research Policy 14, 235–251.

Clark, K., Wheelwright, S., 1992. Organizing and leading heavyweight development teams. California Management Review.

Cusumano, M., Gawer, A., 2002. The elements of platform leadership. MIT Sloan Management Review 43 (3), 51.

Cusumano, M., Nobeoka, K., 1998. Thinking Beyond Lean. Free Press, New York.

Cusumano, M., Mylonadis, Y., Rosenbloom, R., 1992. Strategic Maneuvering and Mass-market Dynamics: the Thriumph of VHS over Beta. Business History Review 66 (1), 51–95.

David, P., 1987. Some new standards for the economics of standardization in the information age. In: Dasgupta, P., Stoneman, P. (Eds.), The Economic Theory of Technology Policy. Cambridge University Press, Chapter 8.

David, P., Greenstein, S., 1990. The economics of compatibility standards: an introduction to recent research. Economics of Innovation and New Technology 1, 3–42.

Dess, G., Beard, D., 1984. Dimensions of organizational task environments. Administrative Science Quarterly 29, 52–73.

Dierickx, I., Cool, K., 1989. Asset stock accumulation and sustainability of competitive advantage. Management Science 35, 1504–1512.

DiMaggio, P., 1988. Interest and agency in institutional theory. In: Zucker, L. (Ed.), Institutional Patterns and Culture. Ballinger, Cambridge, MA, pp. 3–22.

Dosi, G., 1982. Technological paradigms and technological trajectories. A suggested integration of the determinants and directions of technical change. Research Policy 11, 147–162.

Farrell, J., Saloner, G., 1985. Standardization, compatibility, and innovation. Rand Journal of Economics 16, 70–83.

Farrel, J., Saloner, G., 1986. Installed base and compatibility: innovation, product preannouncements, and predation. The American Economic Review 76, 940–954.

Gallagher, S., Park, S., 2002. Innovation and competition in standard-based industries: a historical analysis of the US home video game market. IEEE Transactions on Engineering Management 49 (1), 67–82.

Garud, R., Kumaraswamy, A., 1993. Changing competitive dynamics in network industries: an exploration of Sun Microsystems' open systems strategy. Strategic Management Journal 14, 351–369.

Garud, R., Rappa, M., 1995. On the persistence of researchers in technological development. Industrial and Corporate Change 4, 531–555.

Garud, R., Jain, S., Kamaraswamy, A., 2002. Institutional entrepreneurship in the sponsorship of common technological standards: the case of Sun Microsystems and Java. Academy of Management Journal 45, 196–214.

Gawer, A., Cusumano, M., 2002. Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation. Harvard Business School Press, Harvard.

Grindley, P., 1995. Standards Strategy and Policy. Oxford University Press, Oxford.

Hannan, M., Freeman, J., 1977. The population ecology of organizations. American Journal of Sociology 82, 929–964.

Katz, M., Shapiro, C., 1985. Network externalities, competition, and compatibility. The American Economic Review 75, 424–440.

Katz, M., Shapiro, C., 1986. Technology adoption in the presence of network externalities. Journal of Political Economy 94, 822–841.

Katz, M., Shapiro, C., 1992. Product Introduction with network externalities. Journal of Industrial Economics 40, 55–83.

Khazam, J., Mowery, D., 1994. The commercialization of risk: strategies for the creation of dominant designs. Research Policy 23, 89–102.

Klepper, S., 1996. Entry, exit, growth, and innovation over the product life cycle. American Economic Review 86, 562–583.

Klepper, S., Simons, K., 2000. Dominance by birthright: entry of prior radio producers and competitive ramifications in the US television receiver industry. Strategic Management Journal 21, 997–1016.

Kuhn, T., 1970. The Structure of Scientific Revolutions, second ed. University of Chicago Press, Chicago.

Lieberman, M., Montgomery, D., 1998. First-mover (dis)advantages: retrospective and link with the resource-based view. Strategic Management Science 19, 1111–1125.

Liebowitz, S., 2002. Re-Thinking the Network Economy. AMACOM, New York.

McCardle, K., 1987. Dropout behavior in R&D races with learning. Rand Journal of Economics 18, 287–296.

Meyer, M., Lehnerd, A., 1997. The Power of Product Platforms. Free Press, New York.

Meyer, M., Tertzakian, P., Utterback, J., 1997. Metrics for managing research and development in the context of the product family. Management Science 43, 88–111.

Moore, G., 1999. Crossing the Chasm: Marketing and Selling Technology Products to Mainstream Customers. Capstone Publishing Limited.

Nelson, R., Winter, S., 1982. An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge, MA.

Porter, M., 1985. The Competitive Advantage: Creating and Sustaining Superior Performance. Simon & Schuster, New York.

Reinganum, J.F., 1981. On the diffusion of new technology: a game theoretic approach. Review of Economic Studies XLVIII, 395–405.

Richardson, J., 1993. Parallel sourcing and supplier performance in the Japanese automobile industry. Strategic Management Journal 14, 339–350.

Roberts, E., 1991. Entrepreneurs in High Technology. Oxford University Press, Oxford.

Roller, H., Waverman, L., 2001. Telecoms infrastructure and economic growth: a simultaneous estimation. American Economic Review.
Rosenbloom, R., Cusumano, M., 1987. Technological pioneering and competitive advantage: the birth of the VCR industry. California Management Review.
Sahal, D., 1982. Patterns of Technological Innovation. Addison-Wesley, Readings, MA.
Sanderson, S., Uzumeri, M., 1997. Managing Product Families. Irwin, Homewood, IL.
Scherer, F.M., 1992. International High-Technology Competition. Harvard University Press, Cambridge, MA.
Schilling, M., 1998. Technological lockout: an integrative model of the economic and strategic factors driving technology success and failure. Academy of Management Review 23 (2), 267–284.
Scott, W., 1994. Institutional analysis: variance and process theory approaches. In: Scott, W., Meyer, J. (Eds.), Institutional Environments and Organizations: Structural Complexity and Individualism. Sage, California.
Shapiro, C., Varian, J., 1999. The art of standards wars. California Management Review 41, 2.
Suarez, F., Utterback, J., 1995. Dominant designs and the survival of firms. Strategic Management Journal 16, 415–430.
Teece, D., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy. Research Policy 15, 285–305.
Tegarden, L.F., Hatfield, D., Echols, A., 1999. Doomed from the start: what is the value of selecting a future dominant design? Strategic Management Journal 20, 495–518.
Tushman, M., Anderson, P., 1986. Technological discontinuities and organizational environments. Administrative Science Quarterly 31, 439–465.
Tushman, M., Rosenkopf, L., 1992. Organizational determinants of technological change: towards a sociology of technological evolution. Research in Organizational Behavior 14, 311–347.
Tripsas, M., 1997. Unraveling the process of creative destruction: complementary assets and incumbent survival in the typesetter industry. Strategic Management Journal 18, 119–142.
Utterback, J., 1994. Mastering the Dynamics of Innovation. Harvard Business School Press, Harvard.
Utterback, J., Abernathy, W., 1975. A dynamic model of product and process innovation. Omega 3, 639–656.
Utterback, J., Suarez, F., 1993. Technology, competition and industry structure. Research Policy 22, 1–21.
Wade, J., 1995. Dynamics of organizational communities and technological bandwagons: an empirical investigation of community evolution in the microprocessor market. Strategic Management Journal 16, 111–133.
Willard, G., Cooper, A., 1985. Survivors of industry shake-outs: the case of the US color television sets industry. Strategic Management Journal 6, 299–318.