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Swift and Smart: The Moderating Effects of Technological Capabilities on the Market Pioneering–Firm Survival Relationship

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We extend the concept of first-mover advantage to the context of high-technology industries with multiple product generations, and propose that the notion of *first-mover advantage* needs to be viewed not only through a dynamic lens, but also in conjunction with technological capability. Our main finding is that first-mover advantages are best understood in tandem with the firm's technological capabilities; early entry is beneficial only for pioneers that are technically strong. However, pioneers that are low on technological capabilities suffer from poor survival rates vis-à-vis market responders or nonentrants into new product generations.

Key words: dynamic capabilities; first-mover advantage; strategy; industry evolution; entrepreneurship; technology strategy
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Introduction

In spite of 839 publications on first-mover advantage (FMA) in peer-reviewed journals, its existence has neither been conclusively proved nor refuted (Suarez and Lanzolla 2007). Notwithstanding methodological advances that have alleviated concerns related to survivor bias, sample selection issues, and definitional confounds in dependent variables (Boulding and Christen 2003, Lieberman and Montgomery 1998, VanderWerf and Mahon 1997), this inconclusiveness of FMA prompted Finkelstein (2002, p. 39) to skeptically comment that the "holy grail of first mover advantage is as elusive as it is exaggerated."

We contend that the problem lies in two theoretical misspecifications of models relating entry timing to organizational outcomes: one on the "macro" industry level, and the other on the "micro" firm level. Both have largely been ignored in the FMA literature. On the macro side, ignoring the evolutionary dynamics of the industry has led to a static, legacy-based view of FMA, which is predicated on the idea that a one-time pioneering act during the incipient stage of an industry could lead to sustained advantages over time. This premise is, however, problematic given research that indicates that new product generations within an industry can level the playing field between both incumbents and entrants, as well as between pioneers and late movers. Thus, legacy-based advantages could be patently atheoretical in such situations. On the micro side, firm-level capabilities may complement market-pioneering efforts, namely, scientific or technological know-how embedded in a firm's product. This is another possibly serious flaw because the realization of potential first-mover advantages from market initiatives is likely to be contingent on a firm's technological competence. This important fungible resource (Granstrand et al. 1997, Danneels 2002) determines how competitive a firm's products are along accepted scientific parameters of performance. Complementary resources play a crucial role in entrepreneurial rents (Stieglitz and Heine 2007), and heterogeneity in such resources across firms can explain variance in firm performance (Robinson et al. 1992, Rosenbloom and Cusumano 1987, Teece et al. 1997, Klepper 2002). Therefore, studying how market-creating capabilities affect profits, market share, or survival without considering the impact of complementary capabilities is inherently problematic.

Both the micro and macro gaps have a common feature; because of the evolutionary nature of the technology and product market, it is important to consider the relevant know-how, i.e., market-pioneering and technological capabilities, in an *evolving* context. This relates to recent strategic thinking on dynamic capabilities (Eisenhardt and Martin 2000, Helfat 2007) that emphasizes achieving new and innovative forms of competitive advantage through exercising strategic choices that guide capability evolution (Lee 2008). At its essence, the idea of dynamic capabilities concerns change, and the "capacity of a firm to purposefully create, extend, or modify its resource base" (Helfat 2007, p. 4). In this view, firms continually realign and redesign their resources through a process of search and selection to "achieve new resource configurations as markets emerge" (Eisenhardt and Martin 2000, p. 1107). Continual efforts at strategic renewal—through creating new market spaces or responding to existing ones—while simultaneously sustaining its technological and product market position is critical to a firm's survival in rapidly changing environments (Burgelman 1991, Floyd and Lane 2000, Gans and Stern 2003, Huff et al. 1992). We draw insights from the strategy literature to address this important "static" problem in entry timing research where the dynamics of evolutionary change, both on market- and technology-related domains of firm capabilities, have been ignored.

To address the "macro" concern, we consider an evolutionary context where technological discontinuities create a set of upwardly shifting S-curves in an industry (Foster 1986). Herein, we consider firms' abilities to create new markets through pioneering entry into emerging product generations. Research has documented how "technological subfields" in the disk drive and medical diagnostic industries created new market segments that had far-reaching consequences on both industry structure and composition (Mitchell 1989, Christensen 1997a). Such new product generations presented both incumbents and potential entrants with multiple strategic opportunities: be a market pioneer, respond through late entry, or not enter. Importantly, these punctuations in the industry life cycle may serve as potential levelers in a Schumpeterian (Schumpeter 1942) sense because they may disturb the status quo, negating legacy advantages and offering the opportunity to redefine the competitive scenario. This leads to a dynamic theory of FMA: Early entry is not a one-time act that creates a *legacy-based advantage*, but one that needs to be examined in a dynamic context characterized by the emergence of multiple product generations as a result of industry evolution. In other words, we need to consider entry timing through the lens of a firm's *dynamic capability to pioneer or respond to new market opportunities.*

Regarding the lacuna at the "micro" firm level, we propose that technological capabilities, conceptualized in a dynamic setting, complement the relationship between entry timing and firm performance. Our focus on this complementary asset is motivated by research that indicates that such assets not only foster successful entry into new product markets (Wernerfelt 1984), but also explain firm survival over the industry life cycle (Helfat and Lieberman 2002, Klepper and Simons 2000). Recent strategy research has also found firm performance to be a function of interdependent capabilities (Agarwal et al. 2004), thereby emphasizing the need to consider portfolios of resources that are complementary and together enable value creation and appropriation (Steiglitz and Heine 2007, Moran and Ghoshal 1999, Teece 1986). Whereas firms need technological capabilities to engage in scientific inventions (Bierly and Chakrabarti 1996, Cohen and Levinthal 1990), they also need marketing know-how to appropriate the potential economic rents embodied in their technological breakthroughs (Dierickx and Cool 1989, Teece 1986). Their complementary nature creates a valuable synergy (Day 1994) that maximizes the value of market opportunities to a firm (Park and Zaltman 1987, Walker and Ruekert 1987) and inhibits competitive imitation due to the inherent difficulty of developing the two capabilities simultaneously (Grant 1991, Lippman and Rumelt 1982, Reed and DeFillippi 1990). From this perspective, it is imperative for FMA studies to consider technological know-how as a critical resource that is complementary to market creation.

In an empirical setting marked by rapid changes and the emergence of new technological subfields and product markets—the disk drive industry during the 1977–1997 period—we examine the outcomes of firms' capabilities in market creating and responding. We further investigate the interaction effects of technological capability and timing of entry. Our paper thus extends the concept of first-mover advantage to industry contexts with multiple product generations to examine two specific relationships: first, the main effects of market-pioneering and market-responding behaviors on the rate of survival, and second, the role of a firm's technology position as a moderator in the market pioneering/responding–survival relationships. We find that incumbents from prior product generations are equally likely to pioneer new markets as new entrants in the industry. Moreover, firms that fail to keep up with the evolving industry, in terms of either new markets or technological development, are more likely to exit the industry. Specifically, we find that when timing of entry is considered in isolation of other capabilities, market responding provides more benefits than either market pioneering or not responding to emerging market opportunities. However, when considered in conjunction with the complementary dynamic capability in the technological realm, our results show a more nuanced relationship. Pioneering elevates survival rates for firms that sustain technology leadership, and this group is the most advantaged relative to others over time. Conversely, when pioneering efforts are not matched with efforts at keeping up with the changing technological frontier over time and firms fall below a certain threshold of technological capability, pioneering activities hurt a firm compared to late or even nonentry into later generations.

Theoretical Framework and Hypotheses

Market Creation and Response as Firm Capabilities

Although industries and products are typically characterized as evolving through smooth and predictable S-curves (Gort and Klepper 1982), such heuristic portrayals may mask occurrences when emerging new product generations cater to entirely new user segments, and in doing so transform the competitive landscape of the industry. This is consistent with the description of technological progress as one where long periods of incremental innovation are punctuated by bursts of radical change (Abernathy and Utterback 1978, Tushman and Anderson 1986). The new technical subfields and new product markets create fresh entrepreneurial opportunities within the industry. Yet, much variance can underlie such shifts, making them distinct phenomena from the perspective of both entrants and industry incumbents. In the case of incumbents, some resources and capabilities that were useful in an earlier market may remain relevant in the new segment of the market, whereas others may become obsolete (Christensen 1993, Mitchell 1991). For example, within the diagnostic imaging industry, the five major technical subfields that emerged represented very different domains of scientific knowledge, yet the specialized market assets retained their value (Mitchell 1989). However, in data storage, even though the innovations drew on similar underlying scientific knowledge, the disruptive technological innovations often created new product-markets with new, very different user characteristics that rendered redundant market assets that were effective in earlier generations (Christensen 1993).

Importantly, new product generations can level the playing field among incumbents as well as between incumbents and entrants. The emergence of a new product generation creates a fresh opportunity to capitalize on potential strategic and economic advantages associated with being a market pioneer, even as it removes many path-dependent advantages associated with early entry that may have accrued to the market pioneers of the prior product generation. However, existing literature has tended to emphasize a static, legacy-based advantage associated with entry timing, and has overlooked the evolutionary forces that reshape industries as a result of technological inventions and market innovations. In this context, relating competitive advantage to being a market pioneer during the inception of an industry (or for that matter a prior product generation) is a potentially flawed thesis, because such legacy-based advantages are unlikely to be sustained in high-velocity markets that are undergoing disruptive changes (Eisenhardt and Martin 2000, Suarez and Lanzolla 2007).

Investigating what firms do when faced with multiple opportunities over time allows us to study the impact of firms' strategic capabilities to create, or respond to, such technological and market shifts. Extant entry timing literature has ignored whether firms are advantaged by being able to morph along with discontinuous changes in their product markets. However, this ability to create new markets is part of an important class of organizational capabilities that has been termed "dynamic capabilities" (Teece et al. 1997, Eisenhardt and Martin 2000), which both constrains and enables a firm's ability to adapt to changes in its competitive environment (Teece et al. 1997). Viewing entry timing through the lens of dynamic capabilities thus suggests that a relevant metric to consider may not be whether a firm was a market pioneer in first product generation, but whether it possesses the ongoing capability to engage in the act of creating or responding to new markets in changing industries.

Market Pioneers, Market Responders, and Survival

Legacy-based FMA (resulting from pioneering the very first product generation in an industry) may be difficult to sustain in high-velocity environments (Suarez and Lanzolla 2007). Rapid evolution of technologies and markets can annul experience curve advantages (Lieberman 1989) and lead to obsolescence (Tushman and Anderson 1986). Incumbent firms often fail to enter new market niches because of routinization and inertia (Miller and Chen 1994). Experience with a particular set of operating routines can restrict an organization's ability to produce new products, acquire new resources, and enter new market niches (Teece et al. 1997, King and Tucci 2002). However, a firm's *dynamic* capability to create new markets and pioneer emerging product generations is likely to offset such debilitating effects of change on legacy advantages, and thereby enhance its likelihood of survival. Firms that can buck the trend and strategically transform themselves through periodic creation of new markets exhibit the capability of ambidexterity in being able to take care of the present even as they are creating the future (Tushman et al. 1997). Organizations that possess such entrepreneurial capabilities for strategic renewal are likely to exhibit enhanced performance (Agarwal and Helfat 2009).

Although market pioneers bear high product and market development costs, and face greater levels of risks emanating from demand and technological uncertainties (Lieberman and Montgomery 1988, 1998), firms that consistently engage in market pioneering across new product generations are also likely to benefit from various demand- and supply-side isolating mechanisms that underlie first-mover advantage (Rumelt 1987). By repeatedly getting a head start on the learning curve, preempting scarce assets in strategic factor markets, and increasing buyers' switching costs, firms that exhibit sustained market-pioneering capabilities are likely to enjoy strategic and economic benefits due to advantageous positions in resource space and creation of entry barriers (Lieberman and Montgomery 1988, Suarez and Lanzolla 2007). These benefits are likely to be stronger when products can be sharply differentiated from older generations, and early market entry offers an escape from commoditization and intense price competition. In such situations, reputation effects and temporary price umbrellas are likely to provide an important monopoly window to firms that systematically engage in market pioneering of new product generations (Adner 2002). Therefore,

Hypothesis 1 (H1). *Sustained market-pioneering capabilities increase the likelihood of survival.*

Once a new market has emerged through the efforts of market pioneers (whether a new entrant or an incumbent from earlier generations), incumbent firms in prior market generations of the industry must decide whether or not to respond and move into the new product generation space.[1] Potential responders thus face a difficult trade-off. Having lost the market-pioneering opportunity, should they enter the new market? Their decision relates to the trade-off between minimizing the threat of obsolescence and the need to focus resources on their extant markets. By entering new markets after they have been established by the market pioneers, market responders may offset the risks of being first, yet share the gains of a growing market segment. This wait-and-see strategy is especially beneficial in industries in which new markets render earlier segments obsolete (Christensen 1993, Mitchell 1991). The choice is not a trivial one in dynamic product markets that face rapid commoditization: firms may be inclined to "sit it out" rather than invest in markets that are moving toward price-based competition. Yet, by not responding, they face the risk of being locked out forever from the market.

There is reason to believe that entry into new markets, even if late, is better than not entering at all. Christensen (1997a) documents the failure of firms that paid close attention to their current customer needs but missed opportunities to enter new product generations. Conversely, Tegarden et al. (1999) report that in the personal computer industry, firms improved their chances of survival if they undertook the strategic decision to embrace the new product generation even if they were late to enter. King and Tucci (2002) find that incumbents that broke their inertia and entered emergent market segments enjoyed higher sales, and thus gained value relative to firms that did not respond. Firms that are able to undertake such transformational experiences, even if late in the game, are able to maintain their adaptability and reduce their inertia, and thereby enhance their survival chances (Katz and Allen 1985, Tushman and Romanelli 1985). Accordingly,

Hypothesis 2 (H2). *Sustained market-response capabilities increase the likelihood of survival.*

Technological Know-How: A Complementary Dynamic Capability

Thus far, our focus has been on how entry timing into new product generations impacts firm survival. Literature suggests that, in high-velocity environments, having a number of distinct capabilities enables firms to alter their resource bases and adapt to changing competitive conditions (Eisenhardt and Martin 2000). Specifically, the notion of dynamic capabilities spans a diverse range of routines, including those related to technological capabilities, marketing, product development, and resource acquisition, recombination, and integration (Teece et al. 1997). Importantly, Teece (1982) called attention to examining capabilities related to the market (as in our emphasis on market pioneering and responding) and to the underlying technological domain. While not discounting the importance of other capabilities, we focus our attention in this paper on dynamic technological capabilities as important to firm survival, particularly because it complements our dynamic timing of entry capabilities.

A crucial determinant of survival is a firm's proprietary technical/innovative capability (Schoonhoven

[1] We note that one way in which firms may choose to respond to emerging product generations is by "skipping" a certain market altogether and entering or initiating the next product generation (de Figueiredo and Silverman 2007). For the focal product generation, however, the firm's decision is thus de facto to *not* respond to an opportunity. In the empirical section, we conduct robustness checks related to the incidence of skipping as a response.

et al. 1990). Because technological knowledge is typically tacit and developed over time, it is a source of competitive advantage. Technological capabilities can create differentiation advantages for firms and thus relate positively to survival, particularly under conditions of intense competition. Furthermore, in process-enabling industries, such disk drive production, rapid and smooth introduction of new manufacturing processes is highly important for competitive performance. Technology development is often targeted at discovering parameters whose unfamiliarity causes defects in manufacturing. Early specifications of a process technology generally fail; engineering experimentation and analysis generate knowledge and thereafter codification of the parameters of the technology (Hatch and Macher 2002). This sequence requires both conscious learning by doing and scientific breakthroughs. For example, in the case of the disk drive industry, technological capabilities were dependent on capabilities related to miniaturization, error tolerances, and clean rooms. As the underlying science behind the technology of manufacturing disk drives evolved, obsolescence could only be averted through dynamic capabilities that ensured continuing mastery over new sets of technological challenges.

In industries that experience rapid advancement, technological competition often resembles an arms race, where instead of absolute goals, the relative goal of staying ahead of other competitors becomes paramount. In such contexts, technology capability needs to be conceptualized in both dynamic and relative terms such that it is measured in comparison to other competitors over time, instead of in absolute, static terms. From this perspective, there appears distinct ways in which technology-related capabilities can impact survival. First, environmental selection processes will lead to the exit of those that are relatively weaker on the parameter of importance. As noted by Lee (2008), the survivor principle suggests that firms that occupy lower positions on technology frontiers will be eliminated from the industry, thus allowing firms better equipped to satisfy the market's demands to survive. Because a firm's position depends not only on its own efforts, but also on the industry-wide advancement of technology, the ones that are unable to keep up with the industry-wide advancement of technology will face exit pressures. Second, the ability of a firm to integrate, build, and reconfigure its technological competencies to address rapidly changing environments will determine survival. However, whether firms adapt to the new technological realities and merely succeed in improving their technological capabilities from one period to the next is not important per se; what matters is their relative position in the technology race in the current period. Barnett and McKendrick (2004) observe that even as organizations greatly improve their technologies in absolute terms, they often move backwards in relative ranks over time because rivals improved even faster. This is further supported by work by Lee (2008), which points to the "Markovian" property of capabilities, such that initial capabilities may have little impact on current capabilities. This highlights the issue of contemporaneous rank. In industries with rapidly evolving technologies, lagging in position relative to the contemporaneous technology frontier not only signals lower quality, but also increases the probability of failure. Thus, the ability to sustain technological leadership, or maintain a contemporaneous superior technological position, based on scientific breakthroughs and complex organizational learning, enhances firm performance. Therefore,

Hypothesis 3 (H3). *Sustained technological capabilities increase the likelihood of survival.*

Given the nature of the relationship between market-related and technological capabilities, the potential complementarities between the two deserve close attention. A key reason relates to the mixed empirical findings on the main effects of each. Just as scholars have documented the inconclusiveness of FMA research (Suarez and Lanzolla 2007), there is increased skepticism regarding the unbridled optimism surrounding technological innovation (Adegbesamn and Ricart 2007). Recent findings show that an emphasis on innovation neither translates into strategic advantage, nor improves bottom lines as expected (Linder et al. 2003, Andrew and Sirkin 2003). Despite the potential of leveraging technological inventions across multiple market applications and domains (Danneels 2002), firms often fail to realize the benefits from technological resources (Thomke and Kuemmerle 2002). This failure to leverage technological competence (Danneels 2007) and appropriate value latent in the technological inventions has potentially led to conflicting findings regarding technological innovativeness and firm performance (Capon et al. 1990, Leiponen 2000).

To profit from innovation, therefore, a firm needs to keep up with *both* new technologies and new markets (Griffin and Hauser 1996). The complementarity of these capabilities creates a synergy that increases a firm's effectiveness and efficiency. As noted by Danneels (2007), the creation of complementary assets requires resource allocation and transformation of generic resources into specific resources. Developing new, complementary capabilities requires a strong strategic intent, because it involves a deliberate managerial decision to divert resources away from the production of output to the production of competence (Dorroh et al. 1994). As indicated by Christensen (1997a, b), the "innovator's dilemma" is predicated by the tendency for incumbent firms to focus on their current consumers' needs and ignore developing capabilities that may enable them to tap into emerging, yet nascent segments.

The inherent difficulty of developing these two capabilities simultaneously can be a valuable isolating mechanism (Grant 1991, Lippman and Rumelt 1982, Reed and DeFillippi 1990), separating winners from losers. Various organizational pathologies, which researchers call learning traps (March 1991, Levinthal and March 1993), localize search in proximate areas (Ahuja and Lampert 2001, Cyert and March 1963), thus often causing firms to fail in realizing the full value of their capabilities (Moran and Ghoshal 1999). Indeed, recent conceptualizations of firms' capabilities have emphasized the creation of new sources of economic rents (Eisenhardt and Martin 2000, Teece et al. 1997). Profiting from innovation requires a blend of research and development (R&D) capabilities (value creation) and capabilities to pursue new markets (value appropriation), particularly in environments that may have high imitability and low dependence on existing complementary assets (Gans and Stern 2003). Regardless of whether firms enter new markets relatively early or late, such efforts at renewal help them shed inertia and develop new competencies that maintain their relevance during periods of change (Burgelman 1991). Firms that invest in technological capabilities while also adapting to new market needs are better off than firms constrained by inertia in any one dimension. Such strategic renewal efforts permit firms to adapt to changing environments rather than stagnating and falling victim to selection processes unleashed by industry evolution (Agarwal and Helfat 2009). Therefore, we expect that the payoff from pioneering and responding to new markets will be higher when a firm is able to simultaneously maintain higher levels of technological capabilities. Because the two components of the dynamic capabilities required for renewal, namely, market creating/responding and technological, are likely to have a positive synergy on survival, we hypothesize the following:

Hypothesis 4 (H4). *Technological capabilities positively moderate the relationship between* (a) *market-pioneering and* (b) *market-responding capabilities and the likelihood of survival.*

Thus far, we have focused our attention on the synergies between the dual dynamic capabilities—entering new markets and technological capabilities, while without distinguishing how the *order* in which firms enter may impact this synergy. Our final hypothesis relates to the intriguing question of the relative strength of the synergy between dynamic technological capabilities and that of pioneering versus responding. In other words, although we have argued that the ability to maintain technological superiority is of greater help when firms possess the ability to pioneer new markets or to respond to them, it is not clear whether the size of the effects are different between the two market-related capabilities. This is important because discriminating effects would suggest that the interrelationship between the two sets of dynamic capabilities that are fundamental to the renewal of firms in dynamic environments, namely, technological (value creation) and commercialization (value appropriation), is contingent on entry timing into new product generations. At the core, this would contribute to a more nuanced understanding of Schumpeter's (1942) distinction between invention and innovation, and how the payoff from a firm's ability to engage in both value creation and appropriation concurrently differs based on the timing of commercialization.

We contend that technology plays a stronger synergistic role for market pioneers than for responders. Market pioneers who also maintain higher levels of technological capabilities possess the cospecialized ability to both create new markets and sustain them through technological inventions (Gambardella and Torrisi 1998, Teece 1982). Firms that are able to stay on top of the technology curve while demonstrating the dynamic capability to create new markets are likely to be better off than firms that are similarly endowed on the technology front but are characteristically responders, or late movers into new markets. The mechanism behind our prediction is twofold: First, technology leadership operates as an isolating mechanism through which FMA is derived (Lieberman and Montgomery 1988) by encompassing "cost advantages arising from advanced appropriation of scarce input resources, forestalling bids for product characteristic spaces, and economies of scale created from preemptive investment in the plant and equipment; and switching costs arise from habit formation in buyers or from the installed-base effect in the presence of network effects" (Suarez and Lanzolla 2007, p. 379). Second, research has shown that late movers can overthrow pioneers through a process of continuous innovation based on learning and technological superiority (Shankar et al. 1998). However, when pioneers are able to maintain their technological leadership, such an avenue to losing potential FMA to responders is preempted. Together, these mechanisms suggest that technologically superior pioneers are likely to have higher rates of survival than similarly endowed responders. Therefore,

Hypothesis 5 (H5). *The synergistic effect of sustained technological capabilities with market-pioneering capability is stronger than with market-responding capability.*

Data and Methodology

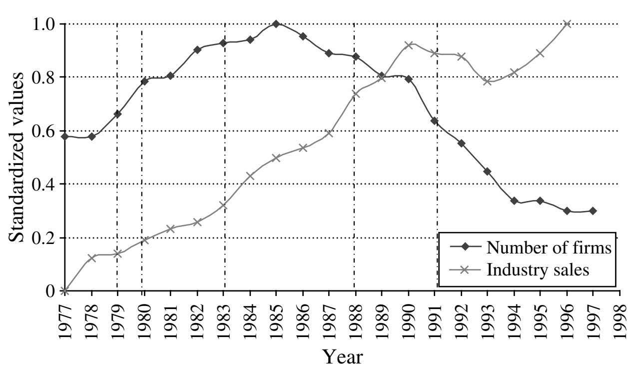
Empirical Context

We tested the hypotheses in our study using data from the rigid disk drive industry over the period 1977–1997. Disk drives are magnetic information storage devices. In 1973, IBM introduced the first completely sealed and removable disk drive, the 14-inch Winchester, causing the industry to take off shortly thereafter. Figure 1 depicts the standardized values for the number of firms and sales in the industry, with the annual value of each variable divided by the maximum value observed for it in the study. Both variables conform to trends documented in industry evolution studies (Agarwal 1998, Gort and Klepper 1982). The first 10 years of the period studied showed a rapid increase in both number of firms and sales. The 39 incumbents that had entered between 1973 and 1976 were joined by 153 new entrants after 1977, an increase that fueled rapid growth in industry sales. A shakeout of firms ensued in 1986, and sales continued to increase, though at a decreasing rate.

The smooth trends in number of firms and sales, however, mask discontinuous changes within the industry. As shown in Figures 1 and 2, architectural innovations led to five new disk diameters during the 20-year period considered in our study. Each diameter innovation created a new market. The smaller diameters enabled the creation and growth of new markets including desktop computers, laptop computers, personal digital assistants, geographic positioning systems, and other handheld electronic devices. Importantly, as Christensen (1993, 1997a) documents, not only did the markets for these new diameters grow faster than the markets for older diameters, but in time the new diameters replaced the older ones and rendered them obsolete.

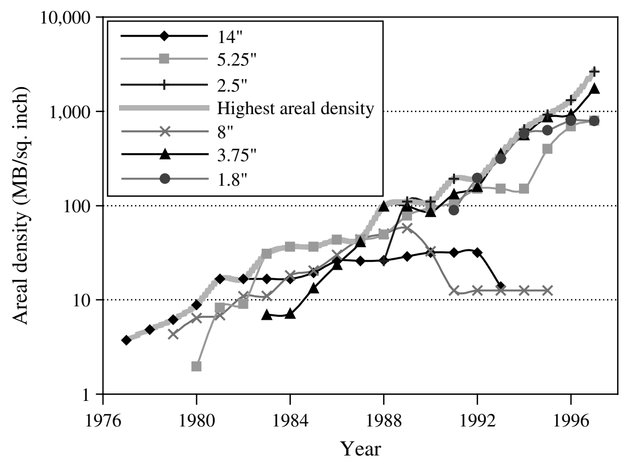
In addition to new markets, rapid technological change due to numerous incremental and modular innovations resulted in technology S-curves within each successive market. Areal density (megabytes per inch of storage capacity) is a critical technological performance parameter for disks, and Figure 2 depicts the rapid increase in areal density within and across disks of successive diameters. Thus, the multiple new markets and the rapid change in technology make the disk drive industry an ideal empirical context for our study.

Figure 1 Number of Firms and Sales in Disk Drive Industry



Note. The dotted vertical lines represent the timing of the successive introduction of new markets within the industry during the sample period.

Figure 2 Areal Density of Drives by Diameter



Data Sources

We collected data from sources that documented events at the time of occurrence and tracked information in the industry for *all* firms entering and exiting it, to avoid survivor bias. Specifically, we used information compiled from the *Disk/Trend Report*, a market research publication that has covered the disk drive industry since 1977 and has been used in several past studies (Agarwal et al. 2004, Christensen 1993, King and Tucci 2002, Lerner 1997). These data were supplemented by information from company news releases, scientific journals, books, and directories (e.g., the *Directory of Corporate Affiliations* and the *International Directory of Company Histories*). The final database contains the census of firms in the industry during 1977–1997 and includes detailed information on firm and industry characteristics.

Variables

Firm Survival. The dependent variable in our study, *firm survival*, is computed as a dummy variable that takes a value of 1 if a firm survived to the following year (with acquisitions being treated as "censored" observations) and 0 otherwise.

Timing of Entry Into Market Measures: Market Pioneers and Responders to Markets. Our *market-pioneering* and *market-responding* measures are based on new diameter introductions, which formed the basis on which new markets were formed. Our measures of the two variables are consistent with our dynamic conceptualization of pioneering and responding capabilities, and based on the idea that new product generations present firms with multiple market-pioneering and market-responding opportunities. Because the number of such opportunities depends on a firm's overall time of entry into the industry as well as when the new markets emerged, our measures of the two variables vary over both time and firms. We also note that in keeping with our theoretical focus, our timing of entry variables relate to firm entry into the new markets rather than entry into the industry.

Regardless of whether they are incumbents in the industry (i.e., firms that existed in the industry prior to the focal market introduction) or new entrants, firms that entered in the first year of a new market are identified as market pioneers in that product generation. Our measure of market pioneers as a cohort of firms that creates new markets, and subsequently benefits from it, is consistent with earlier treatment in the literature (Rosenbloom and Cusumano 1987). Although only one firm can be considered a true pioneer on the basis of strict order of entry (Golder and Tellis 1993), more than one firm may simultaneously engage in market-pioneering activities and experience similar time lines in undertaking new market orientation strategies, such as scouting opportunities, assessing uncertainty, and ramping up for production.

Specifically, we adopt the Agarwal et al. (2004) measure of pioneering markets (PM_{it}), defined as the number of times a firm introduces a drive in a new market within the first year of the market's introduction into the industry, divided by the total number of new markets introduced in the industry since the year of entry for the firm.[2] In robustness checks, we also examine whether our results are sensitive to a more stringent definition of pioneering as introducing the drive in the first quarter, rather than the first year. Between 4% and 7% of the total entrants in each market are classified as pioneers based on the one-year window, and the range is between 2% and 7% if the more stringent definition of the first quarter is used.

Firms change from being entrants into the industry to incumbents the first time a new market is introduced in the industry after their entry. Our *market-responding* variable captures whether incumbent firms that did not pioneer a market subsequently entered it during their life span. Responding to markets (RM_{it}) is thus analogously defined as the number of times an incumbent firm entered a market *after* the first year of the market's introduction into the industry, divided by the total number of new market introductions in the industry since the year of entry for the firm for the time until time t. Mathematically, our measures take these forms:

$$PM_{it} = \frac{\sum_{k=E_i}^{t} P_{ik}}{\sum_{k=E_i}^{t} D_k} \quad \text{if } \sum_{k=E_i}^{t} D_k > 0 \quad \text{and} \qquad = 0 \quad \text{if } \sum_{k=E_i}^{t} D_k = 0, \tag{1}$$

$$RM_{it} = \frac{\sum_{k=E_i}^{t} R_{ik}}{\sum_{k=E_i}^{t} D_k} \quad \text{if } \sum_{k=E_i}^{t} D_k > 0 \quad \text{and} \qquad = 0 \quad \text{if } \sum_{k=E_i}^{t} D_k = 0, \tag{2}$$

where E_i is the year of entry of the ith firm, t is the current year of operation, P_{ik} is a dummy variable that indicates whether the ith firm was a market pioneer when a new market was introduced (P_{ik} equals 1 if the firm introduced a drive for a new market *within* the first year of the market's introduction into the industry, and 0 otherwise), R_{ik} is a dummy variable that indicates whether an existing firm entered the relevant market subsequent to the first year after its introduction (R_{ik} equals 1 if the firm produced a drive for the new market for the first time *after* the first year of the market's introduction into the industry, and 0 otherwise), and D_k is a dummy variable that indicates whether there was a market introduction during that year (D_k equals 1 if a market was introduced, and 0 otherwise). For each firm operating in the industry at the time of a new market's introduction, the denominator of the variable is increased by 1, and the numerator for PM_{it} (RM_{it}) increases by 1 only if the firm was a market pioneer (follower) for that diameter. For firms that entered between two consecutive market introductions, both variables take the value of 0 until the year of the next market introduction. Tables A1–A3 and the related descriptions in the online technical appendix (provided in the e-companion)[3] provide detailed examples of how both *market-pioneering* and *market-responding* variables change over time based on new diameter introductions and firm decisions regarding entry into new markets. The baseline group in our analysis thus consists of firms that have operations only in the market that they entered in; i.e., these firms never enter, either early or late, new markets that emerge subsequent to their entry into the industry.

[2] Our choice of a one-year window in the operationalization of the measure was primarily driven by considerations of consistency with the bulk of received literature. Among the studies that use a "window" rather than a strict order of entry scale, the span ranges from the exact date that the first firm entered (e.g., Golder and Tellis 1993) to several years after the first entry year (e.g., Agarwal and Gort 2001). The majority of the studies, however, use a one-year window (e.g., Bayus et al. 1997, Robinson and Min 2002, Agarwal et al. 2004).

[3] An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

Technological Capabilities. As indicated above, a critical technological performance measure of disk drives relates to areal density. Our measure of this variable is based on the average of a firm's diameter-specific relative technological position for all the diameters it produced in a particular year, using the following two-step procedure. The areal density (A) of the best drive produced by firm i in diameter j in year t is first divided by the highest areal density in that diameter available in the market that year to obtain the firm's diameter-specific relative technological position (TC_{ijt}):

$$\mathrm{TC}_{ijt} = \frac{A_{ijt}}{\max(A_{ijt})}. \tag{3}$$

As discussed in Agarwal et al. (2004), measuring a firm's technological capabilities in comparison with the best drive in that market circumvents problems related to cumulative and absolute increases in technological know-how over time, because it is a *relative* time-varying measure that reflects a firm's competitive positioning. We then average this measure over all diameters ($j = 1$ to n) produced by the firm in year t to obtain a measure of the firm's average relative technological capability (TC_{it}) in that year:

$$\mathrm{TC}_{it} = \frac{\sum_j \mathrm{TC}_{ijt}}{\sum_j}. \tag{4}$$

In robustness checks, we use alternative measures of technological capabilities. Specifically, instead of using the average of the best drives across all diameters produced by a firm, we used (a) the areal density of the best drive in the latest diameter produced by the firm (latest technological capabilities), (b) the areal density of the best drive in the diameter prior to the last diameter introduced (recent technological capabilities), and (c) the inverse of the coefficient of variation in the areal density, measured as TC_{it} divided by the standard deviation in the areal densities across the drives produced by the firm (variation-adjusted technological capabilities).[4]

Control Variables. Several firm-level and industry-level variables are included as controls. Among firm-level controls, *firm tenure* is measured as the number of years elapsed since a firm entered the disk drive industry; a squared term permits potential nonlinear effects of tenure. We use the logged value, in millions of dollars, of all disk drive sales per year as our measure of firm sales. *Foreign firm* is a dummy variable taking a value of 1 if a firm originated outside the United States and 0 otherwise. Two measures are used for a firm's product development capabilities: *number of drives* in a firm's portfolio and the *number of new drives introduced* by the firm. Because our data are left truncated until 1976, we control for any systematic effect for firms that entered prior to 1977 by coding the dummy variable *incumbent76* as 1, and 0 otherwise. Given our focus on firms entering a new market, we code the dummy variable *incumbent in a prior market* as 1 for incumbents in the industry prior to the new market introduction, and 0 for new entrants (firms that entered since the last market was introduced). The dummy variable *diversified firm* is equal to 1 for firms that had operations in other industries, and is 0 for pure play disk drive manufacturers. Finally, in robustness checks, we replace the *incumbent in 1976* and *firm entry year dummies* with the *entry year of the firm into the industry* (imposing the limitation of 1976 as the entry year for firms that entered prior to 1977).

Among industry-level controls, *industry sales* is the logged value of all disk drive sales per year, and *industry growth* is the annual percentage change in industry sales. The technological frontier of the industry is measured as the *highest areal density in the industry* over all the diameters produced in a given year. *Growth in areal density*, measured as the percentage change in highest areal density between any two years, was used to control for the rapid changes in areal density. To control for competitive density effects, we use both linear and quadratic specification for the *number of firms* in a year and include the *number of new entrants* in the year. Finally, we include dummies for *firm entry year* to control for differences in founding conditions.

Table 1 provides descriptive statistics and correlations for all the variables. The correlations do not indicate the presence of multicollinearity, and the variance inflation factors confirm its absence. In Table 2, we provide the count and average technological capabilities at time of entry into markets based on whether the firms were entrants or incumbents in the industry, and whether they were pioneers, responders, or did not enter subsequent markets after their initial market entry. On an average, 88% of the firms in the industry survived to the following year. As shown in Table 1, the average value of pioneering across all firm-year observations is 0.09, and of responding is 0.28. Among the new entrants in the industry, 11 firms pioneered a new market, whereas 181 firms entered after the first year of a market's introduction. Among the incumbents, there were 10 instances of pioneering, 92 instances of responding, and 120 firms who did not enter a new product market. Thus, it is notable that that the pioneers into new product generations have been almost evenly split between entrants and

[4] We note that, consistent with our other variable measures, our measure of technological capabilities is on an annual basis. Although we cannot conduct robustness checks for a measure based on quarterly technological capabilities due to missing quarterly observations, the correlation coefficient of *technological capabilities* measured quarterly, and annually for firms when such data are available, is 0.70.

Table 1 Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. *Survival*	0.88	0.33	0	1	1																			
2. *Pioneering markets*	0.09	0.29	0	1	0.03	1																		
3. *Responding to markets*	0.28	0.43	0	1	0.08	−0.1	1																	
4. *Technological capabilities*	0.38	0.27	0	1	0.11	0.12	0.21	1																
5. *Firm tenure*	6.03	5.76	0	41	0	0.07	0.45	0.3	1															
6. *Firm tenure*^{2}	69.57	156.01	0	1,681	0.04	0.08	0.3	0.26	0.89	1														
7. *Firm sales*	6.96	11.26	−18.42	16.3	0.24	0.02	0.18	0.16	0.26	0.17	1													
8. *Diversified firm*	0.18	0.38	0	1	0.05	−0.06	0.37	0.12	0.46	0.39	0.19	1												
9. *Foreign firm*	0.23	0.42	0	1	−0.04	−0.04	−0.14	−0.2	−0.25	−0.18	0.03	−0.16	1											
10. *Incumbent in 1976* dummy	0.31	0.46	0	1	0.08	−0.08	0.34	0.16	0.55	0.42	0.19	0.53	−0.36	1										
11. *Industry sales*	16.34	0.67	14.76	17.12	−0.13	−0.09	0.15	0.08	0.31	0.23	0.13	0.03	0.27	−0.24	1									
12. *Industry growth*	0.14	0.1	−0.11	0.3	0.08	0.08	−0.09	−0.11	−0.23	−0.19	−0.07	0.04	−0.13	0.14	−0.52	1								
13. *Highest areal density in industry*	192.87	434.56	3.73	2,637.50	−0.04	−0.06	0.13	0.1	0.29	0.26	0.12	−0.02	0.09	−0.1	0.49	−0.47	1							
14. *Growth in high areal density*	−6.14	46.95	−705.73	0.98	−0.03	0.04	0.08	0.1	0.12	0.05	0.16	0.05	0.02	0.05	0.18	−0.07	0.06	1						
15. *Number of firms*	62.84	16.86	25	83	0.05	0.1	−0.08	−0.1	−0.26	−0.23	−0.1	0.06	−0.09	0.07	−0.37	0.6	−0.81	−0.01	1					
16. *Number of firms*^{2}	4,215.06	1,897.21	625	6,883	0.05	0.1	−0.06	−0.09	−0.24	−0.22	−0.09	0.07	−0.1	0.06	−0.34	0.58	−0.74	0.01	0.99	1				
17. *Number of entrants*	8.01	4.48	0	16	0.05	0.11	−0.08	−0.08	−0.26	−0.21	−0.13	0.01	−0.14	0.12	−0.58	0.51	−0.59	−0.05	0.73	0.74	1			
18. *Incumbent in prior submarket*	0.4	0.49	0	1	0.07	0.2	0.79	0.26	0.49	0.34	0.16	0.3	−0.14	0.25	0.15	−0.08	0.09	0.07	−0.04	−0.02	−0.06	1		
19. *Number of drives*	9.43	14.02	0	119	0.13	0.1	0.43	0.38	0.63	0.59	0.26	0.39	−0.21	0.36	0.13	−0.14	0.14	0.06	−0.18	−0.18	−0.17	0.44	1	
20. *Number of new drives introduced*	2.17	4.73	0	73	0.08	0.04	0.1	0.25	0.2	0.22	0.11	0.1	−0.07	0.08	0.04	−0.08	0.01	−0.01	−0.05	−0.07	−0.09	0.14	0.56	1

Notes. $N = 1{,}199$ observations. All correlations above $|0.06|$ are significant at the 0.05 level.

Table 2 Number of Entries and Technological Capabilities at Time of Entry Into New Markets

	Number of entries	Technological capabilities at time of entry (std. dev.)
New entrants in the industry[a]		
Pioneers[b]	11	0.59 (0.31)
Nonpioneers	181	0.38 (0.27)
Incumbents in the industry[c]		
Pioneers[b]	10	0.48 (0.27)
Market responders	92	0.41 (0.17)
No entry in subsequent markets	120	0.38 (0.28)

[a]The F-statistic for differences among the different types of firms in the new entrant group = 1.37 (not significant).
[b]The F-statistic for differences among pioneers that are entrants versus incumbents = 1.36 (not significant).
[c]The F-statistic for differences among the different types of firms in the incumbent group = 1.62 (not significant).

incumbents. Moreover, not only are the technological capabilities of these two groups similar at the time of entry (Table 2), they also evolve the same way over the first five years subsequent to entry into the new market (Figure 3). Across all firms, the average firm technological capabilities in a year is 0.38. The first quartile value is 0.16, whereas the value at the third quartile is 0.57. The top 10% of the firms had technological capabilities higher than 0.8.[5]

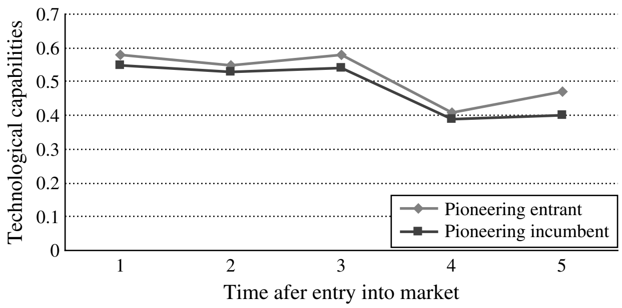
Estimation

We use hazard rate methodology to test our hypotheses relating to the probability of a firm surviving in a given year. Several discrete and continuous time models are available for the estimation of hazard rates (Allison 1995); we use a firm-year observation structure with a complementary log-log specification. Because the data on survival are updated only annually, this formulation allows us to recover continuous-time hazard rates from discrete-time data. Also, such a specification allows for easier incorporation of time-varying covariates. Furthermore, we control for firm-level unobserved heterogeneity by using a random-effects specification.[6] Our results are robust to alternative hazard rate estimation techniques, including Cox proportional hazard and piecewise exponential models.

[5] The distribution of mean levels of technological capabilities by firm closely corresponds with the distribution of technological capabilities when observations are firm-year. The within-firm variance in technological capabilities is half of the variance reported for technological capabilities (see Table 1), indicating some persistence over time.

[6] Fixed-effect models are not available in the standard statistical packages because a sufficient statistic allowing the fixed effects to be conditioned out of the likelihood does not exist. Incorporating unconditional fixed-effects estimates with the use of firm dummies results in biased estimates (Allison 1995).

Figure 3 **Technological Capabilities of Pioneering Firms Subsequent to Entry into Markets**



Additional issues that could pose concerns about the reliability of the coefficients are potential sample selection bias and endogeneity of the decision to enter new markets. Our data include measurements on all firms that chose to enter new markets. In other words, the dependent variable, *survival*, is observed for all members of the sample that entered these new markets. This fact renders the concern of sample selection moot. On the other hand, endogeneity is a valid concern, because the decision to enter new markets is potentially affected by a firm's technological capabilities, and vice versa. We address this issue both conceptually and methodologically. As explained in our theory section, it is not clear that such a relationship exists for the contemporaneous values of each variable, particularly when technological capabilities are measured on a relative scale. A manager facing a decision to launch into a new market operates with imperfect knowledge concerning competitor capabilities and customer preferences. Also, at a conceptual level, the structures, processes, and systems for developing technological and pioneering capabilities are different. Christensen (1997a) documents that several firms operating on the technological frontier in this industry chose *not to* enter the new markets, even when they were capable of producing the relevant diameters.

Empirically, the variables for market entry and technological capability are weakly correlated (see Table 1). Because the types of innovations that underlie increases in areal density and thus relate to technological capabilities are different from the architectural breakthroughs that relate to market-pioneering/-responding capabilities, there is no theoretical reason to expect a causal relationship between the two measures. Also, we examined whether the mean levels of technological capabilities *at time of entry* were systematically different between the firms that were market pioneers, responders, or did not enter subsequent markets, and between new entrants and incumbents. Table 2 provides average technological capabilities for each type of firm. F-tests reveal no significant differences between market pioneers who were incumbents or new entrants, and between incumbents that were market pioneers, responders, or did not enter subsequent markets. Furthermore, we explicitly tested for endogeneity per the Granger (1969, 2003) methodology. Our tests confirm an absence of causality in either direction; that is, the coefficients for the lagged value of technological capabilities in the regressions modeling pioneering/responding to markets, and the coefficient of the lagged values of either pioneering or responding to markets in the technological capabilities regression, are not statistically significant. Thus, endogeneity between technological capabilities and timing of entry does not appear to be a salient issue. To the extent that unobserved firm-level effects may impact *both* market-pioneering and technological capabilities, our random-effects panel data specification accounts for unobserved heterogeneity.

Results

In Table 3, we provide our results. In the context of our pioneering and responding capabilities variable, the baseline group consists of those incumbents that *never* entered another market in the industry, and focused operations only in the market that they entered. The coefficient estimates in Model 1 indicate that the main effect of pioneering markets is *not* significant, indicating that H1 is *not* supported. *Responding to markets* has a positive and significant effect on survival, providing support for H2. Taken together, the coefficients of Model 1 also permit us to directly compare the effects of market pioneering, market responding, and no subsequent market entry on survival. There is no significant difference in the main effect on *survival* of firms that were market pioneers, and firms that did not subsequently enter new markets. However, relative to these firms, market responders had significantly higher survival probabilities. Furthermore, the coefficient of technological capabilities is positive and significant, providing support for H3 that higher levels of technological capabilities enhance the probability of survival.

Model 2 in Table 3 reports the coefficients for the interaction effects. The simple effect of technological capabilities is not significant. The simple effect of market pioneering is negative and significant; indicating that at zero and low levels of technological capabilities, market-pioneering capabilities reduce the probability of a firm's survival. The interaction term between market-pioneering and technological capabilities is positive and significant, indicating that firms that are both market pioneers and have higher levels of technological capabilities have higher probabilities of survival. The simple effect of responding to markets is not significant, but the interaction effect

Table 3 Probability of Firm Survival

Variable	Model 1	Model 2
Intercept	4.43**	8.36**
	(2.38)	(3.48)
Pioneering markets	0.12	−1.40**
	(0.18)	(0.64)
Responding to markets	0.34*	−0.08
	(0.19)	(0.43)
Technological capabilities	0.28*	−0.38
	(0.16)	(0.28)
Pioneering markets × *Technological capabilities*	—	4.28**
		(1.62)
Responding to markets × *Technological capabilities*	—	1.34**
		(0.75)
Firm tenure	−0.13***	−0.27***
	(0.03)	(0.05)
Firm tenure^2	0.006***	0.01***
	(0.001)	(0.003)
Firm sales	0.03***	0.04***
	(0.003)	(0.006)
Diversified firm	−0.07	−0.27
	(0.14)	(0.21)
Foreign firm	0.07	0.13
	(0.11)	(0.19)
Incumbent in 1976 dummy	0.08	0.29
	(0.16)	(0.30)
Industry sales	−0.49***	−0.75***
	(0.14)	(0.21)
Industry growth	−0.60	−0.69
	(0.61)	(0.81)
Highest areal density in industry	0.001**	0.001***
	(0.0005)	(0.0006)
Growth in high areal density	−0.002	−0.002
	(0.003)	(0.005)
Number of firms	0.13**	0.15***
	(0.04)	(0.05)
Number of firms^2	−0.001**	−0.001***
	(0.0003)	(0.0004)
Number of entrants	−0.002	−0.008
	(0.02)	(0.02)
Incumbent in prior submarket	0.11	0.26
	(0.18)	(0.27)
Number of drives	0.02**	0.02**
	(0.01)	(0.01)
Number of new drives introduced	0.007	0.007
	(0.02)	(0.02)
Pioneering markets × *Incumbent in prior market*	—	—
Order of entry into the industry	—	—
Number of observations	1,199	1,199
Chi-square test statistic	87.61	86.21
Log likelihood	−349.22	−338.97

Notes. Standard errors are in parentheses. Please refer to Table A5 in the online appendix for the marginal effects at mean levels of the variables.

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

of responding to markets and technological capabilities is positive and significant. The results indicate that although responding to markets does not help or hurt firms that have zero levels of technological capabilities, at higher values of technological capabilities, market-responding capabilities increase the probability of survival. Taken together, the coefficients of the interaction terms of technological capabilities and the market-pioneering/-responding variables provide support for both Hypotheses 4(a) and 4(b). Notably, the interaction of *technological capabilities* with *pioneering markets* is much higher in magnitude and more strongly significant than the interaction of *technological capabilities* with *responding to markets* ($t = 1.91$, $p < 0.05$). Thus, the moderating effect of technological capabilities for firms that pioneer markets is much stronger than for firms that respond to markets, thereby supporting H5.

The effects of the control variables are similar in all models. The coefficients of tenure and tenure squared indicate a U-shaped relationship with survival. Increases in firm sales increase the probability of survival, but being a foreign firm, an incumbent in 1976, or an incumbent in a prior market has no significant effect on survival. Number of drives in the portfolio has a positive impact, but the number of new drive introductions does not affect survival. Among the industry variables, higher industry sales decrease the probability of survival, but there is no effect of either industry growth or the number of entrants on survival. Interestingly, the pace of growth in areal density does not seem to impact survival. Increase in areal density aids survival, and the number of firms in the industry has the expected inverted U-shaped relationship with survival.

Additional Analysis and Robustness Checks

Our theoretical and empirical framework examined the role of contemporaneous capabilities—both in terms of entering new markets and in keeping up with the technological frontier. To examine whether there also exist any legacy-based advantages, we present the results of the analysis where (a) we include a dummy variable for firms that entered the industry during the first generation,[7] and (b) we use a "*time-invariant*" *technological capabilities* measure to capture the firm's technological capabilities at the time of its most recent entry into a new market. The results are presented in Table 4. As seen in Model 1, there is no significant effect on survival for firms that entered in the first generation, and furthermore, time-invariant technological capabilities do not

[7] We note that IBM, the pioneer of the first generation (and of some of the subsequent generations as well), survived the entire length of the sample period.

impact survival, either in the main effect (Model 2) or the interaction effects (Model 3) models. Given the absence of any legacy-based advantage—either because of early entry into the industry, or by entering with higher levels of technological capabilities—a key takeaway from this supplemental analysis is that what matters for survival is that firms keep up with the evolving industry, in terms of either new markets or technological development.

Furthermore, our analysis regarding timing of entry into new markets made two implicit assumptions. First, whereas we included a control for whether the firm was new to the industry versus new to the market, we assumed that there was no difference among pioneers who were entrants versus incumbents.[8] The results in Model 4 in Table 4 show that the relationship between pioneering new markets and survival is stronger for incumbent firms. The positive and significant coefficient for the interaction term between *market-pioneering capabilities* and the *incumbent in industry* dummy has two implications. First, among incumbents, firms that develop market-pioneering capabilities have a higher probability of survival than firms that do not. Second, among the cohort of firms that have market-pioneering capabilities, incumbent firms have a higher probability of survival relative to new entrants. This result may potentially be due to entrants lacking some of the unobserved capabilities of the incumbents, despite the parity in technological capabilities (e.g., established reputation and legitimacy).

The second assumption relates to incumbent behavior in the face of a new market introduction by another firm. It may be the case that some incumbents choose to "skip" a market and introduce a later generation; their response is better characterized by leapfrogging behavior rather than late entry in the same market. de Figueiredo and Silverman (2007), for instance, find evidence that firms often choose to "skip" adjacent segments in industries characterized by niche markets, such as the laser printer industry. In doing so, these firms may have more foresight or capability than others in avoiding cannibalization while at the same time strategically renewing themselves and staying abreast of industry evolution. We examined the incidence of such behavior in our data and found only five instances where firms engaged in skipping behaviors. Interestingly, none of the firms that skipped markets were market pioneers in the next generation, and furthermore, there was no systematic relationship between skipping behavior, firm tenure in industry, and technological capabilities. Two of these five firms had high technological capabilities on average, whereas the remaining three had relatively low technological capabilities. As a result, in our empirical context, we find that incumbents did not systematically forego existing new opportunities in favor of entering (early or late) into newer markets.

To test the sensitivity of our results to the measures employed for the key variables, we conducted numerous robustness checks. In the context of our measure of market-pioneering capabilities, our measure used a one-year window from a diameter's introduction in the industry. An important question arises: is one year a reasonable window, and are the results robust to a more stringent definition with a shorter time span? Because our data provide information on entry on a quarterly basis, we were able to construct an alternative measure of market pioneering based on the first-quarter window. The measure for market responding was suitably adjusted to include entry after the first quarter of the market's introduction into the industry. The results based on these measures in Model 5 in Table 4 are similar to those in Model 2 in Table 3, and the interaction of technological capabilities with pioneering markets is much higher in magnitude and strongly significant than the interaction of technological capabilities with responding to markets ($t = 3.22$, $p < 0.001$). These results thus indicate that the results are robust to alternative and more stringent measures of market pioneering.

Similarly, we experimented with three alternative measures of technological capabilities: latest, recent, and variation-adjusted technological capabilities. The results are reported in Table A4 in the online appendix. The correlations between all measures, with the exception of variation-adjusted technological capabilities, range between 0.88 and 0.97. The correlation of the variation-adjusted technological capabilities with each of the other three measures is around 0.07. Nonetheless, all of the coefficient estimates are remarkably consistent, and provide strong support for the hypotheses. The only exception is that the simple effect of the variation-adjusted technological capabilities in the interaction model is *negative* and significant, as opposed to insignificant for the others.

We also conducted robustness checks related to a key control variable, entry into the industry. In Model 6 in Table 4, we replace the incumbent in 1976 dummy and entry year dummies with a continuous entry year measure to capture order of entry into the industry effects. The insignificant coefficient indicates that the year of firm entry into the industry has no effect on its probability of survival. Finally, we

[8] There is no similar distinction among entrants and incumbents for responding capabilities because by definition, and as noted earlier, only incumbent firms that responded to new market introductions after the first year were included in the responding category. New entrants that entered a market after the first year but did not respond when a new market opportunity was introduced are included in the baseline model.

Table 4 Probability of Firm Survival

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	7.31**	6.71**	7.26**	7.84**	8.27**	−97.34
	(4.16)	(3.57)	(3.59)	(3.48)	(3.47)	(80.54)
Pioneering markets	−0.97	0.28	−0.23	−3.12**	−3.28**	−1.26**
	(0.77)	(0.29)	(0.57)	(1.02)	(1.64)	(0.62)
Responding to markets	0.12	0.39	0.09	0.16	0.05	0.20
	(0.47)	(0.31)	(0.45)	(0.43)	(0.39)	(0.35)
Technological capabilities	0.22*	—	—	−0.36	−0.34	−0.33
	(0.35)			(0.27)	(0.27)	(0.27)
Pioneering markets × Technological capabilities	3.28*	—	—	6.10**	6.94**	4.21**
	(2.00)			(2.14)	(3.91)	(1.60)
Responding to markets × Technological capabilities	0.79	—	—	1.37**	1.52**	1.39**
	(0.84)			(0.76)	(0.71)	(0.76)
Time-invariant (TI) technological capabilities	—	0.26	0.08	—	—	—
		(0.26)	(0.29)			
Pioneering markets × TI technological capabilities	—	—	0.90	—	—	—
			(0.91)			
Responding to markets × TI Technological capabilities	—	—	0.56	—	—	—
			(0.75)			
Firm tenure	−0.22**	−0.18***	−0.18***	−0.27***	−0.26***	−0.22***
	(0.11)	(0.08)	(0.08)	(0.06)	(0.06)	(0.06)
Firm tenure^2	0.008**	0.007***	0.006***	0.01***	0.01***	0.01***
	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Firm sales	0.04***	0.04***	0.04***	0.04***	0.04***	0.04***
	(0.009)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)
Diversified firm	−0.14	−0.11	−0.13	−0.27	−0.27	−0.25
	(0.23)	(0.21)	(0.20)	(0.21)	(0.21)	(0.21)
Foreign firm	0.16	0.07	0.07	0.09	0.12	0.11
	(0.23)	(0.19)	(0.19)	(0.19)	(0.19)	(0.19)
Incumbent in 1976 dummy	0.08	0.15	0.15	0.27	0.23	—
	(0.38)	(0.30)	(0.29)	(0.30)	(0.29)	
Incumbent in first generation	0.44	—	—	—	—	—
	(0.44)					
Industry sales	−0.69***	−0.65***	−0.65***	−0.74	−0.74***	−1.16***
	(0.27)	(0.23)	(0.23)	(0.81)	(0.21)	(0.32)
Industry growth	−0.65	−0.74	−0.74	0.002***	−0.62	−0.67
	(0.89)	(0.81)	(0.81)	(0.0007)	(0.81)	(0.81)
Highest areal density in industry	0.002**	0.002***	0.002***	−0.0005	0.001***	0.001***
	(0.0007)	(0.0007)	(0.0007)	(0.003)	(0.0006)	(0.0006)
Growth in high areal density	−0.001	−0.0005	−0.0005	0.13***	−0.003	−0.003
	(0.004)	(0.003)	(0.003)	(0.05)	(0.005)	(0.005)
Number of firms	0.14**	0.13***	0.13***	−0.0009***	0.14***	0.17***
	(0.06)	(0.05)	(0.05)	(0.0004)	(0.05)	(0.05)
Number of firms^2	−0.001**	−0.0009***	−0.0009***	−0.0014	−0.001***	−0.001***
	(0.0005)	(0.0004)	(0.0004)	(0.002)	(0.0004)	(0.0004)
Number of entrants	−0.005	−0.0014	−0.0014	0.16	−0.009	−0.009
	(0.02)	(0.002)	(0.002)	(0.25)	(0.02)	(0.02)
Incumbent in prior submarket	0.19	0.16	0.16	0.02**	0.14	—
	(0.28)	(0.25)	(0.25)	(0.01)	(0.27)	
Number of drives	0.02**	0.02**	0.02**	0.008	0.02**	0.02**
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
Number of new drives introduced	0.01	0.008	0.008	0.007	0.007	0.007
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Pioneering markets × Incumbent in prior market	—	—		2.05**	—	—
				(0.80)		
Order of entry into the industry	—	—		—	—	0.06
						(0.04)
Number of observations	1,199	1,199	1,199	1,199	1,199	1,199
Chi-square test statistic	27.20	31.84	32.29	86.09	86.09	89.19
Log likelihood	−299.62	−303.68	−303.70	−334.99	−334.99	−338.88

Note. Standard errors are in parentheses.
*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

examined the data to discern variances in entry patterns among the early industry entrants (firms that entered the industry prior to 1977) and firms that entered at later times. Twenty-six (67%) of the 39 early entrants to the industry entered subsequent product generations, which runs counter to the conjecture that such firms are likely to occupy and grow primarily in the market defined by the initial product generation. Interestingly, later entrants seem to respond with less frequency (48%) to subsequent markets than the entry cohort prior to 1977. However, it is not clear that this necessarily implies that later entrants are following the early cohort into subsequent markets. Of the 39 firms that entered prior to 1977, 3 firms (8%) pioneered subsequent product generations. Similarly, of the 153 entrants after 1977, 11 firms (7%) pioneered subsequent product generations. Thus, there is no significant difference among the cohort of firms that entered after 1977 in their rate of pioneering relative to the early cohort.

Discussion

Despite FMA's universal appeal and substantial traction amongst scholars and practitioners, researchers have been unable to provide conclusive empirical evidence to either support or refute its existence. As a result, FMA research seems close to being dismissed as an urban legend in the halls of strategic management, as managers are cautioned against basing costly actions on the belief that being first in a new market is valuable (Boulding and Christen 2003, Finkelstein 2002). Against this background, our research assumes heightened significance. We contend that such conflicting findings may be caused by two key theoretical misspecifications in existing models: failure to incorporate evolutionary dynamics at the "macro" industry level, and complementary technological capabilities at the "micro" firm level (Suarez and Lanzolla 2007). Ignoring evolutionary dynamics has led to a static view of FMA wherein researchers have attributed legacy-based advantages on firms that entered an industry during its incipient stages and were early enough to benefit from an emerging market. Furthermore, considering market-creating capabilities in isolation has ignored, from a Schumpeterian sense, the invention aspect of innovation. Specifically, we study how survival is affected by market pioneering (H1) and market responding (H2), how a firm's ability to stay close to the technological frontier impacts survival (H3), and how the relationship between technological capabilities and entry timing affects survival (H4 and H5).

Our paper is thus based on the premise that when industries evolve, entrepreneurial entry into emerging product markets is as important to firm survival as are technological capabilities. Our findings broadly support our thesis. Although pioneering, examined in isolation, offers neither advantage nor disadvantage with respect to a firm's likelihood of survival, its effects come to life when considered in tandem with technological capabilities. The lack of support for our H1 indicates that pioneering by itself does not necessarily enhance survival chances for a firm. This nonfinding is extremely important in our empirical context, because it suggests that even in a fast-changing industry characterized by continuous innovation, short product life cycles, and rapid commoditization, sustained market pioneering does not necessarily have desirable outcomes. Thus, it seems that just as legacy-based first-mover advantages may not exist in fast-moving industries (Suarez and Lanzolla 2007), neither does an advantage due to sustained market pioneering across multiple markets within an industry. The dualism inherent in pioneering may account for its limited effects: Risks of market pioneering may temper its benefits, thus resulting in a null effect. Conversely, the positive effect of subsequent or late entry on survival is intriguing. It hints at the counterintuitive possibility that in markets where late movers may incur a disadvantage from technological, scale, or reputational lockout, in fact late movers are advantaged over market pioneers. Further, entering new markets late is better than not entering at all.

The support found for H3 indicates that technological capabilities prima facie help survival. The more fully specified models that include interaction terms with the timing of entry, however, indicate that technological capabilities help *only when* a firm creates or adapts to changes in the industry and enters—either late or early—new market segments. To aid interpretation of the results from an analysis in which the dependent variable models a probabilistic outcome, Hoetker (2007) recommends the use of graphical analysis and computation of marginal effects for (nonmean) values of the independent variables. In Figure 4, we graph the probability of survival at mean levels and one standard deviation above and below mean levels of technological capabilities for firms that pioneer and respond to markets. For technological capabilities that are at or one standard deviation above mean levels, increasing levels of market pioneering positively affects survival; firms that have a combination of being on a 0.64 or higher level on technological capabilities have a 99% survival rate if they have pioneered in half of the opportunities presented to them. However, at technological capabilities that are one standard deviation below mean levels, market pioneering has a detrimental effect, even relative to firms that subsequently choose not to enter the new market. This is not the case for firms that respond to

Figure 4 **Estimated Probability of Survival for Pioneering and Responding to Markets**

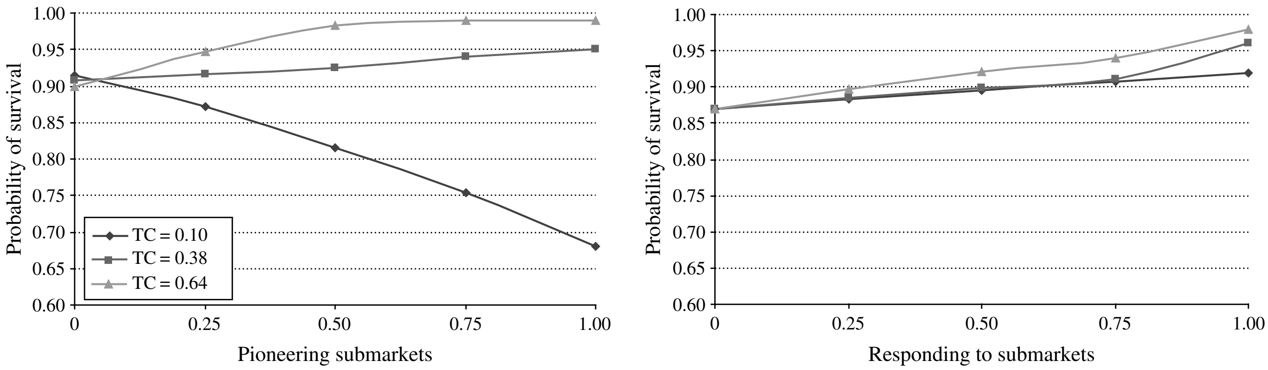
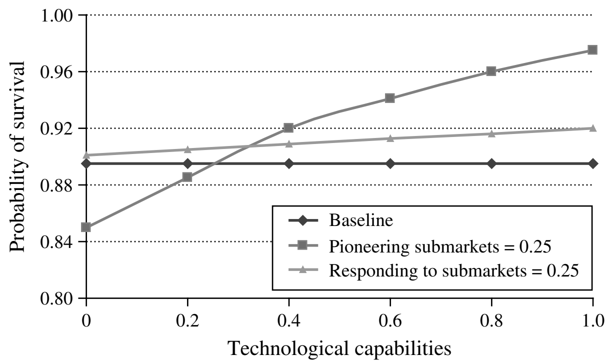


Figure 5 **Probability of Survival for Technological Capabilities**



markets; regardless of the level of technological capabilities, responding to markets has a positive effect on survival, and higher levels of technological capabilities enhance this relationship.

Similarly, Figure 5 presents the marginal effects at varying levels of technological capabilities for the three types of firms: the baseline represents firms that never transition to another market, and the other two lines represent firms that took at least one of four potential opportunities to either pioneer or respond to new markets. Absent entry into newer markets, firms do not find superior technological capabilities beneficial. When technological capabilities are low, firms that pioneer at least once have a lower probability of survival than both the baseline group and firms that respond; however, the pioneers enjoy significantly higher levels of survival when their technological capabilities are higher. Market responders have a consistently higher probability of survival than the baseline group, and this probability increases with technological capabilities.

Limitations

The limitations of our study present avenues for future research. First, future research could investigate the generalizability of our findings in other industries where the nature of the innovations may have been less disruptive. Second, our empirical context did not permit us to examine whether firms can exhibit foresight and avoid cannibalization by leapfrogging or skipping market segments (de Figueiredo and Silverman 2007). Future research could examine whether such strategies enhance the performance benefits of market pioneering when defined on a discontinuous rather than continuous scale. Also, it would be useful to examine potential industry level contingencies that could help explain why firms engage in skipping behavior in some industries (e.g., the laser printer industry, as in de Figueiredo and Silverman 2007), but not in others (e.g., the disk drive industry). It may be that the laser printer industry, unlike disk drives, provided firms with a segmented context wherein new markets did not displace older ones over time, so that cannibalization concerns outweighed concerns related to obsolescence. Third, our paper focused on only technological capabilities as a complementary asset. Future work that examines how other capabilities interact with market-pioneering or market-responding capabilities will help unravel additional contingency conditions. A fourth potentially fruitful avenue relates to whether initial entry into the industry conditions heterogeneity in firm behavior related to new product generations, and whether some kind of imprinting effect may be at work that relates initial timing conditions to subsequent strategic moves. Finally, as do King and Tucci (2002), we study the relative value of entry into new markets. However, we do not look at the value of proactive exit from obsolescing markets. Helfat and Eisenhardt (2004) highlight the importance of intertemporal economies of scope and redeployment of resources from one market to another. It would be interesting to simultaneously study the performance implications of early exit from older markets, early entry into new markets, and straddling in multiple markets.

Conclusions

Our paper contributes to several literature streams. For the first-mover advantage/timing of entry literature, we draw attention to how existing notions of legacy-based FMA are inconsistent with evolutionary doctrines wherein technological innovations "creatively destroy" industries from within by creating new segments of customers and applications and leveling the playing field. We thus propose a dynamic view of market-pioneering capabilities. We address the "micro" gap in existing studies by incorporating technological leadership into our model of market pioneering. Our findings indicate that the relationship between market-creating/-responding and technology capabilities is more complex than envisaged. While we do find evidence that they are cospecialized, our results also show the hazards of developing market-pioneering capabilities without a concomitant investment in technological capabilities. Absent investment in maintaining a superior technological position in the industry, market pioneering may actually be harmful. Our paper also complements Suarez and Lanzolla (2007), who argue to include environmental dynamics in FMA studies, and in doing so have possibly triggered the next generation of research on entry timing. Our work is a beginning in this direction as we empirically demonstrate that a firm's ability to create or respond to generational shifts may create advantages if accompanied by a "microlevel" capability on the technological domain. Our findings indicate that in industries with a high pace of change in technological and demand conditions, even reconceptualizations of FMA to sustained pioneering efforts are not sufficient for creating an advantage; firms need to simultaneously develop along *both* market (demand side) and technological (supply side) dimensions to gain benefits in performance.

Our results also relate to the perceived trade-off in the new-product development literature between entry timing and technological performance (Griffin and Hauser 1996, Lilien and Yoon 1990). This literature focuses on the need for balance between minimizing time to market and maximizing technological performance (Cohen et al. 1996, Bayus 1997, Hatch and Macher 2002), resulting in the following question: Should a firm launch early to generate first-mover advantages or wait to make a "better" product, and therefore delay entry? Instead of a static interpretation, however, we show that rather than focusing on time-of-launch trade-offs, firms should consider the joint evolution of both timing of entry and technological capabilities, because the temporary advantages of early entry can quickly be overturned if the firm becomes a technological laggard.

Finally, our work adds to emerging dialog on strategic renewal (Agarwal and Helfat 2009). It has become apparent that firms need to invest in sustained regeneration to guard against obsolescence during environmental shifts (Huff et al. 1992, Burgelman 1991, Floyd and Lane 2000). Although no one questions the importance of strategic renewal, researchers have long debated its inherent conflicts and difficulties. Scholars have advanced the importance of organizational ambidexterity—a firm's ability to be efficient in today's markets even while conducting entrepreneurial activities that may require cannibalizing current operations—and have proposed structural (Tushman et al. 1997) and cultural (Gibson and Birkinshaw 2004) solutions. Our research focuses on *capability-based ambidexterity* that arises from an organization's portfolio of strategic capabilities, and thus contributes to an area where our understanding is limited, namely, strategic entrepreneurship in high-velocity environments (Hitt et al. 2001).

In conclusion, our paper highlights the need to consider two primal, complementary principles of value creation and appropriation together. When accompanied by poor technological capabilities, early entry into new markets hurts firms compared to firms that enter late, or firms that do not enter at all. Pioneering therefore does not appear to be a virtue for poor technological performers. However, firms that are both fast and technologically good experience the best results. For higher levels of technological capabilities, we find not only that pioneering increases a firm's likelihood of survival compared to responding, but that the benefits of pioneering for survival increase disproportionately with increases in technological capabilities. In other words, speed helps only for those who are smart. Bereft of smartness, speed can kill.

Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

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