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THE PERFORMANCE OF INCUMBENT FIRMS IN THE FACE OF RADICAL TECHNOLOGICAL INNOVATION

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A persistent theme in the academic literature on technological innovation is that incumbent enterprises have great difficulty crossing the abyss created by a radical technological innovation and, thus, go into decline, while new entrants rise to market dominance by exploiting the new technology. However, this tendency is not universal. There are outliers in any population, and much can be learned from examining this group. Here we identify a number of factors that help to explain incumbent performance in markets shaken by a radical technological innovation.

A persistent theme in the literature on innovation is that incumbent enterprises have great difficulty crossing the abyss created by a radical technological innovation that revolutionizes competition in their industry. Scholars depict incumbents as going into decline, while new entrants exploit the new technology and rise to market dominance. As an empirical phenomenon, the declining performance of incumbent enterprises in the face of radical technological innovation has been observed repeatedly over the years, in numerous studies (e.g., Abernathy & Utterback, 1978; Christensen, 1997; Cooper & Schendel, 1976; Foster, 1986; Henderson & Clark, 1990; Rosenbloom & Christensen, 1998; Sull, Tedlow, & Rosenbloom, 1997; Tripsas & Gavetti, 2000; Tushman & Anderson, 1986; Utterback, 1994). Scholars often attribute this decline to incumbents' failure to embrace the new technology. The reasons given to explain such failure include the differential economic incentives new entrants and incumbents confront, forces of inertia within incumbent firms, and the embeddedness of incumbents within an established industry network that does not initially value the new technology. For convenience, we refer to this exposition of the process of innovation as the *standard model*.

While we accept the view that the relative economic performance of incumbent organizations often declines when markets are revolutionized by radical technological innovations, we do not believe that this tendency is universal or necessarily terminal. There are outliers in any population, and much can be learned from examining this group. When confronted by a significant market dislocation triggered by radical technological innovation, some incumbent organizations can and do adapt, survive, and regain historic performance levels. Rosenbloom (2000), for example, outlines in great detail how NCR, a dominant enterprise in the era of mechanical cash registers, was able to adapt and ultimately prosper after the arrival of electronics and then digital computing. As Rosenbloom points out, the experience of NCR stands in stark contrast to that of other players in the business equipment market. For example, Smith Corona, one of the dominant firms in the typewriter industry, failed to adapt to the arrival of the personal computer and word processing software and went bankrupt.

Pointing to such cases, several authors have argued that the counterexamples to the standard model are too numerous to be ignored (Ahuja & Lampert, 2001; Leifer et al., 2000; Methe, Swaminathan, Mitchell, & Toyama, 1997; Rosenbloom & Christensen, 1998; Rothaermel, 2001). Incumbent enterprises can and do survive mar-

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ket breaks triggered by the arrival of radical technological innovations. Some even pioneer radical technological innovations. In practice, there is significant variation in the relative performance of incumbent enterprises following a technological discontinuity. Against this background, the central question that motivates this paper is *What factors moderate the predicted decline in the relative economic performance of incumbent enterprises following the arrival of a radical innovation in technology?*

To answer this question, we begin by taking a closer look at the nature of technological innovation and its impact upon an industry. We then review the factors that inhibit the ability of incumbents to adapt to the changes unleashed by a radical new technology. We build on this analysis to identify the characteristics of an incumbent enterprise that enable it to successfully embrace and use a radical technological innovation.

RADICAL TECHNOLOGICAL INNOVATION

Definitional Issues

It is important to be clear about the definition of a *radical technological innovation*. Since the focus of our analysis is on incumbent firms in an established industry, a radical technological innovation can only be defined by referring to the technology used by incumbents *prior* to the appearance of this radical innovation. The term *technology* refers to the scientific methods and materials used to achieve a commercial or industrial objective (from the *American Heritage Dictionary* [4th ed.]). An *incremental* technological innovation builds squarely upon the *established* knowledge base used by incumbent firms, and it steadily improves the methods or materials used to achieve the firms' objective of profitably satisfying customer needs. In contrast, a *radical* technological innovation involves methods and materials that are novel to incumbents. These novel methods and materials are derived from either an entirely different knowledge base or from the recombination of parts of the incumbents' established knowledge base with a new stream of knowledge (Freeman & Soete, 1997). To incorporate novel knowledge into their activities, incumbent firms must have absorptive capacity and must be able to develop new capabilities (Cohen & Levinthal, 1990).

Two brief examples might clarify this concept. First, the arrival of electric lighting represented a radical innovation in lighting technology because it stemmed from a knowledge base—electricity—that was novel to the incumbent gas utility firms that dominated the lighting industry. Second, the advent of the ultrasound constituted a radical innovation in medical imaging technology. It stemmed from a knowledge base—dynamic continuous imaging based on an understanding of the physics of sound waves—that was novel to incumbent firms in the medical imaging industry, whose prior experience was with static imaging using X-rays. In these cases the radical technological innovation required a quantifiably different knowledge base, from which methods and materials were developed to satisfy the needs of consumers served by incumbents.

It is important to emphasize that while radical innovations in technology can be identified by referring to the knowledge base employed by incumbents, what *cannot* be identified ex ante with certainty is whether and when a radical technological innovation will become a commercial success. Many seemingly promising innovations fail the test of market acceptance. It is not uncommon for a swarm of competing new technologies to vie with each other as potential replacements for an established technology, with only one or two ultimately rising to the fore (Foster, 1986; Freemen & Soete, 1997; Rogers, 1995). Ex ante, there is substantial *uncertainty* as to the commercial potential of a radical technological innovation. Our focus, however, is not on what determines the success or failure of a particular radical innovation (Markus, 1987) but on the factors that moderate the predicted decline in the relative economic performance of an incumbent firm when its industry is revolutionized by a *successful* radical technological innovation.

It is also important to be clear about the distinction between invention and innovation. *Invention* refers to the discovery of new methods or materials—that is, to the discovery of new knowledge. *Innovation* refers to attempts to commercialize an invention (Freeman & Soete, 1997).

Finally, we should clarify our definition of a decline in relative economic performance. What we mean is that the profitability of an incumbent firm will fall relative to its own historic performance and to previous industry norms.

The Process of Creative Destruction

The standard model suggests that incumbent enterprises do not normally commercialize radical technological innovations. Rather, new entrants most frequently pioneer radical innovations (Cooper & Schendel, 1976; Dosi, 1988; Foster, 1986; Freeman & Soete, 1997; Henderson & Clark, 1990; Sull et al., 1997; Tripsas & Gavetti, 2000; Tushman & Anderson, 1986; Utterback, 1994). There are, of course, exceptions to this depiction: for example, IBM, an incumbent in the era of mechanical business equipment, pioneered electronic business equipment (computers). However, even when this is the case, other incumbents must respond to this challenge. Thus, our research question remains valid: what factors moderate the predicted decline in the relative economic performance of incumbent enterprises following the arrival of a radical innovation in technology?

If a radical technological innovation is successful in the marketplace, it frequently constitutes a discontinuity that dramatically alters the established demand and supply conditions. Incumbents see demand decline for their existing product lines as consumers switch their purchases to products based on the new technology—a phenomenon captured in Schumpeter's evocative phrase *creative destruction*. According to Schumpeter, in the long run, "the process of Creative Destruction is the essential fact about capitalism. . . . it is not [price] competition which counts but the competition from . . . *new technology* . . . competition which strikes not at the margins of profits of existing firms but at their foundations and their very lives" (1942: 83–84; emphasis added). Thus, radical technological innovations create new market opportunities while simultaneously damaging, destroying, or transforming demand in many existing product markets.

The standard model suggests that incumbents have the most at risk during this process. This model depicts incumbents as being slow to recognize the threat posed by new technology and new entrants, as well as muted in their response to this threat (Christensen, 1997; Foster, 1986; Utterback, 1994). As a consequence, new entrants are predicted to rise to dominance in an industry following the discontinuity triggered by a radical technological innovation, whereas the relative performance of incumbents is predicted to decline.

Incumbent Inflexibility

Why do incumbents often fail to pioneer radical innovations, and why do they apparently find it difficult to respond to the innovations of new entrants? Several explanations have been offered in the literature. We can characterize these explanations as being rooted in economics, organization theory, and strategy. These explanations complement each other and help to illuminate the phenomenon of incumbent inflexibility.

Economic explanations. Economists have emphasized the different incentives incumbents and new entrants face (Henderson, 1993). Economic models are based on the assumption that incumbent firms enjoy market power and monopoly rents owing to entry barriers. These models suggest that incumbent enterprises have an incentive to invest in *incremental* innovations that add to their established knowledge base, maintain entry barriers, and protect or enhance their existing rent stream (Gilbert & Newbery, 1982; Reinganum, 1983). Moreover, extensions of these models suggest that, under conditions of uncertainty, incumbent enterprises already enjoying a degree of market power will rationally invest *less* in producing radical innovations than new entrants, for fear of cannibalizing the stream of rents from their existing products (Gilbert, Newbery, & Reinganum, 1984; Reinganum, 1983).

Conditions of uncertainty are the norm when it comes to pioneering radical innovations. Incumbent enterprises seek to maximize the returns from known technology, rather than devote resources to pioneering new technology with an uncertain payoff. Hence, they preferentially channel funds into R&D activities that support incremental additions to their existing knowledge base and produce a fairly predictable stream of rents. Moreover, the economic models suggest that incumbents have a disincentive to invest in technological innovations that, if successfully commercialized, might create disequilibrium conditions that erode any market power the incumbents enjoy (Henderson, 1993; Reinganum, 1983). The problem is akin to opening Pandora's box: once the box of new technology has been opened, even by an incumbent, the technology may trigger changes that alter the structure of the industry and lead to the demise of the incumbent.

Conditions are reversed for new entrants, because incentives are skewed toward undertaking investments that enable them to circumvent barriers to entry in an industry and to gain share from incumbent firms, thereby upsetting the status quo. Indeed, given entry barriers and the advantages enjoyed by incumbents, the only way new entrants can compete against established players is by doing something different. New entrants are unlikely to be able to circumvent the entry barriers that protect incumbents by pursuing incremental innovations, particularly given the capital resources that incumbents can devote to such innovations. Pioneering a technological innovation is the essence of doing something different: inventing one's way around barriers to entry is a classic strategy by which new firms enter established markets (Barnett & Crandall, 1986).

This insight was explicit in the earlier work of Schumpeter (1934), who stressed that small entrepreneurial firms were likely to be the sources of innovation. However, he later claimed that large established firms with some degree of monopoly power were likely to be the drivers behind innovation (Schumpeter, 1942). The economic models help resolve the apparent contradiction in Schumpeter's work. They suggest that differential incentives will lead incumbents to drive forward with incremental innovations, whereas entrepreneurial new entrants will pioneer radical innovations.

Organization theory explanations. Organization theorists and sociologists tend to emphasize the role that inertia plays in constraining incumbents' actions. Following Hannan and Freeman (1984), population ecologists have argued that organizations are valued for their predictability and reliability and, hence, that they tend to foster information systems and processes that enhance these attributes. The flip side of this equation is that these systems require formalization and bureaucracy—attributes that tend to inhibit change and result in inertia. Thus, paradoxically, the systems that help ensure organizational survival in stable environments contribute to inertia and organizational decline when the company is confronted with rapid change.

Moreover, Hannan and Freeman (1984) predict that proactive attempts at organizational change disturb the systems that produce predictability and reliability and increase the risk of organizational failure. This prediction has been borne out in several studies, which suggest that, in the short run at least, the hazard rate of organizational failure rises as organizations attempt to alter their systems and processes to confront a changed environment (Amburgey, Kelly, & Barnett, 1993; Barnett, 1994; Ruef, 1997). Thus, the predictions and findings of the population ecology literature are consistent with the predictions of the standard innovation model.

Others have noted that organizations based in stable environments develop highly structured routines for reducing the costs of information acquisition and utilization and for coping with bounded rationality (Arrow, 1974; Cyert & March, 1963; Nelson & Winter, 1982; Simon, 1955). These routines, which have a high economic value in a stable environment, imply that the organization engages in limited search and selective knowledge acquisition activities (Levitt & March, 1988). The drawback of such routines is that they imply that the organization does not search outside its standard frame of reference and, thus, may fail to notice, analyze, and respond with alacrity to the competitive threat posed by new entrants pioneering radical technological innovations.

Miller (1990, 1993) has pushed this insight further, arguing that organizations tend to simplify their routines around the functions or competencies underlying their original success, while neglecting most others. Miller contends that while such architectural simplicity may make sense in a stable environment, the dominance of the organization by a single function can trigger decline, if the environment changes in ways counter to the world view of that function. A similar theme is echoed in the work of Leonard-Barton (1992), who documents how the core competencies of a firm can become core rigidities that limit its ability to adapt to a changed environment.

Cohen and Levinthal (1990) suggest that a lack of *appropriate* absorptive capacity may help explain the inability of incumbents to respond to the discontinuity created by a radical technological innovation. Absorptive capacity refers to an organization's ability to "recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990: 128). Drawing from learning theory, Cohen and Levinthal argue that an organization needs *prior related* knowledge to better identify, assimilate, and use new knowledge. Herein lies the rub, for a radical technology is, by definition, based on a knowledge stream that is new to incumbent firms. Even if incumbents have excellent absorptive capacity capabilities regarding their established knowledge domain, they may lack the prior knowledge required to recognize the value of new knowledge that falls outside of their expertise, to assimilate it, and to apply it to commercial ends.

Further, Cohen and Levinthal (1990) suggest that there is an increasing returns aspect to knowledge accumulation, with those that gain an early lead able to build on that knowledge advantage, whereas those that fail to invest in knowledge acquisition risk being locked out (Schilling, 1998). The notion of absorptive capacity suggests that incumbents may find it difficult to catch up once they have fallen behind in the race to accumulate the knowledge underlying a radical innovation.

Yet another thread in the organization theory literature stresses the importance of power and politics as impediments to organizational change (Cyert & March, 1963; Pfeffer, 1992). The exercise of power and politics, particularly regarding the control of scarce resources, is held to be endemic within organizations (Pfeffer & Salanick, 1978). An organization can be viewed as a coalition of various interest groups that must cooperate for the organization to succeed but that must also compete with each other for control over scarce resources. In times of stability, the organization settles into what might be termed a *truce* (Cyert & March, 1963). Embedded in that truce is a distribution of power and influence. Organizational change, by necessity, involves a redistribution of power and influence. This breaks the truce and triggers political behavior within organizations as actors try to maintain their power and influence. Absent strong leadership, such turf battles can slow down, dilute, or halt any attempts to achieve a meaningful transformation of an organization (Pfeffer, 1992). The result is relative organizational inertia and organizational decline.

A final source of inertia may be macrocultural homogeneity in an industry—specifically, shared beliefs about customers, technologies, and the best way to compete in an industry (Abrahamson & Fombrun, 1994). Some scholars have argued that institutional pressures and constraints tend to produce macrocultural homogeneity within an industry (DiMaggio & Powell, 1983). Others suggest that mass media, the educational sector, and management consulting organizations may engineer the homogenization of beliefs (Abrahamson, 1991). Whatever the causes, there may be merit to the argument that beliefs widely shared by managers across organizations can contribute to industry-wide inertia. Such interorganizational phenomena would help to explain the collective sloth exhibited by U.S. automobile firms in their response to Japanese competitors in the 1970s and 1980s (Womack, Jones, & Roos, 1990), or the failure of the entire U.S. steel industry to respond to new entrants using minimill technology (Barnett & Crandall, 1986).

Strategy explanations. A third group of explanations for incumbent inflexibility in the face of radical technological innovations might be described as strategy explanations. These explanations focus on the fact that every firm is embedded within a value network of suppliers, customers, investors, complementary product providers, communities, and so on, to which the firm has made strategic commitments (Christensen, 1997; Ghemawat, 1991; Rosenbloom & Christensen, 1998; Sull et al., 1997). Incumbents pay attention to this network for a good reason, since the historic success of incumbents has been based upon satisfying the demands of and cooperating with various constituents of the network. However, when faced with a disequilibrating event, such as the appearance of a radical technological innovation, this network may produce fatal inflexibility.

Christensen (1997), for example, has explained incumbent failure in the face of new technologies by linking resource dependence theory (Pfeffer & Salancik, 1978) to a firm's internal resource allocation processes (Bower, 1970). Based on resource dependence theory, a firm's strategies are constrained by external forces that provide critical resources to the firm, such as customers, suppliers, and investors. These external constraints explain why a firm focuses on satisfying its established customers in existing markets. This tendency is reinforced by the firm's internal resource allocation processes, which are designed to optimize the profitability of the firm's current operations. Christensen goes on to argue that firms are embedded in value networks and that these networks, in turn, hamstring incumbent flexibility in the face of new technologies that might potentially replace existing ones. He labels these *disruptive technologies* and argues that incumbent firms generally ignore them, because they provide inferior performance initially and, thus, only serve small fringe markets with different customers. However, these kinds of technologies generally have the tendency to progress faster than the performance improvements demanded by mainstream customers; as a consequence, they eventually invade the incumbents' markets. Moreover, the incumbents are then unable to respond effectively to such stealth innovations, since they are facing the inertia created by the value network built around the old technology.

Related to this phenomenon is Ghemawat's (1991) insight that irreversible strategic commitments made at a given point in time may limit the flexibility of incumbent enterprises and, hence, constrain their ability to respond to subsequent changes in the operating environment. Incumbents have commitments to established customers, suppliers, communities, and so forth. These commitments cannot be broken easily, and they tend to require substantial resources to service them, leaving less for investment in radical technologies.

The Attackers' Advantage

The inertia assumption embedded in the standard model is one of relative rather than absolute inertia. Scholars do not argue that incumbents are incapable of recognizing the threat posed by a radical innovation but that their recognition is slow and that any change is difficult to execute. Market demand shifts more rapidly than incumbent strategy, and the incumbents go into decline (Hannan & Freeman, 1984).

Added to this is the observation that the instruments of market change—the new entrants—have many advantages (Foster, 1986). New entrants do not have to battle internal forces of inertia; they do not have long-standing commitments to established value networks; and they can focus on small, out-of-the-way market niches and grow with those niches, migrating up-market as their technology matures and its performance attributes improve (Christensen, 1997). New entrants also have the economic incentive to make investments in unproven technologies that have a high-risk, high-return profile. The empirical fact is that the majority of new entrants fail, but new technologies often induce significant entry, and it only takes a handful of the "experiments" to be successful for a discontinuity to usher in the decline of long-standing incumbents (Utterback, 1994).

INCUMBENT PERFORMANCE

Although the standard model has significant explanatory power, it does not tell the entire story. Some incumbents survive, some prosper, and some pioneer radical new technologies and dominate the postdiscontinuity marketplace (Ahuja & Lampert, 2001; Methe et al., 1997; Rosenbloom & Christensen, 1998; Rothaermel, 2001). While the average performance of incumbent enterprises does decline following the arrival of a radical innovation in technology, there is considerable variation in the speed and size of this decline, even within a given industry.

Our theory development (Bacharach, 1989) is motivated by the question of *why* some incumbents survive and prosper following radical technological changes, whereas the majority of them do seem to go into economic decline. In this effort we develop a set of falsifiable propositions that predict incumbent performance following a market discontinuity triggered by radical technological innovation. Thus, we identify several factors that moderate the predicted decline in the relative economic performance of incumbent enterprises following the introduction of a radical technological innovation.

Our starting point is the umbrella proposition that, to be relevant, *these factors must neutralize or diminish the power of one or more of the various sources of incumbent inflexibility that we discussed above.* They must create incentives for incumbents to invest in technologies with radical potential and to accumulate the associated absorptive capacity. They must overcome internal forces of inertia based on routine systems that produce predictability and reliability. They must counteract the tendency to engage in limited search. They must neutralize political opposition to change in an organization. Finally, they must counteract the tendency for organizations to overvalue the feedback from their existing customers, to ignore small, out-of-the-way market niches, and to let existing strategic commitments drive attempts at pioneering new technology to the margins of the organization.

Economic Factors: Opening Pandora's Box

How can an incumbent firm deal with the economic incentive to underinvest in novel technologies, the successful commercialization of which may create disequilibrium conditions where established revenue streams are cannibalized? The answer addresses two issues: (1) the need to avoid technological lockout by building strategically relevant absorptive capacity (Cohen & Levinthal, 1990) and (2) the need to view technology investments from a real options perspective (Dixit & Pindyck, 1994).

One problem incumbents face is the identification problem: how can they identify ex ante an emerging technology that might ultimately become the basis for a radical technological innovation? There is no easy solution to this problem, because not all emerging technologies survive, and accurate ex ante identification of a successor technology is impossible for anyone who does not have access to a time machine. As noted earlier, it is not uncommon to see several emerging technologies competing to replace an incumbent technology (Foster, 1986).

Today, for example, the ability to shrink the width of lines on silicon semiconductor chips is fast approaching the fundamental limits imposed by quantum physics. Unless a successor technology is found, these limits will bring three decades of improvements in the price/performance ratio of computing power to a halt. Several radical new technologies are emerging as potential replacements for silicon-based computing, including computing paradigms based on molecular switches, DNA, quantum computing, and three-dimensional microprocessor architecture (Kurzweil, 1999). If history were a guide, we would predict that few, if any, of these technologies would emerge as a replacement. Given such inherent uncertainty, how should an incumbent proceed?

The first thing to recognize is that an incumbent needs to make investments in accumulating *basic* know-how related to emerging technologies. If the incumbent fails to do this, it may lack the absorptive capacity required to assimilate whichever of the technologies subsequently comes to the fore (Cohen & Levinthal, 1990). Indeed, an incumbent that fails to support basic research may lack the ability to identify emerging technologies in the first place, since its search routines may be too constrained (Levitt & March, 1988). Moreover, Cohen and Levinthal's arguments suggest that it is not enough for an incumbent to underwrite basic research in academic institutions, as many do. The incumbent must also undertake some basic research itself so that it acquires the knowledge required to identify, appraise, and value the research being produced by academics.

There are two kinds of technological research and two kinds of absorptive capacity: (1) that based on invention, which is devoted to discovering new technologies, and (2) that based on innovation, which is devoted to the commercialization of a technology. To increase its probability of survival, an incumbent must invest in both. The reality, however, is that many firms invest in applied research aimed at commercialization but not in basic research aimed at the discovery of knowledge and invention (Mowery, 1998). We submit that the probability of incumbent survival is greater if the firm undertakes basic research aimed at the discovery of knowledge, in addition to applied research.

However, it is important to recognize that simply investing in basic research is not a solution to the problem. Basic R&D spending will not lead to adaptability in the face of a technological discontinuity unless the *basic* research function of the firm is *coupled* with *applied* research and product development efforts (Buderi, 2000). In large incumbent organizations the problem is exacerbated when basic research is undertaken at central research labs while applied research (i.e., product development) is undertaken within business units, as is often the case. While investments in basic research can increase the absorptive capacity of the firm, the effects may not translate into commercial technology, unless the business units can shape the direction of basic research. For this to happen, the firm needs to couple basic and applied research or integrate them horizontally.

There are a number of *mechanisms* for achieving coupling between basic and applied research. These mechanisms are designed to increase horizontal information flows and influence resource allocation. For example, representatives of business units might sit on the resource allocation committee of the central research unit, or the firm may place a certain percentage of basic research funding in the hands of business units, which can elect to fund basic research efforts on a sliding scale, depending on their perception of the commercial relevance of the new technology (Buderi, 2000). Whatever the precise mechanism, the theoretical principle remains the same: there must be a coupling (horizontal integration) between basic and applied research functions to share information and influence resource allocation.

At the same time, a careful balance has to be struck. It is possible that established business units will not recognize the radical potential of nascent technologies and will underinvest in them in favor of technologies that are incremental as opposed to radical. Some business units' control over the allocation of basic R&D resources will increase the commercial focus of central research labs and improve the rate at which basic research advances are converted into commercial products. But too much control will stifle the ability of central R&D to undertake the kind of exploration of nascent technology that is required to accumulate the absorptive capacity necessary to increase the adaptive ability of an incumbent firm.

It follows that *loose coupling* (Weick, 1976), as opposed to *tight coupling*, seems to be optimal. Loose coupling implies the development of mechanisms for coordination and integration between business units, as well as central research allowing research personnel some freedom in their choice of research initiative to pursue, but not complete freedom. Indeed, we postulate an inverted U-shaped relationship between the tightness of coupling and the postdiscontinuity performance of an incumbent firm. If coupling is too loose, central research personnel may ignore commercial considerations in their resource allocation decisions. If coupling is too tight, there may be too little explorative research by central research units.

Proposition 1a: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the firm's basic research function is loosely coupled with applied research functions.

Proposition 1b: There will be an inverted U-shaped relationship between the extent of coupling and the postdiscontinuity performance of an incumbent firm.

Basic research can help an organization broaden its search activities, counteracting, to some degree, the phenomenon of limited search (Levitt & March, 1988), but it does not guarantee that the organization will undertake the investments necessary to develop a potentially radical technology. The economic models on incentives suggest that the net present value (NPV) of making incremental investments in an established technology generally will be greater than the NPV of investing in a radical technology. This is because of the higher discount rate applied to a radical technology, reflecting its greater uncertainty. The traditional NPV approach, however, may be misleading when these investments hold the promise of significant economic returns in the event they do succeed (Dixit & Pindyck, 1994).

Over the last decade, academics have developed real options theory to guide investment decisions under uncertainty (Dixit & Pindyck, 1994; McGrath & MacMillan, 2000). In this approach researchers see investing in a technology with a highly uncertain future as taking an option on a technology that may or may not be exercised at some future date, depending on how the arrival of new information changes the assessment of the option value of that technology. An investment is modeled as a sequence of option payments over time in a technology. An objective of each payment is to collect more information, thereby reducing the uncertainty that surrounds the value of a nascent technology. An important message contained in this literature is the idea that the firm should not prematurely close down investment in a radical but unproven technology, primarily because doing so may lead to lockout. It is better to keep options open and to pay (i.e., invest) to collect more information. In this sense, the work on real options dovetails with Cohen and Levinthal's thesis that a failure to invest in a technology may lead to a lack of relevant absorptive capacity and, hence, to lockout.

Although few corporations have historically used a formal real options methodology, some have certainly acted in a way that is consistent with the formulation. They have kept their options open by investing in basic research designed to support or disprove the working hypothesis about the potential of nascent technologies. Thus, it is important to realize that real options methods represent the formalization of an informal decision-making paradigm that effective managers long have adhered to. These managers have eschewed simplistic financial analysis based on NPV techniques when evaluating investments in nascent technology, choosing instead to keep their options open. Although this does not imply that these managers ultimately will pursue risky investments in a potentially disruptive technology, particularly given other inertial forces at work in the organization, such a decision-making paradigm does suggest that such investments will not suffer a premature death.

> *Proposition 2: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the decision-making paradigm that managers use when evaluating investments in technology is consistent with a real options perspective.*

Organizational Factors: Counteracting Inertia

The pursuit of basic research can dovetail with a real options perspective to help a company make the investments needed to build absorptive capacity in a radical technology and to avoid lockout. However, such approaches do not guarantee that the company will subsequently *act upon* these investments. Organizational inertia constitutes a powerful explanation of why incumbents fail to commercialize radical technology, even when they themselves develop that technology. How, then, can a company attenuate forces of inertia—forces that theorists suggest are endemic within established companies?

We propose that what is required is a set of cultural norms, systems, and procedures that (1) legitimize and institutionalize autonomous action within organizations and (2) structurally isolate units charged with the *commercialization* of radical technology. By *autonomous action* we mean the tendency for individuals deep within an organization to take actions on their own initiative, even if those actions are inconsistent with the stated strategy of the organization as articulated by top management. Work by Burgelman (1983, 1991, 1994) and Mintzberg and McHugh (1985) suggests that senior managers do not have a monopoly on identifying strategic initiatives, including those initiatives based on radical new technology. Successful strategies frequently begin as initiatives that are championed by midlevel managers, and these initiatives may directly conflict with the prevailing goals of the organization. In Mintzberg and McHugh's language, they emerge from the grassroots of an organization in the absence of prior strategic planning.

Autonomous action can be *legitimized* through the culture of the organization. Burgelman (1994) outlines how an important element of Intel's culture was a tradition of encouraging open debate about the merits of different strategic initiatives. Burgelman cites former CEO, Andy Grove, who stated that there was an informal norm that knowledge should not be overwhelmed by hierarchical positioning. No one was ever told to "shut up." It was culturally acceptable for midlevel employees to question the validity of the stated strategy of the organization. These permissive values and norms stand in stark contrast to Kotter and Heskett's (1992) characterization of the culture of General Motors as an environment where people who showed too much initiative were not promoted. Whether an organization ends up legitimizing autonomous action, as at Intel, or inhibiting it, as at General Motors, may be a path-dependent product of the history of the organization, including the core values of the founders and early events in the firm's history (Schein, 1992).

Autonomous action may be particularly important for the survival of incumbent enterprises facing a radical technological innovation. Top managers typically rise to dominance by successfully executing the *established* strategy of the firm. As such, they may have an emotional commitment to the status quo and often are unable to see things from a different perspective (Burgelman, 1994; Miller, 1990). In this sense they are a conservative force that promotes inertia (Miller, 1990). Middle managers, however, are less likely to have the same commitment to the status quo and have more to gain from promoting new technologies and strategies within the firm, as long as the culture allows for such behavior. Moreover, middle managers often sound the alarm about the opportunities and threats posed by radical new technologies, "because they spend time outdoors where the storm clouds of creative destruction gather force and—unaffected by company beliefs, dogmas, and rhetoric—start blowing into their faces" (Burgelman & Grove, 1996: 11). Nevertheless, for such behavior to have a tangible impact on the firm, it must not only be *legitimized* but also *institutionalized*.

The legitimization of autonomous action implies that the organization operates with values and norms that permit the questioning of established strategies and encourage midlevel managers to exercise their strategic voices. Institutionalization requires that the organization put systems and procedures in place (March & Simon, 1958) that translate those voices into action and investments. Specifically, the institutionalization of autonomous action requires the establishment of internal processes that enable the voices of autonomous actors to shape resource allocation within the firm (Bower, 1970; Burgelman, 1994).

Burgelman (1994) stresses the role that the internal ecology of the organization plays in institutionalizing autonomous action. He uses the term *internal ecology* to refer to the internal processes that allocate scarce resources among competing claims. An important issue here is the extent to which such processes can be depoliticized and made competitive so that the exercise of organizational politics and power aimed at preserving the established organizational truce do not conspire to hamstring attempts to allocate resources to nontraditional areas.

The principle that midlevel managers should have input into resource allocation processes seems to be a sound one, particularly given the earlier observation that middle managers are more likely to sound the alarm than top managers. It follows that formal systems and procedures allowing midlevel managers to influence the allocation of corporate resources may increase the probability that an incumbent firm will undertake investments in radical technology, even if doing so runs counter to the emotional commitments of top managers and the stated strategy of the organization.

Generally, an organization can deal with the legitimization issue by setting aside funds for investments in new product or business ideas, putting processes in place that give midlevel managers the opportunity to put such ideas forward, and including midlevel managers in the process of evaluating these initiatives (i.e., peer review). When coupled with an organizational culture that fosters autonomous action, the result should be an increased probability that the firm will identify, incorporate, and act upon the appearance of a radical technological innovation.

> *Proposition 3: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the values and norms of the firm legitimize autonomous action.*

> *Proposition 4: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if autonomous action is institutionalized through internal systems and procedures specifically designed to encourage and fund the initiation as well as provide regular evaluation of new products and services.*

We have mentioned how founder effects and early events in the history of an enterprise help shape a firm's attitudes and processes toward autonomous action. This is consistent with the proposal, often articulated by strategy researchers, that the current state of the firm's capabilities is the path-dependent product of its cumulative history up to this point (Teece, Pisano, & Shuen, 1997). Environmental influences probably also play an important role. Autonomous action is more likely to be legitimized and institutionalized in organizations based in industries that have a history of turbulence. In such industries the ability to adapt to unpredictable events becomes an important survival and performance capability. It follows that such firms are more able to adapt to future turbulence than firms whose entire history has been spent in more benign and stable environments. In the language of organization theory, firms based in environments with a history of stability likely have developed mechanistic structures that make adaptation to changed circumstances more problematic, whereas firms based in environments with a history of instability likely operate with more organic structures that enable more rapid responses to unpredicted events (Burns & Stalker, 1961).

> *Proposition 5: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the markets the firm serves have a*

history of turbulence that the firm has navigated in the past.

Even if an incumbent firm's autonomous action is legitimized and institutionalized through a combination of culture, systems, and procedures, and reinforced through historical experience, the firm will not necessarily commercialize a radical new technology successfully. Christensen (1997) argues that, even with the best of intentions, initiatives designed to exploit a radical new technology can fail, because commercialization of the technology may require a business model different from that used by the firm. It can prove difficult, if not impossible, to manage two different business models within the same physical organization.

This point has been made most forcibly by Porter (1985), who argues that the simultaneous pursuit of low-cost and differentiation strategies is not possible, precisely because these different strategic postures are based on very different business models that place different demands on the firm and require different kinds of investments, and that must be managed in different ways. Generalizing from this point, one can argue that the simultaneous pursuit of different business models within the same organizational unit will lead to a failure to execute one or perhaps both models.

However, a solution to this problem has existed since the 1920s: the adoption of a multidivisional structure (Chandler, 1962; Christensen, 1997). If they are to survive on their own merits, different technologies that require radically different business models should be placed into functionally self-contained and autonomous units and managed on an arm's length basis by corporate managers. This makes sense, even if the technology is disruptive in the sense implied by Christensen (1997), or potentially so, and may ultimately result in head-to-head competition with the established businesses of the firm.

Some critics might view such intrafirm competition as irrational and wasteful, since it often involves a duplication of resources and product cannibalization. However, the benefits of hedging bets regarding technology can outweigh the costs and can enhance the chances of incumbent survival in the face of a radical technological change. Moreover, an autonomous division is more likely to avoid the traps identified by Christensen (1997). A new autonomous division is less likely to have commitments to an established industry value network and customer set and is more likely to discount feedback from established customers and to focus on and grow with underserved customers, migrating upmarket as the technology matures.

Moreover, an organizational structure with independent, stand-alone divisions charged to commercialize radical new technologies might be endowed with benefits ascribed to loosely coupled systems (Weick, 1976). In light of Weick's (1976: 3) definition of loosely coupled systems, we can view the multidivisional structure as one in which each division is, in some form, responsive to headquarters and the other divisions, but each division also has its own identity and is physically separated from headquarters and the other divisions. The loose coupling of business units thus allows the organization to respond to individual radical technologies, without having them affect the other business units. This implies that if an attempt to commercialize a radical new technology fails, and many will ultimately fail, it will not affect the entire organization.

Loosely coupled business units also allow local adaptation and increased sensitivity to environmental changes. Subsequent new radical technologies might be spotted sooner, which may translate into a head start for the newly spun-off division in commercializing the new technology. Furthermore, the entire organizational structure might display more diversity in its response repertoire to radical technological changes that newly created divisions can draw upon.

Proposition 6: Following market discontinuities triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the firm establishes a loosely coupled, stand-alone division to commercialize the new technology.

Strategic Factors: Breadth of Impact and Gestation Period

Not all radical technologies have the same impact on incumbent firms and industry structure. The arrival of the personal computer revolutionized the structure of the computer industry and led to the demise of many incumbents. Alternatively, it has been almost twenty-five years since Genentech, the first biotechnology firm, went public, and although the technology has given birth to a large number of new firms, the drug business is still dominated by the same pharmaceutical firms that dominated it prior to the biotechnology revolution (Rothaermel, 2001). However, relative to the prior technology used by incumbents, biotechnology arguably represented a more radical technology than the personal computer. The science underlying biotechnology involves skills very different from the science underlying chemical synthesis (molecular biology as opposed to chemistry). In contrast, the science underlying the personal computer relied on the same broad discipline as the science underlying mainframe and midrange computers (electrical engineering).[1]

Why, then, has there been a difference in outcomes? Why has the less radical technology produced more radical effects? Holding other things equal, an answer to this puzzle can be found in the facts that radical technologies differ in (1) their breadth of impact on the value creation activities of incumbents and (2) their gestation periods. These differences influence the postdiscontinuity performance of incumbents.

We outline this argument below. We note at the outset that although these factors can be identified ex post and, thus, used retrospectively to explain the differential performance of incumbents, it is more problematic to identify them ex ante and, thus, move from an explanatory analysis to normative recommendations. Still, we explain that there is some potential for doing this.

Breadth of impact. A retrospective reading of the history of technology indicates that not all radical technological innovations are equivalent in terms of their impact on the various value creation activities of a firm and that differential effects may help explain incumbent survival and performance (Freeman & Soete, 1997; Tripsas, 1997). Radical technologies diminish the value of the accumulated R&D knowledge of an incumbent. Since they also typically require new production processes, the value of established production processes also may be diminished (Clark & Wheelwright, 1993). While radical technologies diminish the *upstream* value chain activities of incumbents, it does not follow, however, that the new technology will simultaneously diminish the value of the *downstream* activities, particularly in marketing, sales, and after-sales service and support (Abernathy & Clark, 1985). If the downstream value chain activities of incumbents retain their value, incumbents may then be in a position to benefit from the radical new technology via interfirm cooperation with new entrants (Rothaermel, 2001; Teece, 1992).

The breadth of impact of a radical technology on the assets of incumbents directly affects the ability of incumbents to strike deals with new entrants—deals that enhance the incumbents' survival and performance prospects. In the biotechnology industry, for instance, it has become commonplace for incumbent pharmaceutical companies to enter into joint venture and licensing arrangements with smaller biotechnology enterprises (Deeds & Hill, 1996). On the one hand, these smaller biotechnology firms have used the alliances to gain access to the incumbents' downstream regulatory, marketing, and sales networks. These downstream assets have retained their economic value, despite the arrival of biotechnology, and it would be very expensive and time consuming for new entrants to build those assets. On the other hand, incumbent pharmaceutical firms have used the alliances to gain access to the scientific research and products of emergent biotechnology firms. Both incumbents and new entrants have benefited from this arrangement, which essentially constitutes the matching of complementary assets (Rothaermel, 2001). This suggests that the new entrants focus on the upstream activities of the value chain, whereas the incumbents focus on the downstream activities.

The critical issue is the impact of the radical technological innovation on the *downstream* value chain activities of incumbents. Downstream complementary assets, which are often nontechnological in nature but necessary to commercialize a new technology, may, in fact, determine who profits from technological innovation (Teece, 1986). Critical complementary assets put the incumbents in a strong bargaining position vis-à-vis the new entrants. If forward integration is costly and time consuming, the incumbent's position is further enhanced.

[1] In many ways, the real radical technology in the computer industry was not the personal computer per se but Intel's development of the first microprocessor in 1971, a product that, when invented, had no obvious market potential (Freiberger & Swaine, 2000).

Thus, a technology can be radical in the sense that it relies upon a new knowledge base and new production processes, but if it does not alter the way the new products are commercialized, it may not lead to incumbent decline. The theoretical insight is that a radical technology that diminishes the value of *both* the upstream and downstream assets of incumbents will drastically increase the probability of incumbent decline. If the radical technological innovation does not impact the value of the downstream activities, incumbents may be in a position to enter into alliances with new entrants on favorable terms, thereby enhancing their postdiscontinuity performance.

> *Proposition 7: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the firm possesses downstream complementary assets that are critical to the commercialization of the new technology.*

An important question centers on whether the trajectory of a technology can be determined early enough in its development for this retrospective explanation of historical events to be used as the basis for future predictions and normative recommendations. The final outcome of a radical technological innovation can lead to one of two states: (1) one in which customer relationships are altered and (2) one in which they are not. Given the inherent unpredictability associated with the trajectory of new technology, it is obviously difficult to predict which state a market will ultimately fall into when a radical technology first appears. However, the probability of correctly making such a prediction increases over time, as the technology begins to mature, as its applications emerge out of the mists of uncertainty, and as its trajectory becomes more certain. In other words, the breadth of impact of a technology is an *emergent attribute* that becomes more evident over time, thereby enabling an incumbent firm to adjust its strategic responses.

The critical task an incumbent faces is to observe how new entrants and competitors are using the technology. If the technology is changing product and process paradigms, but does not entail selling to new customers, altering the uses of products, or selling the products in different ways, then the downstream assets of incumbents will retain some value. This gives incumbents leverage that enables them either to enter alliances with new entrants or to acquire the new entrants on favorable terms. These actions (strategies) should improve the chances of incumbent survival and should enhance incumbent performance.

If the new technology also alters the way that products are sold, to whom they are sold, and how they are used, then incumbents have less leverage. This implies that the incumbents are less able to enter alliances or make acquisitions on favorable terms and are more likely to decline. At the very least, such information should inject incumbents with an additional sense of urgency, for it suggests that their strategic flexibility is limited by their lack of valuable complementary assets. Finally, it should be noted that collecting and acting on information about this emergent attribute of technology requires absorptive capacity and an organization that has legitimized and institutionalized autonomous action.

Gestation period. The gestation period for a radical technological innovation can be defined as that period between invention and successful commercialization. The complexity and scale of the engineering problems required to commercialize a new technology, and the resulting capital commitments, can lengthen the gestation period. In the literature scholars draw a distinction between "big science," where substantial time and capital commitments are required to develop a technology, and "little science," where innovation can occur in a garage (Freeman & Soete, 1997). Government regulations can also impact gestation periods. For example, FDA regulations regarding preclinical testing, clinical trials, and product and process approval imply that the gestation period for developing new products based on biotechnology can exceed a decade (Robbins-Roth, 2000).

Industry standards may be an additional factor influencing the gestation period. Industry standards guarantee compatibility between complementary products (e.g., computer hardware and software). Standards reduce the risks to consumers when they make a purchasing decision. Standards also allow for mass production based on a single dominant design, which can bring down both production costs and price points. Accordingly, as several observers have noted, a technological innovation may not take hold in a market until standards are established (Utterback, 1994). Industry standards are likely to take longer to establish when (1) multiple competing and incompatible standards are vying for dominance, (2) sponsoring companies are not able to agree on a single standard, and (3) positive feedback loops or network effects are not strong enough to lead to the rapid emergence of one particular standard (Shapiro & Varian, 1999).

Longer gestation periods have a number of consequences. For new entrants, longer gestation periods strain capital resources, increasing the probability that the firms will exhaust their capital resources before they have successfully marketed new products. For incumbents, longer gestation periods provide the time to invest in building the appropriate absorptive capacity. Long gestation periods also enhance incumbents' bargaining power vis-à-vis cash-strapped new entrants, better enabling them to enter into alliances with new entrants on favorable terms or to acquire the new entrants for their technology.

Proposition 8: Following a market discontinuity triggered by a radical technological innovation, the longer the gestation period of that technological innovation, the higher the performance of an incumbent firm.

Proposition 9: When Propositions 7 and 8 hold, an incumbent can use strategic alliances to gain access to radical technological innovations pioneered by new entrants, thereby increasing the incumbent's postdiscontinuity performance.

As with breadth of impact, the question remains as to whether this retrospective explanation of historical events can be used to predict future outcomes. Can the gestation period of an innovation be determined ex ante? Given the fact that the future is unknowable, the identification of a gestation period is riddled with hazards and unpredictability. Nevertheless, we submit that the prevailing regulatory framework, capital commitments, and scale of engineering problems are all factors that can be assessed to some degree early in the development of a technology. The gestation period of a radical technological innovation is not totally obscured by the mists of uncertainty. There are exogenous factors, such as government regulations and the emergence of industry standards, and endogenous factors, such as the scale and complexity of the engineering problems, that impact the gestation period of an innovation.

Scale, Scope, and Slack

One final factor that seems to be a predictor of incumbent performance in the face of radical technological innovation is organizational slack. Following Cyert and March's (1963) seminal work, Bourgeois defined organizational slack as "that cushion of actual or potential resources which allows an organization to adapt successfully to . . . external pressures for change in policy, as well as to initiate changes in strategy with respect to the external environment" (1981: 30). Prior to a radical technological innovation, large incumbent organizations often enjoy advantages of scale and scope and, thus, are typically able to generate significant organizational slack. Much of this can be invested in basic research facilities and/or in the acquisition of companies pioneering radical new technology.

The argument goes back to Schumpeter (1942), who theorized that large firms with market power were better able to undertake risky long-term investments in basic R&D. Neo-Schumpeterians, such as Nelson and Winter (1982), also have argued that larger firms are better able to appropriate returns from successful R&D efforts because of their financial resources and market power and, thus, have an incentive to invest in basic R&D. Other things being equal, this investment should increase incumbent performance through its impact on absorptive capacity. Moreover, organizational slack can help a firm to respond quickly to an unanticipated change.

Proposition 10: Following a market discontinuity triggered by a radical technological innovation, the performance of an incumbent firm will be higher if the firm has accumulated significant organizational slack from its established operations.

SYNTHESIS AND CONCLUSION

We opened this article by noting that the standard model of the innovation process suggests that new entrants pioneer radical technologies while incumbents decline. The explanations for incumbent decline include the disincentives that they have for investing in radical technology, organizational inertia, the embeddedness of incumbents within an established value network that skews information, and the prior strategic commitments of incumbents. Despite the explanatory power of the standard model, we have argued that it does not provide the entire story. Although the performance of incumbents does decline following a market discontinuity ushered in by radical technology, some incumbents survive; some subsequently adapt and improve their performance; and some get out in front of the change, exploit the new technology, and experience sustained performance. In fact, there are entire industries, such as the pharmaceutical industry, where the incumbents seem to survive and prosper, despite the appearance of radical technology (Rothaermel, 2001).

Thus, our thesis is that there are a number of factors that reduce the expected decline in the economic performance of incumbent firms, and thereby reduce the associated risk of bankruptcy. Investments in basic research can help to raise awareness of emergent technologies, thereby counteracting limited search and enabling a firm to accumulate the necessary absorptive capacity. Such investment is likely to be particularly effective if the basic research and applied business units are loosely coupled. A real options perspective for evaluating technology investment decisions can help to counteract the negative effect of economic incentives that undervalue investment in radical technologies. The legitimization and institutionalization of autonomous action within the incumbent organization can help counteract internal inertial forces and increase the probability that the incumbent will commit early on to commercializing a radical technology. Creating an autonomous division to perform this task can help to protect the nascent technology from political opposition and other forces of inertia within the enterprise. In addition, an autonomous division can promote product cannibalization and help the firm to discount feedback from its existing value network.

Moreover, incumbents may be better able to deal with a radical technology if its appearance does not diminish the value of their downstream assets. These assets provide incumbents with some leverage that can be used to enter into alliances within new entrants, if these downstream assets are necessary to commercialize the new technology. Similarly, a long gestation period for the technological innovation might increase the performance of incumbents via its effect on the relative bargaining power of the incumbents and new entrants, which allows incumbents to enter alliances with new entrants on favorable terms.

We also have argued that history plays a role. Incumbent firms that have successfully navigated radical technological changes in the past are more likely to do so in the future. Finally, the accumulated organizational slack derived from prior dominance may help incumbents to successfully navigate the abyss created by a technological discontinuity. We argue that these various factors are not independent of each other.

Clearly, some of the propositions that we have offered are not entirely unique, since others have made similar, though not identical, arguments over the years. However, we submit that the contribution of our paper rests in three areas. First, although others have made similar arguments, several of our propositions have few precedents in the literature.

Second, we have drawn on the prior literature to present a set of arguments that serve to counterbalance the impression implicit in the standard model of the innovation process that new entrants typically pioneer radical technologies while incumbents frequently go into a terminal decline. We agree that new entrants often do pioneer radical technological innovations, and we accept that many incumbent firms see their performance slump as they fail to cross the abyss created by a technological discontinuity. Some ultimately go bankrupt. However, we believe there are enough exceptions to this generalization to make the study of incumbent survival and performance in the face of radical technological innovation an interesting and fruitful theoretical and empirical exercise. In this paper we attempt to set out the theoretical underpinnings for future empirical exercises.

This brings us to the third contribution of the article. We were able to synthesize disparate literature streams and develop a more integrated view of incumbent performance following radical innovation, drawing from the literature on economics, organization theory, and strategic management. We submit that the complementary insights found in these bodies of literature do indeed tell a coherent story about incumbent survival and performance in the face of a radical technological innovation. Not only do they tell a coherent story—they also complement each other to provide a more holistic perspective of the phenomenon.

How should one go about empirically testing the propositions advanced here? Clearly, some of our propositions are not amenable to large-scale quantitative testing. We believe that an integrated approach drawing on qualitative field work, survey data, and secondary archival data may allow researchers to test the propositions advanced in this paper. In recent empirical studies researchers have combined qualitative and quantitative methods to present a richer understanding of complex phenomena (e.g., Kale, Dyer, & Singh, 2002; Rothaermel, 2001). We argue that such an integrated approach will present a fruitful avenue for future research attempting to empirically test our model predicting incumbent performance following radical technological change. Alternatively, given that some incumbents do not survive a technological discontinuity, a hazard rate model could be used to predict the probability of incumbent survival, with some of the factors identified in this article entering the model as independent variables.

In conclusion, we believe our theory development contributes to the understanding of *why* some incumbents continue to perform well following radical technological change. In particular, our propositions adhere to the principles of falsifiability and utility (Popper, 1959). In this spirit we hope that our theorizing will motivate empirical work in this fascinating area.

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