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The Incumbent's Curse? Incumbency, Size, and Radical Product Innovation

A common perception in the field of innovation is that large, incumbent firms rarely introduce radical product innovations. Such firms tend to solidify their market positions with relatively incremental innovations. They may even turn away entrepreneurs who come up with radical innovations, though they themselves had such entrepreneurial roots. As a result, radical innovations tend to come from small firms, the outsiders. This thesis, which we term the "incumbent's curse," is commonly accepted in academic and popular accounts of radical innovation. This topic is important, because radical product innovation is an engine of economic growth that has created entire industries and brought down giants while catapulting small firms to market leadership. Yet a review of the literature suggests that the evidence for the incumbent's curse is based on anecdotes and scattered case studies of highly specialized innovations. It is not clear if it applies widely across several product categories. The authors reexamine the incumbent's curse using a historical analysis of a relatively large number of radical innovations in the consumer durables and office products categories. In particular, the authors seek to answer the following questions: (1) How prevalent is this phenomenon? What percentage of radical innovations do incumbents versus nonincumbents introduce? What percentage of radical innovations do small firms versus large firms introduce? (2) Is the phenomenon a curse that invariably afflicts large incumbents in current industries? Is it driven by incumbency or size? and (3) How consistent is the phenomenon? Has the increasing size and complexity of firms over time accentuated it? Does it vary across national boundaries? Results from the study suggest that conventional wisdom about the incumbent's curse may not always be valid.

> One lesson from stories of corporate innovation is that it's rare for incumbent firms in an industry to reinvent that industry. Leadership in the typewriter industry, for example, changed hands from Remington to Underwood to IBM (with the "golf-ball" typewriter) to Wang (with the advent of word-processing) and now to Microsoft. Never once did the leader at a particular stage pioneer the next stage.
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> —*Business Times* (1996, p. 9)

> [T]he most important breakthroughs in military technologies have come not from the one or two companies that were the incumbent contractors in a category, but from wannabe's and upstart firms hoping to challenge them.
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> —*Washington Post* (1997, p. F5)

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Reports about radical product innovation often follow this script: An entrepreneur working either independently or within a corporate setting invents a design for a radically new product. This person then makes the rounds of incumbents in the industry, seeking support to develop further and commercialize the revolutionary product. But the entrepreneur encounters indifference or even hostility from the incumbents. After much search and hard work, the entrepreneur manages to piece together the funds to introduce the radically new product. In some cases, the product takes off. The entrepreneurial firm succeeds well beyond the expectations of its founder, generally at the expense of the incumbents that resisted the innovation. Declining sales of the older product cause the incumbents to lose their secure positions, and the entrepreneurial firm comes to dominate the transformed market. Ironically, when the new firm becomes entrenched in the market, it suffers from the same curse that afflicted incumbents in the previous product generation. When the next wave of radical product innovation hits the market, this firm resists it, just as its predecessors had resisted the current product. This resistance to innovation leads to the firm's own decline or demise, and the cycle continues.

The literature frequently describes this sequence of events when recounting the development of radically new products. Chester Carlson (dry copiers) is a classic example (Dessauer 1971; Hiltzik 1999; Smith and Alexander 1988). Recent research in technology management, economics, and marketing supports all or part of this script (e.g., Christensen 1997; Ghemawat 1991; Henderson 1993; Utterback 1994). We term this thesis the "incumbent's curse," because it

argues that incumbents in a particular product generation are so enamored with their success or so hampered by their bureaucracy that they fail to introduce the next generation of radically new products.

For example, Henderson (1993, p. 248) argues that incumbents' efforts with respect to radically new technologies are characterized by "incompetence" and "underinvestment." Ghemawat (1991, p. 161) suggests that incumbents are prone to "technological inertia" because of their many investments in the existing market. Scherer (1980, p. 438) cites cases to argue that "new entrants contribute a disproportionately high share of all really revolutionary new industrial products and processes." Some authors claim that established firms are slow to introduce not only radical product innovations but also "seemingly minor" changes (Henderson and Clark 1990, p. 9). Every change in configuration in the computer disk drive industry (e.g., from 8.5-inch disks to 5.25-inch disks to 3.5-inch disks) was initiated by a nonincumbent and led to the downfall of the previously dominant firm (Christensen 1993). Indeed, Rosenbloom and Christensen (1994, p. 655) note that the inability or unwillingness of incumbents to introduce radically new products is one of the prominent "stylized facts" in the literature on innovation management.

However, the previous conclusions are based on case studies of individual products, not on cross-sectional studies that use large samples of products (e.g., Ghemawat 1991; Henderson and Clark 1990; Mitchell 1991). The cases studied have been quite specialized, including photolithographic aligners (Henderson 1993; Henderson and Clark 1990), medical diagnostic imagers (Mitchell 1991), and private branch exchanges (Ghemawat 1991). The few multiproduct studies that exist use convenience rather than formal sampling (Cooper and Smith 1992; Rosenbloom and Christensen 1994; Tushman and Anderson 1986; Utterback 1994). Moreover, most of these studies use data from the United States. This state of knowledge raises the following questions:

- How pervasive is the phenomenon of the incumbent's curse? In particular, what percentage of radical innovations follow the script outlined previously?
- How consistent is the phenomenon? Has the increasing size and complexity of firms over time accentuated it? Does it vary across national boundaries?
- Is the phenomenon a curse that invariably afflicts large incumbents in current industries? Is it driven by incumbency or size?

The current study explores these questions. Research on this topic is important for several reasons. First, radical innovation is an engine of economic growth and a source of better products. An understanding of these issues is important for consumers and public policymakers. Second, radical innovation changes the entire shape of industries and makes the difference between the life and death of many firms (see, e.g., Cooper and Schendel 1976; Schumpeter 1942). Indeed, the history of business is littered with the graveyards of entire industries that were destroyed by radical product innovations. The telegraph, gas lighting, and typewriter industries are cases in point. Thus, managers need to know how to initiate and manage radical product innovation. Third, many large incumbents, especially in technologically intense industries, spend huge amounts of resources on research and development (R&D). A confirmation of the incumbent's curse would suggest the need for a reconfiguration of either their resources or their departments responsible for innovation. For example, after listening to speaker after speaker emphasize the incumbent's curse at the Marketing Science Institute's 1997 conference on really new products, one senior manager from a large multinational firm commented that his overarching feeling was "one of hopelessness." More research on the extent and causes of these problems may engender insight instead of hopelessness.

Insight is the goal of the current study. We aim to build on a growing stream of research in the marketing literature on the sources of radically new products and the characteristics of radically innovative firms (e.g., Chandy and Tellis 1998; Gatignon and Xuereb 1997; Ghemawat 1991; Moorman and Miner 1997; Olson, Walker, and Ruekert 1995). In the next three sections, we describe the theory, method, and results of this study. The last two sections discuss the implications and limitations of the research.

Theory

Definitions

A radical product innovation is a new product that incorporates a substantially different core technology and provides substantially higher customer benefits relative to previous products in the industry (Chandy and Tellis 1998). A radical product innovator is the firm that first commercializes a radical product innovation (Ettlie and Rubenstein 1987). In an innovation context, incumbency reflects whether a firm participated in the previous generation of products. Thus, an incumbent is a firm that manufactured and sold products belonging to the product generation that preceded the radical product innovation (Henderson 1993; Mitchell 1991; Mitchell and Singh 1993). Firm size refers to the scale of operations of an organization (Price and Mueller 1986).

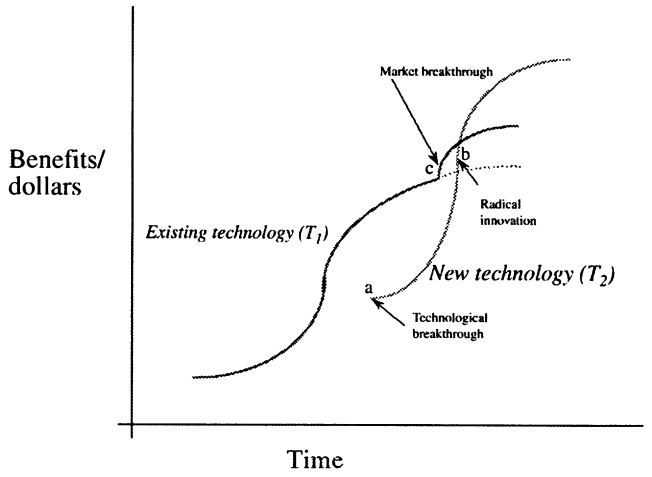
To provide a theoretical background to understand the behavior and performance of firms in the realm of radical innovations, we next discuss the theory of S-curves.

Theory of S-Curves

The theory of S-curves comes from the technology management literature and explains the origin and evolution of radical innovations (Foster 1986; Sahal 1985; Utterback 1994; Utterback and Abernathy 1975). This theory suggests that technologies evolve along a series of successive S-curves that drive various new product introductions (Chandy and Tellis 1998). The S-curve emerges because a new technology offers few consumer benefits when first introduced, offers rapidly increasing consumer benefits as it develops, and offers slowly increasing consumer benefits as the technology matures (see Figure 1).

To understand this phenomenon better, consider an existing technology (T_1), which is in its maturity. Assume that at some point during the maturity of this technology, a new technology, T_2, emerges, which leads to a new product, called a technological breakthrough (point a in Figure 1).

FIGURE 1
S-Curves



Notes: Figure adapted from Chandy and Tellis (1998).

Initially, because of problems implementing the technology, T_2's benefits are inferior to those of T_1, so the new product's sales are below those of existing products and occur mostly to highly innovative, price-insensitive consumers. However, with research, T_2 begins to improve rapidly in consumer benefits and ascends its own S-curve. A point may come (point b in Figure 1) when T_2 passes the existing technology, T_1, in benefits. At this point, the market considers the new product based on T_2 a radical product innovation. Sales of the new product then take off as consumers increasingly shift to the new product to satisfy their needs. Sales of the old product may correspondingly decline.

Faced with this competition, supporters of the old technology, T_1, may make a renewed effort to be competitive by redoubling their efforts in the old technology. This effort may result in some short-term improvement in T_1, called a market breakthrough (point c in Figure 1). However, investments in the new technology, T_2, generally yield much greater benefits to consumers than do those in T_1, so products based on T_2 continue to outsell those based on T_1. The old product dies out when the new product completely replaces it.

As time passes, T_2 ceases to improve substantially, and sales based on the new product slow down. If another radical product innovation emerges, the cycle may repeat itself. If this new innovation never surpasses the old one in consumer benefits, it dies out without ever triggering a takeoff.

Incumbents and Radical Innovation

The theory of S-curves suggests three reasons incumbents may be reluctant to introduce radical innovations: perceived incentives, organizational filters, and organizational routines.

Perceived incentives. Incumbents may perceive smaller incentives to introduce radical product innovations than nonincumbents (Conner 1988; Scherer 1980; for a more nuanced analytical view, see Tirole 1988). The reason is that they derive a significant stream of rents from existing products based on the current technology, whereas nonincumbents derive no such rents. Note in Figure 1 that radically new products hold the potential to make existing products obsolete. Introducing a radically new product could therefore jeopardize the rents from existing products. Incumbents therefore have a lower marginal incentive than nonincumbents to develop or commercialize radical innovations in the short run (Ali 1994; Reinganum 1983). Indeed, mathematical models of innovation indicate that incumbents would maximize overall profits by not introducing a radical product innovation even when (1) the radical innovation itself is more profitable than the existing product (Reinganum 1983) and (2) the fixed cost of offering the radical innovation is zero (Ghemawat 1991). What these models do not fully take into account is the dynamic nature of the radical innovations that can completely obsolete the old products and completely replace the existing market in the long run.

Organizational filters. Organizational filters are cognitive structures that screen out information unrelated to the organization's important tasks to focus its attention on these tasks. Organizational theorists argue that the organizational filters of incumbents make them less effective at radical innovation (e.g., Hannan and Freeman 1977; Henderson and Clark 1990; Nelson and Winter 1982). Incumbents' success in the current product category is partly due to organizational filters that enable them to focus efficiently on their current challenges. In particular, these filters help them process consumer requests or complaints, channel them to the manufacturing department or distributors, and ensure that the current products meet consumer expectations as effectively as possible. Thus, the filters serve to direct managers' attention to maximize the utility of the current technology for current customers. However, radical product innovations involve a substantially new technology. As a result, these very organizational filters may cause incumbents to be less effective than nonincumbents at spotting, developing, and marketing radical product innovations (Henderson 1993).

Organizational routines. Organizational theorists also state that incumbents develop organizational routines or procedures to carry out the repetitive tasks of manufacturing and distributing large volumes of the current product efficiently (Hannan and Freeman 1977; Henderson and Clark 1990; Nelson and Winter 1982). Within the R&D department, the routines are geared toward efficiently developing incremental innovations based on the current technology. However, the routines are ineffective at developing radical product innovations, because the latter are based on a substantially different technology (Henderson 1993). Moreover, adoption of radical innovations would obsolete many of these routines and require the development of new routines, which is difficult, costly, and risky (Hannan and Freeman 1977; Nelson and Winter 1982). Managers may reason that these very routines have helped the firm ride through the success of the current technology. Thus, they have a vested interest in the current organizational routines (Staw 1981) and are reluctant to embrace radical innovations.

Opportunities of incumbents. Although the previous theory suggests that incumbents are less likely to innovate radically than nonincumbents, we should not ignore the oppor-

tunities of incumbents in terms of market capabilities (e.g., Srivastava, Shervani, and Fahey 1998). Indeed, if incumbents can muster the willingness to cannibalize their own investments (Chandy and Tellis 1998), they can exploit their many resources to lead with radical innovations. We highlight three market capabilities—customer knowledge, customer franchise, and market power—and note the opportunities they create for radical innovation.

First, incumbents have greater knowledge about customers in the market. They communicate with them and understand their needs and may have detailed records of their purchases and behavior. Thus, incumbents may be better able to gauge the value of radical innovations and market them when they are introduced than nonincumbents. Second, incumbents enjoy a customer franchise that can be beneficial in the context of radical innovation. Consumers perceive radical product innovations as risky purchases (see Bauer 1960; Folkes 1988; Gregan-Paxton and John 1997). To the extent that consumers in a particular market are familiar with an incumbent, they would be less apprehensive about purchasing a radical product innovation from this firm. Third, incumbents also possess greater market power, which gives them preferential access to distribution channels relative to nonincumbents (Mitchell 1989). It may also enable them to sustain their market presence during the long and unprofitable period until the product takes off. Recent research indicates that this period till takeoff averaged 17.7 years for products introduced before World War II and 5.8 years for products introduced after World War II (Golder and Tellis 1997; see also Urban and Hauser 1993).

Summary. The literature and extant theory strongly suggest that incumbents are less likely than nonincumbents to introduce radical innovations. At the same time, incumbents have many market capabilities to do so. Although the focus of empirical studies so far has been mostly on noninnovative incumbents, at least some incumbents may be successful at developing and introducing radical innovations. This conflict underscores the need for empirical research, based on a large cross-section of innovations, that can identify the actual pattern of radical innovation by incumbents.

Firm Size and Radical Product Innovation

Incumbents that have successfully survived in a market tend also to be large. Thus, size and incumbency are likely to be positively correlated. Our concern is the role of size in radical innovation after we control for the influence of incumbency. Here again, the literature strongly suggests that large firms may not be radical innovators, primarily because of the theory of inertia (Acs and Audretsch 1991; Cohen 1995; Cohen and Levin 1989; Scherer 1991). We review this theory subsequently and then briefly discuss the opportunities of large firms.

Theory of Inertia. As firms grow large, they are prone to the forces of bureaucratic inertia (Tornatzky and Fleischer 1990). The key factor that contributes to such inertia is the number of employees that work in large firms. The numbers of employees make it difficult to manage large firms, so these firms develop layers of administrative staff and formal rules of communication to adapt to this situation (Blau and Schoenherr 1971; Kasarda 1974; Terrien and Mills 1955). Although the staff and rules may cause large firms to function more effectively in serving current customers with current technology, they can also render them slow to react to radically new products (e.g., Kimberly 1976).

Note in Figure 1 that radical innovations not only are an outgrowth of the current technology but also result from the application of a substantially different technology to the same problem. In a large firm, new ideas that give birth to radical innovations must move through more layers of administration. Innovative employees often must labor through layers of bureaucratic resistance to get approval for their ideas. The process increases the likelihood of screening or tempering of radical ideas. Alternatively, the time and trouble it takes to gain approval distracts scientists from concentrating on creative work (Acs and Audretsch 1991; Scherer 1980). In the extreme case, these impediments can frustrate innovators and lead them to look elsewhere for support or to start their own companies.

A related problem is that of rewards for innovators in large organizations. As organizations grow in size, they involve more levels of screening and group decision making. Thus, the contributions of individuals get increasingly diluted, so innovators are less able to capture the benefits of their efforts (Cohen 1995; Schumpeter 1942) and have fewer incentives to develop radically new products (Cohen and Levin 1989). In summary, large firms are less likely than small firms to provide the responsive, risk-taking atmosphere needed for the development of radical product innovations.

Opportunities of large firms. Large firms have great opportunities to develop and introduce radically new products. In particular, large firms have enormous financial and technical capabilities, which they can harness for radical innovation. Large firms may have the economies of scope to spread the risks of new ventures widely (Arrow 1962; Galbraith 1968). Similarly, large firms have a large volume of sales over which to spread the fixed costs of R&D (economies of scale; Comanor 1965). As a result, large firms are less vulnerable to the failure of a particular development project, because it would entail a smaller proportion of their resources than it would for a small firm.

The deeper pockets of large firms also enable them to maintain state-of-the-art scientific facilities and hire quality scientific personnel. Moreover, some researchers argue that capital market imperfections provide an advantage to large firms, because these firms have greater access to internal and external funds to finance risky R&D projects (Cohen and Levin 1989). Thus, large firms may be more capable of pursuing radical innovations than small firms.

Summary. The theory of inertia strongly suggests that large firms would be unlikely to introduce radical innovations. At the same time, large firms have many financial and technical capabilities to do so. Thus, there is a conflict about the role of size on radical innovation. This conflict began with the work of Schumpeter (1942) and continues today (Chandy and Tellis 1998). Empirical research that helps enlighten the debate would be useful.

Country, Incumbency, and Radical Innovation

The proportion of innovations from incumbents compared with nonincumbents is likely to be lower in the United States than in other industrialized nations, such as Japan and those in Western Europe (Acs and Audretsch 1991; Imai 1990;

Scherer 1991). The reason for this discrepancy may be differences in institutions and popular culture between the United States and these other nations (Patel and Pavitt 1995).

Institutions. The United States has historically enjoyed an active market for venture capital, which makes financing for less established firms easier in the United States than in many other countries (Saxenian 1994). Thus, financial institutions may play a role in encouraging radical innovation among less established firms in the United States compared with Japan and Europe. At the same time, government policies in the latter countries have traditionally favored technology ventures by large, established firms over those by small firms (Fitzroy and Kraft 1991; Scherer 1991; Urabe, Child, and Kagono 1988). Large incumbents in these countries enjoy financial and technological support that is unavailable to similar firms in the United States (Magaziner and Patinkin 1989). Therefore, incumbents and large firms in Japan and Europe are more likely to indulge in radical innovations than those in the United States.

The entrepreneur in popular culture. Popular culture in the United States celebrates risk takers. Indeed, American entrepreneurs are celebrated figures—the pride of Americans, the ideal of would-be entrepreneurs, and the envy of foreigners seeking to emulate their success. In the United States, failure is stigmatized less than in some other countries (see Patel and Pavitt 1995). On the contrary, succeeding after a string of failures enhances the glory of the entrepreneur. Therefore, people are more motivated to engage in entrepreneurial ventures to commercialize new technology in the United States than in other countries. This factor could increase the pool of small, nonincumbent firms that are likely to become radical innovators in the United States.

Summary. On the basis of the previous arguments, we expect the profile of U.S. radical innovators to be different from that of non-U.S. radical innovators. Specifically, we expect a greater proportion of U.S. innovators than innovators from other countries (especially Japan and Western Europe) to be small firms or nonincumbents. Stated differently, the incumbent's curse is more likely to apply in the United States than in non-U.S. contexts. Table 1 summarizes the theoretical discussion and the propositions it suggests. The next section describes our research approach, sampling frame, and measures to test these propositions.

Method

Research Approach

We collected our own data to address the questions posed previously, because we could not find any satisfactory database of radical innovations. We use the historical approach to data collection (Golder 2000; Savitt 1980; Smith and Lux 1993) for three reasons. First, we study events from the past, many from the distant past. Second, the easier alternative approach of surveying current managers can suffer from severe memory or self-report biases. Third, the historical approach enables us to study the effects of time on the incumbent's curse. Specifically, this approach can provide an answer to the question, Are today's incumbents more or less innovative than the incumbents of the distant past? An understanding of temporal changes requires attention to the time order of events that is best obtained by the historical approach. Historical research is tedious and time consuming, but well worth the effort because of the insight and novelty of findings it provides. Thus, in scope and design, our study is similar to Golder and Tellis (1993), though in content it is similar to Foster (1986) and Utterback (1994).

We use the following five criteria to include data in our study:

1. *Confirmation*: At least two published sources cite the same fact.
2. *Neutrality*: The sources have no overt interest to bias their reports.
3. *Independence*: The sources are based on independent observation (i.e., they did not come from a single source, such as United Press International).
4. *Reliability*: The sources are well respected or have a history of good reporting.
5. *Contemporaneity*: The sources report as close to the time of the event as possible.

Overall, we use information from more than 250 books and 500 articles in periodicals. The information search and data collection tasks are time and effort intensive, involving one author and nine trained assistants over a period of four years.

Sampling Frame

To avoid sampling biases, we use a relatively formal sampling frame to choose the product categories and innovations for our study. This approach contrasts with prior

TABLE 1
Summary of Theoretical Discussion

Type of Firm	Theory Against Radical Innovation	Theory for Radical Innovation
Incumbent	Incentives, filters, and routines enhance commitment to current technology at the expense of radical innovation.	Market capabilities facilitate radical innovation.
Large firm	Bureaucratic inertia dampens radical innovation.	Financial and technical capabilities facilitate radical innovation.
U.S. nonincumbents	—	Institutions and culture foster radical innovation by entrepreneurs.

research, which relies on convenience samples. We choose the sample to satisfy three objectives:

- First, in the interests of effort and comparability, we restrict our study to two broad product classes: consumer durables and office products. These two product classes have been studied in previous research, especially in the literature on innovation diffusion and market pioneering (Golder and Tellis 1993, 1997; Gort and Klepper 1982; Sultan, Farley, and Lehmann 1990). The current research on these categories adds to the cumulative knowledge in the area. These two product classes are also attractive because innovations in these classes have widely varying dates of introduction. Thus, they enable us to identify generalizations over time or historical trends in the pattern of radical product innovation.
- Second, we seek product categories with high unit sales. In practice, we restrict the sample to categories with more than one million units in sales in 1994, the last year for which sales data were available when this study began. This cutoff value for sales is a conservative figure; it helps ensure that the categories in our sample include innovations that have truly had a large enough impact on consumers to form huge markets. The 1994 volume of *Predicasts* provides the list of categories and their annual sales. This goal leads to a list of 49 product categories.
- Third, we require that the core technology used in at least one innovation in the category varies substantially from the technology used in the previous product generation. Prior theory suggests that such shifts in technology trip incumbents (Cooper and Smith 1992; Utterback 1994). To determine a radically new technology in each category, we use a two-step procedure. First, we identify the most significant product innovations in each product category. We obtain information on the innovations from books on the history of the respective categories, as well as from past issues of business and technology periodicals. To ensure the eligibility of information and increase the relevance to current products, we restrict the sample to innovations introduced after 1850. The procedure leads to 93 significant innovations. Second, each significant innovation is assigned a rating for radicalness relative to the previous product generation by a team of three experts. The Measures subsection describes the rating procedure in greater detail.

Our sample size compares favorably with those in other empirical studies on consumer durables. In their comprehensive meta-analysis on diffusion models of new products, Sultan, Farley, and Lehmann (1990) show that prior studies on average have a sample size of 14 product categories. Golder and Tellis's (1993, 1997) studies on market pioneering and sales takeoff have sample sizes of 35 and 31 product categories, respectively.

The sample derived from this procedure enjoys several strengths. First, the sample does not suffer from survival bias. The reason is that we include any incumbent or entrant, large or small, surviving or dead, so long as it was the first to introduce the radical innovation. We are able to do so by referencing articles about the radical innovation written close to the time the innovation occurred, not by relying on self-reports by current participants in the industry. Second, the domain of our sample is international, because the country of origin of the firm or the innovation is not a criterion for selection. Third, our sample covers an extensive time period: Introduction dates span close to 150 years. Fourth, all our data come from publicly available sources that are accessible to any interested party.

Measures

Radical Innovation. At present, the literature does not contain a measure of the radicalness of innovations, yet this is a critical variable in the field of innovation and new products. To initiate research in scale development and provide greater objectivity to the classification and rating of innovations, we develop a new index of radicalness.

Recall that our definition of a radical product innovation involves two dimensions: whether a new product (1) incorporates a substantially different core technology and (2) provides substantially higher customer benefits relative to the previous product generation in the category. We had three experts rate the innovations on these two dimensions of radicalness. Each dimension involves a nine-point scale. For differences in core technology relative to the previous product generation, they rated each innovation on a scale ranging from 1 (not at all different) to 9 (substantially different). For superiority in user benefits relative to the previous product generation, they rated each innovation on a scale ranging from 1 (not at all higher) to 9 (substantially higher).

All three raters are knowledgeable about the history of innovation in the product classes studied. All three raters have published articles on innovation or new products in leading marketing journals. Nevertheless, because we are studying a wide variety of 94 innovations, for which even experts may not remember all the details, and because we wanted to ensure that all raters were exposed to consistent information, we gave the raters key information on each of the two dimensions (consumer benefits and technology) for each of the current innovations and its previous product generation.

Firm size. A firm's size has many measures, the most common being number of employees, sales volume, or value of assets. Empirical research indicates that in the context of radical innovation, these alternative definitions of firm size provide similar results (Agarwal 1979a, b; Chandy and Tellis 1998; Child 1973). The most common measure of size in the innovation literature is the number of a firm's employees (Cohen and Levin 1989; Pavitt, Robson, and Townsend 1987). This measure is theoretically appealing, because many of the problems of large firms (such as increased bureaucracy and inertia) are due to the increased need for coordination as a firm employs more people (Kimberly 1976). Therefore, we operationalize firm size as the number of employees in the firm.

To measure firm size, we determine the number of full-time employees in the firm at the time the radical product innovation was commercialized (e.g., Cohen and Levin 1989; Pavitt, Robson and Townsend 1987). We define a firm as small if it employed fewer than 100 employees, medium if it employed between 100 and 2500 employees, and large if it employed more than 2500 employees (see Pavitt, Robson, and Townsend 1987). In our analysis, we use both a continuous measure of firm size and the previous categorical measure. Our results are robust to the cutoff between small and medium firms in the categorical measure.

For publicly traded firms, we obtain size information from publications such as *Moody's Industrial Manual* (which extends back to the turn of the century) and the *Standard & Poor's* manual. For privately held firms, we obtain information from historical records such as company direc-

tories (e.g., the *Industrial Laboratories Directory*), contemporary journalistic accounts, biographies, and other sources (e.g., employee time sheets for 1880 from the Edison Electric Light Co.). For some small start-up firms, we are unable to nail down the precise number of full-time employees at the time the firm commercialized the radical product innovation. However, in every case we are able to determine if the firm had fewer than 100 employees at that time.

Information on the number of employees is more commonly available than that on the alternative measures. Nevertheless, to validate this measure of firm size, we also collect information on firm sales and assets in the year of introduction of the innovation for 27 of the innovating firms in our sample for which data are available. We convert the sales and asset information into 1980 U.S. dollars by multiplying the raw sales and assets figures by the appropriate exchange rate and inflation rate indices. We then correlate these standardized sales and assets variables with the number of employees in the relevant firms. The correlation between the number of employees in a firm and its standardized sales is .75 ($p < .001$), and that between employees and standardized assets is .73 ($p < .001$). Thus, in addition to theoretical support, our measure of size is also closely related to the alternative measures.

Innovator and incumbent. As in Cooper and Schendel's (1976) and Utterback's (1994) studies, we define the radical innovator as the firm that first commercialized the radical innovation.[1] Following Golder and Tellis (1993, 1997), Gort and Klepper (1982), and Gort and Wall (1986), we define the introduction date as the date of first commercialization of the radical innovation. To measure incumbency, we first identify the product generation that preceded the radical product innovation. Following Henderson (1993), Mitchell (1991), and Mitchell and Singh (1993), we then define a firm as an incumbent if it manufactured or sold products that belonged to the previous product generation on the introduction date. We define it as a new entrant if it did not. Six of the innovations in our sample fulfilled needs that were not met by any previous product. For example, no specific products fulfilled the needs later met by telephone answering machines. In these cases, the previous product generation is defined as the service or technology by which the particular need was fulfilled before the introduction of the innovation (e.g., human answering service in the case of telephone answering machines).

Time. To study trends in the incumbent's curse over time, we compare the profile of radical innovators before and after World War II. However, to detect continuous trends over time, we also use a continuous measure of time that ranges from 1 for the first year in our sample (1851) to 148 for the last year in our sample (1998).

When presenting the categorical analyses, we focus on the pre– and post–World War II period in particular, because that period saw the birth of many fundamental new technologies in the electronics, telecommunications, and computing fields (Sakudo and Shiba 1994; Teitelman 1994). These technologies were first applied to civilian uses in the period after the war. World War II was also a major economic event that significantly altered the business environment of many countries. Many incumbents found their fortunes dramatically changed by the war, and a new generation of start-ups rose to commercialize the technologies developed during this period. Finally, separating pre–World War II innovations from post–World War II innovations splits our sample neatly on the basis of recent and earlier technological breakthroughs. Products in the earlier sample generally represent breakthroughs in electrification, mechanization, and chemistry. Products in the later sample are largely based on breakthroughs in electronics and computing.

Nationality. We measure nationality as the country where the firm was headquartered at the time it introduced the radical innovation. In all but one of the innovations in our sample, the firms' development efforts leading to the radical innovation were based in the country where the firms were headquartered.

Results

From the original set of 93 innovations, we could collect reliable information on each of the key variables of interest for 64 innovations, which constitute the sample for our analysis. The Appendix presents the list of innovations in the sample. This section first presents bivariate categorical analyses of the dependent variable and then presents multivariate analyses of the continuous variables.

Categorical Analysis

To get a better feel for the phenomenon, we first present bivariate categorical analyses of the key relationships. To do so, we categorize three of our continuous variables: radical innovation, time, and size. First, we classify the sample of 64 innovations as radical if the average rating from all three raters on each dimension is equal to or more than 5 on the nine-point scale. Fifty-three innovations meet this criterion. Second, we label firms with fewer than 100 employees as small, 100–2500 employees as medium, and more than 2500 employees as large. Unfortunately, we have only six medium firms by this criterion, so we collapse the class of small and medium firms into one group. Third, we categorize time as pre– and post–World War II, for reasons stated previously. This section reports the characteristics of radical innovations on each of the key variables of interest.[2]

Role of size and incumbency. Recall that the incumbent's curse suggests that incumbents are much less likely than nonincumbents to introduce radical innovations. Of the innovations in the sample, 53% are from nonincumbents, whereas 47% are from incumbents. These proportions are not significantly different from each other ($\delta = 6\%$, $p > .40$). This result implies that incumbents may be as likely to introduce radical innovations as nonincumbents. Thus, the overall results do not support the incumbent's curse.

[1]This definition thus excludes all firms that commercialized the innovation after the first firm. As we note in the Additional Analysis section, relaxing this definition to include later entrants makes our results even stronger.

[2]We also conducted the same analyses using the full list of 64 significant innovations. The key results from this analysis are consistent with those presented in this article.

TABLE 2
Radical Innovators by Incumbency and Size

	Small and Medium	Large
Nonincumbent	42%	11%
Incumbent	17%	30%

FIGURE 2
Incumbency Status of Radical Innovators over Time

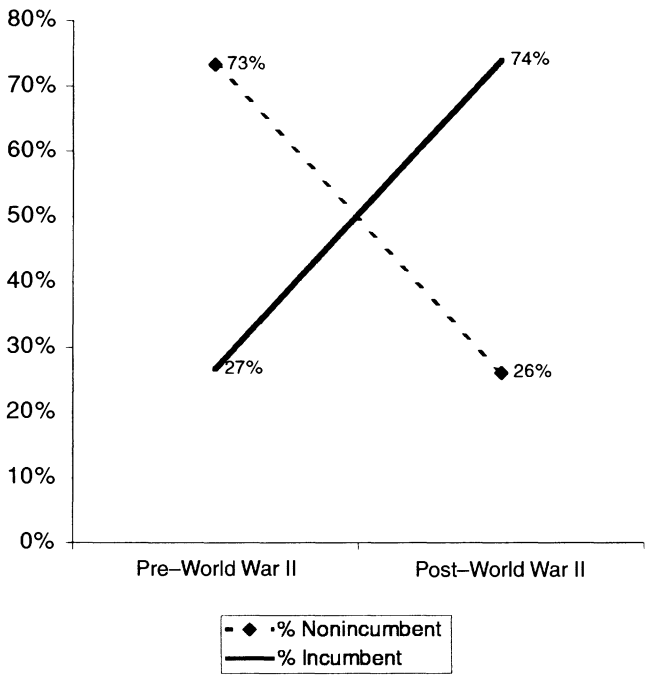
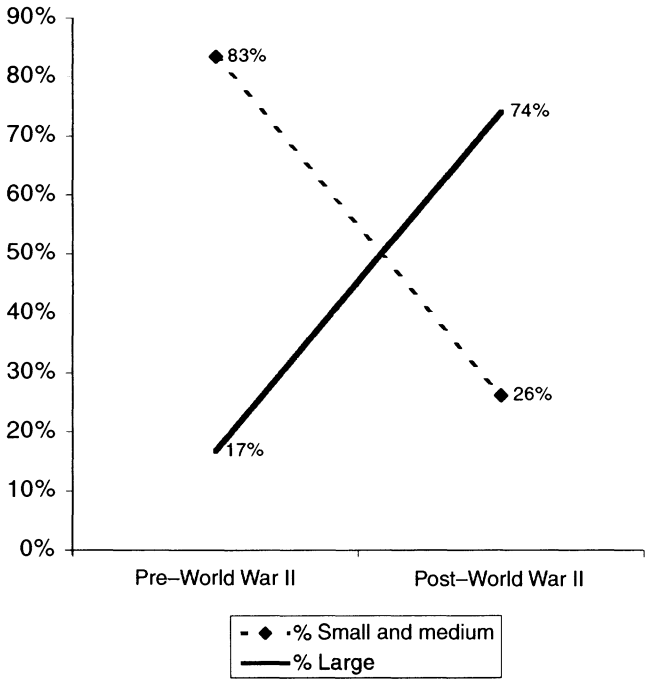


FIGURE 3
Size of Radical Innovators over Time



Our theoretical discussion suggests that large firms are less likely to introduce radical innovations than small firms because of inertia and bureaucracy. To test this proposition, we classify radical innovations by firm size. Overall, 58% of the innovations in the sample are from small and medium firms, whereas 42% of the innovations are from large firms. The difference between these two proportions is statistically significant ($\delta = 30\%$, $p < .001$). This result seems to support the theory of the inertia and bureaucracy of large firms.

A valid question at this point is how the combination of size and incumbency affects radical innovations. Table 2 shows a dramatic interaction effect of these two variables. Smaller nonincumbents are almost four times as likely to be radical innovators than large nonincumbents. In contrast, large incumbents are almost twice as likely to be the radical innovators than are small and medium incumbents. Thus, size seems to favor incumbents and disfavor nonincumbents.

Trends over time. The previous results indicate that when analyzed separately, incumbents tend to introduce radical innovations in roughly the same proportion as nonincumbents. Has this pattern remained steady over time? We use the term "older" for pre–World War II innovations and "recent" for post–World War II innovations.

Figure 2 shows that the older innovations in the sample are mostly from nonincumbents (73%); relatively few are from incumbents ($\delta = 47\%$, $p < .0001$). But a very different picture emerges when we focus on recent innovations. Incumbents significantly outnumber nonincumbents for recent innovations in the sample (74% to 26%, $\delta = 48\%$, $p < .0001$). These results indicate that whereas the incumbent's curse may have been a problem in the late nineteenth and early twentieth centuries, it is not common in recent times.

As with incumbency, the reversal over time also occurs for the size of innovators. Figure 3 shows that small and medium firms account for a majority (83%) of older innovations in the sample relative to large firms (17%) ($\delta = 67\%$, $p < .0001$). The pattern changes dramatically in recent times, when smaller firms account for only 26% of the innovations compared with 74% for large firms ($\delta = 48\%$, $p < .0001$).

These results suggest that small firms or nonincumbents were more radically innovative previously, probably because of their nimbleness or lack of inertia relative to the complexity of prevailing technology. However, in recent times, large firms and incumbents account for more radical innovations, probably because their large financial, technical, or market capabilities enable them to master the complex technologies better. A review of the historical evidence brings to light an additional explanation for the innovativeness of incumbents and large firms in recent years. In the post–World War II period, large firms and incumbents insti-

FIGURE 4
Nationality of Radical Innovators over Time

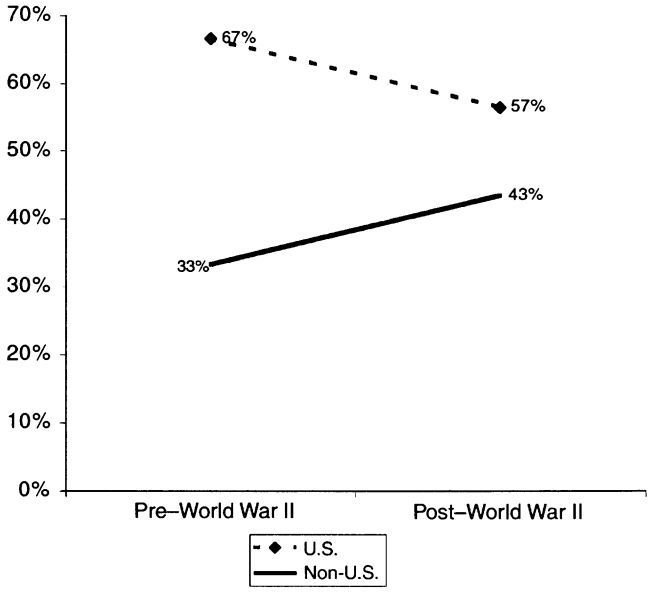
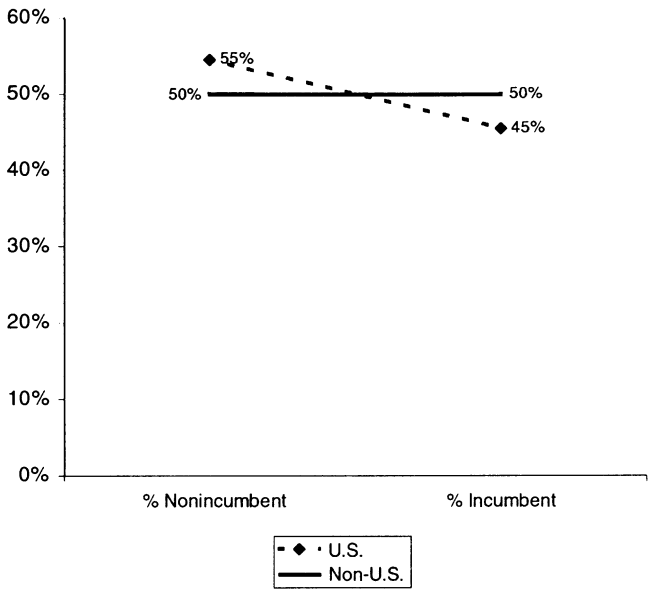


FIGURE 5
Radical Innovators by Incumbency Status and Country of Origin



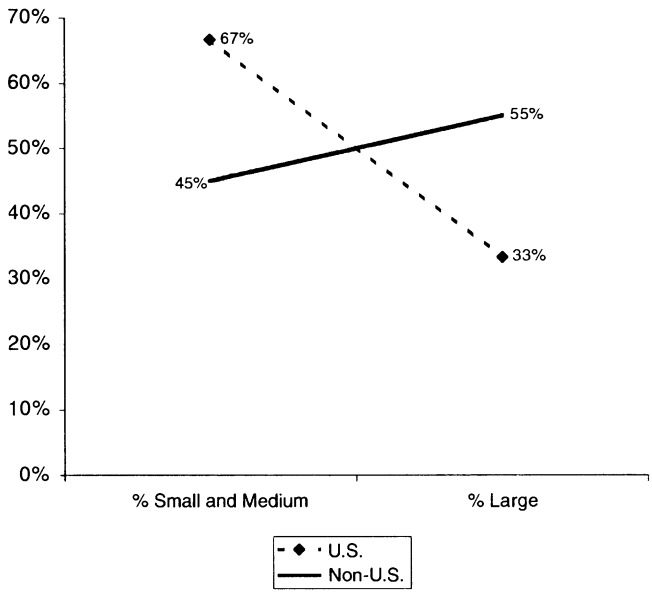
tuted organizational features that better support radical innovation (Chandler 1956; Williamson 1975). These organizational features may make them willing to cannibalize their own past investments (Chandy and Tellis 1998). We cover this issue in greater depth in the subsequent discussion.

International comparisons. What proportion of radical innovations come from U.S. firms? Of the innovations in the sample, 62% are by U.S. firms ($\delta = 24\%$, $p < .001$). However, unlike the previous results, this proportion remains steady across time periods (Figure 4). Of the older innovations in the sample, 67% are from U.S. firms, compared with 57% of the recent innovations, but this difference is not significantly different from zero ($\delta = 10\%$, $p > .45$).

The major change across these two periods is the emergence of Japan as a source of innovation. Whereas all but one of the older non-U.S. innovations are from European firms, both Japanese and European firms are responsible for recent non-U.S. innovations. These results suggest that in the product classes we study, the United States dominates but does not exclusively control the field of radical innovation. It also suggests no strong temporal patterns in U.S. innovativeness in these categories. Western European nations seem to have lost some ground in recent years to Japanese firms.

We had expected that because of institutional (e.g., government policies, availability of venture capital) and cultural (e.g., attitudes toward entrepreneurship) factors, U.S. innovations would be more likely to come from nonincumbent, small firms than non-U.S. innovations. Figure 5 presents the results on incumbency among U.S. and non-U.S. innovators. Of the U.S. innovations in the sample, 55% are by nonincumbents, compared with 45% by incumbents, though this difference is not statistically significant ($\delta = 10\%$, $p > .29$). Non-U.S. innovations come from incumbents and nonincumbents in equal proportions ($\delta = 0\%$).

FIGURE 6
Radical Innovators by Size and Country of Origin



An analysis of the size distribution of U.S. versus non-U.S. innovators reveals similar patterns. Figure 6 shows that a majority of the U.S. innovations in the sample are from small and medium firms rather than large firms ($\delta = 33\%$, $p < .001$). However, non-U.S. innovations come from small and medium firms rather than large firms in roughly equal proportions ($\delta = 10\%$, $p > .36$).

We also conducted a further analysis of the trends over time within the sample of radical innovations introduced by U.S. firms (n = 33). This analysis indicates that the sources of U.S. radical innovations also change dramatically in the post–World War II period. The older U.S. innovations tend to come from smaller firms and nonincumbents, whereas the more recent U.S. innovations tend to come from large firms and incumbents, thus paralleling the results for the overall sample. However, because of the limited sample size in this analysis, we do not present quantitative results or significance levels (see Frank and Althoen 1994).

The results so far are based on a bivariate analysis of radical innovations by categorized independent variables. The previous results do not distinguish between highly radical and less radical innovations, nor do they explain the variation of the relationship over the range of time and firm size. Therefore, we next present multivariate results from our full sample of 64 innovations, thus using the full range of information available in our sample.

Multivariate Results

To understand the extent to which our key variables (incumbency, size, time, and nationality) explain the level of radicalness of the innovations, we estimate the following regression equation:

$$\begin{aligned}(1)\ \text{Radicalness of Innovation} = {} & \beta_0 + \beta_1\text{Incumbent} + \beta_2\text{Large} \\ & + \beta_3\text{Time} + \beta_4\text{US} \\ & + \beta_5(\text{Time} \times \text{Incumbent}) \\ & + \beta_6(\text{Time} \times \text{Large}) \\ & + \beta_7(\text{Time} \times \text{US}) + \varepsilon,\end{aligned}$$

where Radicalness of Innovation is a variable $= \Sigma_{i = 1 \text{ to } 3}$ (Technology Rating)$_i$ + $\Sigma_{i = 1 \text{ to } 3}$ (Benefits Rating)$_i$, (Technology Rating)$_i$ is rater i's rating of the extent to which the core technology in the innovation is substantially different from that used in the previous product generation, and (Benefits Rating)$_i$ is rater i's rating of the extent to which the product provides substantially superior benefits relative to the previous product generation. Incumbent, Large, and US are dummy variables defined as previously; Time is a continuous variable ranging from 1 (for the year 1851) to 148 (for the year 1998). βs are coefficients to be estimated, and ε is a vector of errors assumed to be i.i.d. normal.

The choice and specification of independent variables follows from our theoretical discussion. To test the extent to which our results are robust to differing operationalizations of firm size, we also estimate the following regression equation:

$$\begin{aligned}(2)\ \text{Radicalness of Innovation} = {} & \gamma_0 + \gamma_1\text{Incumbent} \\ & + \gamma_2\text{Employees} + \gamma_3\text{Time} + \gamma_4\text{US} \\ & + \gamma_5(\text{Time} \times \text{Incumbent}) \\ & + \gamma_6(\text{Time} \times \text{Employees}) \\ & + \gamma_7(\text{Time} \times \text{US}) + \nu,\end{aligned}$$

where Employees is the number of full-time employees in the company in the year it introduced the innovation, γs are coefficients to be estimated, ν is a vector of errors assumed to be i.i.d. normal, and all other variables are defined as previously.

Table 3 presents the stepwise results of estimating Equation 1. The regression results, as well as the tests of bivariate correlations, are generally consistent with the results of the categorical analyses. In particular, the regression analysis indicates that the main effect of incumbents (Model 1) and large firms (Model 3) on radical innovations is negative.

However, in the regression with all independent variables (Model 4), neither the main effect of incumbency nor its interaction with time is significantly different from zero. This result indicates that innovations introduced by incumbent firms are no less radical than those introduced by nonincumbents. (Incumbency and size are positively related, so the difference in these results from the bivariate case also may be due to the collinearity between incumbency and size.) The results also indicate a strong interaction between firm size and time, similar to that in the categorical analysis. The results indicate that though larger firms introduce less radical innovations, in recent years the trend is just the opposite. Indeed, the size and sign of the standardized coefficient of this interaction is such that it more than cancels out the negative effect of size on radicalness. Thus, in recent years, innovations introduced by large firms are more radical than those introduced by smaller firms. Similarly, there is a strong interaction of time × US. The coefficient indicates that in recent years, innovations introduced by U.S. firms are more radical than those introduced by non-U.S. firms.

The previous analysis uses a truncated measure of size. Table 3 (Model 5) also presents the results using a continu-

TABLE 3
Regression Results

	Dependent Variable: Radicalness of Innovation				
	Model 1 β (|t-Value|)	**Model 2** β (|t-Value|)	**Model 3** β (|t-Value|)	**Model 4** β (|t-Value|)	**Model 5** β (|t-Value|)
Incumbent	−.21 (1.7)	−.41 (1.3)	−.19 (.6)	−.31 (1.0)	−.27 (.4)
Large	—	—	−.85 (1.6)	−1.05 (1.9)	—
Employees	—	—	—	—	−4.06 (2.1)
US	—	—	—	−.51 (1.7)	−1.28 (1.0)
Year	—	−.47 (2.7)	−.56 (3.2)	−.92 (3.6)	−.96 (1.5)
Year × Incumbent	—	.43 (1.1)	.00 (.0)	.14 (.3)	.29 (.3)
Year × Large	—	—	1.17 (2.0)	1.45 (2.3)	—
Year × US	—	—	—	.59 (1.9)	1.42 (1.3)
Year × Employee	—	—	—	—	4.37 (2.2)
Adjusted R^2	3%	12%	16%	19%	5%

ous measure of size—number of employees. Note that the pattern of results is similar across the two measures, despite different sample sizes. These results indicate that the effects of firm size are strong and robust. We observe them in the categorical analyses, the bivariate regression, and the multivariate analysis with two alternative measures.

Additional Analyses

Our research design and results raise three issues that merit further discussion: relevant population, definition of firm size, and definition of radical innovator.

Relevant Population

When analyzing the sources of radical innovations, we contrast innovative large firms and incumbents to innovative small firms and outsiders, respectively. However, to interpret these figures fully, we must also contrast the proportion of small, medium, and large firms in the sample with the proportion of small, medium, and large firms in the overall manufacturing economy. Similarly, we must contrast the proportion of incumbents and outsiders in the sample with the relevant proportions in the overall manufacturing economy. For example, our categorical analyses indicate that small, medium, and large firms account for 47%, 11%, and 42%, respectively, of the radical innovations in the sample. But if small, medium, and large firms also account for 47%, 11%, and 42% of the manufacturing economy, our results would only indicate that firms in each size class contribute radical innovations in a number proportionate to their number in the population.

To contrast these proportions, we sought to collect data on the number of small, medium, and large firms in the manufacturing economy. The U.S. Census Bureau has reported this information as part of its *Census of Manufactures* starting in 1909. Thus, we are able to include the information for all U.S. innovations introduced after 1909. We also include similar information on seven of the eight Japanese innovations and one each of the Dutch and German innovations (through their respective *Census of Manufactures*).

An analysis of the U.S. data indicates that during our period of analysis, the proportion of large firms (i.e., those with 2500 or more employees) never exceeds .25% of the total number of firms in the U.S. manufacturing economy. The proportion of large firms in the U.S. manufacturing economy ranges from a high of .22% (in 1967) to a low of .04% (in 1909). The proportion of medium (i.e., 100–2499 employees) firms in the U.S. manufacturing economy ranges from a high of 10.82% (in 1972) to a low of 5.27% (in 1909), whereas the proportion of small firms ranges from a high of 94.69% (in 1909) to a low of 88.99% (in 1972). Simply from a probabilistic sense, medium and (especially) small firms would be expected to contribute a much larger number of innovations than large firms. But this is not the case. Large firms account for a substantially larger proportion of radical innovations relative to their number in the economy. The data from the non-U.S. sources also provide similarly large contrasts.

A similar argument can be made for the proportion of incumbent firms in the economy, relative to the proportion of innovations accounted for by them. The number of incumbents in any particular product class is likely to be many times smaller than the number of nonincumbents in the economy, simply because the economy consists of many such product classes. Yet incumbents account for almost half the number of radical innovations overall in the product classes studied here and about three-fourths of the radical innovations introduced after World War II. As do large firms, incumbents account for a disproportionately larger number of radical innovations relative to their number in the economy.

Definition of Firm Size

In the categorical analyses, we define a firm as small if it had fewer than 100 employees, medium if it had between 100 and 2499 employees, and large if it had 2500 or more employees. What happens if we select different cutoff points for firm size? Table 4 presents the results of a sensitivity analysis reflecting different cutoffs for small and medium firms. The cutoff points are based on the categories used by the U.S. Census Bureau in classifying the size of firms. Because the 2500 or more employees category is already the U.S. Census Bureau's category of largest firms in the manufacturing economy, we do not vary our definition of large firms.

As Table 4 indicates, there is a sharp decrease in the proportion of innovations from medium firms as the lower cutoff for medium firms increases from 20 employees to 100 employees. Beyond this point, the decreases are much less steep. Thus the cutoff point of 100 employees captures most of the innovative small firms in our sample.

Definition of Radical Innovator

Recall that we define a radical innovator as the firm that first commercializes a radical innovation. This definition excludes other early entrants in the product category, even though these entrants may introduce their products soon after the first entrant. What would the size and incumbency profile of such early entrants be?

Several researchers argue that incumbents would be the most likely to enter markets early (e.g., Ali 1994; Conner 1988; see also Nault and Vandenbosch 1996). They suggest that because of fears of cannibalization, many established firms refrain from commercializing their innovations as long as possible—perhaps until outsiders introduce the radically innovative products to the market. Thus, such firms do not seek to be the first to commercialize the radically new technology. But when products based on the new technology enter the market, incumbents rush in with their own equivalent products. They capitalize on their marketing and technology resources to take full advantage of their slightly later entry.

TABLE 4
Percentage of Innovations by Small and Medium-Sized Firms, Based on Definition of Small Firm

Definition of Small Firm	% Small	% Medium
> 20 employees	36%	23%
> 100 employees	47%	11%
> 500 employees	49%	9%
> 1000 employees	55%	4%
> 2500 employees	58%	0%

If this reasoning holds, our results would underrepresent the innovative performance of large firms and incumbents. After a new entrant commercializes a radically new product, many large firms and incumbents may also enter with similar products. Thus, large firms and incumbents may be even more innovative than our results indicate.

Discussion

This sample of consumer durables and office products shows that small firms and nonincumbents are slightly more likely to introduce radical product innovations than large firms and incumbents. Yet in recent years the pattern has changed dramatically. Recently, large firms and incumbents are significantly more likely to introduce radical innovations than small firms and nonincumbents. Furthermore, the innovations introduced by recent large firms and incumbents are no less radical than those introduced by small firms and nonincumbents. Thus, our results indicate that the incumbent's curse may apply, but to an older economic period. The curse may apply even less to countries outside the United States. In our limited sample, although the United States accounts for a simple majority of radical innovations, it does not account for an overwhelming proportion of them. Also, its share of radical innovations has not changed much over time periods.

In the hope of motivating further research on some of the counterintuitive findings from this study, we highlight two important issues raised by this study: lessons from large or incumbent innovators and opportunity for nonincumbents and small firms. The factors we highlight could also provide directions to current managers in similar innovation contexts. Because we do not have precise measures for these factors, this discussion is exploratory in nature.

Lessons from Large or Incumbent Innovators

Contrary to conventional wisdom, our research indicates that today's incumbents and large firms account for many radical innovations, especially since World War II. This finding dovetails with recent research that suggests that a considerable proportion of dominant firms in today's high-tech industries are willing to cannibalize their own past investments to introduce radical product innovations (Chandy and Tellis 1998). Yet not all incumbents and large firms are able or willing to make the transition to the new technology that is embodied in a radical product innovation. For example, in the market for watches, Societe Suisse pour I'Industrie Horlogere, a dominant mechanical watch producer, did not introduce quartz watches until late in their life cycle. By that time, its market position had been considerably weakened (Glasmeier 1991). However, Hattori-Seiko, another dominant producer of mechanical watches, was the first firm to introduce the analog quartz watch. Still another incumbent, the Hamilton Company, was the first to introduce the digital quartz watch. Why do some dominant firms maintain their innovative vigor despite the supposed liabilities of size and incumbency? This question has strong implications for large and incumbent firms that are currently contemplating radical innovations. Although we do not have conclusive evidence on this question, our historical research suggests two possible causes: dynamic organizational climates and strong technological capability.

Dynamic organizational climates. One reason for the innovation performance of some large, incumbent firms may be that such firms have organizational climates that resemble those of small firms. After World War II, fundamental changes occurred in the structure of many large, incumbent firms (Chandler 1990). Many of these firms created autonomous business units with significant authority over their lines of business and separate profit and loss responsibilities (Chandler 1956; Williamson 1975). The benefits of this organizational structure quickly became popular, so that by the mid-1950s, the practice of decentralization became widespread among large U.S. corporations (Chandler 1956, p. 111). As discussed previously, growth in size and complexity can lead to bureaucratic inertia that dampens the innovativeness of firms. In contrast, decentralization leads to smaller, autonomous organizational units that enable the large firm to respond to and create technological innovations while maintaining its resource advantages.

Decentralization may also have fostered internal competition: incumbent and nonincumbent business units within a large incumbent that compete for markets (Chandy and Tellis 1998; Forrester 1965). As a result, even though a particular business unit may have a strong stake in the existing product category, other business units within the incumbent firm, which do not derive many rents from the existing products, may not be as committed to these products. These latter business units also do not have the established routines that may constrain the actions of the incumbent units. They are therefore likely to support radical product innovations, because these products represent considerable opportunity but relatively little threat to their existing lines of business. The firm as a whole is thus supportive of radical product innovations despite its incumbency and even in the absence of external competitors.

The history of the quartz watch provides a good illustration of the effects of autonomy and internal competition on radical innovation. The first quartz watch was commercialized by Hattori-Seiko in 1969. This product resulted from a "technology contest" between the company's Suwa Seikosha and Daina Seikosha divisions (*BusinessWeek* 1978). The organization was structured such that these two divisions maintained separate research, design, and manufacturing facilities. Hattori's central office informed both divisions of its anticipated product needs. These divisions then independently developed product prototypes from which Hattori chose models to mass-produce for the market (Hoff 1985).

Technological capability. Our theoretical discussion highlights the role of technological capabilities in influencing radical innovation by large firms. Incumbent firms with strong technological capability are likely to become aware of scientific breakthroughs at an early stage and are in a position to pursue those that could lead to radical product innovations. The General Electric Company's historical emphasis on basic research provides a rich illustration of the role of technological capability in radical innovation.

The General Electric Company established its Research Laboratory in 1900 (Birr 1957; Bright 1949). Scientists at the laboratory published actively in leading scientific jour-

nals. The lab was insulated from immediate business demands and staffed by people with advanced scientific training (Reich 1985). Willis Whitney, its founding director, was elected to serve as president of the American Chemical Society in 1909, and Irving Langmuir, a scientist at General Electric, won the 1932 Nobel Prize for chemistry for work conducted at the firm between 1912 and 1915 (Brown and Weeks 1952; Wise 1985). The research conducted at the laboratory played an important role in the company's ability to develop and commercialize fluorescent lamps even while it was the dominant player in incandescent lamps. Few other small firms at that time had the technological capability to introduce these new products.

Note that an emphasis on basic research alone yields meager payoffs if firms do not also have an organization that is suited to developing and marketing commercially viable innovations. Although basic research may provide a source of ideas in the early stages of radical product development, a dynamic organizational climate is critical in the commercialization of radically new products. Xerox's failure to commercialize the many innovations emerging from its Palo Alto Research Center is a classic illustration of this point (Smith and Alexander 1988).

Opportunity for Nonincumbents and Smaller Firms

Successful development of a radical innovation today can require huge expenditures in R&D. The reason is that advances in technology make new products far more complex than they were a century ago, or even a few decades ago. At the same time, the noise from competing advertising and promotion for myriad old and new brands raises a formidable barrier for any new entrant. Thus, the image of tinkerer–innovators fashioning radical innovations in their small garages may not always be true. However, our research indicates that even in these noisy markets, small firms or nonincumbents introduce radical innovation.

How can a firm with relatively few resources succeed in a process that presumably requires large outlays in R&D? The case histories of innovative small and medium firms in our sample provide some clues.

One option is to make use of spillovers from research conducted at other, resource-rich firms. Some small firms focus on the development part of the R&D process, relying on off-the-shelf components from other industries to introduce technologies that are radically new in a different industry. For example, the first personal computer was developed and introduced by Ed Roberts, a practicing physician and founder of Micro Instrumentation and Telemetry Systems, who incorporated many components (such as integrated circuits) that were the result of basic research by other companies. However, such a business model leaves the firm vulnerable to imitators. Success may be hard to sustain unless there is a steady stream of ever improving off-the-shelf components in the industry or the product takes off quickly enough to provide the firm with the resources to build its own technological base.

A different (and perhaps more sustainable) innovation model is that which the Haloid Corporation followed in the steps leading to the introduction of the plain paper copier (see Dessauer 1971; *Fortune* 1949; Jewekes, Sawers, and Stillerman 1969). The idea for electrostatic copying came from Chester Carlson, an inventor, who also developed a primitive prototype of the product. After failing to interest any of the large incumbents in the photographic copier business (the previous product generation), Carlson finally succeeded in obtaining the support of the Battelle Memorial Institute, then the world's largest nonprofit research organization. The managers at the Haloid Corporation, a medium-sized incumbent in the photographic copier industry, saw a description of the electrostatic technology in the April 1945 issue of *Kodak's Monthly Abstract Bulletin*. In 1946, after other large incumbents (including Kodak) had turned down the opportunity to license the technology and participate in its development, Haloid signed a contract with Battelle to partly fund further development of the technology. Although Haloid's $25,000 investment represented a significant proportion of its $138,000 net income in 1947, this and other subsequent contributions by Haloid were insufficient to fund the development of a commercially viable copier fully. It was through Battelle's strength in basic research and, in 1948, a $120,000 research grant from the United States Signal Corps that the commercial Xerographic copier became possible.

Thus Haloid, a medium-sized incumbent with limited technological capability, relied on the resources of a strong research organization and funding from the federal government to develop its radically new product. Over time, Haloid (which changed its name to Xerox after the new product became an important revenue source) bought many of the key Xerography patents from Battelle. This patent protection, together with further research on its own part, enabled the firm to protect its market position against later entrants.

In summary, small nonincumbents have at least two options in developing and introducing radical product innovations: (1) use research spillovers from more resource-rich firms and (2) actively partner with organizations with technological capabilities and financial resources they do not have themselves. Of these two options, the second may be a less imitable and more sustainable option in many industries.

Limitations

Although the historical method allows for unique and fairly objective insights on radical innovation, it also imposes constraints on the scope of our study. These limitations highlight the need for additional research on the topic. First, the labor-intensive nature of the study limited our sample to a small number of innovations (64) in a limited number of categories (49) in only two classes of goods—office products and consumer durables. Furthermore, our list of innovations does not exhaustively cover all the significant innovations in the two product classes we study. Therefore, generalizations, especially to other classes, must be made with caution. Second, our study focuses on relatively successful innovations. Including failed or less successful innovations in the sample may lead to additional insights. Third, we have information on only external characteristics of the firm, such as incum-

bency, size, and country of operation.[3] Further research could gather information on internal characteristics of such firms to test some of the organizational propositions suggested previously.

Conclusion

Inactive. Incompetent. Arrogant. These are some of the terms researchers use to describe how incumbent and large firms have fared in radical product innovation (Ghemawat 1991; Henderson 1993; Utterback 1994). Many academics and practitioners accept such terms as appropriate descriptors of these firms. Radical innovation is likened to a game of chutes and ladders, in which incumbents abruptly lose their positions to upstart outsiders (see Utterback 1994, p. 189).

But do these terms reflect reality? Events in which the mighty are humbled and the little guy finishes first are likely to be more eye-catching than are those in which the mighty remain mighty. Unless a large, nonconvenience sample is used, observers may miss the latter, less salient events. For this reason, we research a relatively large cross-section of radical innovations selected on certain explicit criteria.

Our research of innovations in the consumer durables and office product categories suggests that incumbents or large firms are not necessarily doomed to obsolescence by nimble outsiders. In particular, our research leads to the following main conclusions regarding radical innovations in these industries:

- Over a 150-year period, small firms and nonincumbents introduce slightly more radical product innovations than large firms and incumbents.
- However, the sources of radical product innovations change substantially after World War II. Large firms and incumbents introduce a majority of radical product innovations over this time period. Thus, the incumbent's curse is less prevalent in recent times.
- The United States accounts for almost two-thirds of radical product innovations in the sample, and Western Europe accounts for most of the remaining. Japan accounts for only a few innovations, but those have been entirely in recent years. The distribution of radical innovations between the United States and other nations remains steady over time.
- Small firms and outsiders account for many more innovations in the United States than they do in other countries. Thus, the incumbent's curse is less prevalent in Western Europe and Japan than in the United States.

Dynamic organizational structures and strong technological capability may keep large, incumbent organizations nimble and innovative, but many managers and academics have tended to focus on inertia-prone incumbents (e.g., Ghemawat 1991; Henderson 1993; Henderson and Clark 1990; Scherer 1980; Utterback 1994; for recent exceptions, see Christensen 1997; Tushman and O'Reilly 1997). In focusing on the Remingtons and Underwoods of the world, let us not forget the examples of General Electric (in fluorescent lamps), Philips (in compact disc players), and Seiko (in analog quartz watches). Despite their large size and incumbency in the incandescent lamp, tape recorder, and mechanical watch industries, these firms were the first to introduce radical innovations that changed the landscapes of these industries. Perhaps the incumbent's curse is not as inevitable as it seems.

[3]We also checked if innovations introduced by incumbents and large firms were the result of their acquisitions of innovative small firms and nonincumbents. We found that such acquisition-based innovations are rare in our sample. We further checked if, conversely, innovations introduced by nonincumbents and small firms were the result of technology developed within incumbents and large firms, but commercialized by nonincumbents and small firms. Such innovations are also rare in our sample.

APPENDIX
Full List of Significant Innovations in Sample

Radical Product Innovation	First Commercialized by	Year of Commercialization
Air conditioner	Buffalo Forge Company	1902
AM radio	Wireless Telegraph and Signal Co.	1897
Analog answering machine	American Telegraphone Co.	1903
Analog quartz watch	Seiko	1969
Autofocus color celluloid roll camera	Konishiroku Photo Industry	1977
Black-and-white celluloid roll camera	Eastman Dry Plate & Film Co.	1889
Ballpoint pen	Eterpen Co.	1943
Camcorder	Sony	1983
Cassette tape player	Phillips	1964
Compact disc player	Phillips and Sony	1979
Cellular telephone	Motorola	1983
Color celluloid roll camera	Lumiere Brothers	1907
Desktop computer	MITS	1975
Digital answering machine	Sharp	1988
Digital camera	Sony	1983
Digital high-definition television	Panasonic	1998
Digital quartz watch	Hamilton Co.	1972
Digital video disc (DVD) player	Toshiba	1997
Disposable shaver	Bic Corp.	1975
Dot-matrix printer	Remington Rand	1953

APPENDIX
Continued

Radical Product Innovation	First Commercialized by	Year of Commercialization
Dry ink (electrostatic) copier	Haloid Co.	1951
Electric blanket	General Electric	1936
Electric blender	Waring Blender Co.	1937
Electric can opener	Udico Corporation	1956
Electric clothes washer	Hurley Machine Co.	1908
Electric dishwasher	Willard and Forrest Walker	1913
Electric fan	Crocker & Curtis Co.	1882
Electric garbage disposer	General Electric	1934
Electric percolator	Landers, Frary, & Clark	1908
Electric shaver	Schick Inc.	1931
Electric toaster	General Electric	1908
Electric typewriter	Blickensderfer Co.	1902
Electrochemical fax	Caselli	1865
Electronic black-and-white television	Allen B. Dumont Laboratories	1939
Electronic color television	RCA	1954
Electronic desktop calculator	Sharp	1964
Electronic pocket calculator	Bowmar	1971
Electronic watch	Bulova	1960
Fluorescent lamp	General Electric	1938
FM Radio	General Electric	1937
Incandescent vacuum lamp	Edison Electric Light Co.	1880
Instant camera	Dubroni	1864
Internal combustion automobile (petrol)	Carl Benz	1888
Laptop computer	Tandy Corp.	1983
Laser disc player	Phillips	1978
Laser printer	IBM	1976
Magnetic tape player (reel-to-reel)	AEG	1934
Mechanical black-and-white television	Television Ltd.	1930
Mechanical color television	CBS–Columbia	1951
Mechanical dishwasher	Josephine Cochrane	1889
Mechanical refrigerator	John Gorrie	1851
Mechanical typewriter	Sholes/Densmore	1872
Mechanical vacuum cleaner	Vacuum Cleaning Co.	1901
Microwave oven	Raytheon	1953
Mini-disc player	Sony	1992
Palm computer	Amstrad	1993
Phonograph	Edison Speaking Phonograph Co.	1878
Portable computer	Osborne Computer	1981
Safety shaver with disposable blades	American Safety Razor Co.	1903
Single-player video game	Nutting Associates	1971
Photoelectric scanning fax	Arthur Korn	1907
Telephone set with cord	Bell Telephone Co.	1876
Videocassette recorder	Ampex Corp.	1956
Voice mail	ECS	1980

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