Why Are Some Organizations More Competitive Than Others? Evidence from a Changing Global Market

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In this paper, we question the idea that large organizations have advantages that make them particularly potent rivals. We argue that the ability of large organizations to ameliorate competitive constraints insulates them from an important source of organizational development and protects them from being selected out if unfit. Consequently, we predict that although large organizations are likely to do well in technology contests, they also are likely to become weak competitors over time compared with small organizations. We specify this prediction in an explicit model of "Red Queen" competition, in which exposure to competition makes organizations both more viable and stronger competitors. We find support for our ideas in empirical estimates of the model obtained using data on hard disk drive manufacturers. Large organizations led the technology race in this market yet failed to develop into stronger competitors through Red Queen competition compared with their small counterparts. We also find evidence that all organizations in this market generated increasingly global competition, regardless of the competitiveness of their home markets. In these ways, our model elucidates important reasons why some organizations are stronger competitors and reveals how strategies that isolate organizations from competition may backfire.●

Various organizational theories regard competition to be a central force shaping, and generated by, organizations. In contrast to the field of economics, in which competition is characterized as a property of markets or market segments, organization theories typically highlight the fact that organizations themselves differ in their competitiveness. For instance, resource dependence and network researchers have revealed important differences among organizations in terms of their competitive positions (Pfeffer and Salancik, 1978; Burt, 1992; Podolny and Stuart, 1995). At the interface of organization theory and strategic management, central importance is given to organization-specific differences in capabilities that make them more or less competitive (Barney and Zajac, 1994). Similarly, organizational ecology research often allows for competitive differences among forms of organizations (Carroll and Hannan, 2000). Through such research, we have made considerable progress in addressing the question so often asked in casual discussions about business: Why are some organizations more competitive than others?

Perhaps the single most important characteristic determining an organization's competitiveness is size, because various sources of competitive advantage are known to co-vary with size. Institutional economists have long argued that with organizational size comes the opportunity to exploit economic and technical advantages through the rationalization of production (Simon, 1945; Chandler, 1977), innovation (Galbraith, 1967), and transactions (Williamson, 1985). The strengths of large organizations also are featured in sociological research. Large, established organizations affect their environments (Selznick, 1949), shaping other organizations (DiMaggio and Powell, 1983) and reducing competitive threats (Pfeffer and Salancik, 1978). Similarly, scholars have noted the political-economic importance of large organizations as "consequen-

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tial actors" that affect state policies (Laumann and Knoke, 1987), that are favored by their connections to elite networks (Mizruchi, 1982; Mintz and Schwartz, 1985; Palmer and Barber, 2001), and that are rewarded for being prestigious (Podolny, 1993). In this light, it is not surprising that studies reveal an overwhelming survival advantage for large organizations (Carroll and Hannan, 2000).

Although the competitive advantages of large organizations are well understood, these very advantages, when viewed dynamically, can be seen to make larger organizations weaker competitors in the long run. To frame our arguments, we draw a distinction between two distinct logics of competition prevalent in the literature: competition as contest and competition as constraint. Understood as a contest, competition favors organizations that can remain up to date. In many contexts, such as in changing, global industries, this logic highlights the advantages of large, technically sophisticated organizations that can stay on the cutting edge. By contrast, understood as a constraint, competition stimulates organizational development and selects out weak competitors, further intensifying competition in a self-exciting process known as the "Red Queen." Under this second logic, the very strengths that make large organizations good at managing the constraints of competition in the short run may backfire in the long run, insulating them from the Red Queen process and so rendering them less competitive as a result. Consequently, the answer to the question "Why are some organizations stronger competitors?" hinges on which logic of competition guides one's analysis. Our purpose in this study is to show that this difference is important theoretically and to demonstrate this difference empirically in a study of the global hard disk drive market.

TWO LOGICS OF DYNAMIC COMPETITION

Many theories include some logic of competition among organizations. Two such logics appear across various organizationally focused treatments of the subject and are interesting because they have very different dynamic implications. Some theories depict competition as a race or contest among organizations that strive to surpass one another in different ways. These theories emphasize that in any given organizational context, ongoing changes in products, services, and technologies are typical and often are the means through which organizations compete. By contrast, other theories conceive of competition as a constraint on organizations, such as when price competition disciplines an organization to lower costs or improve quality at a given cost. Each of these logics has dynamic implications for organizational size.

Competition as Contest

Several theories conceive of competition among organizations, at least implicitly, as a race-like contest in which organizations are rewarded for remaining up to date, often with reference to technology or product-development races. Perhaps the earliest theoretical treatment of such competition comes from evolutionary economics, which elaborates a rational-choice approach to this dynamic problem. The challenge from an evolutionary-economics perspective is to understand the incentive properties of the contest: Is it rational to invest in being first? Schumpeter's (1934, 1950) often-cited answer is that competition renders investments in innovation irrational, unless by being first one can enjoy a period of monopoly-like returns that (may) make innovation pay off (referred to as "entrepreneurial rents"). As Nelson and Winter (1982) noted, an organization in a permanent monopoly position would not have an incentive to disturb this status quo by innovating—the so-called "lazy monopolist" problem (see also Jewkes, Sawers, and Stillerman, 1969; Kamien and Schwartz, 1982). Similarly, political analyses of organizational behavior reveal that internal organizational politics might rationally lead organizations to resist innovation (see Schön, 1967; Zald, 1970; Frost and Egri, 1991). But as long as competition is likely to materialize eventually (Fudenberg and Tirole, 1985), Schumpeter's story holds in that the promise of a temporary monopoly provides an incentive to invest in risky innovation. Because such a monopoly position typically corresponds to larger organizational size, the implication is that size enhances an organization's chances of racing well.

Tempering the Schumpeterian hypothesis, other researchers have argued or demonstrated that (typically large) incumbent organizations sometimes resist radical technological changes, preferring instead to engage in innovations that build on the status quo (Menzel, 1960; Normann, 1971; Tushman and Anderson, 1986; Dosi, 1988; Henderson and Clark, 1990; Banbury and Mitchell, 1995; Christensen and Bower, 1996). In some instances, radical technological innovations require fundamental organizational-structural transformations, which in turn are likely to be resisted, especially in large, complex organizations (Hannan and Freeman, 1984; Carroll and Teo, 1996; D'Aunno, Tucci, and Alexander, 2000; Hannan, Pólos, and Carroll, 2003a, 2003b). Keeping in mind the problem of structural inertia, then, suggests that the role of organizational size in technological races depends on whether the changes build on the status quo: with the exception of radical changes that destroy incumbent advantages, large organizations tend to race well along established, programmatic technological trajectories.

Schumpeter's argument has motivated much of the empirical literature on technology diffusion, in which early adoption of a technology is claimed to provide larger benefits than later adoption, among survivors, that is (see Mansfield, 1961, 1968; Rogers, 1995). Some of the studies in this vein look at the global disk drive industry, using part of the data we analyze here. Christensen, Suarez, and Utterback (1998) found that disk drive manufacturers are more likely to survive if they remain up to date technologically. Lerner's (1997) disk drive study showed that organizations running just behind the technological leader have been most likely to move up in the race, reinforcing the importance of the technological-contest perspective in this industry. Regarding organizational size, Lerner found that larger disk drive manufacturers are especially likely to adopt new technologies, a finding consistent with Schumpeter's ideas and with other work in the technology diffusion literature (see Mansfield, 1963a; Rogers, 1995; Swamidass, 2003).

Various other theories have focused on differences among organizations in their ability to innovate (Cohen and Levinthal, 1990; Iansiti and Clark, 1994; Teece, Pisano, and Shuen, 1997). The classic rendering of this argument also is by Schumpeter (1950), who argued that large organizations have the capability to bring new ideas to market and the long-term time horizons to make this rational. Investigating this claim, Mansfield (1963b) found that the largest firms are most likely to account for a large part of an industry's successful innovations. Nelson and Winter (1982) added the possibility that organizations may come to routinize the innovation process and, in so doing, rationalize the timing of relatively rapid product introductions. They concluded that this rationalization favors large firms (see also Cohen and Klepper, 1996; Klepper and Simons, 2000). Similarly, Galbraith (1967) argued that large organizations were the innovative engines in the U.S. economy during much of the twentieth century because these organizations were able to manage the innovation process. Chandler (1962) emphasized the structural advantages of large organizations as engines of innovation, in arguments that drew on the Carnegie School (Barnard, 1948; Simon, 1945), which depicted complex organizations as especially effective mechanisms for coordinating and controlling activities entailing multiple time horizons. Cyert and March (1963) noted that with increasing size, organizations were able to build into their procedures mechanisms for innovation and improvement. More recently, empirical research supports this idea, finding that larger organizations are more likely to make relatively programmatic changes of many kinds (Haveman, 1992, 1993; Minkoff, 1999; Greve, 1999; Haveman and Nonnemaker, 2000; Sørensen and Stuart, 2000; Palmer and Barber, 2001; Henisz and Delios, 2001; Khessina, 2002; Chuang and Baum, 2003). Overall, the picture painted by these various literatures features large organizations as particularly adept at adaptive change in technology and product races, at least when the changes involved are incremental or programmed (Jewkes, Sawers, and Stillerman, 1969; Abernathy and Utterback, 1978).

Similar arguments on the advantage of large scale also feature prominently in the international business literature. Globalization has been viewed as an outcome of oligopolistic competition, whereby the largest firms in concentrated industries drive foreign investment through a follow-the-leader process (Knickerbocker, 1973; Yu and Ito, 1988; Li and Guisinger, 1992). Such competition is seen as the norm across industries and is reflected in international business textbooks (Vernon, Wells, and Rangan, 1996: 55). The leading theories in international business similarly underscore the advantages of scale in global competition. Dunning's (1993) "eclectic theory" of the multinational corporation (MNC), for example, emphasizes that MNCs require certain "ownership advantages" over purely domestic firms to stay ahead in global markets (see also Hymer, 1960). In addition to its intangible assets, the scale at which an MNC operates is a central ownership advantage and provides economies in sourcing, production, research and development (R&D), advertising, and administration. Both Porter's (1990) analysis of how firms sustain advantages in international competition and Chandler's (1990) comparative history of the expansion of the modern corporation comport with this view.

The racing metaphor is widely used in analyses of global competition. Time-to-market pressures are severe in a range of global industries, including semiconductors, hard disk drives, and some segments of the clothing industry (Abernathy et al., 1999; McKendrick, Doner, and Haggard, 2000; Leachman and Leachman, 2004). Faster cycle times also affect the R&D strategies of global firms. In a number of industrial contexts, evolutions in product and process technologies are occurring at such a rapid pace that many firms have established foreign R&D sites to accelerate the generation and acquisition of new knowledge (Kummerle, 1999; Murtha, Lenway, and Hart, 2001; Le Bas and Sierra, 2002). Others have emphasized the benefits to moving early in establishing an international network, which can lead to reputation, scale, and learning advantages. Firms that move quickly into new segments can displace international leaders that are slow to exploit the structural changes (e.g., Porter, 1990). In sum, there is widespread consensus that large organizations with global reach are thereby advantaged when competition takes on the qualities of a technology or product race.

From Competitive Constraints to the Red Queen

Sociological theories typically regard competition not so much as a race as a powerful constraint operating on organizations. Following Thompson (1967), resource dependence theory places special emphasis on competition as a primary source of uncertainty that constrains organizations, their structures, and their actions (Pfeffer and Salancik, 1978). More recent organization theories make reference to Simmel (1955), whose observation that competition constrains actors to work toward the benefit of others forms the basis of ecological and network theories of competition alike (Hannan and Freeman, 1989; Burt, 1992). In organizational ecology, competition is thought to play an especially important role in selecting for or against various forms of organizations depending on whether they conform to environmental requirements, both technical and institutional (Carroll and Hannan, 2000). The related variation-selection-retention framework also portrays competition as a constraining force driving selection among organizations (Aldrich, 1999). Research on network structures among organizations, similarly, regards competition as a primary constraint shaping the actions and fates of organizations (Burt, 1987).

Global competition also can be understood as a constraint, one that is shaped by powerful institutional forces (Ghoshal and Westney, 1993). While the behaviors and structures of firms generally reflect the practices and business models of their home markets, firms engaged in global competition are subject to quite different institutional environments (Rosenzweig and Singh, 1991; Kostova and Zaheer, 1999). All states influence firm behaviors through coercive and normative pressures, but states vary in their policies toward competition, labor markets, corporate governance, and the like (Lindblom, 1977; DiMaggio and Powell, 1983; DiMaggio, 1990; Westney, 1993; Hall and Soskice, 2001). Thus, states constitute powerful institutional agents shaping how global competition affects firms.

By and large, research has examined competitive constraints as a force to be reckoned with at a given point in time. But what happens, over time, when an organization responds to competitive constraints? This response, in turn, represents a further constraint on the organization's rivals; in fact, a defining characteristic of competition is that one organization's solution becomes its rivals' problem. The resulting increased constraints, again in turn, are likely to trigger responses among rivals, again intensifying competitive constraints on the first organization, and so on. This escalating system of reciprocal causality, dubbed "Red Queen" competition by the biologist Van Valen (1973), has been found to strongly affect rates of founding, growth, and failure among organizations (Barnett and Hansen, 1996; Barnett and Sorenson, 2002).[1] Our aim here is to see how organizations shape this coevolutionary process in unintended ways as they become large and strategically formidable.

Among organizations, Red Queen evolution can come about both through organizational learning and by natural selection. To consider the role played by organizational learning, we build on the model developed by March and his colleagues (March, 1988, 1994) and several of the basic assumptions in that model. First, assume that people in organizations "satisfice" when confronted with the need to make decisions (March and Simon, 1958). A so-called problemistic search for alternatives is triggered when performance falls below some aspiration level and is continued until performance is considered satisfactory (Cyert and March, 1963). This search proceeds sequentially, presumably, stopping at the first satisfactory solution, rather than continuing until the best possible solution is found. Search also is assumed to remain "local," restricted to solutions that are only incrementally different from current practice, and only moving to more distant possible solutions when no satisfactory local solutions are found (Levinthal and March, 1981). In this search process, learning through imitation might also occur (Mezias and Lant, 1994). By these assumptions, organizations adapt incrementally in an effort to maintain at least a minimum, satisfactory level of performance.

Now consider a population of competing organizations, each behaving according to the satisficing model. In this context, the organization-learning process does not end once a given organization improves its performance by adopting some new practice. Instead, the innovating organization, by improving its own performance, now has increased the intensity of competition felt by the other organizations in the population. At some point, this increased competitive intensity may reduce performance in other organizations enough to trigger search in these organizations. As each of these organizations finds solutions that restore its performance, in turn, competition again increases for the rest of the population, again triggering the search for improvements. So learning and compe-

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In an influential article, Van Valen (1973) invoked the Red Queen metaphor to describe the coevolutionary process in which viability and competitiveness each strengthen the other. Stronger competitors increase selection pressures, yielding more fit survivors, which in turn generate stronger competition and so on in a self-accelerating process of reciprocal causality. The Red Queen refers to a character from Lewis Carroll's *Through the Looking Glass*, to whom Alice comments that although Alice is running, she does not appear to be moving. The Red Queen responds that in a fast-moving world "it takes all the running you can do, to keep in the same place." As this image suggests, the relative positions of players in Red Queen competition may be stable, even though the race is producing absolute change for the system as a whole.

tition are linked causally, each accelerating the other in the ongoing process of Red Queen evolution.

In addition, aspiration levels might in fact change endogenously as part of Red Queen evolution. We know that aspiration levels among individuals adjust rapidly (Lant, 1992) and that often they are defined by social comparison in competitions that hinge on the relative positions of players (Herriott, Levinthal, and March, 1985; Frank and Cook, 1995). If organizational aspiration levels are influenced by comparisons with their competitors, as is often the case, then we might see aspirations ratcheting upward among organizations involved in Red Queen evolution. In this way, making aspiration levels endogenous is likely to maintain the process of Red Queen evolution over time.

Red Queen evolution can also result purely through natural selection among organizations. Assume that organizations differ with respect to their fitnesses and that these differences remained fixed over time. Assume also that competition culls from organizations according to these fitness levels, so that as competition intensifies, the less fit organizations are selected out (see Levinthal, 1997). Among surviving organizations, then, those that have faced very little prior competition would include both fit and unfit organizations. By contrast, fitness levels will generally be higher among organizations that have survived considerable prior competition. Both through selection and learning, then, the process of Red Queen evolution implies that organizations are both more viable, and more competitive, the more that they have faced competition in the past.

The relative stability of players in Red Queen evolution results from the mutually reinforcing increases in each organization's viability and the potency of each organization's rivals. Our model of Red Queen evolution separates the two parts of this dynamic, distinguishing between the organizational and the ecological implications of exposure to competition (see Barnett, 1997):

$$r_j(t) = r_j(t)^* \exp[\beta E_j + \alpha(\Sigma_{k \neq j} E_k)],$$

where $r_j(t)$ is the failure rate for organization j; $r_j(t)^*$ is j's baseline failure rate as a function of its age t, its current competitive context, and other observables; α and β are coefficients to be estimated; and E refers to the cumulative prior exposure to competition of organization j or its current rivals k, measured in organization-years so that, for instance, if organization j competed with four rivals during each of its first and second years of life, it would have a value of $E_j = 8$ during its third year of life. If prior exposure to competition increases organizational viability, as implied by Red Queen evolution, then we can expect $\beta < 0$. Meanwhile, the ecological consequences of Red Queen evolution materialize if $\alpha > 0$, where j's rivals' prior exposure to competition increases their competitive strength. Whether the twin consequences of Red Queen evolution are offsetting, then, is treated by our model as an empirical question that depends on the exact magnitudes of α and β as well as the observed values of E for any given organization and its rivals.

Organizational Size and Red Queen Evolution

Thus far we have assumed that an organization responds to competitive constraints by searching for improvements, but for large organizations there is an alternative to the ongoing process of Red Queen evolution. Organizations that have attained positional advantage—market position, social prestige, centrality in social networks, political power, and the like—may attenuate or even eliminate the threat of competition from others. In fact, the modern field of strategic management in business education exists primarily to investigate and teach methods for finding safety from the forces of competition, stimulated in large part by Porter's (1980) application of industrial organization economics to the problem of competitive constraints. In sociology, similar ideas appear in Selznick's (1949) early work on cooptation, featuring large organizations of political importance that absorb interests and avert threats. More recently, researchers have found large organizations to be especially capable of staking out and defending their strategic position (Haveman, 1993; Barnett, Greve, and Park, 1994) and of maintaining interlocks with other important actors (Kono et al., 1998). Yet precisely because large organizations are capable of averting competitive constraints, they may be less susceptible to the Red Queen process.

When faced, nonetheless, with competitive constraints, large organizations also have distinct advantages in coping with these pressures. Large organizations typically buffer key parts of the organization from the external environment, especially when they face complex and changing environments (Thompson, 1967; Meyer and Rowan, 1977). In light of Red Queen evolution, this ability implies that key parts of large organizations may remain insulated from competitive threats and so may not recognize the imperative for change. Small organizations, by contrast, typically are less able to insulate themselves from competitive threats. Theory and evidence also show that larger organizations are more capable of decoupling key activities from environmental pressures, especially competition (Meyer and Rowan, 1977; Pfeffer and Salancik, 1978), while small organizations are known to exhibit tight linking between environmental pressures and internal processes (Hickson, Pugh, and Pheysey, 1969). Moreover, large organizations often experience an increasing isolation of their leadership (Michels, 1949; Gusfield, 1957) and throughout their rank and file see a smaller proportion of organizational members having contact with the external environment (Blau, 1977). Overall, large organizations are less directly affected by competition (Barron, 1999; Bothner, 2003) and so are less likely to conform to the predictions of the Red Queen model.

Even when affected by competitive threats, however, large organizations are likely to be less responsive than are small organizations. As Hannan and Freeman (1984) argued in their theory of structural inertia, with size come pressures for reliable behavior. Leadership in large organizations tends to become less immediately responsive to external demands over time because of increased formalization and rule-governed behavior (Weber, 1946; Bendix, 1956). Consequently, large organizations typically are designed to behave according to established routines, continuing to behave in expected ways rather than responding sensitively to performance feedback (Greve, 2003). Furthermore, when adjustment to performance feedback does occur, such adjustment is likely to be less profound than in small organizations. Change in a small organization entails obtaining cooperation from a smaller number of people, groups, and other organizational units. Large organizations, by contrast, are likely to require cooperation from proportionately more parties. Moreover, large organizations are typically more complex than small organizations, and with increasing complexity comes an exponential increase in the numbers of ways that changes can be blocked (Hannan, Pólos, and Carroll, 2003a, 2003b). Again, these arguments point to large organizations being less responsive to the Red Queen process.

Finally, size per se often gives organizations technical advantages that can help them weather competitive constraints. In general, it is well known that larger organizations are less likely to fail, other things being equal (Carroll and Hannan, 2000; McKendrick et al., 2003). This may result from many advantages of size, including the tendency for larger organizations to behave more reliably (Haunschild and Sullivan, 2002). Large organizations enjoy cost advantages in many industries, in which case competition favors larger organizations over smaller organizations when they occupy the same niche (Carroll and Swaminathan, 2000; Dobrev, Kim, and Carroll, 2002). In this light, it is not surprising that density-dependent competition has been found to have a considerably weaker effect on organizations as they grow large (Barron, 1999).

Institutional advantages also help large organizations to maintain themselves despite market pressures. Meyer and Rowan (1977) noted the survival-enhancing legitimacy of organizational practices regardless of their market efficiency, especially as organizations become large and complex. DiMaggio and Powell (1983) regarded this idea as central to two kinds of isomorphism, observing that large organizations benefit others because of their legitimacy. Large organizations also are advantaged in dealing with competition due to their typically higher social status. In general, high social status eases pressures for conformity that affect lower-status actors (Phillips and Zuckerman, 2001; Rao, Greve, and Davis, 2001; Zuckerman et al., 2003; Bothner, 2003). Relatively high social status is known to help large organizations cope with competition (Podolny, 1993).

As organizations grow large, we therefore expect that they will become less disciplined by competition, and so less susceptible to the forces of Red Queen evolution. These arguments apply both to the learning and the selection components of our theory. Confronted by weaker competitive discipline, large organizations are less likely to be stimulated to search for solutions. Similarly, competition generates selection processes that are more likely to eliminate small organizations from the population if they fail to improve.

Large organizations, by contrast, enjoy advantages that make it more likely that they will continue to survive despite their failure to respond to competition. So natural selection reasoning also suggests that large organizations will be less responsive to the stimulus of competition and consequently less likely to conform to the predictions of the Red Queen model.

Operationally, these ideas imply a Red Queen model with separate parameters for large and small organizations:

$$r_j(t) = r_j(t)^* \exp [\beta_S E_{Sj} + \beta_L E_{Lk} + \alpha_S(\Sigma_{Sk \neq j} E_{Sk}) + \alpha_L(\Sigma_{Lk \neq j} E_{Lk})],$$

where E_{Sj} refers to organization j's prior competition experienced at times when it was a small organization, and E_{Lj} is j's prior competitive experience during times when it was a large organization. Similarly, E_{Sk} and E_{Lk} represent the prior competitive experience of j's rivals k, distinguishing between competition experienced when these rivals were small or large organizations, respectively. If we are correct that organizations limit the Red Queen process as they attain the power and stature that come with size, then we should see evidence of Red Queen evolution among small organizations more strongly than among large organizations. In terms of our model, this would imply:

Hypothesis 1: $\beta_S < 0$ and $\beta_S < \beta_L$, such that prior exposure to competition when an organization is small reduces its failure rate more than does prior exposure to competition when an organization is large.

Hypothesis 2: $\alpha_S > 0$ and $\alpha_S > \alpha_L$, such that a rival's exposure to competition increases the strength of its rivalry, especially when this exposure happens to a small rival organization.

To summarize, theories of competition that follow a racing logic highlight the strengths of large organizations, especially in contexts like the hard disk drive market, in which technological change is ongoing and relatively programmatic and global reach is especially important. Conceiving of competition as a constraint, by contrast, focuses our attention on the dynamics of Red Queen competition. Following this logic, the very strengths that make larger organizations able to manage constraints also make them less susceptible to the survival- and competitiveness-enhancing consequences of the Red Queen process. Overall, then, we expect to see large organizations do well when it comes to keeping up in the hard disk drive technology race but to be less enhanced by exposure to competition than are their smaller rivals. In global competition, however, Red Queen evolution implies more complex dynamics.

Global Competition and Red Queen Evolution

Several scholars have argued that when firms from different countries compete, cross-national differences among organizations become apparent, differences that remain unnoticed when firms remain confined within the boundaries of domestic markets (Anand and Kogut, 1997). The national context—including people and their expertise, culture, social structures, industrial networks, and political and market institutions—arguably creates similarities in the strengths and weaknesses shared by organizations from the same country (Porter, 1990; Kogut, 1992; Nelson, 1993). Some have speculated that such cross-national differences might account for much of the observed worldwide variations we see in the viability of firms (Chandler, 1990), and Chesbrough (1999) has found such differences to be important in the hard disk drive market.

Along these lines, and pertinent to our model, is Porter's (1990) idea that competitive experiences in one's home country translate into stronger global competition (see also Porter and Sakakibara, 2001). This possibility can be treated as an extension of our model to the context of global competition. If α_{SF} and α_{LF} represent the competition generated by small and large foreign rivals, respectively, as a function of their own domestic competitive experience, then we would expect:

Hypothesis 3: $\alpha_{SF} > 0$ and $\alpha_{SF} > \alpha_{LF}$, indicating that a foreign rival's exposure to domestic competition in its home country increases the strength of its global competitiveness, especially when this exposure happens to a small foreign rival.

Alternatively, national differences in the competition generated by firms could increase over time among all firms, concurrent with larger trends in the globalization of markets. While global competition may initially reflect firms' national characteristics, over time, as competition increases, capabilities and behaviors among firms may converge, thereby diminishing national differences (McKendrick, 2001). To allow for this possibility, we build into our model an alternative formulation of globalization by distinguishing whether an organization's rivals are foreign or domestic (Zaheer and Mosakowski, 1997). At one extreme, if a firm's domestic rivals generate very strong competition while potential rivals from other countries generate none, then market competition can be seen as strictly domestic. At the other extreme, if the strength of competition generated by both domestic and foreign-based rivals is equally strong, then competition can be regarded as global. At any point in time, the observed pattern of competition in an industry could be described as more or less global depending on how much it resembles one of these two extreme cases. It is possible that competition becomes more global for all organizations over time, regardless of exposure to competition, as markets develop (see Hannan, 1997). In our model, we investigate this possibility as an alternative to hypothesis 3.

METHOD

We investigated our ideas by estimating ecological models of competition on data describing all manufacturers of hard disk drives. Our data are more comprehensive than those analyzed in the prior research on the industry by Lerner (1997), Christensen (1997), Christensen, Suarez, and Utterback (1998), Chesbrough (1999), and King and Tucci (2002). While their data are left-censored (using market research reports that began in 1977), ours cover the entire organizational population dating back to the beginning of the industry in 1956. The Appendix provides details on our data and data-collection methods. The hard disk drive market, described in figures 1 and 2 and table 1, is an ideal setting for our study. The defin-

Figure 1. Hard disk drive manufacturers by home region.

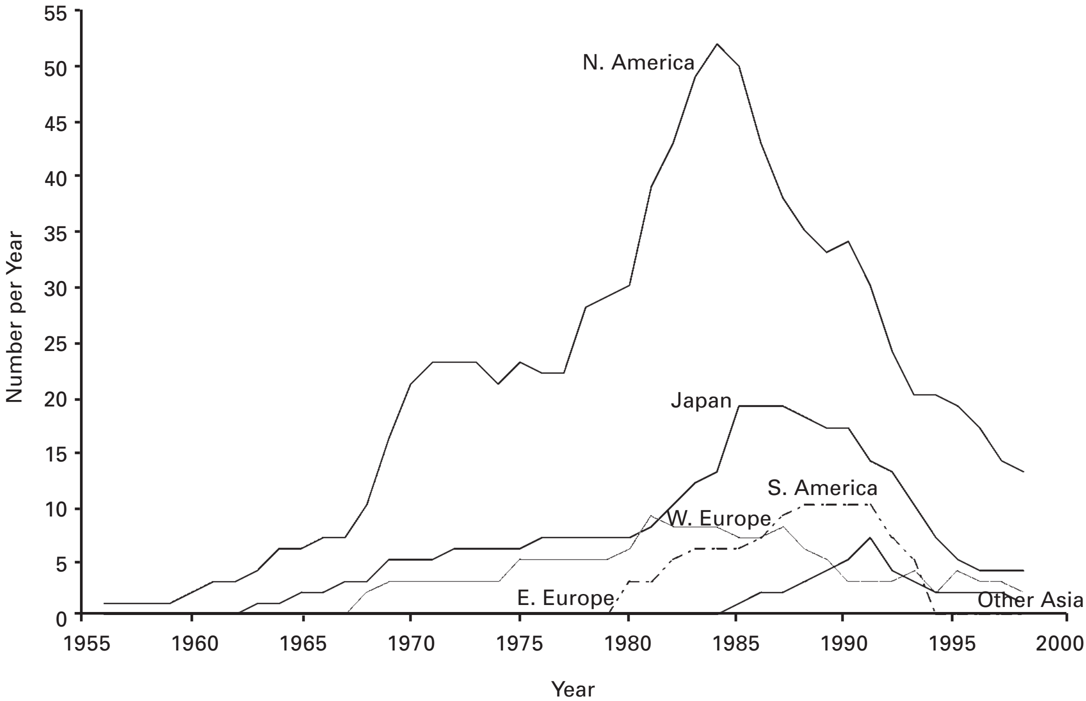


Figure 2. Entries and exits of hard disk drive manufacturers worldwide.

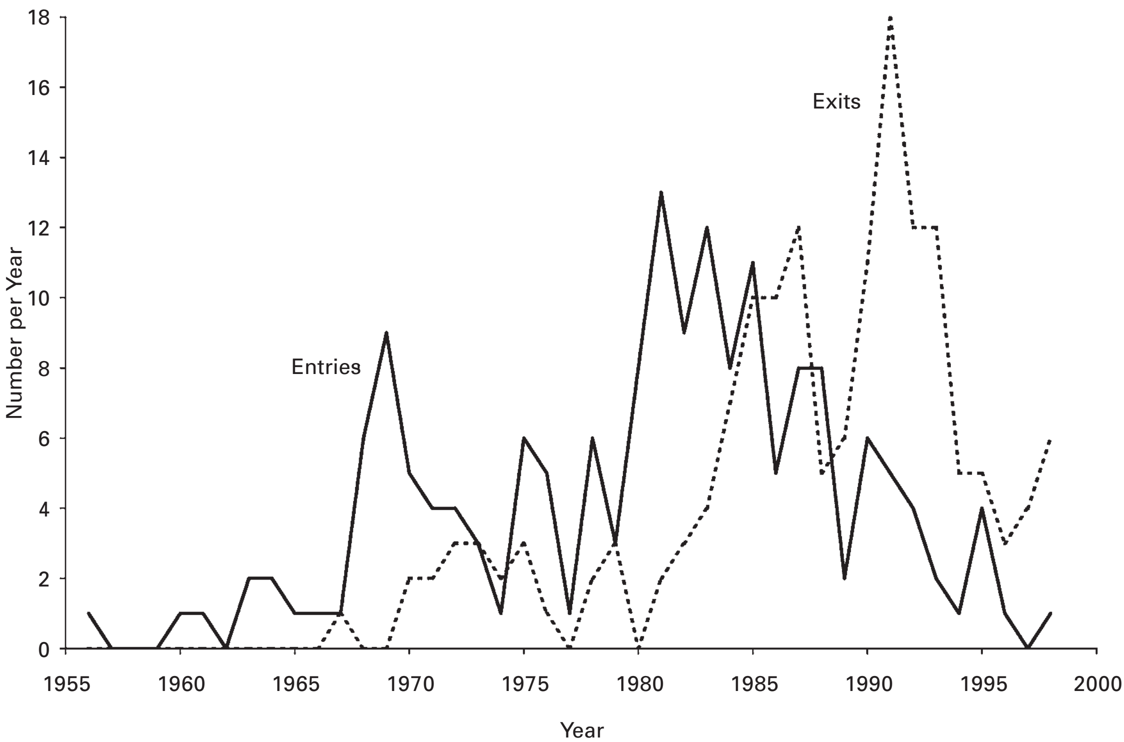


Table 1

Description of Disk Drive Manufacturers Worldwide 1956–1998 (N = 171)

	1956	1960	1965	1970	1975	1980	1985
No. of organizations	1	2	8	29	35	49	86
No. of large organizations	0	1	3	4	12	40	47
No. in med. or high capacity	0	0	2	3	7	29	37
% in med. or high capacity	0	0	.67	.75	.58	.73	.79
No. of small organizations	1	1	5	25	23	9	39
No. in med. or high capacity	0	1	2	14	6	7	18
% in med. or high capacity	0	1.0	.40	56	.26	.78	.46
No. of de novo organizations	0	0	1	7	5	10	27
No. of de alio organizations	1	2	7	22	30	39	59
No. of captive producers	1	1	5	15	19	24	26
No. of orgs. manuf. in Asia	0	0	0	0	0	0	7
No. of organizations producing for sale*****:							
1.8-inch form factor	0	0	0	0	0	0	0
2.5-inch form factor	0	0	0	0	0	0	0
3.5-inch form factor	0	0	0	0	0	0	18
5.25-inch form factor	0	0	0	0	0	2	55
8-inch form factor	0	0	0	0	0	16	20
14-inch form factor	0	0	2	20	26	32	21
24-inch form factor	0	0	0	1	0	0	0
39-inch form factor	0	1	3	1	0	0	0

				Over all years			
	1990	1995	1998	Min.	Max.	Mean	S.D.
No. of organizations	72	30	20	1	86	35.76	27.22
No. of large organizations	28	14	11	0	55	17.95	17.23
No. in med. or high capacity	23	13	9				
% in med. or high capacity	.82	.93	.82				
No. of small organizations	44	16	9	0	49	17.81	14.36
No. in med. or high capacity	18	10	4				
% in med. or high capacity	.41	.63	.44				
No. of de novo organizations	25	15	10	0	28	10.27	9.49
No. of de alio organizations	47	15	10	1	59	25.48	18.60
No. of captive producers	21	7	6	1	29	13.40	9.14
No. of orgs. manuf. in Asia	14	16	16	0	17	4.53	6.36
No. of organizations producing for sale*****:							
1.8-inch form factor	0	6	2	0	9	.86	2.16
2.5-inch form factor	6	16	7	0	16	2.48	4.92
3.5-inch form factor	40	20	15	0	40	8.76	13.29
5.25-inch form factor	29	8	4	0	55	12.30	18.54
8-inch form factor	13	2	0	0	27	5.81	8.78
14-inch form factor	11	0	0	0	33	12.93	12.58
24-inch form factor	0	0	0	0	2	.18	.50
39-inch form factor	0	0	0	0	3	.51	.93

***** These include only "non-captive" product offerings produced for sale. In some years, a relatively small number of organizations produced only "captively" for their own use, in which case these non-captive offerings do not sum to the total number of organizations.

ing characteristic of competition in the industry has been the ongoing race to deliver higher storage capacities on ever-smaller devices at less cost and in less time (McKendrick, Doner, and Haggard, 2000).

Moreover, the industry has become increasingly globalized, both in terms of the nationality of the firms and in the locus of competition. Initially, most countries' hard disk drive markets were predominately domestic, with domestic computer original equipment manufacturers (OEMs) purchasing from domestic hard disk drive firms. Japanese organizations entered the hard disk drive market seven years after the U.S., and Europe twelve years after. Brazilian, Taiwanese, and

Korean companies followed in the early and mid-1980s. Although American firms aggressively marketed drives worldwide early on, most firms kept their primary focus on domestic markets. Perhaps for this reason, organizations in the industry often are identified according to their country of origin, and country factors have been found to be important to the formation of hard disk drive manufacturers (Chesbrough, 1999).

As time passed, however, the hard disk drive market became increasingly global. A watershed event in the computer industry was the debut of the IBM personal computer (PC) in 1981. The PC defined the dominant design in the microcomputer market for many years (Langlois, 1992; Anderson, 1995). In addition to setting the standard for what a desktop computer should include, it featured an open architecture that attracted the entry not only of some of IBM's established mainframe and minicomputer rivals but de novo startups that set out to manufacture IBM "clones." The same open architecture that attracted the new clone manufacturers also stimulated entry into peripheral equipment. While mainframe and minicomputer manufacturers made many of their own peripherals and components, the assemblers of personal computers outsourced almost all of their production.

Competition as Contest in the Hard Disk Drive Market

Technological leadership in the hard disk drive market has been based on a firm's ability to deliver higher-capacity disk drives. Capacity is determined by how many bits can be stored on a square inch of disk, otherwise known as the drive's areal density. Since IBM shipped the first movable-head disk drive in 1956, the industry has undergone tremendous technological change. Until 1991, areal density increased at an annual rate of 30 percent but grew by an astounding 60 percent per year from 1992 to 1997, a faster rate of progress than semiconductors, and an amazing 125 percent in 1998, our last year of study. The average rate of capacity increase was 30–40 percent each year between 1956 and 1991.

Rapid technological change has allowed the market to develop into roughly three segments. One segment is composed of firms that offer the highest capacity drives. A second segment consists of firms that are the early leaders into a "capacity point" in demand by the largest computer manufacturers, which typically excludes the highest capacity drives. The third segment encompasses the technological laggards that serve the secondary market of second-tier mainframe and minicomputer makers and the hundreds of small and medium-sized microcomputer companies. Firms late to market with a new drive thus suffer a severe revenue penalty: if too late, they may find no customers and be forced either to absorb their development costs and start developing an even higher-capacity drive or to exit the industry. Even so, first-to-market innovators typically hold only the slimmest of leads, as other manufacturers generally introduce comparable products within a relatively short time. The likelihood of rapidly decreasing profitability over the life cycle of any given product provides a strong incentive for firms to innovate rapidly. But the result is extremely short product cycles, estimated in 2003 to be from six to nine months. Most firms have had trouble keeping up with such continuous product introductions.

Not only have firms needed to keep up with changes in capacity, they have needed to keep pace with the reductions in the physical size of hard disk drives, from using disks with diameters of 39, 31, and 24 inches to 14-, 8-, 5.25-, 3.5-, and 2.5-inch drives. These changes in "form factor" have proven problematic for many drive manufacturers, and most firms have not survived the transition. For some firms, the inability to introduce smaller form factors was due to technological reasons: scaling down components and getting designs to work properly were engineering challenges. In other cases, as Christensen (1997) has pointed out, new form factors sometimes served new markets, and managers of many incumbent firms were slow to recognize the necessity of change.

As if these technological and marketing challenges are not daunting enough, firms also have had to achieve economies of scale in order to compete effectively on price. While being first to market was in many ways critical, first-to-volume production has often been more important. Many new entrants have been among the first to introduce a particular form factor or hit the highest capacity point. But computer vendors seldom gave a second chance to firms that were unable to ramp up to volume production effectively. As a result, survival in the disk drive industry has increasingly required the marriage of technological prowess to manufacturing ability.

The volatility of this organizational population has limited the ability of market leaders to control pricing or the length of product life cycles. Periodic oversupply and constant price erosion are ways of life for disk drive producers. Disk drive manufacturers might attempt to avoid the pitfalls of the price-sensitive, high-volume, low end of the market by differentiating their products into higher-capacity segments, such as drives for file servers and network storage. But ongoing innovation has made it impossible for firms to sustain a product differentiation strategy for long periods. In this context, then, racing well as technologies advance has been crucial to organizational success. As the pattern in table 1 shows, large organizations have maintained, over most of the industry's history, a clear advantage in terms of the proportion of organizations producing in the medium- to high-capacity ranges. Consistent with Lerner's (1997) analysis of this industry, our data show that larger organizations hold a clear competitive advantage, at least when we conceive of competition as a contest for being technologically up to date.

Model Specification and Estimation

We used the modeling framework of organizational ecology to build our model of Red Queen competition because this approach allows for explicit estimation of competition among organizations. In particular, the so-called density-dependent model allows each organization's viability to vary as a function of the number, or density, of other organizations in the population (Carroll and Hannan, 2000). Failure rates are thought to be non-monotonically related to density, falling with initial increases in density as legitimacy increases but ultimately increasing as competitive effects grow with crowding in the population (Hannan and Freeman, 1989; Hannan and Carroll, 1992). Furthermore, persistently higher failure rates are found for organizations facing greater density at the time of their birth, the so-called density-delay effect attributed to problems caused by building an organization under adverse conditions (Carroll and Hannan, 1989). Our model includes these various density effects. For our purposes, the effects of disaggregated and weighted densities are also estimated, because these allow for competition to depend on both technological and geographic factors.

The hard disk drive market's history of technological differentiation suggests that we should operationalize density using technology-overlap measures (see Carroll and Hannan, 2000). These overlap measures equal density counts if all organizations compete in all technological areas. For any of j's rivals that overlap j's technological domain only partially, however, they contribute to j's overlap score only in proportion to their degree of overlap. We specified the possible technological domain of each organization j to include relatively low-, medium-, and high-capacity positions in each of the various form factors of hard disk drives that existed in a given year. We defined these relative levels to account for changes over time in absolute capacity, as explained in the Appendix. For each firm in each year, we disaggregated the raw count of its rivals into technology-overlap and non-overlap densities. If competition in the industry was technologically segmented, as we suspect, then failure rates will be driven especially by overlap density as opposed to non-overlap density.

Implementing our model of the Red Queen, we tested for the survival implications of each organization j's prior exposure to competition. For each organization in each year t, we measured the sum of its domestic technology-overlap density score in each previous year from its birth through year t-1. If prior exposure to competition enhanced survival chances, as we argue, then this variable should reduce exit rates, especially among small organizations.

Each organization's technology mix was measured using variables that sum the number of form factors (of different relative capacity levels) in which the firm had product offerings. For example, a firm with low-capacity product offerings in three different form factors would have a measure of 3 for "number of low-capacity form factors produced." If this firm also produced medium-capacity products in four form factors and high-capacity products in one form factor, then it would also have a measure of 5 for "number of medium- and high-capacity form factors produced." These variables allowed us to investigate whether and how being relatively ahead or behind in the technology race affected survival rates.

Our main measure of organizational size is a categorical measure that distinguishes between large and small firms, defined relatively for each year, and updated from year to year. For years prior to 1976, this designation was made by examining historical documents to identify major players in the industry in each year. For observations after 1976, we relied on the data source *Disk/Trend*.

Two kinds of control variables were also included in our specification. One set of variables allows the "carrying capacity" for hard disk drive manufacturers to vary over time, by region, and by technologies. We included, for each firm, the number of computer manufacturers in the United States that made a computer corresponding to a form factor produced by the hard disk drive firm. The data on computer OEMs come from various sources, as described in Barnett, Swanson, and Sorenson (2003). This variable reflects the market for a given firm's disk drives and so can capture symbiosis between these complementary parts of the organizational community. Calendar year was included to control for secular trends in the carrying capacity not otherwise captured in our specification. Indicator variables were included measuring whether or not a given organization in a given year was producing in a given form factor. Because organizations could be in any or all form factors at once, there is no omitted category among these indicators. Also, indicator variables were included for the region of the global economy in which each organization was headquartered, with North America serving as the omitted category. This approach allowed us to investigate whether our hypothesized effects account for national differences in failure rates.

Also included were some other organization-level control variables. Along with our large/small categorical measure of size, we included a measure of size in terms of the dollar value of hard disk drive sales, but this measure was available only for large organizations and only after 1976. An indicator variable, allowed to vary from year to year for each firm, was included for firms engaged in any so-called "captive" production of disk drives for their own computers. Another indicator variable represented whether an organization (from any country) was manufacturing disk drives in Asian facilities in a given year, a low-cost production strategy pursued by selected firms (McKendrick, Doner, and Haggard, 2000). Following Carroll et al. (1996), we also included an indicator variable to distinguish between de novo firms, those that entered the industry as a start-up, and de alio entrants, who moved or expanded into the industry from some other industry. Table 2 describes our pooled annual observations over the period of the study.

We modeled the failure rate using a piecewise-exponential specification for each organization's market tenure and estimated the model using the software package STATA. This is an extremely flexible specification that allows failure rates to change freely from period to period. We selected periods to be as fine grained as possible while not being so short as to prevent the estimation of statistically meaningful effects. Although many studies have measured t in terms of organizational age, we measured t in terms of market tenure. For de novo firms that were born as hard disk drive manufacturers, age and tenure are the same. Firms with operations in other markets, however, may have been born before they entered the hard disk drive market. In these cases, market tenure differs from organizational age, and we used tenure rather than

Table 2

Description of Pooled Annual Observations of Disk Drive Manufacturers Worldwide, 1956–1998*

Variable	Min.	Max.	Mean	S D.
Organization's market tenure	0	42	6.91	7.04
Calendar year (1956 = 0)	0	42	27.29	7.99
Number of low-capacity form factors produced by organization	0	4	.73	.77
Number of medium- and high-capacity form factors produced by organization	0	9	1.23	1.48
Hard-drive sales ($mil) by organization (large only)	0	11979.1	243.06	974.19
Number of computer manufacturers in the form factors produced by organization	0	2787	530	508
Entries of computer manufacturers in the form factors produced by organization	0	771	135	141
Number of rivals worldwide in year of organization's founding	0	85	42	25
Number of rivals worldwide	0	85	55	22
(Number of rivals worldwide)^2/1000	0	7.225	3.543	2.352
Number of domestic rivals	0	51	20	15
Overlap with domestic rivals (by form factor and capacity)	0	22	5.65	4.79
Overlap with small domestic rivals (by form factor and capacity)	0	9	1.82	2.01
Overlap with large domestic rivals (by form factor and capacity)	0	17	3.82	3.76
Non-overlap with domestic rivals	0	51	15.11	12.85
Organization's competitive experience	0	167.49	31.41	37.52
Small organization's competitive experience	0	143	10.57	17.20
Large organization's competitive experience	0	167.49	20.84	33.03
Rivals' competitive experience, same region (experience-weighted overlap)	0	1098	270	285
Small rivals' competitive experience, same region (experience-weighted overlap)	0	292	64	69
Large rivals' competitive experience, same region (experience-weighted overlap)	0	873	205	233
Overlap with domestic rivals times calendar year (1956 = 0)	0	616	160	141
Number of foreign rivals	0	85	34	20.59
Overlap with foreign rivals (by form factor and capacity)	0	46	10.65	9.39
Foreign rivals' competitive experience (experience-weighted overlap)	0	1978	402	438
Small foreign rivals' competitive experience (experience-weighted overlap)	0	624	107	126
Large foreign rivals' competitive experience (experience-weighted overlap)	0	1354	295	326
Overlap with foreign rivals times calendar year (1956 = 0)	0	1334	313	291

***** The data include 171 organizations over 1,538 organization-years.

age in our analysis. We also allowed for the possibility that the effects of industry tenure depend on organizational size (Carroll and Hannan, 2000) by estimating separate tenure effects for large and small organizations.

RESULTS

Tables 3a and 3b show estimates of baseline failure rate models that include the various control variables and different specifications of the density of organizations. For comparison, model 1 includes the control variables but no density variables. Model 2 then includes density in the year of an organization's founding and a quadratic specification of contemporaneous density. None of these density effects are statistically significant, nor in model 3 does density have a statistically significant effect when specified without the squared and density-at-birth terms. In model 4, however, strong competitive results appear when worldwide density is disaggregated to distinguish the effects of domestic and foreign rivals, as well as different effects for domestic rivals that overlap in product space and those that do not. These disaggregated density terms show that competition has been strong, but localized in the disk drive market, both geographically and technologically. According to model 4, an organization faces strong competition from domestic rivals that have products in the same form factor and capacity level, while non-overlapping domestic rivals have a much smaller competitive effect. Foreign rivals, meanwhile, actually have a mutualistic effect, lowering the failure rates of other organizations. This pattern is consistent with models that reveal geographically localized competition together with life-enhancing legitimacy effects coming from increases in numbers of organizations over broader geographic areas (Carroll and Hannan, 2000).

The models in tables 4a and 4b investigate Red Queen competition. Model 5 includes the effect of a firm's competitive experience on its own exit rate, as well as the effect of its rivals' competitive experience. Model 6 then distinguishes between these experience effects according to whether competition was experienced when an organization was small or when it was large and also allows the effects of domestic density to vary by the size of rivals. Supporting hypothesis 1, there is strong evidence of Red Queen evolu-

Table 3a

Baseline Models of Competition: Market Exit Rates among Disk Drive Manufacturers Worldwide, 1956–1998*

	Model			
Independent Variable	(1)	(2)	(3)	(4)
Number of low-capacity form factors produced by organization	–.3855 (.2347)	–.3456 (.2389)	–.3621 (.2385)	–.4188• (.2384)
Number of medium- and high-capacity form factors produced by organization	–.2751• (.1570)	–.2714• (.1579)	–.2700• (.1573)	–.2286 (.1599)
Hard-drive sales ($mil) by organization (large only)	–.0031• (.0017)	–.0032• (.0018)	–.0031• (.0017)	–.0032• (.0018)
Organization was founded de novo	.2265 (.2089)	.2260 (.2106)	.2330 (.2093)	.1977 (.2070)
Organization has captive production	.3010 (.2607)	.3037 (.2635)	.3094 (.2602)	.3909 (.2681)
Organization manufactures in Asia	.1507 (.2751)	.1675 (.2875)	.1659 (.2766)	.3116 (.2830)
Number of computer manufacturers in the form factors produced by the organization	–.0003 (.0006)	–.0010 (.0010)	–.0006 (.0008)	–.0001 (.0008)
Entries of computer manufacturers in the form factors produced by the organization	.0007 (.0022)	.0015 (.0024)	.0009 (.0022)	.0009 (.0023)
Number of rivals worldwide in year of organization's founding		–.0015 (.0065)		
Number of rivals worldwide		.0317 (.0357)	.0027 (.0048)	
(Number of rivals worldwide)^2		–.2617 (.3204)		
Overlap with domestic rivals (by form factor and capacity)				.0686•• (.0237)
Non-overlap with domestic rivals				.0318•• (.0123)
Number of foreign rivals				–.0215•• (.0085)
Log likelihood	–106.20	–105.69	–106.04	–98.81
Degrees of freedom	31	34	32	34

• $p < .10$; •• $p < .05$.
* Standard errors are in parentheses. Each model also includes market tenure, calendar year, form factor, and region effects, as shown in table 3b. The data cover 1,538 organization-years, 171 organizations, and 157 exits.

Table 3b

Estimated Market Tenure, Calendar Year, Form Factor, and Region Effects from the Models in Table 3a*

	Model			
Independent Variable	(1)	(2)	(3)	(4)
Organization of market tenure 0–1 year	–5.168••	–5.860••	–5.297••	–6.110••
	(.7406)	(1.065)	(.7805)	(.8324)
Organization of market tenure 1–3 years	–3.370••	–4.039••	–3.488••	–4.280••
	(.5797)	(.9425)	(.6229)	(.6831)
Organization of market tenure 3–5 years	–3.165••	–3.824••	–3.283••	–4.039••
	(.5965)	(.9415)	(.6384)	(.6948)
Organization of market tenure 5–10 years	–3.034••	–3.687••	–3.138••	–3.875••
	(.6226)	(.9606)	(.6560)	(.7050)
Organization of market tenure 10–20 years	–2.679••	–3.349••	–2.789••	–3.477••
	(.6633)	(1.005)	(.6987)	(.7477)
Organization of market tenure 20+ years	–2.398••	–3.184••	–2.529••	–3.095••
	(.7821)	(1.188)	(.8217)	(.8804)
Large organization of market tenure 0–3 years	–2.225••	–2.305••	–2.261••	–2.380••
	(.7384)	(.7446)	(.7414)	(.7418)
Large organization of market tenure 3–5 years	–2.768••	–2.824••	–2.799••	–2.968••
	(1.027)	(1.030)	(1.029)	(1.033)
Large organization of market tenure 5–10 years	–1.830••	–1.899••	–1.860••	–1.947••
	(.5087)	(.5152)	(.5118)	(.5133)
Large organization of market tenure 10–20 years	–1.634••	–1.692••	–1.653••	–1.659••
	(.4889)	(.4933)	(.4899)	(.4903)
Large organization of market tenure 20+ years	–1.069	–.9682	–1.031	–1.250
	(.9609)	(.9704)	(.9625)	(.9574)
Calendar year (1956 = 0)	.0609••	.0584••	.0595••	.0684••
	(.0177)	(.0216)	(.0180)	(.0192)
Japanese organization	–.4071	–.4200	–.4085	.5735
	(.2752)	(.2760)	(.2757)	(.4122)
Eastern-European organization	–.9793	–1.026•	–1.001	.9475
	(.6235)	(.6291)	(.6244)	(.8334)
Western-European organization	–.3682	–.3648	–.3494	1.109••
	(.2954)	(.3037)	(.2972)	(.4934)
South American organization	–.9883••	–1.001••	–.9857••	.5866
	(.3528)	(.3561)	(.3523)	(.5534)
Asian (other than Japanese) organization	.0403	.0435	.0523	1.766••
	(.3932)	(.3958)	(.3937)	(.5975)
Organization produces 1.8-inch form factor	–.3618	–.1215	–.2710	–.6952
	(.6586)	(.7020)	(.6775)	(.7045)
Organization produces 2.5-inch form factor	–.1377	.0998	–.0525	–.2470
	(.5648)	(.6112)	(.5846)	(.5971)
Organization produces 3.5-inch form factor	.6095	.9048	.6988	.2575
	(.5354)	(.6083)	(.5571)	(.6036)
Organization produces 5.25-inch form factor	.4692	.7520	.5298	.1573
	(.5220)	(.5943)	(.5318)	(.5674)
Organization produces 8-inch form factor	.2491	.2933	.2441	.0834
	(.4265)	(.4338)	(.4269)	(.4278)
Organization produces 14-inch (or above) form factor	.1017	.1558	.1192	–.0446
	(.3751)	(.3823)	(.3765)	(.3859)

• $p < .10$; •• $p < .05$.
* Standard errors are in parentheses. For region effects, the U.S. is the omitted category

tion revealed in these models, but only due to competition experienced by organizations when they are small. We do not find differences in failure rates due to experience in other industries (the de novo/de alio comparison). Conditional on survival, firms that faced more competition in the past are less likely to fail, but only if they were small when they experienced this prior competition.

These effects are described in figure 3, based on the estimates from model 14, the preferred specification from the most complete models. Figure 3 shows the combined effects of an organization's market tenure, size, and competitive experience on its own exit rate, controlling for all the other variables in model 14. The solid lines show how the exit rate changed with market tenure for organizations that faced no domestic competition, as would be the case, for instance, if an organization were technologically differentiated from its domestic rivals. Among these "monopolists," exit rates increased with market tenure for both large and small firms. Thus organizations that faced no competition suffered a powerful liability of aging. Among small firms, however, another pattern was possible, as indicated by the dotted line. Small firms that experienced the mean level of rivalry

Table 4a

Models of Red Queen Competition: Market Exit Rates among Disk Drive Manufacturers Worldwide, 1956–1998*

	Model			
Independent Variable	(5)	(6)	(7)	(8)
Number of low-capacity form factors produced by organization	–.3791 (.2364)	–.4252• (.2383)	–.4029• (.2391)	–.4256• (.2386)
Number of medium- and high-capacity form factors produced by organization	–.2204 (.1594)	–.2014 (.1621)	–.2326 (.1606)	–.1959 (.1623)
Hard drive sales ($mil) by organization (large only)	–.0036•• (.0018)	–.0037• (.0019)	–.0035• (.0018)	–.0037•• (.0019)
Organization was founded de novo	.1641 (.2090)	.0641 (.2149)	.0881 (.2132)	.0718 (.2154)
Organization has captive production	.3176 (.2684)	.2279 (.2709)	.2189 (.2727)	.2230 (.2709)
Organization manufactures in Asia	.3642 (.2839)	.1519 (.3202)	.1400 (.3149)	.1493 (.3194)
Number of computer manufacturers in the form factors produced by the organization	.0004 (.0009)	–.0001 (.0009)	–.0001 (.0009)	–.0003 (.0009)
Entries of computer manufacturers in the form factors produced by the organization	.0003 (.0024)	.0008 (.0023)	.0006 (.0023)	.0009 (.0023)
Organization's competitive experience	–.0063• (.0035)			
Small organization's competitive experience		–.0116•• (.0050)	–.0127• (.0050)	–.0121•• (.0050)
Large organization's competitive experience		–.0029 (.0043)	–.0023 (.0042)	–.0032 (.0043)
Overlap with domestic rivals (by form factor and capacity)	.1143•• (.0401)			
Overlap with small domestic rivals		.0291 (.0657)	–.2397 (.2278)	–.2048 (.2279)
Overlap with large domestic rivals (by form factor and capacity)		.1199•• (.0468)	.4259•• (.1623)	.1753 (.2284)
Domestic rivals' competitive experience (experience-weighted overlap)	–.0009 (.0007)			
Small domestic rivals' competitive experience (experience-weighted overlap)		.0041• (.0023)		.0031 (.0026)
Large domestic rivals' competitive experience (experience-weighted overlap)		–.0018•• (.0008)		–.0018 (.0014)
Overlap with small domestic rivals × calendar year (1956 = 0)			.0107 (.0080)	.0092 (.0084)
Overlap with large domestic rivals × calendar year (1956 = 0)			–.0126•• (.0058)	–.0018 (.0093)
Non-overlap with domestic rivals	.0312•• (.0123)	.0239• (.0136)	.0138 (.0140)	.0221 (.0147)
Number of foreign rivals	–.0210•• (.0085)	–.0187•• (.0086)	–.0182•• (.0087)	–.0196•• (.0089)
Log likelihood	–95.76	–91.07	–91.67	–90.46
Degrees of freedom	36	39	39	41

• $p < .10$; •• $p < .05$.

* Standard errors are in parentheses. Each model also includes market tenure, calendar year, form factor, and region effects as shown in table 4b. The data cover 1,538 organization-years, 171 organizations, and 157 exits.

Table 4b

Estimated Market Tenure, Calendar Year, Form Factor, and Region Effects from the Models in Table 4a*

	Model			
Independent Variable	(5)	(6)	(7)	(8)
Organization of market tenure 0–1 year	–6.593••	–6.442••	–5.989••	–6.236••
	(.8721)	(.8962)	(.8757)	(.9012)
Organization of market tenure 1–3 years	–4.670••	–4.431••	–3.986••	–4.196••
	(.7205)	(.7518)	(.7379)	(.7624)
Organization of market tenure 3–5 years	–4.339••	–4.076••	–3.625••	–3.835••
	(.7251)	(.7579)	(.7459)	(.7697)
Organization of market tenure 5–10 years	–4.030••	–3.804••	–3.333••	–3.551••
	(.7334)	(.7640)	(.7544)	(.7791)
Organization of market tenure 10–20 years	–3.466••	–3.245••	–2.771••	–2.979••
	(.7861)	(.8112)	(.8053)	(.8276)
Organization of market tenure 20+ years	–2.955••	–2.934••	–2.466••	–2.611••
	(.9516)	(.9590)	(.9734)	(.9840)
Large organization of market tenure 0–3 years	–2.481••	–2.526••	–2.509••	–2.571••
	(.7445)	(.7457)	(.7438)	(.7467)
Large organization of market tenure 3–5 years	–3.018••	–3.081••	–3.101••	–3.120••
	(1.034)	(1.034)	(1.034)	(1.034)
Large organization of market tenure 5–10 years	–1.976••	–2.150••	–2.190••	–2.192••
	(.5115)	(.5149)	(.5170)	(.5171)
Large organization of market tenure 10–20 years	–1.686••	–1.766••	–1.874••	–1.829••
	(.4947)	(.5027)	(.5030)	(.5048)
Large organization of market tenure 20+ years	–1.175	–.8907	–1.082	–.9360
	(.9794)	(1.008)	(.9974)	(1.013)
Calendar year (1956 = 0)	.0890••	.0935••	.0866••	.0881••
	(.0217)	(.0218)	(.0216)	(.0220)
Japanese organization	.4072	.0758	–.0722	–.0230
	(.4224)	(.4511)	(.4571)	(.4621)
Eastern-European organization	.3456	.1446	–1.563	–.0188
	(.8778)	(.8933)	(.8943)	(.9046)
Western-European organization	.6799	.3276	.0881	.2759
	(.5276)	(.5539)	(.5651)	(.5802)
South American organization	.0174	–.2328	–.5748	–.4698
	(.6044)	(.6146)	(.6516)	(.6697)
Asian (other than Japanese) organization	1.347••	1.081•	.6999	.9871
	(.6234)	(.6381)	(.6681)	(.6935)
Organization produces 1.8-inch form factor	–1.006	–.9478	–.9181	–.9419
	(.7201)	(.7160)	(.7073)	(.7168)
Organization produces 2.5-inch form factor	–.5487	–.2898	–.3212	–.2097
	(.6121)	(.6178)	(.6123)	(.6237)
Organization produces 3.5-inch form factor	.0908	.2963	.4737	.4129
	(.6125)	(.6146)	(.6196)	(.6336)
Organization produces 5.25-inch form factor	–.1011	.1106	.1261	.2043
	(.5805)	(.5821)	(.5772)	(.5879)
Organization produces 8-inch form factor	.0105	.0494	–.0201	.0997
	(.4255)	(.4375)	(.4385)	(.4443)
Organization produces 14-inch (or above) form factor	–.0861	–.2016	–.1409	–.0676
	(.3918)	(.3991)	(.4252)	(.4307)

• $p < .10$; •• $p < .05$.
* Standard errors are in parentheses. For region effects, the U.S. is the omitted category.

observed for a given tenure period saw their exit rates initially increase with market tenure but ultimately fall as their competitive-experience effect dominated. Especially interesting is the comparison with large organizations. Small firms that survive competition ultimately end up less likely to fail than their large counterparts, as the consequences of Red Queen evolution ultimately more than offset the liability of smallness.

Turning to the rivalry side of the Red Queen model, a comparison of models 5 and 6 shows stronger competition from rivals that experienced more competition in the past, but

Figure 3. Effects of age and competitive experience on the exit rate (based on the estimates in model 14).

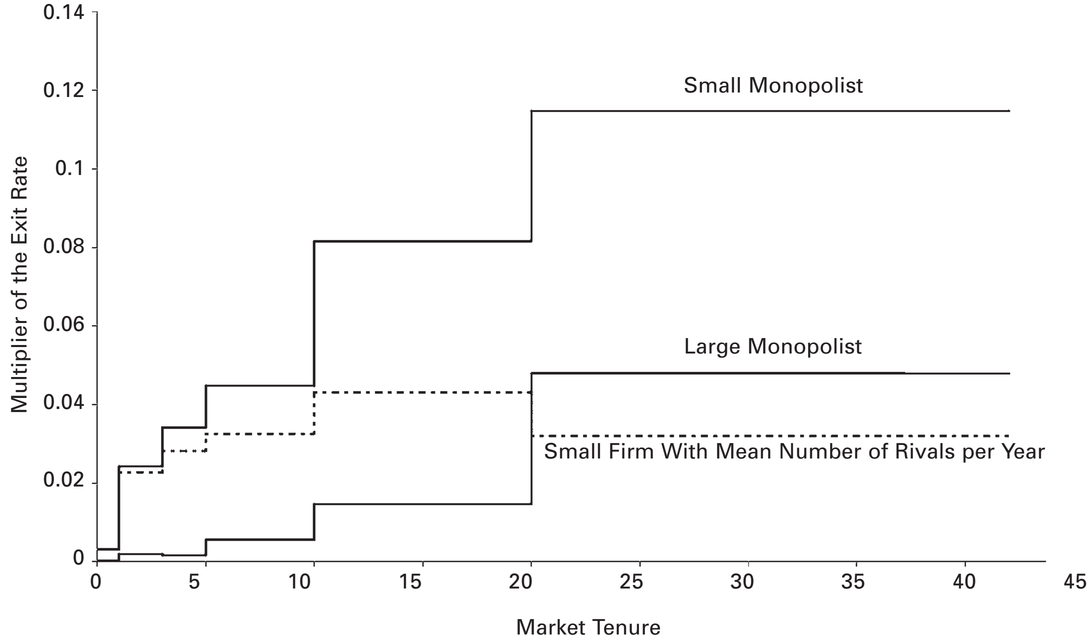
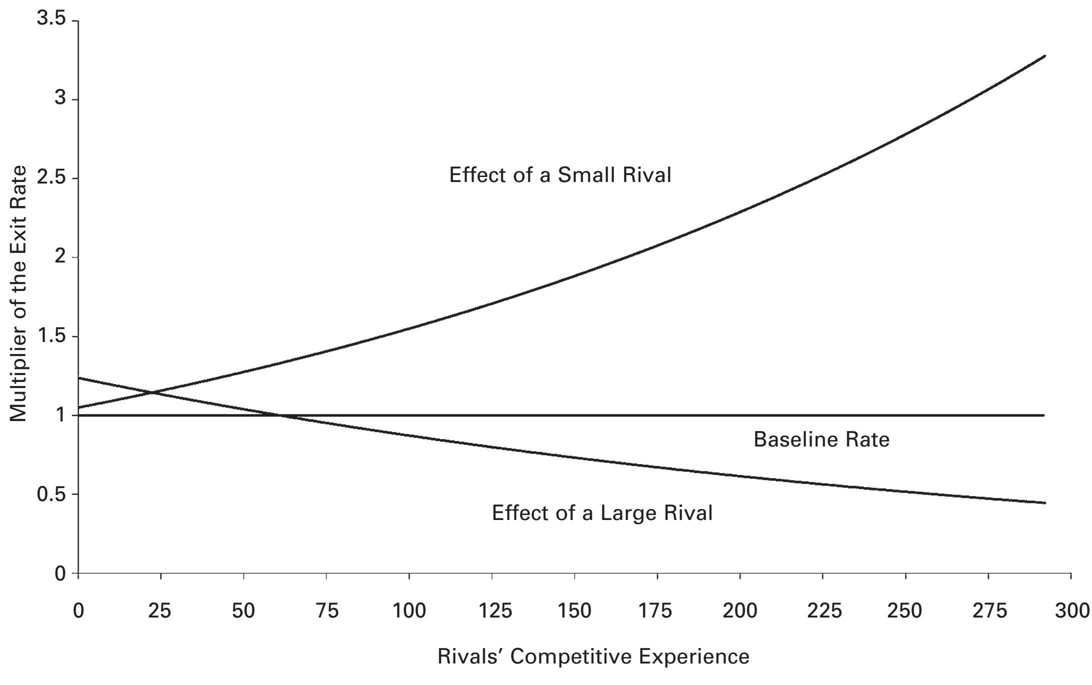


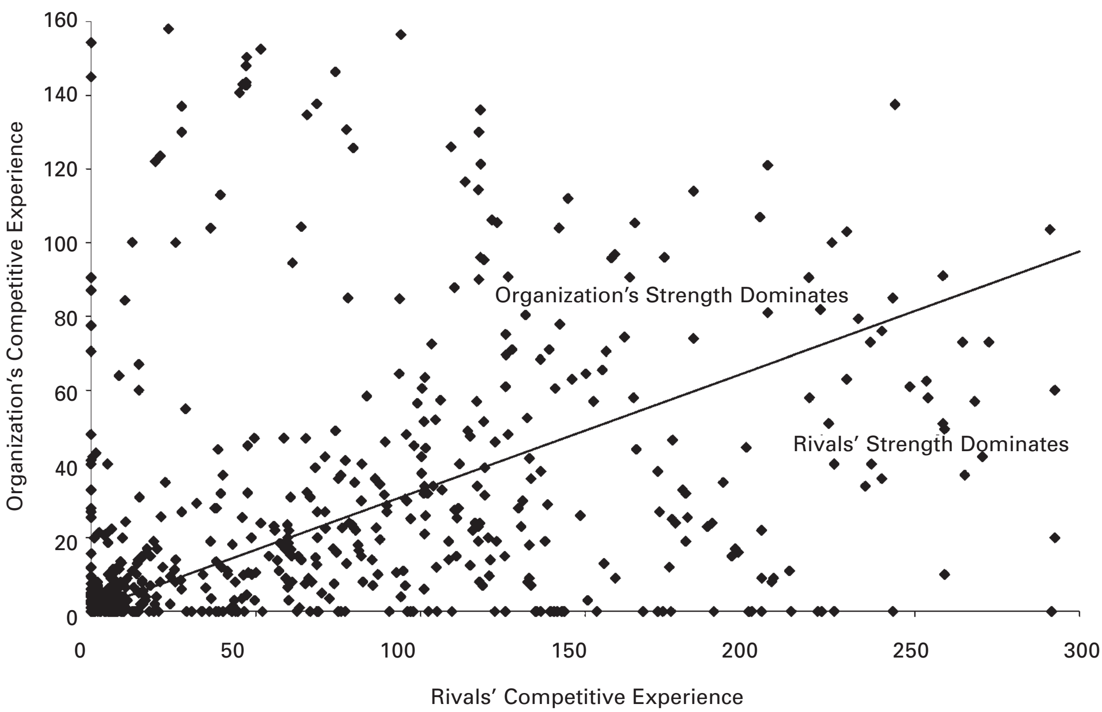
Figure 4. Rivals' effects on an organization's exit rate (based on the estimates in model 14).



again, this holds only if the prior competition was experienced while the rival was small, in support of hypothesis 2. Among rivals with no competitive experience, however, we only find evidence of competition from large rivals. Figure 4 illustrates the implications of these rivalry effects combined. The figure shows how the competitive intensity of an organization's rivals varied according to the rivals' prior exposure to competition (again from model 14). The plot combines the effect of density, the overlap with domestic rivals, and the effect of the competitive experience of these rivals on an organization's exit rate. Among rivals with no competitive experience, only the density effect operates, so large rivals generated stronger competition than did small rivals. Having to compete against one large firm that was previously a monopolist raised an organization's failure rate by about 24 percent, while competing against a small firm that had no competitive experience generated no competition that we could detect. This pattern reverses with competitive experience, however, so that an organization's failure rate increased as its (small) rivals' competitive experience increased. This was a strong effect, implying increases in the failure rate of up to 328 percent over the observed range of this variable; by far the strongest competition in the market came from rivals that had survived competition when they were small. Our findings also show an unexpected but slight decrease in the competition generated by large rivals as they experienced more competition.

Figure 5 illustrates the trade-off implied by these results. Every plotted point in this figure represents an organization-year observation in the data. The points are positioned to show observed pairings of the competitive experience of each organization as of each year (on the vertical axis) versus the observed competitive experience of the organization's rivals in that year (on the horizontal axis). All experience effects here are limited to those accumulated when these organizations were small. The diagonal line indicates the threshold of equality at which the advantages of experiencing competition are exactly offset by the competitive strength of one's rivals because of their experience (according to the

Figure 5. Organization's vs. rivals' competitive experience in the disk drive market (line indicates threshold of equality between organization's and rivals' strength).



estimates of model 14). For observations on this line, then, the advantages and disadvantages of Red Queen competition exactly offset each other. Organizations above this threshold are more likely to survive due to Red Queen competition, and organizations below the threshold face a greater net hazard due to Red Queen competition.

Models 7 and 8 investigate whether the increase in domestic rivalry that we are attributing to Red Queen competition might, instead, be due simply to increasing competitiveness among all organizations over calendar time, instead of increasing competitiveness due to prior exposure to competition. Model 7 suggests that competitive intensity among domestic rivals did increase with calendar time, but this effect vanishes once the Red Queen effect is included in model 8. Neither is the Red Queen effect significant in model 8, but this appears to be due to colinearity, as the coefficients of the rivals' competitive experience terms fall only slightly from model 6 to model 8, but the standard errors increase dramatically. By comparison, the calendar time × domestic rivalry interaction term sees its coefficient fall by an order of magnitude between models 7 and 8. Thus it appears that domestic rivalry increased due to exposure to competition, rather than simply with the passage of calendar time.

A different story emerges for foreign competition. Tables 5a and 5b investigate competition from foreign rivals in greater detail. Model 9 is similar to model 8, except that the density of rivals from other regions of the world is specified as a technology-overlap density, and the domestic competitive experience of foreign rivals is included in order to test hypothesis 3. Model 10 is the same as model 9, except that it also includes interactions between foreign rivals (small and large) and historical time to test for the alternative to hypothesis 3, that increasing global competition occurred marketwide over time regardless of exposure to competition. A comparison of models 9 and 10 clearly fails to support hypothesis 3. Global competition increased in strength over historical time—generated by small and large rivals alike—and once these effects are included, we fail to find evidence that exposure to domestic competition made organizations stronger global competitors. Models 11 through 14 confirm this conclusion, showing the same pattern of results in specifications that also demonstrate that the strength of global competition did not appear to hinge on whether rivals were large or small.

Although we fail to find support for hypothesis 3, we do find strong evidence that competition became increasingly global in the hard disk drive market as calendar time passed. Using the most parsimonious specification of global competition, model 14, figure 6 illustrates the way that competition became more global over time in the hard disk drive market. The plot reflects the negative effect of technology overlap with foreign rivals, together with the positive effect of technology overlap interacted with calendar time. In the early days, the existence of foreign rivals made a firm more likely to survive, lowering failure rates by about 30 percent per rival, for instance, back in 1965. This survival-enhancing effect is consistent with the argument that geographically

Table 5a

Models of Global Competition: Market Exit Rates among Disk Drive Manufacturers Worldwide, 1956–1998*

	Model					
Independent Variable	(9)	(10)	(11)	(12)	(13)	(14)
Number of low-capacity form factors produced by organization	–.3114	–.3762	–.2982	–.3720	–.3705	–.3724
	(.2368)	(.2423)	(.2343)	(.2380)	(.2364)	(.2364)
Number of medium- and high-capacity form factors produced by organizations	–.2066	–.1916	–.2201	–.1881	–.1943	–.1879
	(.1651)	(.1654)	(.1616)	(.1623)	(.1639)	(.1620)
Hard drive sales ($mil) by organization	–.0036•	–.0037••	–.0035•	–.0037••	–.0037••	–.0037••
	(.0019)	(.0019)	(.0018)	(.0018)	(.0018)	(.0018)
Organization was founded de novo	.1057	.1381	.1047	.1371	.1378	.1371
	(.2160)	(.2153)	(.2160)	(.2154)	(.2152)	(.2154)
Organization has captive production	.2436	.3188	.2469	.3180	.3192	.3180
	(.2659)	(.2689)	(.2659)	(.2686)	(.2686)	(.2687)
Organization manufactures in Asia	.1167	.2181	.1304	.2156	.2182	.2159
	(.3236)	(.3216)	(.3206)	(.3204)	(.3192)	(.3197)
Number of computer manufacturers in the form factors produced by the organization	–.0017•	–.0019•	–.0015•	–.0019••	–.0019••	–.0019••
	(.0009)	(.0010)	(.0009)	(.0009)	(.0009)	(.0009)
Entries of computer manufacturers in the form factors produced by the organization	.0030	.0024	.0028	.0025	.0024	.0024
	(.0024)	(.0024)	(.0023)	(.0023)	(.0023)	(.0023)
Small organization's competitive experience	–.0108••	–.0119••	–.0108••	–.0119••	–.0119••	–.0119••
	(.0051)	(.0051)	(.0051)	(.0051)	(.0051)	(.0051)
Large organization's competitive experience	–.0023	–.0036	–.0022	–.0035	–.0035	–.0035
	(.0043)	(.0044)	(.0043)	(.0044)	(.0044)	(.0044)
Overlap with small domestic rivals (by form factor and capacity)	.0334	.0483	.0325	.0479	.0481	.0479
	(.0667)	(.0689)	(.0665)	(.0689)	(.0688)	(.0689)
Overlap with large domestic rivals (by form factor and capacity)	.1451••	.2071••	.1424••	.2127••	.2080••	.2128••
	(.0506)	(.0600)	(.0501)	(.0565)	(.0587)	(.0560)
Small domestic rivals' competitive experience (experience-weighted overlap)	.0056••	.0039•	.0055••	.0039•	.0040•	.0039•
	(.0023)	(.0023)	(.0022)	(.0023)	(.0023)	(.0023)
Large domestic rivals' competitive experience (experience-weighted overlap)	–.0016••	–.0025••	–.0016••	–.0025••	–.0025••	–.0025••
	(.0008)	(.0009)	(.0008)	(.0009)	(.0009)	(.0009)
Non-overlap with domestic rivals	.0228•	.0188	.0220•	.0199	.0192	.0198
	(.0130)	(.0138)	(.0129)	(.0132)	(.0131)	(.0129)
Overlap with foreign rivals	–.0988••	–.4904••	–.0938••	–.4786••	–.4831••	–.4795••
	(.0364)	(.1455)	(.0338)	(.1398)	(.1272)	(.1266)
Foreign rivals' competitive experience (experience-weighted overlap)			.0019••	.0001		
			(.0008)	(.0010)		
Small foreign rivals' competitive experience (experience-weighted overlap)	.0025	.0001				
	(.0018)	(.0023)				
Large foreign rivals' competitive experience (experience-weighted overlap)	.0017••	–.0001				
	(.0008)	(.0013)				
Overlap with foreign rivals × calendar year (1956 = 0)				.0150••		.0150••
				(.0052)		(.0041)
Overlap with small foreign rivals × calendar year (1956 = 0)		.0152••			.0149••	
		(.0053)			(.0041)	
Overlap with large foreign rivals × calendar year (1956 = 0)		.0181••			.0154••	
		(.0059)			(.0043)	
Log likelihood	–89.26	–84.89	–89.34	–84.93	–84.89	–84.93
Degrees of freedom	41	43	40	41	40	40

• $p < .10$; •• $p < .05$.

* Standard errors are in parentheses. Each model also includes market tenure, calendar year, form factor, and region effects as shown in table 5b. The data cover 1,538 organization-years, 171 organizations, and 157 exits.

separated organizations contribute to legitimating one another even as they are too distant to generate noticeable competition. Over time, however, the pattern changes, with foreign rivals generating increasing competition. By the end of the 1980s, organizations are actually driving up the failure rates of rivals in other countries. And by the end of the study period, the competitive effect of foreign rivals has grown to be almost indistinguishable from that generated by domestic rivals. This can be seen by comparing the far right endpoint of the plot in figure 6, which illustrates recent foreign compe-

Table 5b

Estimated Market Tenure, Calendar Year, Form Factor, and Region Effects from the Models in Table 5a*

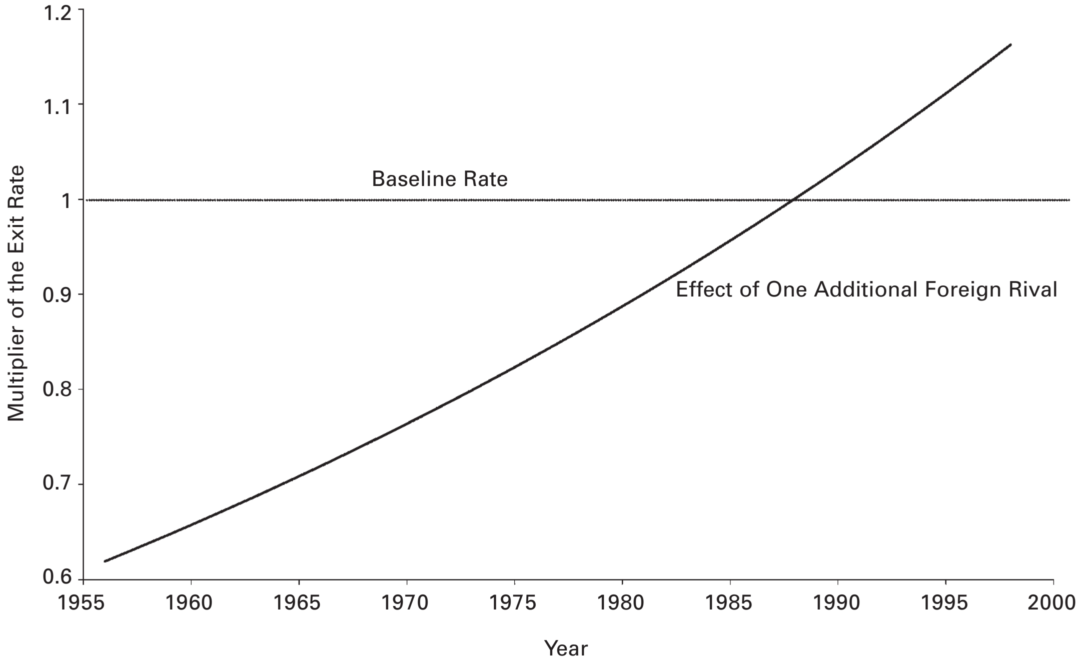
	Model					
Independent Variable	(9)	(10)	(11)	(12)	(13)	(14)
Organization of market tenure 0–1 year	–6.024••	–5.725••	–5.997••	–5.764••	–5.726••	–5.765••
	(.9018)	(.8715)	(.8981)	(.8631)	(.8720)	(.8618)
Organization of market tenure 1–3 years	–4.002••	–3.682••	–3.980••	–3.719••	–3.684••	–3.719••
	(.7573)	(.7186)	(.7538)	(.7105)	(.7191)	(.7095)
Organization of market tenure 3–5 years	–3.662••	–3.332••	–3.646••	–3.376••	–3.338••	–3.377••
	(.7608)	(.7284)	(.7582)	(.7160)	(.7274)	(.7154)
Organization of market tenure 5–10 years	–3.417••	–3.058••	–3.384••	–3.106••	–3.061••	–3.106••
	(.7683)	(.7356)	(.7625)	(.7190)	(.7355)	(.7184)
Organization of market tenure 10–20 years	–2.869••	–2.466••	–2.855••	–2.506••	–2.471••	–2.506••
	(.8072)	(.7721)	(.8057)	(.7622)	(.7712)	(.7620)
Organization of market tenure 20+ years	–2.581••	–2.127••	–2.592••	–2.165••	–2.138••	–2.165••
	(.9314)	(.9144)	(.9287)	(.9051)	(.9080)	(.9052)
Large organization of market tenure 0–3 years	–2.483••	–2.528••	–2.472••	–2.532••	–2.524••	–2.533••
	(.7464)	(.7488)	(.7458)	(.7481)	(.7479)	(.7474)
Large organization of market tenure 3–5 years	–3.075••	–3.065••	–3.068••	–3.062••	–3.061••	–3.062••
	(1.033)	(1.035)	(1.033)	(1.035)	(1.034)	(1.034)
Large organization of market tenure 5–10 years	–2.154••	–2.089••	–2.168••	–2.081••	–2.091••	–2.081••
	(.5170)	(.5197)	(.5161)	(.5186)	(.5195)	(.5182)
Large organization of market tenure 10–20 years	–1.833••	–1.713••	–1.826••	–1.715••	–1.714••	–1.715••
	(.5002)	(.5020)	(.4993)	(.5018)	(.5004)	(.5009)
Large organization of market tenure 20+ years	–.8838	–.8665	–.8604	–.8733	–.8655	–.8730
	(1.002)	(1.010)	(.9972)	(1.009)	(1.007)	(1.009)
Calendar year (1956 = 0)	.0608••	.0467••	.0611••	.0470••	.0464••	.0470••
	(.0237)	(.0232)	(.0236)	(.0232)	(.0230)	(.0229)
Japanese organization	–.3222	–.2302	–.3425	–.2111	–.2314	–.2106
	(.4032)	(.4094)	(.4003)	(.4035)	(.4094)	(.4019)
Eastern-European organization	–.7030	–.5290	–.7365	–.5112	–.5327	–.5106
	(.7844)	(.7971)	(.7802)	(.7927)	(.7961)	(.7916)
Western-European organization	–.1962	–.2275	–.2463	–.1759	–.2292	–.1748
	(.5410)	(.5600)	(.5270)	(.5275)	(.5607)	(.5220)
South American organization	–1.013	–.7999	–1.050•	–.7334	–.8063	–.7301
	(.6288)	(.6659)	(.6221)	(.6256)	(.6508)	(.5856)
Asian (other than Japanese) organization	.4281	.3429	.3826	.3886	.3352	.3907
	(.6745)	(.6791)	(.6635)	(.6574)	(.6755)	(.6433)
Organization produces 1.8-inch form factor	–.0243	.0274	–.0352	.0365	.0408	.0342
	(.7302)	(.7382)	(.7291)	(.7369)	(.7220)	(.7211)
Organization produces 2.5-inch form factor	.1450	.4605	.0616	.4958	.4504	.4969
	(.6488)	(.6655)	(.6135)	(.6342)	(.6540)	(.6301)
Organization produces 3.5-inch form factor	.6689	.5907	.6100	.6388	.5889	.6394
	(.6039)	(.6286)	(.5855)	(.5957)	(.6245)	(.5945)
Organization produces 5.25-inch form factor	.8339	1.080•	.7630	1.111•	1.078•	1.111•
	(.6014)	(.6234)	(.5758)	(.5972)	(.6106)	(.5970)
Organization produces 8-inch form factor	.1178	.4550	.0831	.4667	.4459	.4681
	(.4491)	(.4688)	(.4398)	(.4642)	(.4619)	(.4547)
Organization produces 14-inch (or above) form factor	.0028	.4609	–.0175	.4647	.4535	.4659
	(.4056)	(.4345)	(.4019)	(.4339)	(.4292)	(.4272)

• $p < .10$; •• $p < .05$.
* Standard errors are in parentheses. For region effects, the U.S. is the omitted category.

tition, to the y-intercepts in figure 4, which illustrate the strength of domestic competition. These results show that by the end of the 1990s, competition in the hard disk drive market had become global.

Looking back over tables 3b, 4b, and 5b, it is interesting to see how the effects of national regions change across specifications. These national region effects change dramatically from model 3 to model 4, as domestic and foreign competition are specified separately. National effects continue to change as we elaborate our model by including the effects of exposure to competition in table 4. Once we fully specify the

Figure 6. The development of global competition among disk drive manufacturers (based on the estimates of model 14).



model in table 5, allowing for the globalization of competition, we no longer find statistical evidence of national region effects. Neither do we find evidence that manufacturing in Asia affected failure rates. Apparently, at least to the extent that our models can detect them, national differences in organizational failure rates in the hard disk drive market appear to be due to differences in the competitive landscape.

Fully specifying the competitive landscape also was important to obtaining unbiased estimates of product strategy effects. In particular, some of the models in tables 3a and 4a show marginally significant differences in the failure rate depending on the capacity levels of firms' product offerings. These differences no longer appear once the various competitive effects are fully specified in table 5a. Meanwhile, we initially see no apparent differences in failure rates due to firms' choices of form factors (in tables 3b and 4b), but significantly greater failure rates appear for the 5.25-inch form factor once competition is fully modeled in table 5b. In these ways, we were not able to correctly recognize the survival implications of product strategies until we fully modeled the different sources of competition to which organizations were exposed due to these strategies.

Finally, we find strong community ecology effects. On the one hand, we see clear symbiosis between the population of computer manufacturers and disk drive manufacturers: failure rates fall among hard disk drive firms with increases in the population of computer firms for whom they manufactured. But we do not find that this symbiosis was "internalized" by organizations that vertically integrated between the hard disk drive and computer industries, in that captive producers did not enjoy greater survival chances; in fact, the "captive" variable has a positive, though non-significant effect on the failure rate. It appears, then, that evidence of symbiosis between computer manufacturing and disk drive manufacturing could be found only at the population level.

DISCUSSION AND CONCLUSION

Why are some organizations more competitive than others? As we have demonstrated, the answer to this question hinges on the logic one chooses to guide the study of competition. Understood as a contest, competition in the disk drive industry has clearly favored organizations with the ability to orchestrate continuous product development over time, in short, the largest hard disk drive firms that remained disproportionately at the cutting edge of technology. By contrast, we come up with the opposite answer when competition is understood as a powerful source of constraint that drives organizational development and selection. Guided by this logic, we found that organizations that have been exposed to competition are less likely to fail and that they generate stronger competition—so-called Red Queen competition—but that these benefits accrue only when organizations are small. Large organizations, well known to have advantages that help them cope with competitive constraints, appear to be unresponsive to the Red Queen process.

Regarding global competition, organizations do not appear to project stronger competition globally as a result of their domestic competitive experience. Instead, global competition among disk drive manufacturers increased over calendar time, with all organizations generating increasingly strong global competition. Many scholars, but most notably Porter (1990), have emphasized the continuing importance of home-country effects even as firms engage in global competition. Our findings suggest, however, that at least in the hard disk drive market, competition became increasingly global over calendar time regardless of the competitiveness of one's home country. Consequently, country-specific advantages have faded in importance as time has passed. Similarly, although many have noted country-specific differences in failure rates among disk drive manufacturers (e.g., Chesbrough, 1999), we found that these differences vanish when specified in models that allow for Red Queen development and global competition.

Our findings suggest that neither development nor obsolescence is built into the process of organizations aging. Rather, whether and how organizations develop over time hinges on whether they are exposed to competition. Except for large organizations, those that have endured competition are likely to be better adapted and may even appear to have moved down a learning curve. By contrast, organizations that have remained isolated from competition will not have been spurred by Red Queen evolution and consequently are more likely to exhibit liabilities of senescence and obsolescence as their ages increase (Barron, West, and Hannan, 1994). In neither case, however, are these the inevitable outcomes of aging. We found instead that change in survival chances over time depends on whether organizations have been exposed to competition.

Our results also reveal a possible unintended consequence of technological differentiation. A large literature in strategic management emphasizes the fact that organizations perform better and have better life chances when they are differentiated on various dimensions. Organizational ecology research, too, demonstrates that competition is localized on various dimensions (McPherson, 1983; Hannan and Freeman, 1989; Baum and Mezias, 1992; Baum and Singh, 1994; Podolny, Stuart, and Hannan, 1996; Carroll and Hannan, 2000). Our findings suggest that organizations pay a hidden cost for such differentiation. Isolation from competition has obvious current-time benefits but also has the less-obvious downside that it deprives an organization of the engine of development. The more that change is driven by Red Queen evolution, the more will there be a trade-off between positional advantage that isolates an organization from competition and the advantages that come from the development of new capabilities. In this way, positional- and capabilities-based advantage may be inversely related, with those in safe places enjoying their positions but suffering over time as they fall behind those who remain in the race.

These results speak, as well, to the growing literature on "coevolution" among organizations. Early attempts at linking organizations to their environment in a system of reciprocal causality did not advance beyond speculative frameworks (Emery and Trist, 1965; Terreberry, 1968). More recently, reciprocal causality has been addressed insofar as organizations refer to one another in a process of social comparison (White, 1981) or in strategies of imitation (Mezias and Lant, 1994). Some research describes such reciprocal processes as "coevolution," with reference by analogy to developments in biology (e.g., Baum and Singh, 1994). The strength of research in this vein is that we now know of various regulatory, technical, and organizational processes that run in parallel and that affect one another as they develop over time (see various papers in Baum and McKelvey, 1999, for example). The downside, thus far, is that research on coevolution often fails to produce falsifiable hypotheses. Our model, though it features reciprocal causality, is sufficiently explicit that it makes falsifiable predictions. We hope that other work in the general area of coevolution will take a similarly explicit modeling approach.

To conclude, we think it is useful to consider the dynamic implications of the prevailing sociological view of competition as a constraining force. Seen as part of an ongoing, coevolutionary dynamic, such competition may be managed by large, formidable organizations, but this may not work to their advantage. Intentions notwithstanding, the ultimate consequences of organizations' efforts to strategize around, directly manage, or otherwise control the incidence and impact of competition may be to hinder their own development, or at least to allow organizations to survive that would otherwise have been selected out. Informed by this possibility, our analyses of competition will be able to reveal this potentially important source of competitive weakness among our most formidable organizations.

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APPENDIX: Data on the Global Hard Disk Drive Market

Data on every organization ever to manufacture a hard disk drive were gathered from market research reports, publicly available financial information, industry participants, and an extensive search of the business press. From these disparate sources, we compiled the life history of each disk drive company. These histories cover market entry and exit dates, sales, presence in each year in a given "form factor" (the physical size of a disk drive), products' technical specifications, acquisition history, and nationality for each company that made a hard disk drive since the first known manufacture of a disk in 1956 through 1998. The resulting database includes 171 organizations that manufactured hard disk drives at any time or place over the period. Nearly all organizations (155) exited the industry by the end of 1998. The data cover 1,538 organization-years.

The primary source of data for this study is the *Disk/Trend Report: Rigid Disk Drives,* published annually since 1977 by Disk/Trend, Inc., a market research company in Mountain View, California. These reports track every known company that made hard disk drives, list detailed product specifications and shipment dates, and publish revenue and unit shipment information by form factor and capacity range. The reports do not, however, list the date of first entry for many companies that produced disk drives before 1976. In several instances, companies operating in 1976 shipped their first disk drives in the 1960s, but these products were no longer in production when the first *Disk/Trend Report* was published and so "first shipment" dates could not be determined. We contacted surviving companies for information, spoke with retired engineers involved in the development of a company's first disk drive for both surviving and former disk drive producers and often received copies of written technical and market information in their possession, reviewed company documents in the files of Disk/Trend, Inc., and researched company histories in books, financial reports, and the business press. Reports by two market research firms in particular were basic sources of information on product specifications and shipment dates of firms operating during the 1960s and early 1970s (HTW, 1970; MDS, 1972). These searches resulted in earlier entry dates than would otherwise be inferred from information in *Disk/Trend* for 20 of 32 firms making disk drives as of January 1, 1976. An additional 17 companies made disk drives but exited the industry before *Disk/Trend* was first published. Of these 37 firms (20 plus 17), precise dates of first shipment for 15 companies were unavailable; instead, entry dates were set at three months after first product announcement.

Life events were coded so that name changes and reorganizations were not counted as entries and exits. A number of disk drive companies changed their names or were acquired during the period of study. Name changes sometimes occurred when a parent firm announced a new strategy. In these cases, the disk drive operations may have been combined with some other corporate activity. These were not coded as market exits. For instance, England's Data Recording Instruments put its disk drive operations into a newly formed peripherals operation named Data Recording Equipment in 1978, and its name was changed again in 1982 to Newbury Data after it was combined with other operations. Over time these incarnations were treated as the same entity, so its reorganizations were not counted as entries or exits. Nor did we code as exits any acquisitions of disk drive firms by non-disk drive companies if the disk drive operations were left largely intact. For example, Perkin Elmer acquired Wangco, a disk drive maker. Wangco then continued to make disk drives as a Perkin Elmer subsidiary. The acquisition was thus not coded as an exit (or a new entry). By contrast, if a company was liquidated and the liquidated assets formed the basis of a new company, then the two events were coded as an exit and an entry.

To investigate the technology race in this industry, we coded for each firm whether it shipped a product in a particular form factor and capacity range in any given year. The bulk of shipments were non-captive market transactions, and our analysis of the technology positions of each firm was restricted to these shipments. We did include firms in the survival analysis, however, even if they only engaged in captive production. We relied on *Disk/Trend* technology classifications for all 1976–1998 observations. *Disk/Trend* created product group categories by drive type (cartridge disk drives, disk pack drives, fixed disk drives) and by capacity range (30–60 megabytes, 100–300 megabytes, etc.). Because of the dramatic improvements in disk drive capacity over the years, these categories evolved over time. For instance, in 1976, *Disk/Trend* created nine product groups, including a group consisting of firms shipping disk drives of less than 12 megabytes and one consisting of firms shipping disk drives greater than 200 megabytes. In 1996, nine product groups were also used, but this time the smallest capacity range for a product group was less than 500 megabytes and the largest was for more than 20 gigabytes. We coded whether a given product group (capacity range) represented a relatively "low-," "medium-," or "high-" capacity disk drive for that form factor in that year. Thus, the technological position of a firm in a given form factor was made relative to that of other firms in the same form factor (other firms shipping 5.25-inch drives, for example) and not across form factors, and a disk drive that was a high-capacity product in one year could become a medium- or low-capacity product in the next year or two.

This approach allowed us to specify in our models the precise technological domain of each organization in each year. For instance, an organization offering both 3.5-inch and 5.25-inch products in a given year could have been in any of six technology segments: low-, medium-, and high-capacity within the 3.5-inch form factor and low-, medium-, and high-capacity within the 5.25-inch form factor. If this organization were in all six of these segments, then a rival that overlaps this organization in only one of these six segments would contribute 1/6 to the organization's technology-overlap density score. By contrast, a rival that offered products in all six of these areas would contribute one to the organization's technology-overlap score. At the extremes, if an organization produced in the same form factors and capacity levels as all other manufacturers, then its technology-overlap density would equal simply the number of other organizations. If an organization did not overlap with any other manufacturers, however, then its technology-overlap density would equal 0, reflecting its complete technological differentiation.

Although the *Disk/Trend Report* is an incredibly rich and exhaustive source of information on products, revenues, and shipment volumes, its use requires some care. When a disk drive company acquires another, *Disk/Trend* lists the combined products under the name of the acquiring firm, however, *Disk/Trend* notes the shipment dates of products that were originally developed by the *acquired* firm as the dates of first shipment, not dates of first shipment by the acquiring firm. Knowing this, we took care not to code a company as shipping a particular disk drive earlier than it actually had. Moreover, many products were announced that never shipped, and sometimes the same product was reportedly shipped on two different dates depending on the year of the *Disk/Trend Report*. A couple of companies, such as Memorex Telex, were listed as disk drive companies when in fact they only resold drives made by other manufacturers. In a few cases it was not clear that a company actually ever shipped a product. For example, *Disk/Trend Report* would describe a new company and list its products, all of which were scheduled to be shipped sometime after the publication date of *Disk/Trend Report*. That company would not appear in the next year's report, however, and it was unclear whether the firm in fact shipped the products, only to exit before *Disk/Trend* was published the following year, or else never shipped. We checked each of the more than 10,000 products listed in the *Disk/Trend Reports* (including the same product appearing in more than one year) for such anomalies. When we encoutered problems, we contacted Disk/Trend, Inc. staff, who always kindly helped us to clarify.

We also had to classify products and capacity ranges for 1956–1975, prior to the publication of *Disk/Trend*. This required creating product groups that mirrored the technological state of the industry. We started by extending the 1976 product group classifications back in time until they seemed to collide with the reality of the products being offered. This resulted in a gradual reduction in the number of product groups in the 14-inch form factor and the creation of product groups for larger form factors. First, as was the practice in *Disk/Trend*, we grouped together similarly sized form factors. Thus, 39-inch, 34-inch, and 31-inch products were grouped together as one form factor; 28-inch, 26-inch, and 24-inch products were similarly grouped; and 16-inch, 14-inch and 12-inch products were classified as a single form factor. (For reporting purposes, *Disk/Trend*, for example, grouped 10.5-inch drives with the 14-inch form factor, 9-inch drives with 8-inch, 3.9-inch drives with 3.5-inch, 3-inch drives with 2.5-inch, and 1.3-inch drives with 1.8-inch.) Only a few new capacity ranges were created for the 1956–1975 period. This procedure affected 282 firm-year observations.