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Electronic Companion—"The Red Queen, Success Bias, and Organizational Inertia" by William P. Barnett and Elizabeth G. Pontikes, *Management Science*, DOI 10.1287/mnsc.1070.0808.

Appendix A: History-Dependent Models of Organizational Failure and Change

To test our ideas empirically, we specify models that allow for an organization's viability to depend on its history of exposure to competition as implied by Red Queen theory. We start with a model depicting history-dependent competition within a single market, which we will test within each of two markets in the computer industry: the market for midrange computers and the market for microcomputers. Then we expand the model to allow for our hypothesized cross-market effects, looking at how organizations with a history of competing in the midrange computer market fared if they moved into the microcomputer market.

History-Dependent Competition in a Single Market

Consider initially the dyadic case where a given organization j has been competing against a rival k. Allow h_{jk} to represent the effect on j's viability of its history of competition with rival k. That is, the current-time competitive effect of k on j is specified in the model separately from the historical effect h_{jk}, thus isolating the effect on j's viability of having competed historically with k:

$$h_{jk} = a + b\tau_{jk},$$

where τ_{jk} records the time that j and k have competed historically, b is the marginal effect of this historical competition on j's current-time viability, and the intercept a allows for a fixed cost to be associated with j's adaptation to k's rivalry. This specification assumes that the competitive context of these two organizations has remained stationary over time, at least to the extent that lessons learned in the distant past remain relevant and that adaptations remain appropriate. (We relax this assumption momentarily.)

It is straightforward to allow for the possibility that j competes with an entire population of organizations. Assuming independence across its competitive relationships, and now allowing k to denote any rival from the population, the combined effect of j's historical exposure to competition across the population can be represented by summing across all of j's dyadic competitive relationships:

$$H_j = \Sigma_k h_{jk} = \mathrm{a}K_j + \mathrm{b}T_j$$

where K_j is the number of rivals faced historically by organization j, and $T_j = \Sigma_k \tau_{jk}$, the number of organization-years of rivalry faced historically by j (or, put differently, the cumulative annual density faced historically by organization j). The historical effect H_j thus decomposes organization j's historical exposure to competition in a way that distinguishes the breadth and depth of competitive experience. For a given level of T_j, a low K_j implies fewer, longer competitive relationships, while a high K_j means that organization *j*'s experience has been spread more thinly over many historical rivals.

Allowing r_j to represent the current-time failure rate of organization *j* in a specific market, we can operationalize history-dependent competition by estimating the model:

$$r_j(t) = r_j(t)^* \exp[H_j],$$

where *t* is organization *j*'s market tenure, $r_j(t)^*$ is organization *j*'s baseline failure rate specified as a function of organization-specific factors and variables known to affect the carrying capacity for organizations such as *j*. H_j (and the other independent variables) are modeled in the exponential to prevent the estimation of (meaningless) negative rates, a standard approach in hazard modeling (Tuma and Hannan, 1984). Substituting, the model to be estimated is:

$$r_j(t) = r_j(t)^* \exp[aK_j + bT_j].$$

According to Red Queen theory, we expect to find $a>0$, reflecting the costs associated with adapting to different rivals historically, and $b<0$, the improvement in current-time viability that comes with exposure to historical competition net of the costs of adaptation.

Now we can relax the stationarity assumption. Instead, assume that lessons learned more recently are more applicable to current-time conditions than are distant-past lessons. Under this assumption, one would discount competitive experience from any given year as an inverse function of its distance in the past. In particular, we discount by $1/\sqrt{\delta}$, where δ is the absolute value of a given historical year's distance from the current year, and we impose this discount on each organization-year of competitive experience prior to summing in order to create for each organization *j* at each point in time a recent historical experience term T_{Rj} (see Ingram and Baum, 1997; Darr, Argote, and Epple, 1995). Organization *j*'s distant-past competitive experience is then the difference between its total competitive experience and its recent competitive experience: $T_{Dj}=T_j-T_{Rj}$. Substituting, the model can be expressed in a way that allows for more recent competitive experience to have a separate effect from distant-past experience:

$$r_j(t) = r_j(t)^* \exp[aK_j + b_D T_{Dj} + b_R T_{Rj}].$$

If more recent experience contributes more to organization *j*'s current-time viability than its distant-past experience, then we expect to find $b_R<0$ and $b_R<b_D$. And if a competency trap is operating within the market over time (Levinthal and March, 1981; Levitt and March, 1988), such that distant-past experience turns out to harm an organization's current-time prospects, then we would also find $b_D>0$.

History-Dependent Competition across Multiple Markets

Building on the single-market failure model, it is straightforward to allow for the effects of historical competition across multiple markets described in hypothesis 1. Above and beyond the various market-specific effects in the model, our hypothesis points to historical effects for those organizations that have previously competed in some other market. In particular, surviving such competition in other markets is predicted to harm an organization's viability once it moves into the focal market. To include this historical term in our model, denote the other market by *A*, and the focal market as *B*. Allow T_{Aj} to represent the number of organization-years of rivalry faced historically by *j* in market *A*. We then can estimate:

$$r_j(t) = r_j(t)^* \exp[aK_j + b_D T_{Dj} + b_R T_{Rj} + dT_{Aj}],$$

where the failure rate r_j is with regards to failure in the focal market *B*, and where markets *A* and *B* differ in some fundamental way. According to hypothesis 1, we expect that a history of competing in market *A* harms an organization's viability in market *B*, such that $d>0$.

Of course, what constitutes "different" markets is likely to be important to whether this prediction finds support, and presumably, one would expect to see support for the theory the more substantial the differences between markets. The criteria for market differences, however, are not developed by our theory. There might be some potential merit in considering differences between markets as an extension of our theory, perhaps along the lines of "distance" between environmental states as theorized in Hannan and Freeman's (1977) niche theory. For now, however, we proceed in the more typical, *ad hoc* fashion, exploiting market differences as they appear in our particular study setting.

History-Dependent Competition in a Model of Organizational Change

We empirically investigate hypothesis 2, that a success bias operates among survivors of Red Queen competition, by analyzing entry rates into the microcomputer market among midrange computer manufacturers. Most organization-level research looking at changes of this sort refrains from exploring micro-level aspects of decision making, such as the operation of biases. Instead, organization-level research tends to focus on clearly organization-level aspects of change, while decision biases typically remain beyond our purview. In some cases, theories assume (implicitly) that intendedly-rational decision-makers will choose to change in directions that are viability enhancing, as in models that predict movement into less competitive contexts (e.g. Dobrev et al., 2003) or imitation of other organizations (Greve, 1996; Haveman, 1993b). In other cases, difficulties in the decision-making process are thought to be part of the larger set of organizational forces that inhibit rates of organizational change (Hannan et al., 2003a, 2003b).

Our hypothesis 2, by contrast, allows for the operation of a decision bias in a way that is predictable and visible, albeit indirectly, at the organization level. To test this hypothesis, consider the model:

$$r_{\Delta ABj}(t) = r_{\Delta ABj}(t)^{*}\exp[a_{\Delta}T_{DAj} + b_{\Delta}T_{RAj}],$$

where $r_{\Delta ABj}$ is that hazard of organization *j* in market *A* moving into market *B*, as a function of its tenure *t* in market *A*. $r_{\Delta ABj}(t)^{*}$ is the baseline rate of change, estimated as a function of organizational and environmental factors discussed below. T_{Aj} is organization *j*'s competitive experience historically in market *A*, subscripted to denote recent and distant-past experience (calculated as in the failure analysis). So specified, our hypothesis 2 is supported if estimates reveal $b_{\Delta}>0$ and $b_{\Delta}>a_{\Delta}$, meaning organizations that have survived a history of competition, especially in the recent past, have a higher rate of entry into the new market.

Aside from our hypothesized effects, we specify the baseline change rate $r_{\Delta ABj}(t)^{*}$ as a function of various factors typically featured in such analyses, including both organizational characteristics that trigger or inhibit change, and environmental characteristics that affect rates of organizational change. We briefly and partially review the research on these forces in order to build aspects of each into our baseline model of new market entry.

Studies of organizational change and market entry have long emphasized organizational characteristics as either driving or inhibiting rates of change, with organizational size featured prominently. Life-cycle models envision organizations transforming to correspond to the structural requirements of increased size as organizations grow (Child and Kieser, 1981; Cafferata, 1982; Kimberly and Miles, 1980), while others propose that larger organizations engage in change at a greater rate due to their advantages in wielding resources (Kimberly, 1976; Aldrich and Auster, 1986). Contradicting these claims, Hannan and Freeman (1984) argued that larger organizations are less likely to change in fundamental ways, because their complex structures make the process of change more difficult and disruptive. Amid these differing claims, empirical evidence on the subject is mixed, with some showing large organizations to be more likely to change (Huber et al., 1993), others showing small organizations to be more inclined to change (Baron et al., 1991; Delacroix and Swaminathan, 1991; Halliday et al., 1993), and still others finding middle-sized organizations to be more likely to change or innovate (Scherer, 1980; Haveman, 1993a). In addition, high status organizations appear to be less susceptible to social influence (Bothner, 2003). Given that prestige often correlates with organizational size (Podolny, 1993), this finding bolsters the case for the size-inertia argument. In sum, it seems clear that our model of market entry should distinguish rates of change according to organizational size.

Building on Stinchcombe's (1965) arguments, Hannan and Freeman's (1984) theory of structural inertia predicts decreasing rates of change as organizations age, as their procedures, roles, and structures become institutionalized (see also Barron et al., 1994). In light of these arguments, considerable empirical support has been found for the hypothesis that organizations change at lower rates as they age (Delacroix and Swaminathan, 1991; Amburgey et al., 1993; Halliday et al., 1993; Kelly and Amburgey, 1991; Miller and Chen, 1994), and the findings in Baron et al. (1991) concur, although these authors also find some evidence that very old organizations appear to amenable to change as well. A related research stream advances the Schumpeterian tradition, arguing and demonstrating that established firms often are less able to move into new technological directions compared to entrepreneurial ventures (Tushman and Romanelli, 1985; Tushman and Anderson, 1986; Anderson and Tushman, 1990; Henderson and Clark, 1990). Consequently, we are careful to control for tenure-dependence in our change model

Considerable attention has been paid as well to environmental factors that constrain and trigger change in organizations. In some settings, institutional environmental factors have been shown empirically to be important in determining rates of change (Baron et al., 1991; Edelman, 1992; Halliday et al., 1993; Miner et al., 1990; Singh et al., 1991; Sutton et al., 1994). Perhaps more relevant to our analysis of the computer industry, various aspects of the market environment have been found to determine change rates, such as market volatility (Delacroix and Swaminathan, 1991), market growth and diversity (Miller and Chen, 1994), the speed of market change (Eisenhardt, 1989), and the examples set by other firms in the market (Greve, 1996; Haveman, 1993b). In light of these findings, our model will control for the general economic conditions, market size, entries, and exits for the markets involved in our analysis.

Especially important to our theory are several papers that show change to be affected by current-time competition among organizations. The basic idea and finding among these papers is that organizations move away from densely crowded market niches, and in the direction of less crowded niches, other things equal (Delacroix and Swaminathan, 1991; Greve, 1996; Dobrev et al., 2003). Others show organizations moving among markets in order to ease competitive pressure – that is, to share multiple markets with rivals (Baum and Korn, 1999; Haveman and Nonnemaker, 2000), a strategy known to lessen competitive pressure (Barnett, 1993). With these various results in mind, we control for current-time competition in each market involved in our change analysis.

Model Specification and Estimation

All modeled all transitions using a piecewise constant rate specification. This functional form is flexible across pieces, in that the rates are allowed to vary freely from period to period, and are assumed to remain constant with respect to duration only within each period (Blossfeld and Rohwer, 1996). In order to update the independent variables, we segmented each organization's history into one-year segments. The models were estimated using the stpiece STATA routine written by Jesper Sørensen.

Appendix B: Description of Variables

Market tenure (in years) recorded the time since an organization entered into a given market, up to the point when the organization either exited the market or the study period ended (so-called "right-censored" cases). The last observed year for each exiting organization was coded as the midpoint of the year, an approach that minimizes time-aggregation bias when estimating hazard models (Petersen, 1991).

Organization size was recorded annually for each organization. Three different size measures were available, each from different sources: an organization's number of employees (according to *Computers and Automation*), number of products shipped in a given year by an organization (according to *IDC*), and the number of product-types being sold on the market in a given year (according to *Data Sources*). We compared each organization's size on each of these measures relative to the other organizations in the given market in the given year. Because interval measures could not be translated across the different size variables, we coded for each organization a relative size category – small, medium, or large – for each year. We based these category assignments first based on numbers of employees. Where this variable was not available, we used annual shipments. When neither of these variables were available, we created an estimate of shipments based on the number of product types, using the results of a regression of shipments on the number of product types (in a given market) estimated on those observations that contained information on both of these variables. Also, we employed linear interpolation to fill gaps in the size data for a given variable over the life of a given organization, and extrapolated for up to 4 years forward or backward where necessary. Finally, for the 115 organizations that did not have any size measures, or for organizations that existed without any size measure for more than 4 years consecutively, we assigned a "small" designation after searching for information indicating otherwise.

De Novo organizations, those born as computer manufacturers, and *De Alio* organizations, those born in some other industry, were determined for each organization by Swanson (2002). This variable was coded primarily using a comparison of each organization's founding date with its date of first operation in the computer industry. Secondarily, organizations founded prior to first appearing in the computer industry were individually researched to see whether they were *de novo* computer manufacturers engaged in "pre-production," or whether they were *de alio* organizations. Long time lags before entering the computer industry, an examination of the organization's name over time, and an examination of internet searches, on-line sources, and archival documents (Lexis/Nexis, *Who's Who in Electronics*, *U.S. Electronics Industry Directory* (Harris Publishing Co., various years), and *Electronic Buyer's Guide* (McGraw-Hill, various years) were used to determine this variable for questionable cases. Using this approach 1,906 of these organizations entered *de novo*, while 696 entered as *de alio* organizations.

Market exit was coded for organizations that ceased to operate in a given market. Since most organizations operated in only one market, most market exits (93%) were, in fact, exits from the entire computer industry. Organizations that were acquired by a considerably larger firm were designated as exits, but mere name changes were not treated as exits. Mergers among equals were not treated as exit events. We determined such events by checking every market exit against archival documents and Lexis/Nexis. This approach resulted in the identification of a few cases (N=11) of mergers among relatively equally-sized organizations, such as the merger of Burroughs and Sperry to create Unisys in 1987. For these events, we ended the life history of each of the merging organizations, coded the event as right-censored, and then started up the life history of a "new" organization with a new tenure clock. *Market entry* was coded for organizations in the first year that they are reported as offering (for sale or lease) a general-purpose, electronic digital computer in a given market (microcomputer, midrange, or mainframe).

Current-year organizational densities were computed as the numbers of organizations in the industry or respective market at the beginning of a given year. Because the exact timing of entry and exit was not known for most organizations, density at the beginning of the year was calculated as the density at the start of the prior year, plus entries and minus exits during the prior year. In this industry, an organization can be in more than one market in any given time, and if an organization is in multiple markets, it is counted in each of the appropriate market densities. In this way, the sum of the microcomputer, midrange, and mainframe densities do not necessarily sum to the industry density.

Historical competition was computed by summing the total number of competitors faced each year by an organization over its history, not including the current-year competitors in any given year. This measure, denoted by T_j in our model, is equal to the total number of competitor-years each firm has experienced, up to a given year (not including the number of competitors at the start of that year). We also include in the model K_j, the number of unique competitors each firm has faced historically up to a given year. *Recent versus distant-past historical competition* was calculated using a distributed lag weight prior to summing over the years of an organization's history. Specifically, recent historical competition was T_j calculated with each year's contribution to this sum weighted by $1/\sqrt{\delta}$, where δ is the number of years prior to the current year. Distant-past historical competition was then calculated as the organization's overall historical competition minus its recent historical competition.

Rivals' historical competition in the microcomputer market was computed for each organization. This term was calculated by summing the historical competition scores (T) over each organization's rivals. Similarly, the *sum of rivals' ages* was computed in the same way, but by summing the market tenure of each organization's rivals in a given year.

Exogenous environmental conditions likely to affect organizational survival were also measured in two ways. To reflect general economic conditions in the U.S., we included a measure of *real gross domestic product in the U.S.* (in 1987 U.S. dollars) (U.S. Department of Commerce, c.2001). We also included the *prime interest rate* lagged to the last day of the prior year to reflect the availability of capital (Federal Reserve, c.2002).

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Appendix C: Descriptives

Figure C1. Number of General Purpose Digital Computer Manufacturers in the U.S.

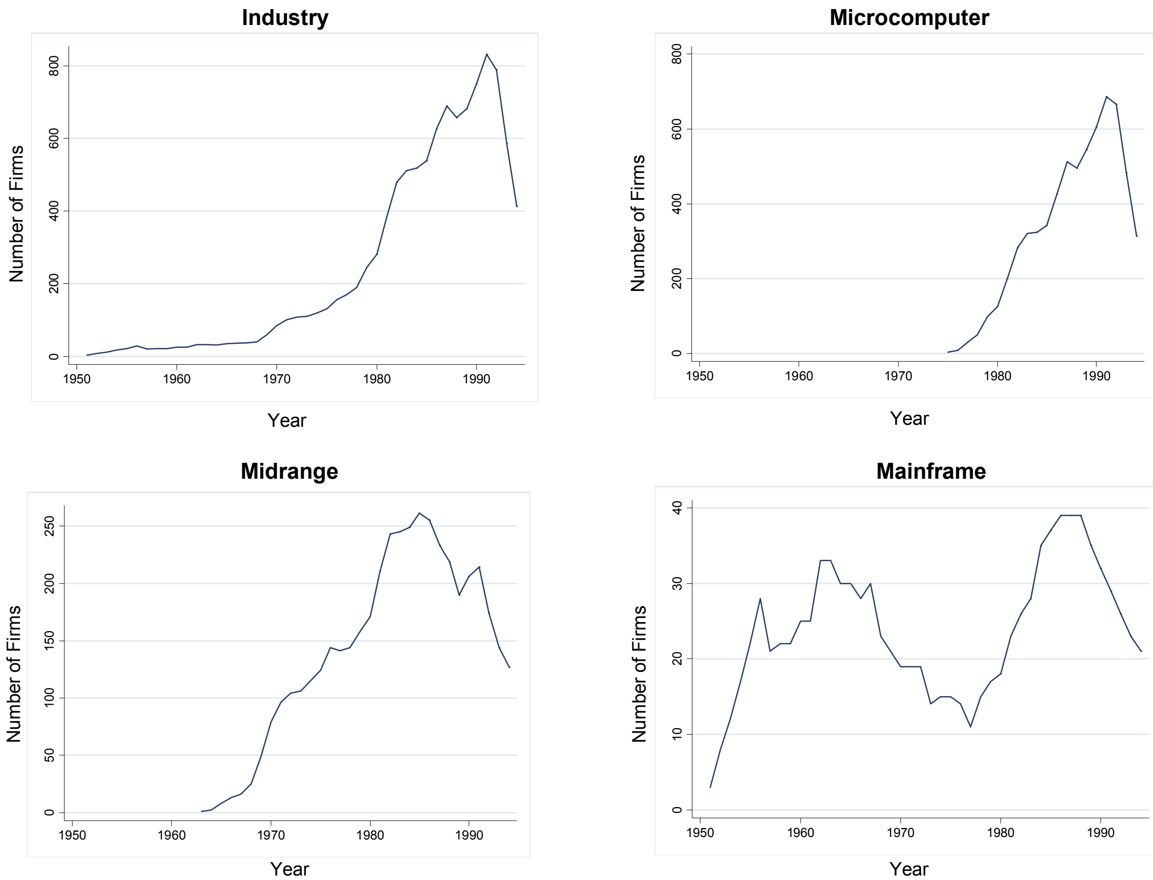


Figure C2. Entries and Exits to and from the Microcomputer and Midrange markets in the U.S.

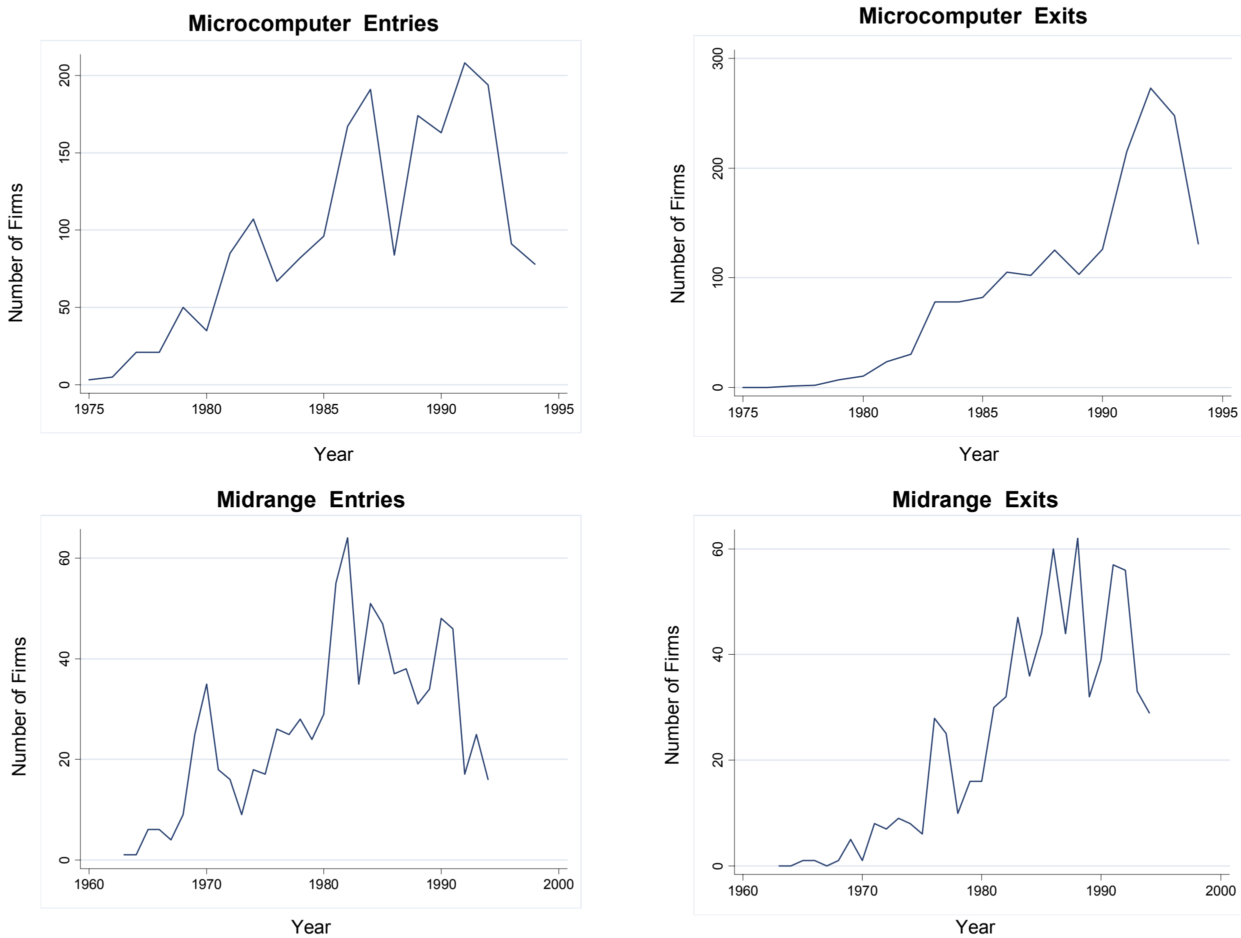


Figure C3. Movement into the Microcomputer Market by Midrange Computer Manufacturers

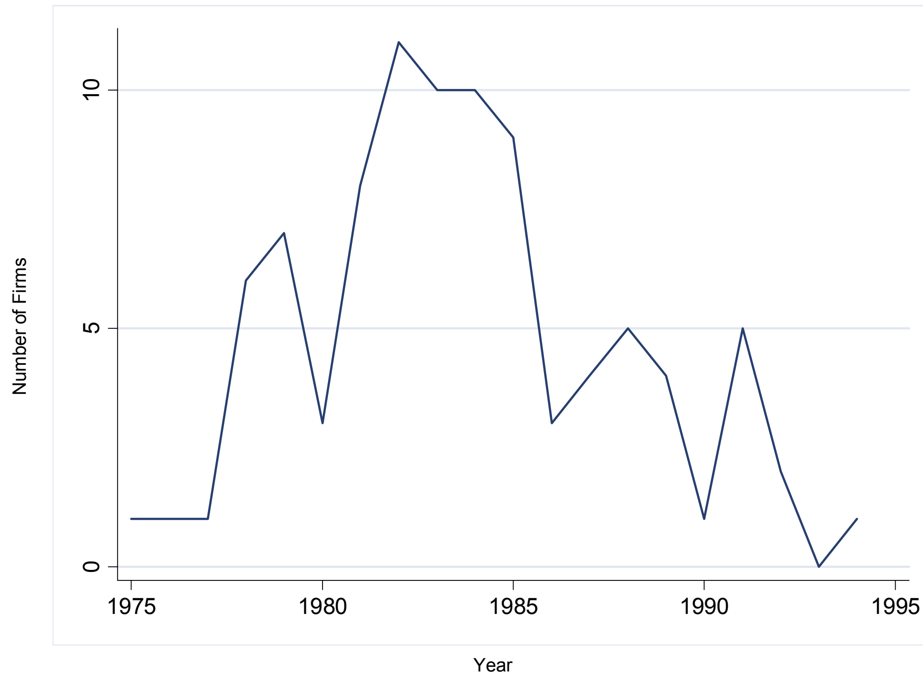
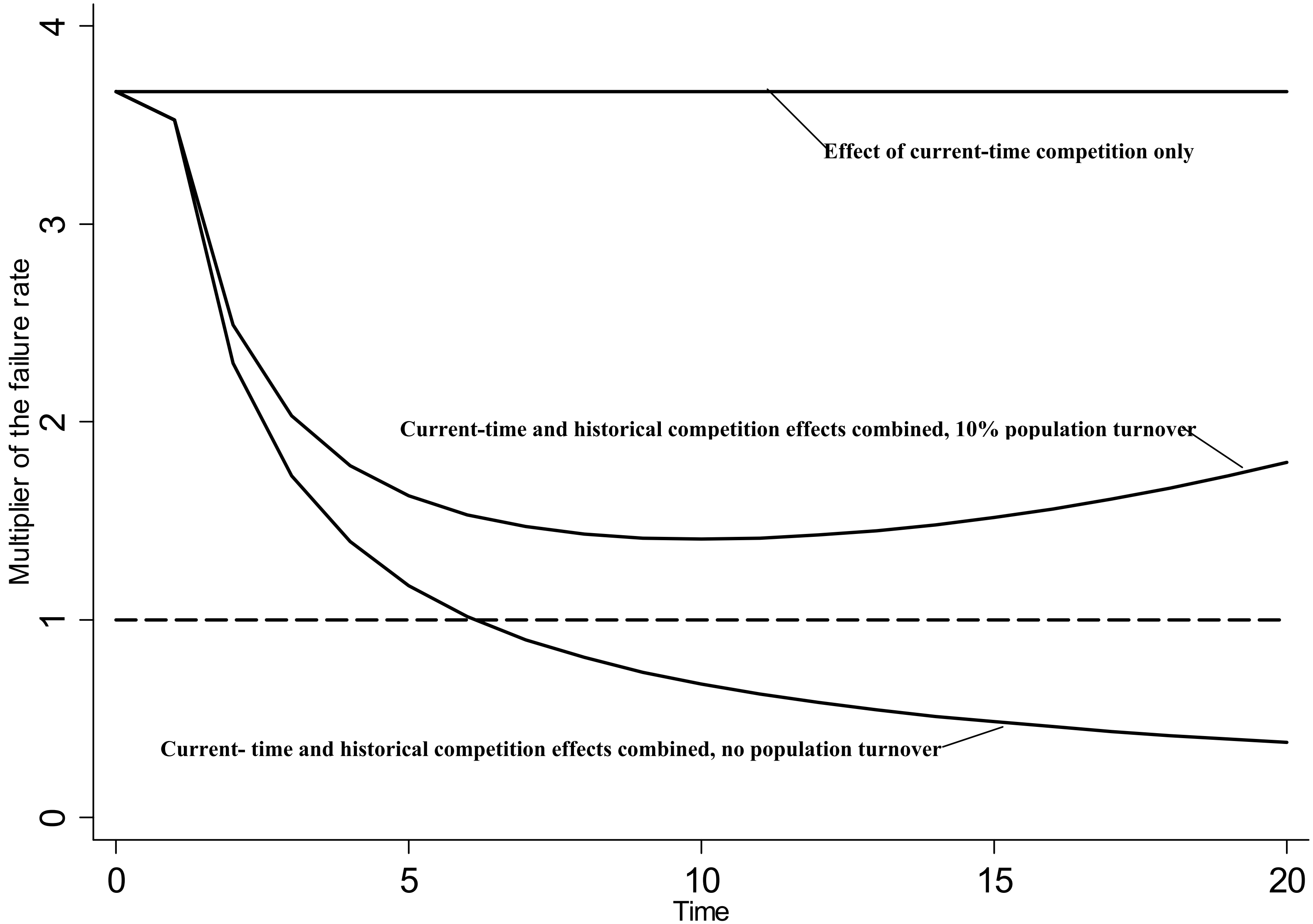
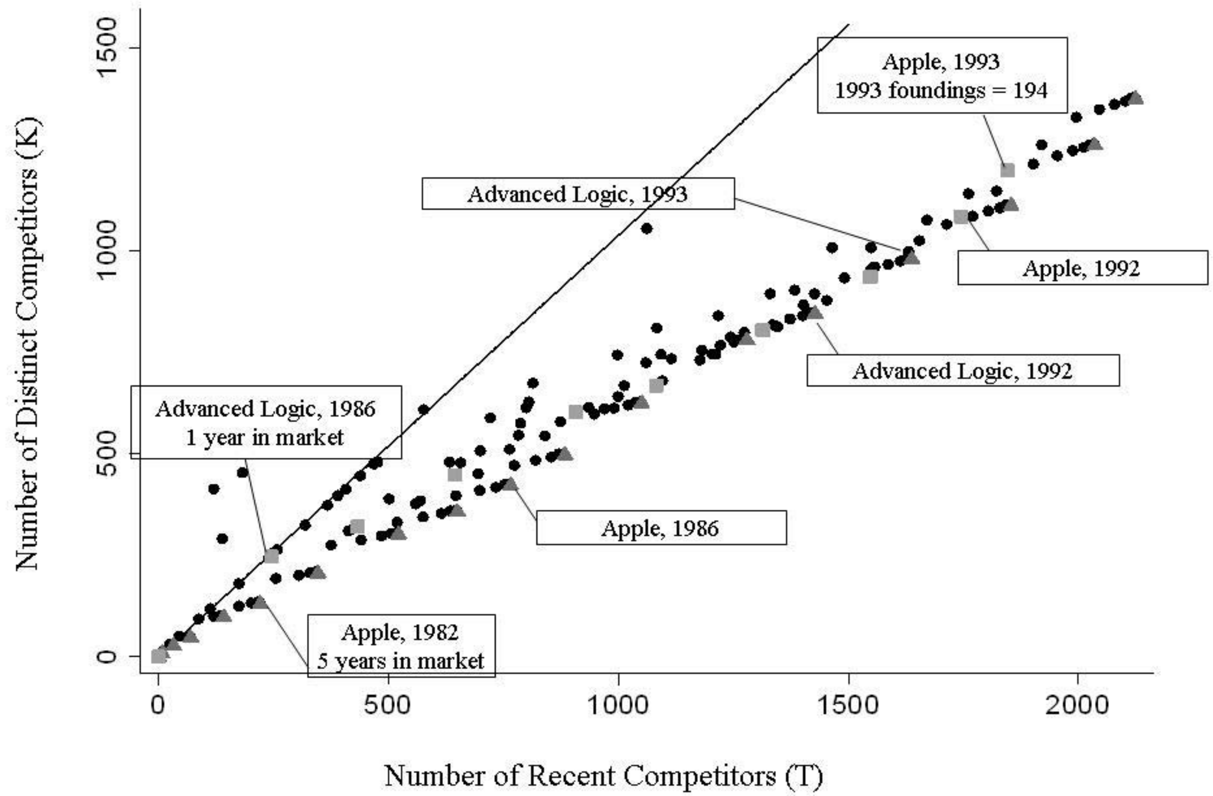


Figure C4:
Offsetting effects of current-time and historical competition in the U.S. microcomputer market*



*Based on the estimates of model 3, and assuming the average observed number of competitors per year (335).

Figure C5
Observed distribution of K and T among U.S. microcomputer firms*



*The diagonal line represents the threshold of equality where the effects of K and T are exactly offsetting based on the estimates of model 3

Table C1: Number of distinct general purpose digital computer manufacturers in the U.S. by market

	1955	1960	1965	1970	1975	1980	1985	1990	1994	Overall
Organizations in the microcomputer market only	0	0	0	0	2	100	253	535	278	1662
Organizations in the midrange market only	0	0	5	66	114	141	169	124	85	542
Organizations in the mainframe market only	22	25	27	6	5	10	23	8	7	97
Organizations in both (and only) the microcomputer and midrange markets	0	0	0	0	0	22	79	58	28	233
Organizations in both (and only) the microcomputer and mainframe markets	0	0	0	0	0	0	1	0	0	2
Organizations in both (and only) the midrange and mainframe markets	0	0	3	13	9	5	4	13	7	41
Organizations in all three markets	0	0	0	0	1	3	9	11	7	25
Organizations in any market	22	25	35	85	131	281	538	749	412	2602

Table C2
Descriptive statistics of the data used in the microcomputer exit rate analysis

	Mean	Standard Deviation	Minimum	Maximum
Dealio entrant	0.2803	0.4492	0	1
Real U.S. gross domestic product	4501	453	3212	5134
U.S. Prime interest rate	9.53	2.82	6	18.87
Small sized organization	0.3198	0.4664	0	1
Medium sized organization	0.5769	0.4941	0	1
Large sized organization	0.1032	0.3043	0	1
Microcomputer market shipments/1000	6896	3745	0	15691
Microcomputer manufacturer entries/1000	0.1335	0.0559	0	0.208
Microcomputer manufacturer failures/1000	0.1120	0.0750	0	0.273
Microcomputer market density at entry/1000	0.2738	0.1390	0	0.478
Microcomputer market density/1000	0.3357	001194	0	0.478
Midrange market density/1000	0.1698	0.0307	0.107	0.217
Mainframe market density/1000	0.0261	0.0051	0.01	0.034
Historical competition faced by org. in the microcomputer market/1000	0.6629	0.8123	0	4.337
Recent historical competition faced in the microcomputer market/1000	0.3755	0.3442	0	1.241
Distant-past historical competition faced in the microcomputer market/1000	0.2874	0.5057	0	3.111
Number of distinct rivals faced in the microcomputer market/1000	0.3313	0.3087	0	1.374
Historical competition faced by org. in the midrange market/1000	0.1471	0.4728	0	3.484
Historical competition faced by org. in the mainframe market/1000	0.0071	0.0587	0	0.814

Table C3
Descriptive statistics of the data for the midrange-to-microcomputer market entry analysis

	Mean	Standard Deviation	Minimum	Maximum
Dealio entrant	0.2696	0.4438	0	1
Real U.S. gross domestic product	4153	558	3222	5344
U.S. Prime interest rate	10.37	.038	6	18.87
Small sized organization	0.5053	0.5000	0	1
Medium sized organization	0.4223	0.4940	0	1
Large sized organization	0.0723	0.2591	0	1
Midrange market shipments/1000	140.2	74.36	60.6	246.5
Microcomputer market shipments/1000	3184	3912	0	15691
Midrange manufacturer entries/1000	0.0363	0.0135	0.017	0.064
Lagged microcomputer manuf. failures/1000	0.0326	0.0162	0.006	0.062
Microcomputer manufacturer entries/1000	0.0851	0.0634	0	0.208
Lagged microcomputer manuf. failures/1000	0.0648	0.0701	0	0.273
Midrange market density/1000	0.1629	0.0366	0.107	0.217
Microcomputer market density/1000	0.2133	0.1529	0	0.478
Historical competition faced by org. in the midrange market/1000	0.4978	0.4935	0	3.429
Recent historical competition faced in the midrange market/1000	0.2367	0.1567	0	0.6189
Distant-past historical competition faced in the midrange market/1000	0.2611	0.3600	0	2.870

Table C4
Descriptive statistics of the data used in the midrange computer manufacturer exit rate analysis

Variables	Mean	Standard Deviation	Minimum	Maximum
Dealio entrant	.3345	.4719	0	1
Real U.S. gross domestic product	4003	663	2128	5135
U.S. Prime interest rate	9.873	3.248	4.500	18.87
Small sized organization	.4364	.4960	0	1
Medium sized organization	.4604	.4985	0	1
Large sized organization	.1032	.3043	0	1
Midrange computer market shipments/1000	.1353	.0848	0	.2465
Midrange computer manufacturer entries/1000	.0345	.0144	0	.0640
Midrange computer manuf. failures/1000	.0314	.0182	0	.0620
Midrange computer market density at entry/1000	.1276	.0630	0	.2170
Microcomputer market density/1000	.2116	.1636	0	.4780
Midrange market density/1000	.1531	.0480	0	.2170
Mainframe market density/1000	.0225	.0071	.0100	.0340
Historical competition faced by org. in the midrange computer market/1000	.5750	.6674	0	3.484
Number of distinct rivals faced in the midrange computer market/1000	.1952	.1550	0	.7020
Midrange computer rivals' historical exposure to competition/1000	115.7	63.98	0	19 .4

Appendix D: Correlation Matrices

Table D1: Correlations for density and historical competition terms from microcomputer failure models

	1	2	3	4	5	6
Microcomputer market density (1)						
Recent historical competition faced in Micro market (2)	0.3633					
Distant historical competition faced in micro market (3)	0.2134	0.894				
Number of distinct competitors faced in micro market (4)	0.3955	0.9823	0.8313			
Microcomputer manuf. entries (5)	0.8585	0.3247	0.2092	0.3556		
Microcomputer manuf. failures (6)	0.5716	0.4793	0.3876	0.5196	0.6063	
Microcomputer manuf density at entry (7)	0.7078	-0.0428	-0.1996	0.041	0.617	0.6384

Table D2: Correlations for density and historical competition terms from midrange failure models

	1	2	3	4	5	6
Midrange market density (1)						
Recent historical competition faced in midrange market (2)	0.3315					
Distant historical competition faced in midrange market (3)	0.153	0.9063				
Number of distinct competitors faced in midrange market (4)	0.3794	0.9721	0.857			
Midrange manuf. entries (5)	0.8044	0.2164	0.1102	0.2601		
Midrange manuf. failures (6)	0.6486	0.4333	0.315	0.5044	0.4595	
Midrange manuf density at entry (7)	0.6446	-0.0317	-0.1855	0.1044	0.485	0.6458

Table D3: Correlations for density and historical competition terms from midrange entry into microcomputer models

	1	2	3	4	5	6
Midrange market density (1)						
Recent historical competition faced in midrange market (2)	0.1637					
Distant historical competition faced in midrange market (3)	0.03	0.8934				
Number of distinct competitors faced in midrange market (4)	0.2445	0.955	0.7975			
Midrange manuf. entries (5)	0.8232	0.1119	0.0406	0.1758		
Midrange manuf. failures (6)	0.5221	0.2688	0.1759	0.3727	0.3782	
Midrange manuf density at entry (7)	0.5742	-0.1243	-0.2275	0.0667	0.4308	0.6378