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THE EVOLUTION OF MARKETS AND ENTRY, EXIT AND SURVIVAL OF FIRMS

Rajshree Agarwal and Michael Gort*

Abstract—The paper examines entry, exit and the survival of firms in terms of evolutionary changes in the market from the first introduction of a product to maturity of the market. It is shown that both entry and exit rates depend systematically on the stage of development of the market in the cycle from birth to maturity. Survival rates depend both on stage of development and on individual firm attributes.

The empirical work is carried out with data for 25 new products. A complete inventory of entering, exiting and surviving firms from the birth of a new product to its maturity was developed.

A neoclassical approach to the analysis of entry and exit into the market views both phenomena as adjustments to equilibrium that are dependent on a variety of market attributes. These market attributes consist of such variables as growth in demand, barriers to entry, scale economies, and still other variables. In the context of a neoclassical model, the probability of a firm's survival for a given interval of time is a function of a vector of market attributes and a vector of attributes that relate to the individual firm. Our departure from this framework is that we introduce the stage of development in a market's evolution as an additional factor in explaining entry, exit and survival.

The stage of development of a market can influence the phenomena we seek to explain in two ways. First, it may systematically affect the values of the explanatory variables—that is, the attributes of the market or of the firm. Second, it may systematically shift the parameters that relate entry, exit and survival to these explanatory variables. Some examples of each form of systematic change may help clarify the issue.

As a market evolves from infancy to maturity, the rate of growth in demand and the minimum efficient size of firm are both likely to change. This illustrates the predictable changes in explanatory variables which, in turn, influence entry, exit and survival. And as the market evolves, the sources of technical change shift between incumbent firms and inventors external to an industry. This alters the relation between rate of technical change and all three phenomena we seek to explain. Further, as a market evolves, the importance of learning by doing as a source of technical knowledge may decline because of the growth of other sources of information (e.g., professional and trade journals). Moreover, the development of an organized labor market for experienced technicians and managers similarly reduces the importance of learning by doing. If true, this would ceteris paribus reduce the impact of the age of a firm on its expected survival.

The analysis of stage of development of a product market starts with the stylized facts developed in Gort and Klepper (1982). Specifically, the product cycle is divided into five stages based on the rate of *net* entry (change in number of firms in the market). Stage 1 corresponds to the initial period when there are at most only several sellers. Stage 2 is the immediately following period of high net entry. It may itself be subdivided into an initial phase of accelerating net entry followed by a period of deceleration. Stage 3 is a transitional plateau in the number of sellers. This stage, unlike stage 2, does not occur for many new product markets. Stage 4, which does occur for the overwhelming majority of markets, is the period of negative net entry and may also be subdivided into phases of acceleration and deceleration in negative net entry. Stage 5 corresponds to maturity in the market and no strong consistent trends in net entry, though there may be fairly large erratic movements.

The paper is divided into two parts. Part I deals with entry and exit and part II with survival. We proceed from hypotheses about the determinants of entry, exit and survival of firms to an analysis of the consistency of the hypotheses with observed stylized facts. While we do not test a fully specified model, our approach is sufficient to dismiss some widely held assumptions about entry, exit and survival and to suggest some new perspectives on the determinants of these variables.

The data on which our analysis is based is drawn from *Thomas Register of American Manufacturers* and consists of a complete inventory of all entering, surviving and exiting firms in each of twenty-five new product markets. The data encompass the period from the first commercial introduction of each product until 1991. The list of products is shown in appendix table A.

I. Entry and Exit

A. *The Basic Facts*

Our purpose at this juncture is to assess the consistency of evolutionary patterns across products. That is, does the development of a market for a new product follow a systematic sequence of changes rather than changes that are the product of random shocks?

Figure 1 and table 1 show the average pattern of gross entry, gross exit and number of firms in a market across the various stages. The figure is intended to be illustrative and is not drawn to exact scale. Table 1 shows the standardized average annual entry, exit and number of firms, with standardization achieved by expressing the relevant statistic for each product and for each stage as a ratio to that product's average for all stages. Thus, the results are not dominated by the markets with a large number of firms nor are they affected materially by the fact that not all of the products experienced all stages of development.

As the figure and table 1 show, the rise in number of firms in stage 2 is propelled by the high gross entry, which begins to decline at the end of stage 2A and reaches its trough in stage 4. Gross exit rises continuously until it reaches a peak in the middle of stage 4 and declines thereafter. The decline in number of firms in the market in stage 4 is, therefore,

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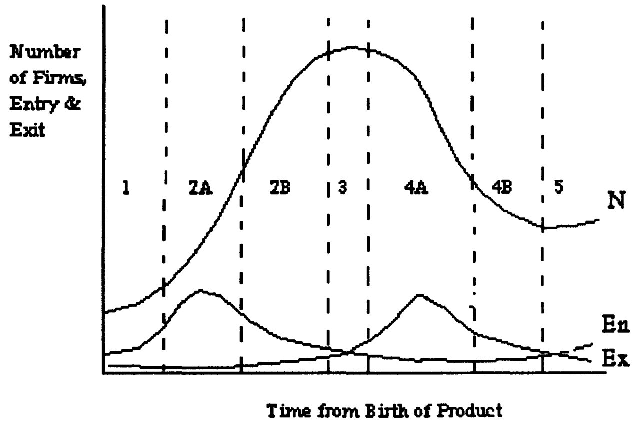
FIGURE 1.—ENTRY, EXIT AND NUMBER OF FIRMS ACROSS STAGES



Note: N = number of firms, En = gross entry, Ex = gross exit.

driven mainly by rising exit. Time series reveal, in general, a negative relation between gross entry and exit except in stage 2A where the positive association results mainly from the rising number of incumbent firms available for exit.

Gort and Klepper (1982) observed that the rate of technical change appears to be bimodal, reaching peaks in both stages 2 and 4. However, they found differences in the sources of technical change in the two intervals. In stage 2, a far larger proportion of the innovations originate from inventors external to the incumbent firms in the market. In stage 2, the innovations are also more likely to be of a fundamental nature in contrast to product refinements that are more characteristic of stage 4 innovations. The former are more easily adopted by followers while the returns to product refinements are more readily appropriated by the firms that develop them since such refinements often derive from proprietary knowledge.

The far higher gross entry in stage 2 than in stage 4 is consistent with the above hypothesis since innovations available to non-incumbent firms are a mechanism for entry insofar as they offset the advantages of earlier entry by incumbents. The observed sharp rise in exit during stage 4 supports the hypothesis that innovations in that interval are harder to imitate than those in earlier intervals of rapid technological advance and hence lead to a higher rate of failures.

More recent work in a Ph.D. thesis by Agarwal (1994) indicates that the rate of patenting most often reaches a peak in stage 4, with the fraction of patents accounted for by incumbent firms rising from stage 2 to stage 4. And in still another study that used the automobile tire industry for an empirical test, Jovanovic and MacDonald (1994) specified a model in which product refinement is an exogenous causal factor and the industry life cycle is associated with an increasing fraction of firms that are innovating high-tech firms. An excellent summary by Acs and Audretsch (1991) stresses the accumulating evidence on the role of product market life cycles in explaining entry and innovation. In sum, the pattern of entry cannot be adequately explained in terns of U-shaped cost curves and as a response to market growth in the context of a well-defined optimal scale of firm.

To the extent that entry responds to the profit rates of the incumbent firms as shown by Kessides (1991), there is an implied hypothesis that profitability is higher in the early stages of a product life cycle. Equally important, however, is the implied hypothesis of systematic changes in the relative profitability of different classes of firms (incumbents vs. new entrants, high-tech vs. low tech firms) over the life cycle. The conclusion that conventional entry barriers, abstracted from life cycle variables, do not effectively explain entry rates is also supported by Mata (1991) for Portuguese manufacturing industries.

There are alternatives to looking at entry and exit rates by stages standardized by each product's average entry and exit over the full product cycle. One such alternative is to express entry and exit for each product in time t as a ratio to the number of existing firms in that market in time $t - 1$. This alternative method of standardizing is especially appropriate when examining exit rates inasmuch as exit can only occur from the stock of already existing firms. Table 2 presents the mean and median entry and exit rates so computed for the twenty-five products. The rates for each product are shown in appendix table A.

TABLE 1.—STANDARDIZED ANNUAL ENTRY, EXIT AND NUMBER OF FIRMS BY STAGES FOR 25 PRODUCT MARKETS

	Stage						
	1	2A	2B	3	4A	4B	5 (to 1991)
Number of Years							
Mean	9.76	13.68	5.77	6.38	10.05	7.06	15.00
Median	7.00	10.00	3.50	5.00	9.00	7.00	10.00
Average Entry							
Mean	0.59	1.77	1.50	0.91	0.51	0.53	1.03
Median	0.44	1.50	1.33	0.90	0.47	0.51	0.93
Average Exit							
Mean	0.15	0.58	0.94	1.45	2.06	1.10	0.99
Median	0.02	0.46	0.81	1.35	2.03	0.99	0.92
Average Number of Firms							
Mean	0.20	0.95	1.39	1.58	1.24	0.91	1.07
Median	0.41	0.87	1.37	1.51	1.22	0.89	1.08

Source: Based on *Thomas Register of American Manufacturers*.
Note: All statistics except number of years were standardized by taking the ratio for each product of the average value of the relevant statistic (entry, exit and number of firms) per year in each stage to its average value per year across all stages experienced by the product.

TABLE 2.—AVERAGE ANNUAL ENTRY AND EXIT RATES FOR EACH STAGE FOR 25 PRODUCTS

	Entry Rate		Exit Rate	
Stages	Mean	Median	Mean	Median
All Stages	0.13	0.12	0.08	0.07
Stage 1	0.39	0.25	0.08	0.02
Stage 2	0.21	0.18	0.05	0.04
Stage 3	0.06	0.04	0.07	0.04
Stage 4	0.05	0.03	0.11	0.09
Stage 5	0.09	0.06	0.06	0.05
F-ratio	30.11		6.51	

Source: Derived from appendix table A1.
Note: Annual entry and exit for each product in year t divided by number of firms in year $t - 1$.

Ignoring the stage 1 results which stem mainly from the low values of the denominator of the ratios, the pattern across stages 2 through 5 largely replicates that shown earlier in table 1. Mean annual entry rates decline from 21% in stage 2 to a low of 5% in stage 4, while exit rates in the same time span rise from 5% to 11%, before falling back to 6% in maturity. The F-ratios show that the differences in mean rates are significant across stages at the 0.01 level for both entry and exit.

Another striking conclusion that emerges from table 2 is that entry and exit rates in American markets are extremely high, the mean annual rate for all stages combined being 13% for entry and 8% for exit. This supports the earlier results of Dunne, Roberts and Samuelson (1988), though the latter were obtained with very different data and for industries a large fraction of which were probably in a mature stage of development. The latter study dealt with 387 4-digit manufacturing industries as distinct from products, and used U.S. Census of Manufactures data. The Dunne, Roberts and Samuelson annual entry rates remained fairly stable at about 10% between successive sets of census years in the 1963–82 period, while their measures of annual exit rates ranged from about 8.5% to 10%. The somewhat higher exit rates shown in their study compared to ours, especially if one compares their rates to ours for stage 5, is to be expected when using census production data as compared with offers of sales, as in the *Thomas Register of American Manufacturers*. Production may temporarily cease while sales continue out of inventories. While our results and those of Dunne, Roberts and Samuelson show an average annual entry rate more than double that obtained by Baldwin and Gorecki (1991) for Canadian manufacturing industries, this is probably a consequence of the exclusion of small companies in the Canadian data. As shown by Baldwin and Gorecki (1990), once small firms are included, entry and exit rates roughly double and become similar to U.S. rates. An entry rate very similar to that of the United States was also observed for German manufacturing industries by Schwalbach (1991).

B. *The Relation of Entry to Exit*

All studies of the relation of entry to exit rates thus far have been primarily cross-sectional. Such studies have the advantage of large samples and broad data bases since they are usually based on national censuses. By comparison, our analysis is very limited in its scope of coverage. The dimension we add, however, is our ability to trace the relation between entry and exit over time for individual products, thereby permitting an examination of evolutionary impacts.

Over time, the positive correlation between entry and exit rates (rates defined as entry and exit in t divided by number of firms in $t - 1$) may arise for two reasons. First, as entry increases the number of firms, competition and, hence, exit may rise. Second, if new entrants have lower survival rates than incumbent firms in the market, high entry should be associated with high exit.

Cross-sectionally, there is an additional possible variable. If barriers to entry also constitute barriers to exit, then entry and exit rates will be correlated across product markets. Jovanovic (1982) argued that firms exit because they discover they are inefficient relative to their competitors. Since there are fixed costs to entry, it takes a non-negligible amount of adverse information, and hence time, to convince a firm to exit. The higher the sunk cost, the more will be the information and time required. MacDonald's (1986) results for 46 food manufacturing industries give some support to this hypothesis. He found that high capital commitments reduce exit and also entry. Thus there is evidence that the same variable operates as a barrier to both entry and exit.

While time series data on entry and exit presented earlier in this paper do not disprove the presence of common variables that affect entry and exit in the same direction, they certainly show that these variables do not dominate the observed pattern over time. Except for stage 2A, entry and exit tend on the whole to be negatively related. This is most dramatic in stage 4 when entry continues to fall while exit rises sharply. Thus it appears that such stage-related variables as growth in demand and the characteristics of innovations, which exert opposite influences on entry and exit, more than offset those variables that affect entry and exit in the same direction.

There are several cross-sectional studies of relations between entry and exit that all point to a positive association between the two. Dunne, Roberts and Samuelson (1988) find a consistent though fairly weak positive relation between entry and exit for U.S. manufacturing industries in the 1963–82 period. Depending on the time period, their simple correlations for entry and exit range from about 0.2 to about 0.4. Cable and Schwalbach (1991) provide a convenient summary of results for other countries for varying periods. For Canada, the correlation was only 0.04, for Germany 0.34, for Belgium 0.66, for Korea it ranged from −0.41 to 0.35, for Norway 0.49, for Portugal 0.03, and for United Kingdom 0.32 (though Geroski (1991) reports some correlations for the United Kingdom as high as 0.79 and 0.67). In sum, most studies report a positive association between entry and exit rates, though in a majority of cases, it is only a moderate one.

Our objective is to assess the extent to which the relation between entry and exit rates is present within each stage of the product market's evolution. Since we defined stages in

TABLE 3.—SIMPLE CORRELATION COEFFICIENTS FOR ENTRY AND EXIT RATES FOR 25 PRODUCTS

Phases	Number of Products	Entry and Exit r	Entry and Exit t	Significant at 0.05 Level
All Phases	25	0.59	3.560	Yes
Within Phase 1	22	−0.24	−1.096	No
Phase 2	25	0.11	0.519	No
Phase 3	24	0.07	0.315	No
Phase 4	22	0.25	1.161	No
Phase 5	23	−0.55	−2.990	Yes

Source: Based on *Thomas Register of American Manufacturers*.
Note: Rates expressed as average of entry (exit) in t divided by number of firms in market in $t - 1$.

terms of net entry, and net entry is a consequence of both gross entry and exit, the definitions of stages could bias the observed relation of entry and exit within stages. Accordingly, for the purpose at hand, the product life cycle is segmented into ''phases'' based on *gross* entry. Gross annual entry in each phase was divided by the average annual entry for all phases to standardize phases across products. Five phases were identified in this way: (1) initial low entry, (2) increasing entry, (3) decreasing though still generally high entry, (4) low entry, (5) erratic pattern that typically characterizes the final phase.

For the five phases combined for the full sample of 25 products, the simple correlation between entry and exit rates is 0.59 (table 3). This result is generally consistent with those reported above for cross-section studies. Within phases, however, there is no significant correlation between entry and exit except for a *negatively* significant correlation for phase 5.

What conclusions can we reach from the correlations? Our results for all phases combined (as well as the cross-sectional results of other studies) support the existence of common industry effects on exit and entry rates. In short, entry barriers also turn out to be exit barriers. The absence of within-phase correlation in the rates, however, shows that gross entry cannot be viewed largely as a substitution for exit, nor is exit primarily a response to unusual entry rates in a preceding period. The *time pattern* of both appears to be driven by variables associated with the evolution of the product market. These variables affect gross entry differently from exit at various junctures of the product cycle. High values for variables that affect gross entry (for example, high growth rate in demand and innovations of non-incumbent firms) are not contemporaneous with high values for variables that affect exit (for example, rises in the fraction of innovation accounted for by incumbent firms). Hence, there is no within phase (or within stage) correlation. In sum, the symmetrical across industry effects are not sufficiently strong to overcome the divergent evolutionary effects that manifest themselves over the product life cycle.

II. Survival

A. A Brief Survey of the Literature

The general thrust of the literature on the survival of firms has taken two principal directions. One starts from the process of learning by doing and examines the impact of learning on survival. Jovanovic (1982) represents a clear statement of this approach. The longer a firm remains in the market, the more it learns about its true costs and its relative efficiency and the less likely it is to fail.

An alternative, but complementary approach reflected initially in the work of Gort and Klepper (1982) views variations in survival as consequences of changes in the rate and character of technological change as an industry evolves over the life cycle of its principal products. This approach is extended by Jovanovic and MacDonald (1994a) who distinguish two forms of technological change, ''pure innovation'' and ''pure imitation.'' They then specify an endogenous model defining the rates at which the two types of technical change proceed as an industry evolves.

There is ample empirical support for the proposition that survival and age are correlated. For example, Dunne, Roberts, and Samuelson (1989), using *Census of Manufactures* data for the 1972–87 period, find a positive relation between firm age and survival throughout the observed age range. Baldwin and Gorecki (1991) examine entry in Canadian manufacturing industries in the 1970–81 period and find high mortality among entrants. Audretsch (1991) studies the experience of 11,000 manufacturing firms over a ten year period (using Small Business Administration data) and reaches a similar conclusion about the relation of age and survival.

Tangential to the relation between age and survival is that between the growth of the firm and survival. Audretsch and Mahmood (1993) find the relation to be positive and this result is also supported by Phillips and Kirchhoff (1988). The result lends itself to alternative interpretations. Consistent with the consequences of successful learning, or successful innovation and imitation, firms that grow as a result of such success can be expected also to be characterized by higher survival rates. Alternatively, growth may itself be an engine for survival via scale economies.

Empirical support for evolutionary cycles in survival rates is inferred by Gort and Klepper (1982) from changes in net entry rates over the product cycle, and particularly from the negative net entry observed in what they characterize as stage 4 of the product cycle. Support for an evolutionary pattern consistent with their model is found by Jovanovic and MacDonald (1994a) in the history of the diesel locomotive. Carroll and Hannan (1990) observe an evolutionary pattern in newspaper publishing, American labor unions, and the beer industry. They attribute variations in survival to effects of ''organizational density'' via the opposing effects of the number of firms on competition, which lowers survival, versus political and social ''legitimacy,'' which raises it.

B. The Analytical Approach

Our departure from existing approaches to survival takes two forms. First, we seek to decompose the forces that affect the probability of survival into the attributes of the market as distinct from those of the firm. Second, we seek to decompose the relevant attributes of the firm into learning by doing versus the initial endowments of the firm.

With respect to market attributes, we try to answer the following questions: (1) What attributes of markets affect the probability of survival? (2) Are these characteristics of markets sufficiently strong to dominate the individual firm attributes with respect to survival, and if so, under what circumstances?

With respect to the first question, we do not identify each specific variable but rather assume there is a vector of product-specific variables that are also time-specific in the sense that they depend on the stage in the evolution of the product market. Among these are the number of competing firms in the market, and the form that technological change takes. In particular, a critical question is whether innovations are of a type to allow the benefits to be appropriated by the innovator, thus placing other firms at a competitive disadvantage—a phenomenon we earlier noted as being characteristic of stage 4 in the product cycle. Thus, for our purposes, the basic question is whether the evolutionary stage of the product cycle controls the survival rate.

As regards the second question, the issue, then, is whether stage-related forces are sufficiently strong to obscure, or at least modify, the way in which individual firm attributes manifest themselves over the evolutionary cycle. We have defined stages in terms of net entry and the latter depends on exit rates as well as entry rates. Thus, some relation between survival and stage at time of exit is to be expected. The relation between survival and evolutionary stage at time of entry is, however, a much more complex question with far less predictable answers, and it is on this that we focus primary attention. But even with respect to the relation of survival rates to stage at time of exit, the relative importance of firm attributes versus evolutionary attributes is an important empirical question that needs to be examined.

The attributes of the firm may be decomposed into skills and information acquired through learning by doing in the course of production and all resources (information, skills and other assets) that comprise the endowments of the firm. For this purpose, resources acquired from outside the firm subsequent to initial entry may be lumped with initial endowments.

A firm acquires skills as a function of experience, and experience is hypothesized to depend on time spent in production (or sale) of a particular product and on the cumulative output (or sales) over time. Thus we have for firm i,

$$S_i = f(E_i)$$

and

$$E_i = e(T_i, \Sigma O_i) \tag{1}$$

where S = probability of survival, E = experience, and T and ΣO, respectively, time spent in production and cumulative output. Since time spent in production is determined by the age of the firm in the market, denoted by A, we have

$$S_i = g(A_i, \Sigma O_i) \tag{2}$$

and we further assume that $g' > 0$, $g'' < 0$ for both arguments in the equation.

The positive sign of the first derivative is intuitively obvious since additional experience (hence acquired information and skills) cannot affect efficiency adversely. The negative sign of the second derivative presupposes that learning by doing occurs most rapidly when skills and knowledge are low, and declines rapidly as experience accumulates. The time it takes to run a mile should decline much faster as a function of additional training (experience) for an economics professor than for an Olympic gold medalist in the event.

The relation between relative efficiency and initial endowments is more complex. We assume that efficiency is a function of a vector of initial endowments denoted by α. Some of these endowments consist of observed variables, such as an initial organization with a record of successful operations in a related industry, and some are unobserved variables such as managerial talent. We further hypothesize that at any given point in time, the attained age of a firm is also a function of the initial endowments, since a firm with superior endowments has a higher probability of survival. Thus we have for firm i

$$A_i = a(\alpha_i) \tag{3}$$

where A = the attained age of the firm and therefore

$$S_i = h(A_i). \tag{4}$$

Thus, survival depends upon learning and upon initial endowments and *both* depend upon the firm's age. However, the relation of survival to age differs depending upon whether the key operative variable is learning or endowments. In particular, what is critical is the structure of the first and second derivatives of h. The first derivative should generally be positive until the firm approaches senility and then should turn negative. Senility, in turn, results from a gradual but progressive inability to adapt initial endowments to changes in the market, in the technology of the industry or in its regulatory environment. The second derivative should initially be positive since the longer a firm has survived the greater is the likelihood that such survival results from superior initial endowments rather than from random forces. But eventually the second derivative should turn negative, as initial endowments become progressively less well adapted to the new environment and as convergence in endowments occurs through the acquisition of resources by initially less well endowed firms. Hence, $h' > 0$ up to senility point P_2 and $h' < 0$ beyond P_2, while $h'' > 0$ to inflection

TABLE 4a.—4- AND 10-YEAR STANDARDIZED[a] SURVIVAL RATES BY STAGE OF PRODUCT CYCLE FOR 25 PRODUCTS

Stage	4-Year Survival[b]	10-Year Survival[b]
1	1.05	1.20
2	1.05	1.03
3	0.90	0.73
4	0.97	0.93
5	0.99	1.03

Source: Based on data from *Thomas Register of American Manufacturers*.
[a] Standardized for each product by taking the ratio of the mean survival rate in each stage to the mean survival rate across all stages experienced by the product.
[b] The F statistic across stages for 4-year survival rates is 2.18 and significant at the 0.10 confidence level while the 10-year survival rate is 3.98 and significant at the 0.05 confidence level.

TABLE 4b.—4-YEAR SURVIVAL RATES FOR TECHNICAL AND NON-TECHNICAL PRODUCTS AND FOR ENTRANTS AND INCUMBENTS

	Entrants[b]	Incumbents[b]
Technical Products[a]	0.80	0.75
Non-Technical Products[a]	0.71	0.76

[a] Technical and nontechnical products were distinguished on the basis of the ratio of R&D employees to total employees in their respective 3-digit industries based on such classification published by Hadlock, Hecker and Gannon (1991). The t-statistic across type of product for entrants is 1.74 and significant at the 0.05 confidence level but is not significant for incumbents ($t = -0.23$). The decision is based on SIC data for 1987 and therefore reflects differences in technology in the later stages. However, we believe the distinction to be largely applicable to the entire lifecycle.
[b] Entrants are those firms that entered the market in year t and $t - 1$. Incumbents are firms in existence prior to $t - 1$. Four year survival rates are first averaged over all t for each product and then averaged across all products within a group (technical or nontechnical). The t-statistic for entrants vs. incumbents is 2.01 and significant at the 0.05 confidence level for technical products and is -0.77 and not significant for nontechnical products.

point P_1 and $h'' < 0$ beyond P_1. These relations are discussed further in the empirical section of the paper.

C. The Role of Evolutionary Stage and the Industry's Technology

We now focus on two questions. First, are variables related to the stage of the product cycle generally sufficiently strong to produce a decline in the probability of survival even when the average age of firms is rising? Second, what are the relative survival rates of new entrants and incumbent firms and what does this say about the importance of experience and/or entrenchment? Is there evidence of a systematic relation between survival rates, defined as the fraction of firms that survive either 4 or 10 years, and the stage of the product cycle in which they enter the market? The answer, as table 4a indicates, is clearly in the affirmative.

Both the 4- and 10-year rates show a U-shaped pattern, reaching a trough for entrants in stage 3 and slowly rising thereafter. The null hypothesis that stage does not matter is rejected at the 0.05 level for the 10-year rates and at the 0.10 level for the 4-year rates. For the 10-year rate, survival does not revert to the stage 2 rate until stage 5. The decline of survival rates from stage 2 entrants to stage 3 entrants reflects the sharp rise in exit rates, especially in stage 4. The 10-year survival rate strongly reflects exits that occurred largely in the early part of stage 4 when exit was highest. However, the rise in exit rates begins much earlier and is clearly visible in stage 2. Similarly, survival rates (as the 10-year survival rate shows) begin their decline in stage 2. Thus, market variables gradually overcome the positive effect on the survival rate of the increasing average age of firms until these market forces themselves attenuate. These relations become sharper in the subsequent section of this paper when we turn to hazard rates.

Because of the effects of learning by doing (experience) as well as possible market entrenchment benefits from earlier entry, one would expect incumbents to have a higher survival rate than new entrants. With new entrants defined as entrants in t and $t - 1$, and incumbents as firms that entered the market prior to $t - 1$, no clear difference in the 4-year survival rate between entrants and incumbents was revealed when firms in high-technology and low-technology products were combined.[1] This result accords with Audretsch (1991) who found no difference in survival rates in sectors with many new firms as compared with all other sectors. However, once the two categories of products are separated (table 4b), a clear pattern emerges. For the 16 "technical" (high technology) products, entrants have a higher survival rate than incumbents. For the 9 nontechnical products, the opposite is true.[2]

The results for nontechnical products are consistent with what one would expect from learning by doing, and are supported by the previously reported results of Baldwin and Gorecki (1991) for 4-digit Canadian manufacturing industries. The lower survival rate observed in their study for entrants than for incumbents was based on data for industries most of which were not characterized by high technology. In contrast, the results for technical products are consistent with the hypothesis that entry frequently follows innovations by inventors and firms initially outside the market. These innovations yield superior knowledge to entrants than to many incumbents and this explains their higher probability of survival over the 4-year interval.

Our interpretation of the higher survival rate for entrants than for incumbents for technical products is supported by the further fact that entrants in the markets of technical products have a significantly higher probability of survival than entrants for nontechnical products (table 4b). In contrast, for incumbents there appears to be no significant difference in the markets of technical and nontechnical products. This is consistent with entry in technical product markets being accompanied by breakthroughs in knowledge. Our interpretation also appears to be consistent with the previously reported results of Audretsch (1991) that found that in sectors with a high small firm innovation rate, survival rates tend to be higher. Small firms are, on the average, more likely to be recent entrants than larger firms.

D. Survival and Firm and Product Attributes

We are now ready to examine the role of firm attributes. The key issues are: (1) What is the role of learning by doing?

[1] High technology or "technical" products were those in 3-digit industries with high ratios of R&D personnel to total employment based on Hadlock, Hecker and Gannon (1991).
[2] The t-statistic is significant at the 0.05 level of confidence for the technical products but, because of small sample size, not for the nontechnical ones.

(2) To what extent is survival a consequence of a Darwinian process that derives from initial endowments? (3) Do firms, like biological organisms, approach senility? (4) How do market attributes modify the impact of learning by doing and of endowments on survival? Empirically, survival rates in this section are gauged in two ways: (i) The probability of *not* surviving a specified number of years at a given starting point contingent on attained age of the firm at that point. This is usually referred to as the "hazard rate." (ii) The median residual life of the firm contingent on its attained age. The latter is measured as the time span required for one-half of the existing firms, of a specified age and at a given point in time, to die. Both (i) and (ii), of course, capture the same phenomenon.

We have already indicated a consistent result in earlier literature that shows a positive relation between age of firm and survival rate throughout the observed age range. Our table 4a, on the other hand, shows some decline in survival as the industry evolves even though the average age of firms generally rises as an industry matures. An examination of table 5 and its accompanying graphical representation offers a solution to the seeming inconsistency.

Table 5 shows moving averages of estimated 4-year hazard rates and moving averages of median residual lives, both decomposed by the stage of the product cycle in which firms entered the market. A moving average is used to reduce the erratic variation resulting from random forces. The method of computing the moving average is described in the note to table 5. Figure 2 is a graphic representation of the hazard rates in table 5. Our analysis of table 5 focuses on hazard rates simply because there are more observations for this variable than for residual lives (a result of the method of computing the median which truncates the observations for the latter.) In interpreting hazard rates in the context of our hypotheses, one needs to keep in mind that the relation between factors that contribute to survival and hazard rates is, of course, inverse.

TABLE 5.—MOVING AVERAGES OF 4-YEAR HAZARD RATES AND MEDIAN RESIDUAL LIVES BY STAGE OF PRODUCT CYCLE

Age Midpoint	Stage 1 (331)	Stage 2 (1436)	Stage 3 (288)	Stage 4 (374)	Stage 5 (556)
		Hazard Rate			
6	4.18	5.71	6.82	7.70	6.84
10	4.35	6.40	6.68	7.72	6.55
14	4.84	6.65	5.86	6.65	6.48
18	5.24	6.76	5.09	5.35	6.08
22	6.10	6.59	3.40	3.81	6.78
26	5.73	6.12	3.26	2.48	6.63
30	5.91	5.22	2.09	1.00	n.a.
34	5.49	4.44	2.85	0.49	n.a.
38	4.38	4.29	2.85	1.03	n.a.
42	3.60	4.29	4.28	1.54	n.a.
46	3.02	4.54	n.a.	n.a.	n.a.
50	3.69	n.a.	n.a.	n.a.	n.a.
54	3.88	n.a.	n.a.	n.a.	n.a.
		Median Residual Life			
6	15.1	11.2	10.6	9.2	10.5
10	14.0	10.6	12.6	10.6	10.9
14	12.9	10.4	16.7	19.1	10.9
18	12.2	10.7	19.2	24.0	10.9
22	11.8	11.9	n.a.	n.a.	n.a.
26	12.7	13.4	n.a.	n.a.	n.a.
30	14.3	14.5	n.a.	n.a.	n.a.
34	16.6	n.a.	n.a.	n.a.	n.a.
38	17.8	n.a.	n.a.	n.a.	n.a.

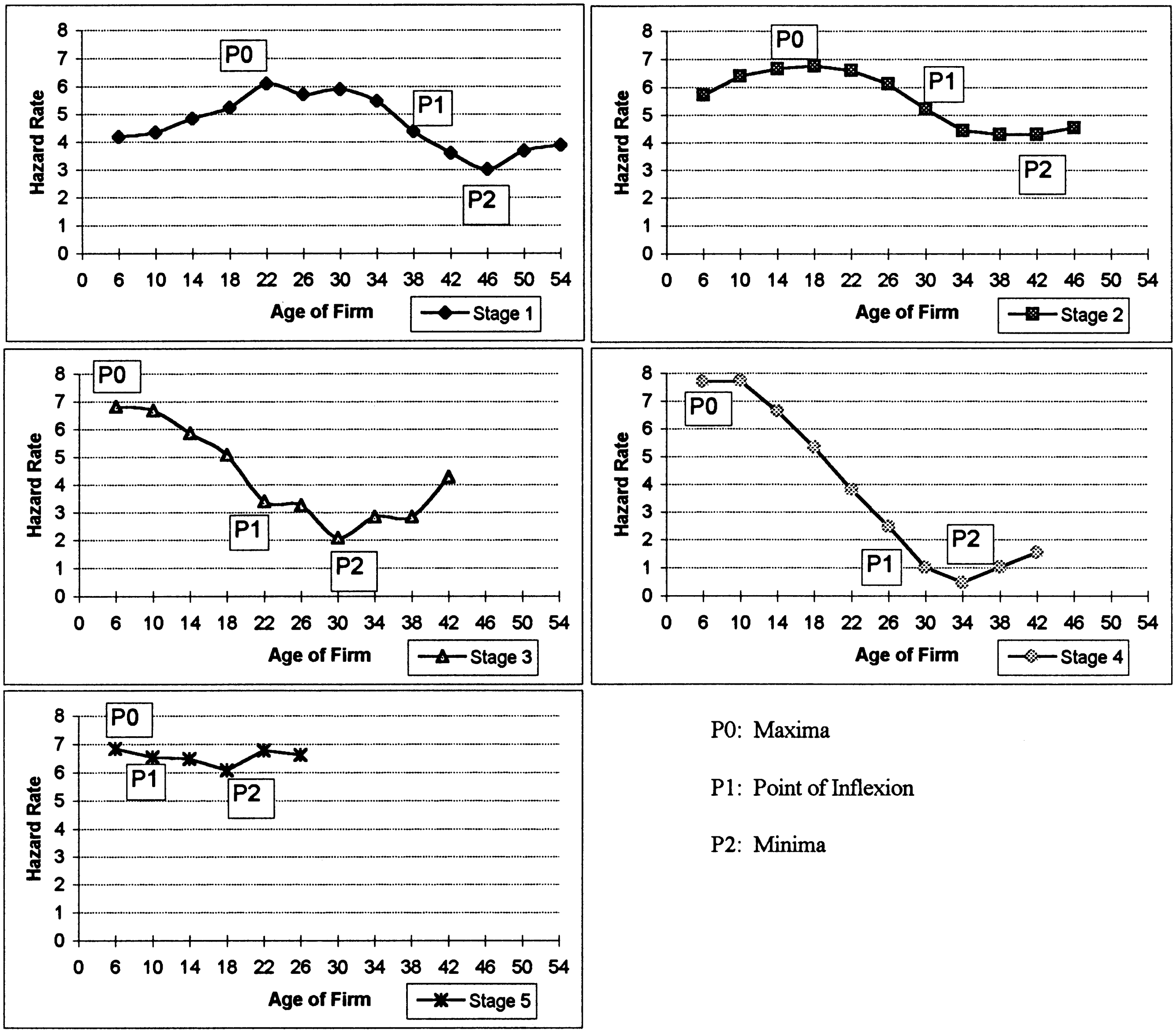
Source: Based on *Thomas Register of American Manufacturers*.
Note: Hazard rates and median residual lives are defined over four-year intervals. The moving averages are calculated using the relevant statistic from three consecutive intervals. Numbers in parentheses below the designation of the stage refer to the number of entrants in that stage (the total for all stages for our sample of products was 2985). The chi-square values for each of three tests of homogeneity showed that the hypothesis of homogeneity across stages could be rejected at the 0.001 level of significance. The three tests used were (a) the Log-Rank test, (b) the Wilcoxon test and (c) -2 log(Likelihood Ratio) test.

The riddle to the apparent inconsistency between the results of table 4a and those of earlier studies on the relation of age and survival is solved when we compare the first two columns of table 5 with the next three, and the graphs for stages 1 and 2 with those for stages 3–5. For stages 1 and 2, we observe rising hazard rates until the point P_0 is reached at about ages 22 and 18 for entrants in stage 1 and stage 2, respectively. These ages (22 and 18) correspond in chronological time to roughly the peak of the exit rate. In these intervals, market variables dominate firm variables. In contrast, for much of the later entrants of stages 3–5, P_0 is reached in the first interval and we observe a falling probability of failure as a function of age from the very start. Thus when most of the data relate to fairly mature markets, the pattern one observes is consistent with the findings on the positive relation of age to survival. The hypothesis of homogeneity of hazard rate functions across stages is tested in three different ways. The chi-square values of all three tests—Log Rank, Wilcoxon, and -2log(Likelihood Ratio)—show that the hypothesis of homogeneity could be rejected at the 0.001 level of significance.

Still another stage-related attribute is the sharply lower hazard rates associated with firms over 26 years old that also entered the market in stage 4. These hazard rates were far lower than for comparably aged firms that were entrants in all other stages. A hypothesis, though one that requires more data for proof than currently available to us is that entrants in the most competitive stage had superior initial endowments. Since stage 4 is generally characterized by the highest exit rate, it may be inferred to be the stage with the most intense competition and hence attractive only to stronger than average entrants.

We now turn to firm attributes. An important conclusion indicated by table 5 is that hazard rates continue to fall far beyond the age at which learning by doing is likely to peak. For early entrants, hazard rates continue to decline past age 40, and even for late entrants they continue to decline until age 18. This argues for the dominant role of initial endowments in determining survival rates. The opportunities for learning from experience are likely to decline far beyond age 40 and probably well before 18. For example, Bahk and Gort (1993) found that "capital learning" is largely exhausted in 6 years and "organizational learning" in the first 12.

FIGURE 2.—ESTIMATED HAZARD RATES BY STAGE OF PRODUCT CYCLE



Source: Based on table 5.
Note: PO: maxima; P1: point of inflexion; P2: minima.

Consistent with our model and based on the effects of initial endowments, all five stages in figure 2 show that P_1, the inflection point at which the second derivative changes signs, actually exists. Similarly, all five stages show P_2, the onset of senility as reflected in a rise in hazard rates (that is, decline in survival rates). It is dangerous, however, to draw parallels between firms and biological organisms. We hypothesize that the reason for senility is the limited adaptability of initial endowments to new economic environments rather than internal organizational decay. Far more powerful data than we currently have, however, would be needed to resolve this question scientifically.

Perhaps the most dramatic result we observe appears in table 6. It shows a systematic and progressive shift to the left of both P_1 and P_2 as one moves from stage 1 entrants to stage 5 entrants.

The age of the firm refers to age in a given market rather than to age from the birth of the firm. In most instances, however, the two are likely to be the same. Why do the inflection and senility points systematically occur at an earlier age for later entrants? We offer three explanations. One explanation is that the speed with which critical aspects of the economic environment change increases as one progresses to the later stages of the product cycle. Thus, initial endowments are rendered obsolete at an earlier age. This explanation seems counter-intuitive inasmuch as the rate of technical change, and especially the rate of fundamental innovations, is generally highest in stage 2. A second explana-

TABLE 6.—INFLECTION AND SENILITY POINTS FOR HAZARD RATES FOR ENTRANTS IN THE FIVE STAGES OF THE PRODUCT CYCLE

Stage of Entry	Age of Firm at Inflection Point (P_1)	Age of Firm at Senility Point (P_2)
1	38	46
2	30	42
3	22	30
4	30	34
5	10	18

Source: Based on table 5.

tion is that average expected returns from investment narrow as the product cycle progresses towards maturity. As a result, less adverse evidence is needed by a firm to elect to leave a market. This, in turn, raises hazard rates. Finally, a third explanation is that later entrants differ from earlier ones. Once again, more powerful data than we now have are needed to test this hypothesis.

III. Conclusions

This paper shows unequivocally the key role that the evolutionary stage of the product cycle plays in determining entry, exit and survival rates of firms. Entry rates appear to be affected profoundly by stage-related changes in both the rate of technical advance and the form that innovations take. Exit is determined largely by stage-related changes in the intensity of competition.

Survival rates reflect both market and individual firm attributes. The role of market attributes, once again related to the stage of the product cycle, is reflected initially in rising hazard rates for early entrants in new markets. The power of market attributes is also reflected in the higher survival rates for new entrants than for incumbents for high-technology products.

Initial endowments appear to be the dominant firm attribute in explaining hazard rates. For early entrants, hazard rates continue to decline past age 40. There is, however, a striking and systematic shift in the age at which hazard rates cease to decline, and the age at which the rate of decline weakens, as one moves from early to later entrants. Once again, we have a phenomenon that is strongly related to the evolutionary stage of the product cycle.

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APPENDIX

TABLE A.—ANNUAL ENTRY AND EXIT RATES FOR 25 PRODUCTS IN 5 STAGES

	All Stages		Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
Products	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit
Antibiotics	.12	.05	.75	.00	.21	.02	.06	.05	.03	.07	.09	.05
Artificial Christmas Trees	.09	.07	.14	.08	.10	.04	.05	.07	.04	.11	.11	.04
Ball-point Pens	.22	.14	.52	.41	.15	.07	.08	.10				
Baseboard Radiant Heating	.11	.05	.33	.00	.19	.02	.04	.03	.04	.08	.02	.07
Cathode Ray Tubes	.15	.09	.38	.19	.16	.04			.03	.07	.10	.09
Electric Shavers	.09	.08			.64	.10	.07	.13	.04	.08	.03	.05
Freezers	.11	.08			.31	.06			.04	.10	.06	.07
Gas Turbines	.14	.05	.42	.02	.09	.05						
Guided Missiles	.15	.06	.50	.03	.34	.03	.05	.04	.02	.09	.05	.07
Gyroscopes	.11	.06	.06	.02	.21	.10			.06	.11	.10	.07
Jet Engines	.12	.06			.20	.03			.05	.09	.09	.05
Locks	.08	.05	.11	.07	.06	.04	.09	.09				
Microfilm Readers	.18	.13	.25	.20	.12	.07						
Nuclear Reactors	.15	.08	.75	.00	.22	.02	.14	.03	.07	.11		
Outboard Motors	.11	.08			.64	.02	.04	.08	.09	.13	.07	.07
Oxygen Tents	.10	.09	.31	.09	.09	.03	.04	.04	.02	.19	.22	.00
Paints	.12	.05	.49	.00	.11	.03			.03	.09	.08	.06
Phonograph Records	.12	.08	.28	.11	.27	.05	.08	.19	.08	.17	.08	.06
Polariscopes	.07	.06	.10	.04	.12	.05	.03	.05	.06	.10	.04	.07
Pumps Heat	.17	.07	.39	.03	.19	.03	.03	.04	.06	.11	.15	.10
Radar Antenna Assemblies	.16	.10	.56	.25	.25	.05			.08	.11	.08	.06
Radiation Meters	.16	.09	.44	.05	.14	.04			.09	.14	.17	.05
Rocket Engines	.13	.05	.80	.00	.17	.03	.04	.04	.05	.09	.09	.06
Styrene	.12	.07	.17	.11	.10	.05	.08	.09				
Video Cassette Recorders	.26	.09	.53	.08	.20	.09						

Source: Based on *Thomas Register of American Manufacturers*.
Note: Entry and exit in each year t for each product expressed as a ratio to number of firms in the product market in year $t - 1$.