Does the Hazard Rate for New Plants Vary Between Low- and High-Tech Industries?

Talat Mahmood

ABSTRACT. Based on a longitudinal data base the hazard rates of over 12000 newly established plants in U.S. manufacturing industry in 1976 are estimated and then compared between low and high-tech industries. It is found that the hazard rate differs across industries, and it also varies between low and high-tech industries. The hazard rate in low-tech industries is reduced in the presence of scale economies, whereas the exposure to risk tends to be higher in high-tech industries. The influence of start-up size in reducing the hazard rate is apparently similar between low and high-tech industries, but its role is found to be more important in the high-technological industries. Market growth and R&D intensity exert no influence on the hazard rate in either the low- or high-tech industries.

I. Introduction

Several empirical studies have attempted to analyze the process by which firms, plants and the entire industry structure evolves over time, or what can be termed as intra-industry dynamics. Orr (1976) carried out an empirical investigation of entry and its determinants over a broad cross section of U.S. manufacturing industries. Acs and Audretsch (1889a and 1989b) examined the extent and determinants of small-firm entry in U.S. manufacturing industries.

More recently, Geroski and Schwalbach (1991) examined the nature of the entry process and constructed models to compare the causes and consequences of the observed entry flows recorded for several countries. These studies attempted to identify more clearly the determinants of entry into manufacturing industries, but they did not explore what happens to the new-firm start-ups subsequent to entry. This question has been addressed by Evans (1987a and 1987b) and Phillips and Kirchoff (1989), and they found that the probability of survival[1] increases with the age of the firms.

Dunne *et al.* (1989) examined the patterns of post-entry employment growth and failure rates. They found that plant failure rates decline with size and age as do the growth rates of surviving plants. One of their conclusions, which they found in their analysis of post-entry performance, was that entering firms that are most likely to survive and grow are firms that are diversifying from other industries. Recently Audretsch (1991) addressed the question of survival in order to identify the extent to which new-firm survival varies across a broad spectrum of manufacturing industries, along with the determinants of new-firm survival. More recently, Audretsch and Mahmood (1991) applied a hazard duration model to 1976 start-ups in U.S. manufacturing. They tested the hypothesis that the hazard rate confronting new establishments is influenced not only by their evolution over time, but also by scale economies, initial start-up size, ownership structure and the underlying technology.

The purpose of this paper is to examine how the hazard rates vary between low- and high-tech industries as well as to explain the effect of market structure characteristics, such as the minimum efficient scale, growth and R & D intensity on the hazard rate. The following section describes the longitudinal data base. The third section presents the estimation method to be implemented. The

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Wissenschaftszentrum Berlin für Sozialforschung
Market Processes and Corporate Development
Reichpietschufer 50
DW-1000 Berlin 30
Germany

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fourth section describes the data and the variables. Empirical results are then presented in section five and finally, the last section provides conclusions.

The major findings of this paper are:

1. The risk confronting new establishments tends to be elevated only in a very few low-tech industries but is reduced in high-tech industries in the presence of scale economies.
2. The exposure to risk can only be reduced in both low- and high-tech industries by increasing the initial plant size.
3. Market growth does not reduce the risk of failure in either low- or high-tech industries.
4. For most industries R & D intensity exerts no influence on the risk of failure confronting new establishments.

II. The longitudinal data base

A longitudinal data set[2] is used based on the actual start-up and closure dates of newly established plants. This data set provides bi-annual observations on all the firms and plants in the U.S. Small Business Administration's Small Business Data Base (SBDB). The data base is derived from Dun and Bradstreet (DUNS) market identifier file (DMI), which provides a virtual census on about 4.5 million U.S. business establishments for every year between 1976 and 1986 (Acs and Audretsch 1990, Chapter Two).

The data base links the ownership of all establishments to their parent firms, thereby enabling the performance of the establishments which are independent firms to be distinguished from those which are branches and subsidies of parent firms. Thus, the data base makes it possible to identify if each record, or establishment, is:

- a single-establishment firm, in which case the establishment is an independent legal entity;
- a branch or subsidiary belonging to a multi-establishment firm; or
- the headquarters of a multi-establishment firm.

Besides a detailed identification of the ownership structure of each establishment, the USELM file of the SBDB links the performance of each establishment at two-year intervals beginning in 1976 and ending in 1986, thereby tracking each establishment over what constitutes a ten-year longitudinal data base.

III. Method of estimation

The method I employ analyzes the life (event) histories of plants. The life history covers two states, "birth" and "death". In our analyses, only one event occurs, i.e., the firm's state changes from birth to death. It is assumed that observations are homogeneous in the probability distribution over duration time, i.e., transition (from birth to death) varies in some unknown way over time but the variation is the same for firms at risk of the event. Censoring presents a special problem in analyzing event history data. I focus here on analysis that is censored on the right (it is not known what will happen in the future). Cox's (1972 and 1975) and Kiefer's (1988) method of partial likelihood (PL) is used to capture the influence of a set of covariates on the duration of establishments survival time or hazard rate, which is the dependent variable. The advantage of this method is that consistent estimation can be obtained if the data also contain censored observations. The following function describes the relationship:

$$r(t) = h(t) * e^{(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)}. \tag{1}$$

The first term, $h(t)$, on the right-hand side of equation (1) is an unspecified time dependent function, which affects the rate of every member of the population in the same way. The second component of equation (1) describes the covariates $x_1, x_2, \ldots, x_n$ (possible time varying) and empirically estimatable parameters $\beta_1, \beta_2, \ldots, \beta_n$.

The influence of the variables are specified as log-linear to avoid negative rates.

A positive coefficient can be interpreted as increasing the value of the hazard function and therefore indicates a negative relationship with survival. A negative coefficient implies the reverse interpretation. In order to explain the effect of covariates on hazard, equation (1) can be reformulated as follows:

$$r(t) = h(t) * e^{a_1 x_1 * a_2 x_2 * \ldots * a_m x_m}, \tag{2}$$

where $a_i = e^{\beta_i}$. Then $(a_i - 1) * 100$ can be interpreted as the percentage effect on the death rates. If $a > 1$, the effect of the variable on the death rate is positive. For $a < 1$ the effect is negative, and for $a = 1$ the effect does not exist.

IV. Explanatory variables

Minimum Efficient Scale (MES): The Comanor-Wilson (1967) proxy is used for measuring MES and is defined as the mean size of the largest plants in each industry accounting for one-half of the industry value of shipments, 1977. This measure has proven in numerous studies at least to reflect the extent to which scale economies play an important role in an industry (Scherer and Ross, 1990). This variable should exert a positive influence on the hazard rate, because new firms typically operate at a scale of output that is less than the MES level (Audretsch, 1991).

Start-up Size: The size of the establishment when it was founded is measured by the number of employees. A negative influence on the hazard rate is expected, i.e., larger start-ups should face a reduced risk, because as the start-up size increases it approaches the MES level of output.

Market Growth: This is measured as the percentage change in the total sales of the four-digit standard industrial classification (SIC) industry within which the establishment operated between 1976—1986. This measure is derived from the Annual Survey of Manufactures of the U.S. Bureau of the Census. The market growth is expected to increase the growth potential of new establishments, and therefore should decrease the degree of risk confronting them.

Research and Development/Sales: The 1977 Federal Trade Commission's line of business company R&D/ Sales ratios are used. The sign of the coefficient is expected to be negative, since new establishments generally do not have access to a large R&D laboratory.[3]

V. Empirical results

Using the actuarial method of Cutler and Ederer the survival and hazard functions[4] are compiled and plotted. The survival rate gives for each time period the share of those establishments founded in 1976 which still existed. The hazard rate gives for each time point the risk of failure, i.e., the (conditional) probability that an establishment will exit in the next short time interval, on the condition that this establishment had survived up to the beginning of the time interval.

Figure 1 presents the survival rates for new plants in five low-tech industries and Figure 2 presents survival rates for three high-tech industries. The plants were classified into the following five low-tech industries: textiles, leather, apparel, printing and lumber & wood-, if their R&D/Sales ratio was less than one percent and high-tech industries: non-elect. machinery, electrical equipment and instruments, if the R&D/Sales ratio is at least five percent. The important observation from these figures is that the survival rates of all low- and high-tech industries declined over time. The dispersion of the survival rates of the plants between the low-tech industries tends to be slightly higher than the plants of the high-tech industries and it differs across low-tech industries. The survival rates of apparel is found to be the hightest among other industries over the decade. The dispersion becomes wider after the recession of 1982.

The survival rates of the plants in low- and high-tech industries tend to be different from each other. The extent to which the technological environment, or what Scherer (1991) terms as the technological opportunity class, influences the ability of new establishments to survive is not found to be similar between low- and high-tech industries.

Figures 3 and 4 present the estimated hazard rates for low- and high-tech industries. Figure 3 shows that the hazard rate differs across low-tech industries. The dispersion of the hazard rate becomes quite visible from the year 1978. It becomes wider from 1980 and shows a peak in the recession year 1982. The most severe effect is found for the leather industry in the recession year. We see that the hazard rate declines at a lower rate after 1984.

Among the three high-tech industries, the electrical equipment industry exhibits the highest hazard rate, and it still remains higher than the other industries after a decade. The general pattern of hazard among low- and high-tech industries seems to be quite similar. Industries in both low- and high-tech opportunity classes show a peak in the recession year 1982. This implies that the recession year 1982 has affected both low- and high-tech industries quite similarly.

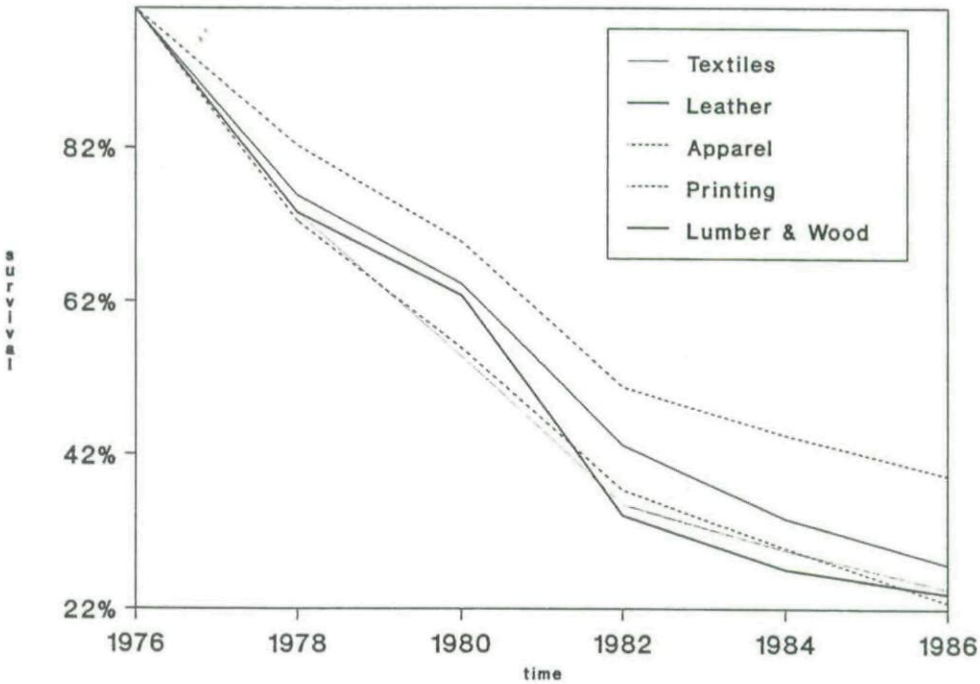

Fig. 1. Survival rates for new plants for low-tech industries.

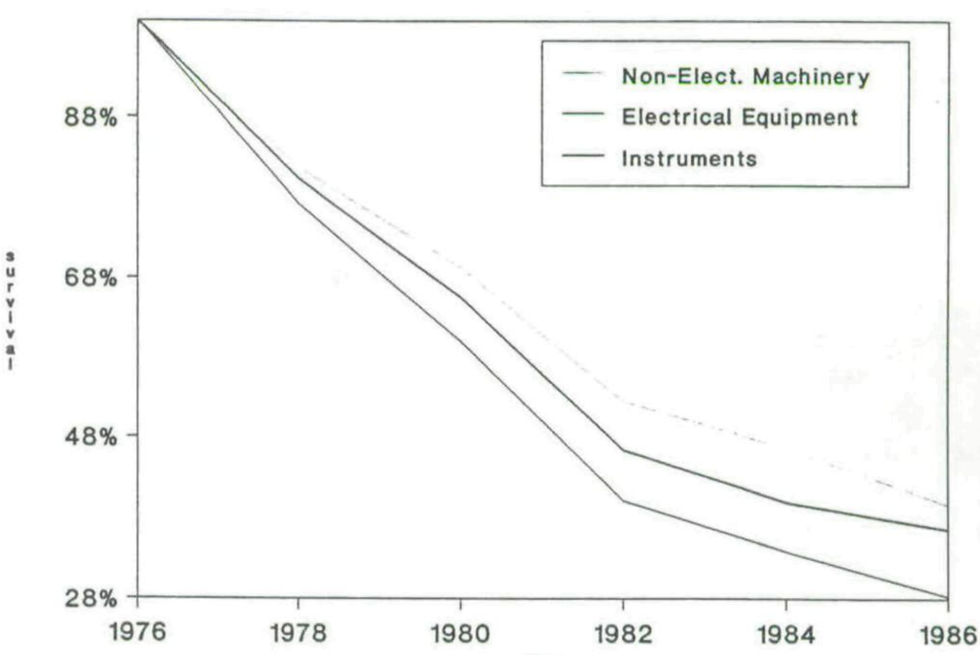

Fig. 2. Survival rates for new plants for high-tech industries.

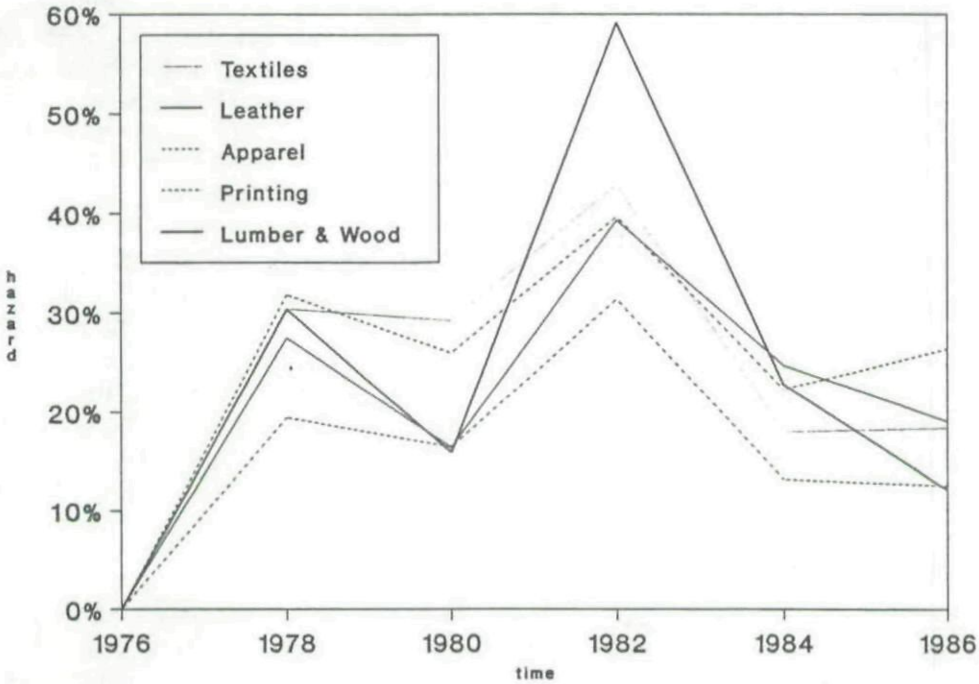

Fig. 3. Hazard rates for new plants for low-tech industries.

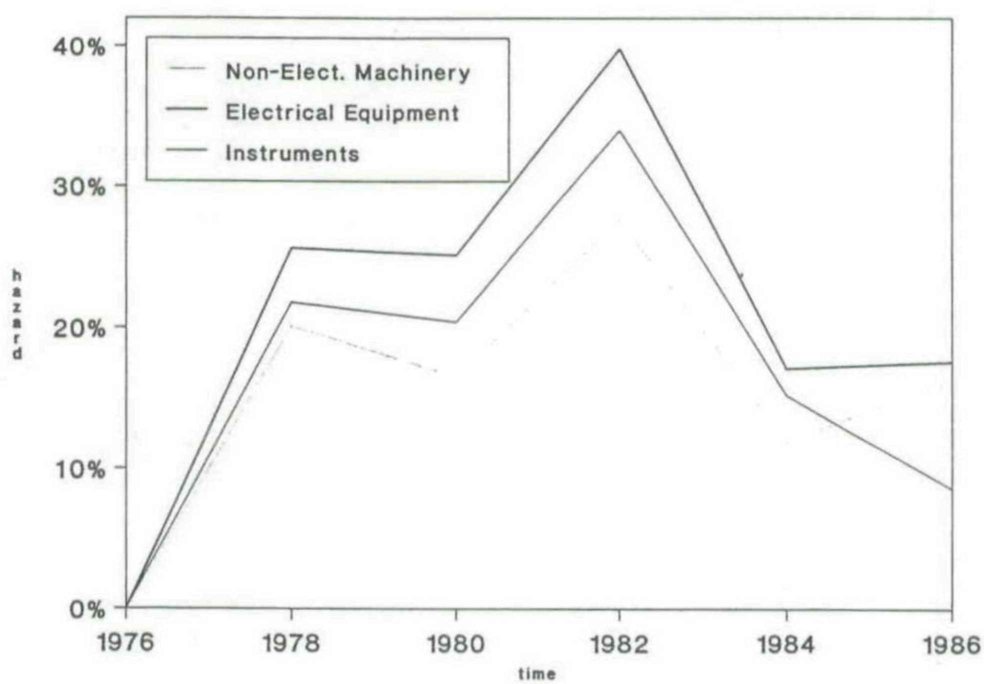

Fig. 4. Hazard rates for new plants for high-tech industries.

The hazard rate was estimated using the Cox-model described in the third section, and the results for the low-tech industries are shown in Table I. Of the nine low-tech industries, a positive and statistically significant coefficient on MES (at the 95% level of confidence for a two-tailed test) is found only for the lumber and printing industries. The effect of a unit ($1000) increase in the minimum efficient scale (MES) would increase the risk of failure confronting new establishment by 2.8 percent[5] in the lumber industry and 2.7 percent in the printing industry. For the remaining industries no significant relationship is evident, implying that only in two industries do scale economies play an important role, while in the other industries it does not matter. For these industries the hypothesis that the hazard rate tends to be elevated where economies of scale play an important role is not confirmed.

The start-up size of the establishment is found to be negatively related to the hazard rate for all nine low-tech industries, but it is statistically significant only for food and apparel. The effect of an increase of one employee would be to decrease the risk of failure by 1 percent for both industries. This indicates that the exposure to risk confronting the establishments in those two industries can be reduced by increasing the initial start-up size. For the remaining seven industries the risk tends to be higher than in the food and apparel industries.

The t-ratios of the coefficients for the variable measuring growth are not high enough to be considered statistically significant at the 95 percent level of significance for all nine low-tech industries. Thus, the empirical results are ambiguous for this industry characteristic. They do not support the hypothesis that the hazard rate tends to be lower for establishments founded in high-growth industries and greater for those in industries with low or even negative growth.

The coefficient of the industry R&D/Sales ratio is positive for the lumber industry and negative for the apparel industry. Perhaps it can be concluded that the risk tends to be lower because more establishments operating in apparel are branches of existing firms and they have higher R&D expenditures. An increase in R&D intensity of one percent in the apparel industry would reduce the hazard rate by about 50 percent whereas an increase of one percent R&D intensity in lumber increases the hazard by 65.2 percent. For the remaining industries the coefficients are not statistically significant and the sign varies.

Table II reports the results for the high-tech industries. The existence of scale economies raises the exposure to risk confronting new establishments in both the machinery and electric equipment industries and moderately as well in the instruments industry. All the coefficients of start-up size are negative but are statistically significant at the 95 percent significance level only for the machinery industry. In the electrical equipment industry the risk faced by new establishments is not strongly influenced by the start-up size. A one unit (one employee) increase in start-up size would reduce the risk of failure by five percent in the machinery industry.

For the new establishments operating in high-growth industries, the risk of failure is expected to lower. The results indicate that in the machinery and instrument industries growth has no significant effect on the hazard rate, while in the electrical equipment industry the probability of failure is reduced by a high growth rate. Of the three high-tech industries, the coefficient of R&D/Sales is positive and statistically significant for machinery, whereas for the other two industries the coefficient is negative but not significant. An increase in one unit of R&D/Sales, that is one percentage point, would increase the hazard rate by one percent in the electrical equipment industry. This implies that R&D/Sales exerts a negative influence on the ability of new establishments to survive.

The results from these tables suggest that the exposure to risk confronting new establishments is less influenced by external effects such as scale economies and R&D for the low-tech industries, whereas the influence is found to be stronger for high-tech industries. Start-up size tends to be important in reducing the hazard rate in both low and high-tech industries.

VI. Conclusions

This study used the semi-parametric hazard duration model to analyze the influence of scale economies, initial start-up size, industry growth and technology on the new-plant hazard rate and examined whether these influences differ between

TABLE I
Cox-regression results for low-tech industries[a]

	Food	Textiles	Apparel	Lumber	Furniture	Paper	Printing	Leather	Metals
Minimum efficient Scale	−0.014	0.053	0.003	0.662	0.027	0.073	0.027	0.104	0.001
	(−0.784)	(1.053)	(0.275)	(2.943)*	(0.357)	(1.158)	(5.603)*	(0.541)	(1.158)
Start up size	−0.003	−0.001	−0.007	−0.001	−0.004	−0.000	−0.001	−0.007	−0.004
	(−0.264)*	(−0.573)	(−4.032)*	(−0.782)	(−1.892)	(−0.238)	(−0.898)	(−1.453)	(−1.625)
Growth	−0.667	0.649	0.929	2.685	0.098	0.532	−0.236	−3.582	4.274
	(−0.284)	(0.295)	(0.867)	(1.596)	(0.059)	(0.281)	(−0.251)	(−0.916)	(1.004)
R&D/Sales	−0.150	0.984	−0.679*	1.295*	—	−0.393	0.382	−3.349	−0.034
	(−0.768)	(0.692)	(−2.675)	(2.435)	—	(−1.095)	(1.793)	(−0.800)	(−0.085)
No. of observations	561	341	947	852	580	156	1902	129	204
Chi square	7.930	2.522	28.399	12.151	5.100	2.459	40.969	4.556	9.615
Log of likelihood	−2414.5	−1396.9	−4686.5	−3914.7	−2598.6	−438.830	−8362.400	−437.580	−610.030

[a] T-statistics in parentheses.
* Statistically significant at 95 percent level of confidence, two-tailed test.

TABLE II
Cox-regression results for high-tech industries[a]

	Machinery, except electric	Electrical equipment	Instruments
Minimum efficient scale	0.009	0.009	0.001
	(1.779)	(1.641)	(0.302)
Start up size	−0.002	−0.001	−0.009
	(−2.408)*	(−0.420)	(−1.801)
Growth	0.897	−2.227	1.692
	(0.796)	(−1.642)	(0.635)
R&D/Sales	0.055	−0.019	−0.075
	(2.019)*	(−0.561)	(−0.919)
No. of observations	1647	710	336
Chi square	27.315	7.271	6.373
Log of likelihood	−7062.400	−3145.300	−1170.800

[a] T-statistics in parentheses.
* Statistically significant at 95 percent level of confidence, two-tailed test.

low-and high-tech industries. The findings of this paper suggest that the hazard rate tends not to elevated in the presence of scale economies in low-tech industries, whereas exposure to risk is found to be positively related to scale economies in high-tech industries. While the influence of start-up size tends to be similar between low and high-tech industries, its role is found to be less important in low-technological industries than in high-tech industries. The rate of growth and R&D intensity has no apparent effect on the hazard rate in either the low- or high-tech industries.

I did not separate branches and subsidiaries opened by existing firms from independent firms, but the effect of ownership structure might play an important role in determining the risk confronting any given plant. Further research is needed to examine the manner in which the ownership structure of plants affects their ability to survive over time.

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Notes

[1] Jovanovic (1982) provides another explanation why establishment survival varies.

[2] Dunne, Robert and Samuelson (1988 and 1989), Evans (1987a and 1987b), Hall (1987), Macdonald (1980), Phillips and Kirchoff (1989), and Baldwin and Gorecki (1991) all had access to such a longitudinal data base.

[3] This measure should show the importance of technology in the industry. Acs and Audretsch (1990) studied the innovative activity of what Winter (1984) termed the technological regime. Industries where small firms have the innovative advantage tend to correspond to the "entrepreneurial regime", while the industries where large firms have the innovative advantage correspond more closely to the "routinised regime". Under the entrepreneurial regime, or where innovative activity tends to emanate more from the small firms than from large enterprises, the hazard rate is expected to have a positive sign in contrast to the routinised regime, where large firms tend to have the innovative advantage.

[4] Our results include all types of plants of various sizes (number of firms). Brüderl and Schüssler (1990) estimated different survival and hazard functions pattern and classified them by the number of employees and legal form. My results seems to be similar to their hypothesis of "liability of adolescence".

[5] The estimated coefficient from equation one was converted according to equation two to explain the percentage effect.

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