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**Survival of Newly Founded Businesses:
A Log-Logistic Model Approach**

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ABSTRACT

Survival of Newly Founded Businesses: A Log-Logistic Model Approach

by Talat Mahmood

Based on a longitudinal data base we test the "liability of adolescence" hypothesis which states that new firm hazard rates follow an inverted U-shaped pattern. That is, the hazard rate is low for the initial period; the end of adolescence is marked by a hazard maximum, from which then rate declines monotonically. We use a log-logistic model which shows that the "liability of adolescence" argument describes the hazard rates of new establishments for all two and three-digit industries fairly well. Further, the rate shows that the desegregation of industries matters, and considerable differences are found within and across two and three-digit low-, moderate- and high-tech industries. In assessing the effect of market environment conditions on risk we find that risk tends to be elevated in a relatively large number of two-digit low- and high-tech industries in the presence of scale economies, but it is substantially reduced in moderate-tech industries. By contrast, the hazard rate tends to be reduced for quite a large number of three-digit low-, moderate- and high-tech industries in comparison with the two-digit industries, indicating a longer adolescence. The influence of start-up size in reducing the hazard rate is apparently similar between two and three digit low-, moderate- and high-tech industries. The impact of market growth on the risk of failure is not much different for both two and three-digit low-, moderate- and high-tech industries. That is, market growth tends not to reduce the risk exposure. R&D intensity exerts influence interchangeably on the risk of failure confronting new establishments within the two and three-digit low-, moderate- and high-tech industries.

ZUSAMMENFASSUNG

Überleben von Neugründungen: Ein log-logistisches Modell

Basierend auf Längsschnittdaten testen wir die Hypothese der „Liability of Adolescence“. Diese besagt, daß die Risikorate einem umgekehrten U-förmigen Verlauf folgt. Das bedeutet, daß die Risikorate in der Anfangsphase niedrig ist; das Ende der „Adolescence“ durch ein Maximum der Risikorate bestimmt wird, welche danach monoton abfällt. Das log-logistische Modell stellt die Ergebnisse für alle zwei- und dreistelligen Industrien am besten dar. Ferner zeigen die Ergebnisse, daß das Niveau der Aggregation eine große Rolle spielt und bemerkenswerte Unterschiede zwischen und innerhalb zweistelliger und dreistelliger low-, moderate- und high-tech Industrien zu finden sind. Bei der Einschätzung des Effekts von Charakteristiken der Marktumgebung auf das Risiko finden wir, daß das Risiko dazu tendiert, in einer relativ großen Anzahl von zweistelligen low- und high-tech Industrien erhöht zu werden, wenn Skalenerträge vorliegen, sich jedoch substantiell in moderate-tech Industrien verringert. Im Gegensatz dazu tendiert die Hazard Rate zu einer Verringerung für eine recht große Zahl von dreistelligen low-, moderate- und high-tech Industrien im Vergleich mit zweistelligen Industrien, was auf eine längere „Adolescence“ hindeutet. Der Einfluß der Anfangsgröße auf die Verringerung der Hazard Rate ist offensichtlich ähnlich in zwei- und dreistelligen low-, moderate- und high-tech Industrien. Der Einfluß des Marktwachstums auf das Risiko ist nicht zu unterschiedlich für zwei- und dreistellige Industrien. Das bedeutet, Marktwachstum tendiert nicht zu einer Verringerung des Risikos. Die FuE-Intensität übt einen Einfluß auf das Risiko sowohl in zwei- und dreistelligen low-, moderate- und high-tech Industrien durch Neugründungen aus.

I. Introduction and background

A number of studies have been undertaken on industry dynamics or about the process by which new firms either survive and grow, or else exit from the industry. A new literature has emerged in the last few years, which focuses on the question, what happens to new firms subsequent to their entry?, both in terms of their likelihood of survival and their growth patterns. Most of the studies use a theory of organizational ecology by Hannan and Freeman (1989), which emphasizes organizational characteristics and environmental conditions; particularly the number of employees and invested capital. In addition, the theory offers a comprehensive set of factors that influence the hazard rate of newly founded business organizations. In particular, this theory deals with the evolutionary process within or between populations of organizations observed over long periods of time (see also Singh and Lumsden (1990)). Originally, Stinchcombe (1965) directed the attention of organizational theorists, based on a hypothesis of a "*liability of newness*", to the age-dependent decline in organizational death rates. A number of studies (Freeman, Carroll, and Hannan (1983)) found that the organizational death risk declines monotonically with age. Later, Brüderl and Schüssler (1990) also empirically tested the Stinchcombe's "*liability of newness*" hypothesis and showed that it is not a good representation of the mortality (hazard) of business organizations. Organizational ecologists often discuss the "*liability of smallness*" in connection with the liability of newness (Aldrich and Auster (1986); Brüderl and Schüssler (1990); Audretsch and Mahmood (1994)). The assumption is that large new businesses have better survival prospects than small new businesses. Initial size may be measured in terms of either the amount of financial capital or the number employed at the time of founding. A large pool of financial resources improves the chances of a new firm to weather the critical start-up period and to cope with random shocks from the environment. Furthermore, large organizations may have advantages in raising more capital (legal form), may face better tax conditions, and may be in a better position to recruit qualified labor. However, smaller firms have the advantage of low overhead costs, and they require minimal resources for sustenance. A successful business may begin on a relatively small scale and build up step-by step in an exploratory fashion.

Similar arguments that characteristics specific to the firm influence their new-firm survival have also been tested by Audretsch (1995) using the industrial organization theory. For example, a greater start-up size of the firm increases the likelihood of survival, since the cost advantage confronting a firm operating at a sub-optimal scale level of output will be reduced. At the same time, the greater the size, the less it will need to grow in order to exhaust potential scale economies and ultimately survive. That is, if the start-up size of the firm is large enough relative to the MES of the industry, the firm need not grow at all and will still be viable in the long run. Both a positive relationship between firm size and post-entry growth rates have been found in the United States Hall (1987); Dunne, Roberts and Samuelson (1988) and (1989); Audretsch (1991); and Audretsch and Mahmood (1995), the United Kingdom Dunne and Hughes (1994), Portugal (Mata and Portugal (1994); Mata, Portugal and Guimaraes (1995)), Germany (Wagner (1994); Mahmood (1996)), and Canada (Baldwin (1995)). In addition other studies (Doms, Dunne and Roberts (1995)) show that firm-specific factors such as capital intensity and the use of specific advanced manufacturing technologies influence new-firm survival. Taken together, the wave of recent empirical studies therefore provides systematic evidence that new-firm survival is in most cases specific to factors particular to the firm and industry. In addition, the innovative environment of the industry has also been hypothesized to influence the new-firm survival of the firms. Empirical evidence for the United States (Audretsch (1991) and (1995)) suggests that the likelihood of survival tends to decrease as the degree of innovative activity in an industry increases. However, the growth rates of those firms that do survive tend to be positively related to the degree of innovative activity in the industry. Other theories also suggests that new-firm survival will be influenced by the degree of scale economies in an industry (Audretsch (1995)).

A set of recent theories - belonging in a broad sense to the "Empiricist" traditions - suggests that new-firm survival is not random across firms, but rather shaped by characteristics specific to the firm. Dixit (1989) and Hoppenhayan (1992) both argue that new-firm survival will be influenced by the amount of sunk costs in the industry. A greater degree of sunk cost, should reduce the likelihood of exit and lead to lower observed growth rates for surviving firms. Audretsch (1991 and 1995) provides the empirical evidence linking the extent of sunk costs to a lower likelihood of exit and lower

observed growth rates of surviving firms. All of these empirical studies actually do not test the theoretical arguments from organizational ecology.

Other recent empirical studies of Fichman and Levinthal (1991) and Brüderl (1992a) use the arguments of organization ecology, in which they modify the liability of newness argument. This suggests that organizational hazard actually follows an inverted U-shaped pattern, rather than continuously declining with increasing age. This argument is associated with the "*liability of adolescence*", which states that organizational mortality rates follow an inverted U-shaped pattern: During the first short period the hazard (mortality) rate is low and the end of adolescence is marked by a mortality maximum, from which rate finally decline monotonically. They argue that newly founded organizations often have stock of initial resources. This stock helps them to survive for some time during which they can establish their new structures. This early stage of an organizational life-cycle is named "*adolescence*". During adolescence mortality rates should be low, whereas at the end of this phase, when initial resources are eventually used up and the final evaluation has to be made, mortality should increase dramatically. Afterwards, the usual arguments for a declining rate apply. Overall this "*liability of adolescence*" results in inverted U-shaped mortality rates.

A wave of empirical literature has now emerged which provides empirical evidence in favor of liability of adolescence. Several studies found non-monotonic mortality rates for a wide variety of organizational populations¹ (Singh, House, and Tucker (1986); Aldrich, Staber, Zimmer and Beggs (1990)). Our study will try to provide further evidence on the liability of adolescence hypothesis by using a longitudinal data set for the U.S. From the theory² of organizational ecology, explained above, we will derive some testable hypotheses and test them applying the log-logistic rate model using our samples.

The purpose of this paper is to use the log-logistic model and test the hypothesis drawn from the organizational ecology and examine how resources and market environment conditions influence hazard rates. Further, it will be shown how hazard rates vary between low-, moderate- and high-tech industries within two-digit and across two and three digit industries.

The following section describes the longitudinal data base. The third section presents the estimation method to be implemented. The fourth section describes the variables. Empirical results are then presented in section five and finally, the last section provides the conclusions.

II. The longitudinal data base

A longitudinal data set 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 (SBA) Small Business Data Base (SBDB). The data base is derived from the Dunn 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 1976-1986 (Acs and Audretsch (1990), Chapter Two).

The data base links the ownership of each establishment to its parent firm, thereby enabling the performance of the establishments which are independent firms to be distinguished from those which are branches and subsidiaries of parent firms. Thus, the data base makes it possible to identify each record or establishment as:

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

III. Method of estimation

The techniques of survival analysis or event-history (see Kiefer (1988), Blossfeld, et al. (1989), Blossfeld and Rohwer (1995)) are used to test our theoretical arguments

derived from the organizational ecology literature. The variable of interest in the analysis of duration is the *length of time* that elapses from the beginning of some event (birth of a firm) either until its end (exit of a firm) or until the measurement is taken (censoring), which may precede termination. The process being observed may have begun at different points in time. Censoring is a pervasive and usually unavoidable problem in the analysis of duration data. The central concept of this method is the hazard rate, which gives (approximately) for every age the probability that a firm will die in the next, short interval, conditional on still being alive. For multivariate analysis, however, parametric rate models can be used which specify the rate as a function of age³. This section describes the standard log-logistic model. In the single transition (episode) case the log-logistic model is based on the assumption that the duration variable follows a log-logistic distribution. This model has the advantage that it is able to capture both inverted U-shaped and monotonically declining rates.

The standard log-logistic model has two parameters α and β (see eq. 1), so there are two possibilities to include variables. This model uses exponential link functions, so one gets the following model formulation for the transition rate from the origin state j to the destination state k . Variables that are supposed to influence the shape of the rate should be attached to the β -vector, whereas α -effects correspond as shift-factors for the maximum rate. This model allows for a monotonically falling (β less than or equal 1) as well as for an inverted U-shaped hazard rate ($\beta > 1$). With this model we will test the "liability of adolescence" hypothesis.

$$r_{jk}(t) = \frac{b_{jk} a_{jk}^{b_{jk}} t^{b_{jk}-1}}{1 + (a_{jk} t)^{b_{jk}}} \quad (1)$$

$$a_{jk} = \exp\{A^{(jk)} \mathbf{a}^{(jk)}\}$$

$$b_{jk} = \exp\{B^{(jk)} \mathbf{b}^{(jk)}\}$$

The time t_{\max} when the rate reaches its maximum, r_{\max} , is given by

$$t_{\max} = \frac{1}{a} (b-1)^{\frac{1}{b}} \quad (2)$$

$$r_{\max} = a(b-1)^{1-\frac{1}{b}} \quad (3)$$

It can be seen from equation (3), that a negative effect of a variable in the α -vector lowers the maximum rate and, from equation (2), that the maximum shifts to the right. It follows that variables which shift the peak, i.e., influence the length of adolescence, should be introduced into the α -vector. If few variables are introduced into both vectors, the β -effect still determines the shape of the rate, but α - and β -effects together determine the maximum.

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)). Consequently, a shorter adolescence is expected indicating a higher risk for new establishments.

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. A longer adolescence and a right shift has to be expected.

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 Manufacturers of the U.S. Bureau of the Census. Market growth is expected to increase the growth potential of new establishments, and therefore should decrease the degree of risk confronting them. This indicates a lower risk and a shift to the right.

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. A lower risk and a shift to the right is expected⁴.

V. Empirical results

A log-logistic distribution was identified on the basis of visual inspection of the transformed survivor functions plots. Among other models, the log-logistic model yielded the best fit among other distributions, such as Weibull, log-normal and exponential distributions.

As described in section III the log-logistic model contains two parameters, so there are two possibilities to include variables, in α and β -vectors, i.e., variables included in the α -vector tend to shift the maximum to the right or left depending on the sign, and variables included in the β -vector influence the shape of the rate (see equation 1, section III). First, we used a log-logistic model without variables in both α and β -vectors and found that the estimated parameters of both models turn out to be statistically significant and their values in magnitude are greater than one. This implies that the rate first rises monotonically up to a maximum and then declines monotonically, indicating an inverted U-shaped hazard rate in our data.

We now compare each model of the low-, moderate-, and high-tech industries without variables in the α -vector by using the likelihood ratio test with the model, including the variables in the α -vector. The likelihood ratio statistics show, with four degrees of freedom at a significance level of 0.05, that the null hypothesis should be accepted. That is, the additional variables in the α -vector do significantly improve the model fit.

We estimated log-logistic rates for the food, textile, furniture and paper industries for two different models; variables in the α -vector and variables without in α -vector. Figures 1.1.1-1.1.4 show the rates for each of the low-tech industries with two different models based on the estimates. The dashed lines correspond to the model in which we include variables in the α -vector and solid lines for all variables not included in the α -vector and remains valid for all subsequent Figures. We observe a different pattern for the food industry between the two models, which, however, differ. We see from the figure that

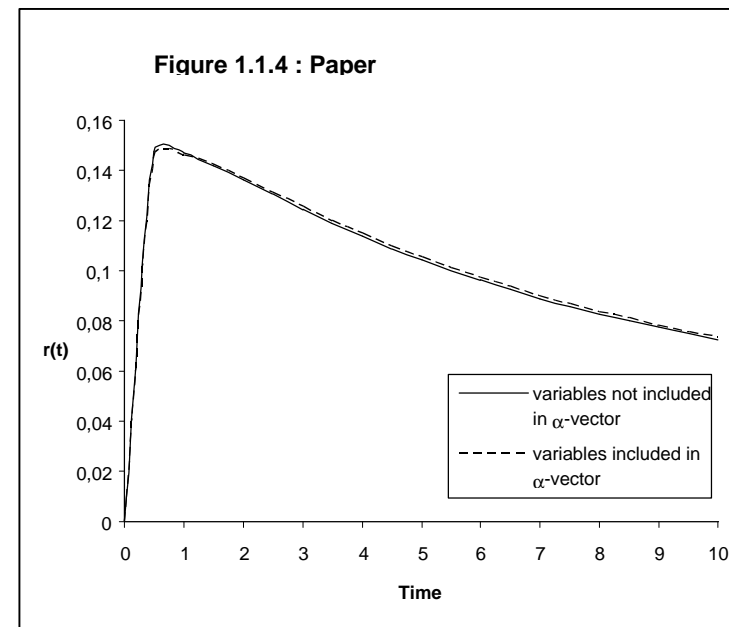
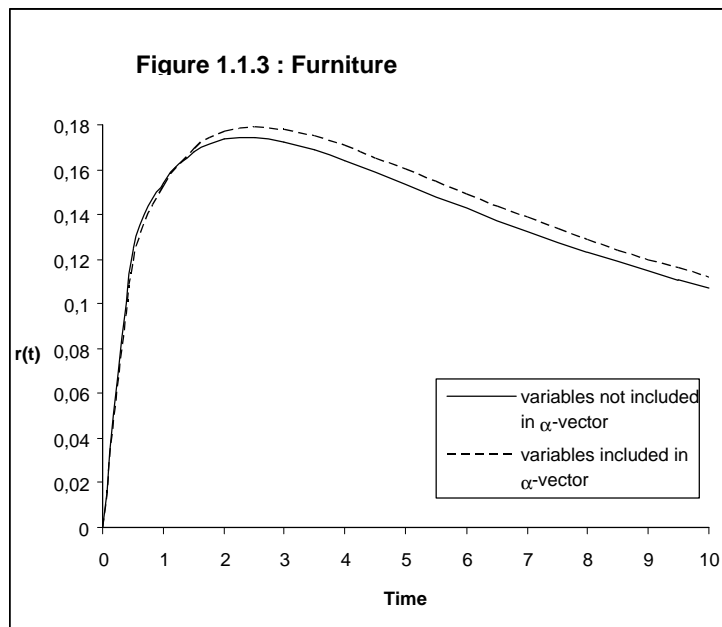
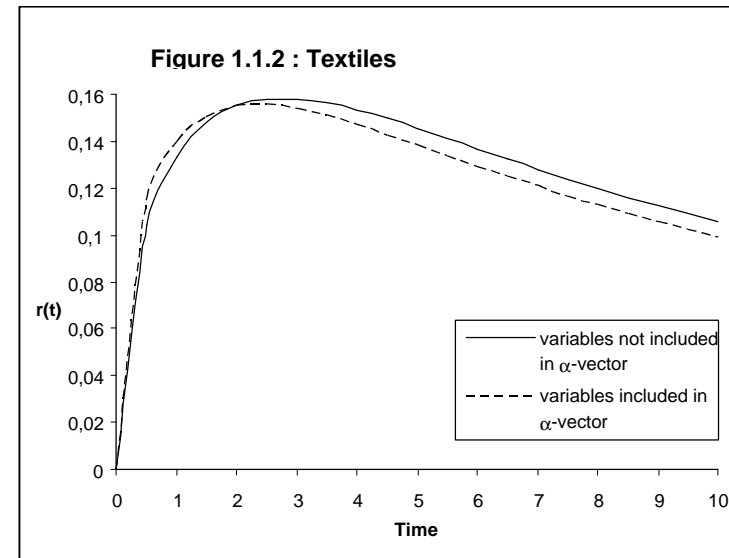
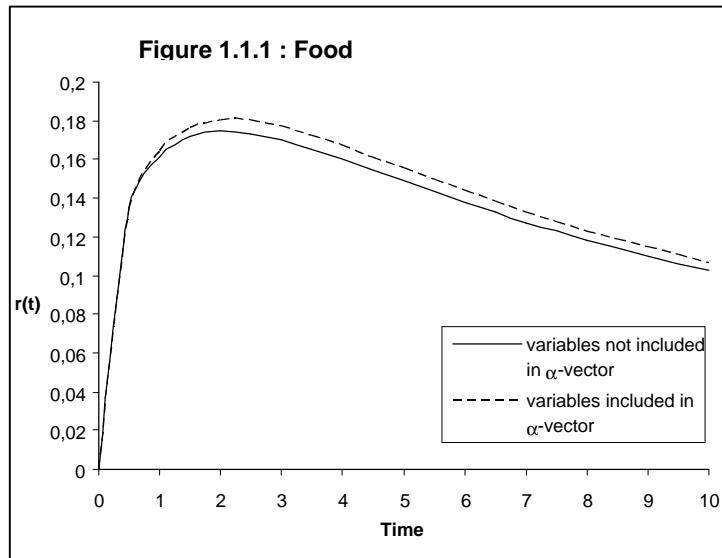
the maximum rate of 2.2 years appears later for the model which includes variables in the α -vector, whereas the maximum rate is found at 2.0 for the model without variables in the α -vector. This demonstrates the scale-effect of the determinants. This suggests that the start-up size shifts the maximum to the right, and lowers the maximum. In contrast, we see from Figure 1.1.2 that the maximum for the textile industry is earlier, with a maximum of 2.7 years than the 2.3 years, for the model including variables in the α -vector. This suggests that the positive sign of MES tends to influence the shift towards the left. Now, we observe the pattern in the furniture industry. We see from Figure 1.1.3 that the maximum rate is later for the model with variables in the α -vector, while it is earlier for the other model. In this industry the start-up size tends to shift the maximum and has a scale effect. Finally, we look at the paper industry. We do not see a significant difference between the two maximums for this industry, which are less than a year. Together these results demonstrate, on the one hand, the relevance of the liability adolescence argument and show that adolescence lasts between less than a year to three years.

We now report the results for the six moderate-tech industries: chemicals, rubber, stone, clay and glass, metals, and transportation and misc. manufacturing industries. Figures 2.1.1 and 2.1.2 show the plots of log-logistic rates for two moderate-tech industries, i.e., transportation and metals (except machinery) for two different models. It can be seen from Figure 2.1.1 that the maximum (2.8 years) of the model which includes the variables in α -vector lies later than the maximum (2.4 years) of the model without variables in the α -vector. This clearly demonstrates the scale-effect of the determinants. The estimated values of the metals industry show for the model without variables in the α -vector a maximum (2.2 years), which tends to be later than that of the other model with an earlier maximum of 1.7 years. The estimates of the two-digit moderate-tech chemical industry (figure not reported here) do not show a significant change in the time of maximum and its rate for the two models. The values for the maximum are 2.2 and 2.1 years, respectively. This suggests that none of the variables influence the shape nor do any variables tends to shift the maximum an any direction. The rubber industry (figure not reported here) shows a similarity with the chemical industry if we look at the value of maximum, which is 3.6 years for the model without variables in the α -vector and 3.5

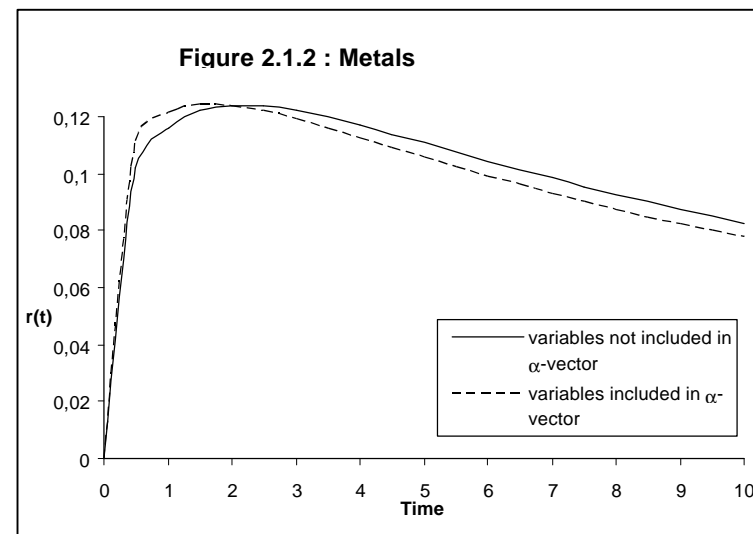
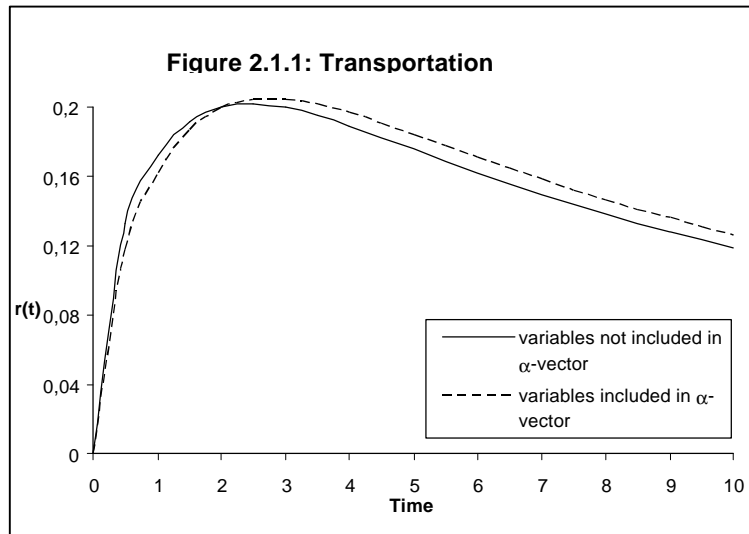
years for the model with variables in the α -vector. This suggests a variation of adolescence between two to three years.

Of the three high-tech industries, we show the plots of log-logistic rates for the machinery and electrical equipment industries. The maximum value of the machinery industry (see Fig. 2.1.3) is 3.1 years for the model without variables in the α -vector, and the value of the other model is 2.4 years. We observe from the difference in the maximum values that variables in the α -vector tend to shift the maximum rate to the left. In the electrical equipment industry the maximum values are 2.8 and 3.0 years. This suggests a shift of the maximum to the right. The variation of adolescence turns out to be between 2.5 years to three years.

Figures 1.1.1. - 1.4 : Log-logistic rate functions for two digit low-tech industries with and without variables in α -vector



Figures 2.1.1 - 1.2: Log-logistic rate functions for two-digit moderate-tech industries with and without variables in α -vector



Figures 2.1.3-1.4: Log-logistic rate functions for two-digit high-tech industries with and without variables in α -vectors

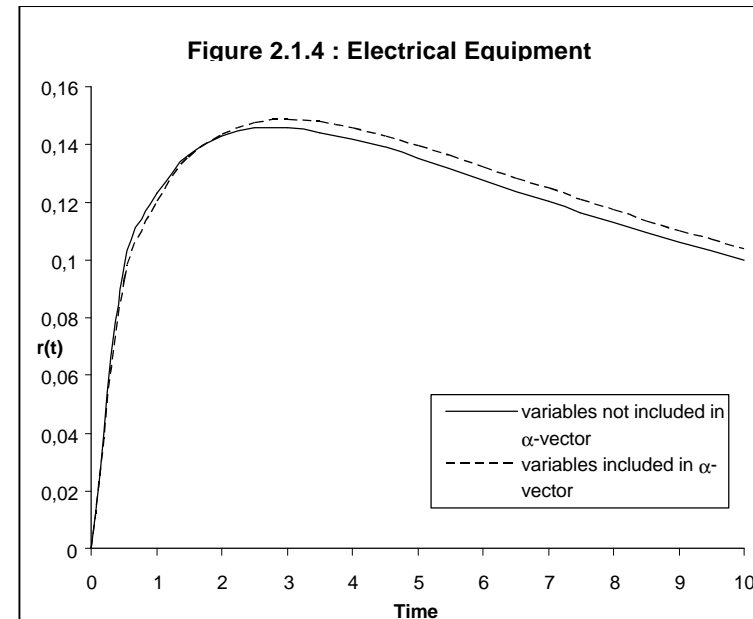
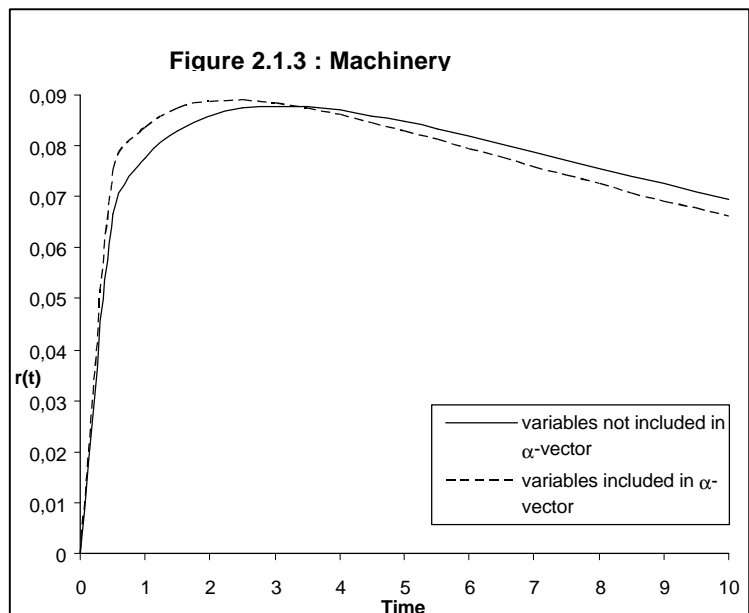


Table 1 reports the empirical findings. We investigate now the impact of determinants in terms of scale and shift-effects on the hazard rate for each of the nine low-tech industries. We first test whether the shift and/or scale effects are influenced in such models where scale economies (MES) play an important role across all nine industries. We observe a positive coefficient for almost eight industries, but in most of the industries no significant relationship is supposed to exist. Only in the food industry is the coefficient negative but insignificant, i.e., the influence of shift-effect towards the right is observed only in this industry. The lumber and printing industries depict high t-ratios indicating a stronger shift-effect to the left. So, it seems that in most of the industries scale economies tends not to play an important role in shifting the maximum. On the other hand, it shows a shorter adolescence than expected and a higher risk.

Now we look at the start-up size variable and its impact on the hazard rate. Of the nine low-tech industries the relationship is found to be negative indicating a lower maximum which is shifted toward the right. The estimated coefficient is found to be significantly (judged by the t-value) different from zero for four industries (food, apparel, furniture and leather), and for all other five industries the coefficient remains insignificant. This implies that adolescence seems to be longer for establishments in the four significant industries, further suggesting that with increasing size, the maximum can be shifted to the right. As expected, we can conclude by stating that start-up size strongly lowers the death risk for newly founded firms.

Growth shows a positive significant effect only in the lumber industry. The risk exposure confronting establishments in this industry is substantially raised. From the remaining eight industries, the sign of the coefficient is found to be negative for food, textiles, printing and leather indicating a shift towards the right. On the other hand, a positive coefficient is found for apparel, furniture, paper and metals indicating an earlier maximum. This result does not support the hypothesis that the risk tends to be lower for establishments founded in high-growth industries and greater for those in industries with low or even negative growth, except in the lumber industry.

Table 1: Regression results for two-digit, low-tech industries^a

Independent Variables	Food	Textiles	Apparel	Lumber	Furniture	Paper	Printing	Leather	Metals
α: Constant	-1.474 (-11.58)	-1.589 (-7.54)	-1.114 (-11.35)	-2.480 (-11.80)	-1.486 (-18.84)	-1.702 (-5.39)	-2.265 (-30.81)	-0.648 (-0.74)	-2.046 (-7.91)
Minimum Efficient Scale	-0.009 (-0.46)	0.054 (1.36)	0.002 (0.17)	0.881 (3.67)	0.058 (0.64)	0.154 (1.72)	0.028 (4.91)	0.106 (0.53)	0.015 (1.42)
Start-up Size	-0.003 (-2.41)	-0.001 (-0.63)	-0.008 (-4.83)	-0.002 (-0.93)	-0.004 (-2.33)	-0.001 (-0.17)	-0.001 (-0.59)	-0.008 (-2.02)	-0.003 (-1.58)
Growth	-1.369 (-0.49)	-1.648 (-0.67)	0.138 (0.11)	4.023 (2.21)	0.065 (0.03)	0.360 (0.15)	-0.705 (-0.70)	-4.583 (-1.17)	5.545 (1.18)
R&D / Sales	-0.117 (-0.53)	0.063 (0.04)	-0.804 (-2.77)	1.523 (2.63)	- -	-0.591 (-1.333)	0.787 (3.29)	-4.213 (-0.93)	0.0961 (0.21)
	β-Vector								
β: Constant	0.309 (7.51)	0.361 (7.01)	0.371 (12.03)	0.335 (9.95)	0.345 (8.69)	0.095 (1.08)	0.267 (10.45)	0.415 (4.98)	0.213 (3.01)
Log of Likelihood	-1218.4	-742.8	-2038.3	-1860.6	-1258.4	-300.6	-3729.1	-280.2	-400.7
No. of Observations	560	341	947	850	580	156	1902	129	203

^a T-values in parentheses

Industry R&D intensity tends to be higher in the lumber and printing industries as can be seen in the statistically significant coefficient. This further suggests that R&D intensity has a strong positive shift-effect to the left. In contrast, risk tends to be reduced in the apparel industry indicating a lower maximum which is shifted to the right. For the remaining food, textiles, leather and metals industries the coefficients are statistically insignificant and their signs vary indicating a shift in both directions.

Table 2 presents the empirical results of all six moderate-tech industries: chemicals, rubber, stone, clay and glass, metals (except machinery), transportation, and misc. manufacturing. As mentioned above, a negative effect in the α -vector shifts the maximum to the right and lowers it. A moderate negative effect is found for the scale economies in the chemicals, stone, clay and glass and transportation industries. This suggests a stronger effect of scale economies on shifting the maximum to the right as compared to the low-tech industries. The result for these industries is not consistent with our MES-hypothesis. On the other hand, a positive significant coefficient is found for the metals industry, indicating a shift to the left. This suggests that the establishments operating in this industry are confronted by a shorter adolescence. A positive effect is also observed in the rubber industry but much stronger in the misc. manufacturing industry.

The start-up size exerts a negative relationship, but in most of the industries the coefficient is found to be insignificant. Surprisingly, this result differs from the low-tech industries. Only in the transportation industry is the coefficient significant indicating a shift to the right. This suggests that the risk is reduced for establishments which increase their start-up size. A moderate negative effect is observed for establishments in the misc. manufacturing industries, suggesting a shift to the right. These results support strongly the resources argument associated with the adolescence hypothesis.

None of the coefficients for industry growth measure is found to be statistically different from zero, although the sign varies across the six industries. Except for rubber and misc. manufacturing industries, the positive sign for the other four industries indicates a moderate scale effect and suggests that the maximum lies earlier. For the remaining two industries the maximum is found to be later. This shows that the risk exposure tends to be higher in

Table 2: Regression results for two-digit, moderate-tech industries^a

Independent Variables	Chemicals	Rubber	Stone, Clay, Glass	Metals (except machinery)	Transportation	Misc. Manufacturing Industries
α: Constant	-1.822 (-8.71)	-2.321 (-0.81)	-1.872 (-19.76)	-1.809 (-25.48)	-1.365 (-8.22)	-1.339 (-10.03)
Minimum Efficient Scale	-0.024 (-1.27)	0.008 (0.03)	-0.030 (-1.02)	0.058 (3.32)	-0.003 (-1.09)	0.063 (1.87)
Start-up Size	-0.001 (-1.09)	-0.001 (-1.05)	-0.003 (-1.27)	-0.002 (-1.14)	-0.005 (-2.11)	-0.004 (-1.86)
Growth	1.582 (0.91)	-3.576 (-0.13)	2.581 (1.13)	0.380 (0.35)	0.261 (0.70)	-0.657 (-0.38)
R&D / Sales	0.099 (1.29)	0.452 (0.15)	0.227 (3.21)	-0.110 (-1.95)	-0.003 (-0.03)	-0.068 (-0.71)
	β-Vector					
β: Constant	0.244 (4.69)	0.238 (4.96)	0.347 (7.59)	0.238 (7.40)	0.398 (9.17)	0.411 (12.82)
Log of Likelihood	-790.6	-991.6	-1039.5	-2218.6	-1016.5	-1843.4
No. of Observations	375	476	614	1068	461	826

^a T-values in parentheses

chemicals, stone, clay and glass, metals and transportation, whereas it is lower in rubber and misc. manufacturing industries. For most of the industries, market growth does not increase the growth potential of new-establishments.

The industry R&D/Sales ratio exerts a positive but insignificant sign in the chemical and rubber industries, whereas in the stone, clay and glass industry the coefficient tends to be statistically significant. This suggests that the scale effect tends to be moderate for the chemicals and rubber industries but much stronger for the stone, clay and glass industry indicating an earlier maximum. In contrast, a negative significant coefficient is found for the metals industry indicating a stronger scale effect and a shift of the maximum to the right. For the remaining two industries the sign is negative but insignificant suggesting a later maximum. We do not observe a relationship supporting the argument that new establishments should face a lower risk.

Table 3 shows the results for the machinery, electrical equipment and instrument high-tech industries. The extent to which the existence of scale economies tends to raise the risk exposure in these three high-tech industries seems to be lower than that of the low- and moderate-tech industries. Of the three industries all the coefficients are found to be positive but insignificant. This suggests that the scale effect is moderate and the maximum lies earlier, further supporting the MES hypothesis.

Of the three high-tech industries the coefficient of the start-up size tends to be negative and significant. This suggests that start-up size shifts the maximum to the right and lowers the risk for newly founded firms. Adolescence tends to be longer for the new establishments operating in these two industries. On the other hand, newly founded businesses in the electrical equipment industry face a higher risk and the maximum is earlier than in the other two high-tech industries. This can be seen from a positive coefficient of the start-up size variable.

Surprisingly, this does not support the resources arguments for new establishments operating in this industry. The sign of the industry growth variable varies across these three industries. In the electrical equipment industry the risk tends to be lower and the maximum lies later, as it can be seen from the negative coefficient. The positive insignificant coefficient of the other

Table 3: Regression results for two-digit, high-tech industries^a

Independent Variables	Machinery (except electrical)	Electrical Equipment	Instruments
α: Constant	-2.154 (-31.67)	-1.665 (-16.72)	-1.564 (-4.65)
Minimum Efficient Scale	0.009 (1.72)	0.008 (1.61)	0.001 (0.05)
Start-up Size	-0.003 (-2.80)	0.001 (0.36)	-0.009 (-2.07)
Growth	1.243 (1.06)	-2.343 (-1.73)	1.805 (0.63)
R&D / Sales	0.071 (2.14)	-0.009 (-0.25)	-0.059 (-0.67)
	β-Vector		
β: Constant	0.239 (8.84)	0.342 (9.27)	0.261 (4.51)
Log of Likelihood	-3335.7	-1542.8	-689.2
No. of Observations	1648	713	336

^a T-values in parentheses

two industries exerts a positive scale effect indicating an earlier maximum. The R&D/Sales ratio effect is also found to be different across these three industries. The significant scale and shift effect is observed for new establishments in the machinery industry indicating a higher risk exposure and an earlier maximum. In the remaining two industries the new establishment faces a moderately lower risk because of the negative coefficient. The maximum tends to lie on the right indicating a longer adolescence.

Now, the Table 4 report the results of three-digit desegregated industries. We grouped the low-, moderate- and high-tech industries according to their three-digit standard industrial classification. The parameters of the log-logistic distribution were calculated for the three low-tech industries (apparel, mills/wood and printing/publishing), for the three moderate-tech industries (clay/pottery/concrete, abrasive, asbestos and minerals and fabricated metals), and finally, for the six high-tech industries (construction and mining machinery, metal working machinery, refrigerators and misc. equipment, electrical/household/wiring/audio, vehicle/aircraft/ship parts and measuring analyzing instruments). In this section we selected the model as in the previous section, on the basis of the likelihood ratio test. We compared the model with the variables in the β -vector to the model without variables in the β -vector for each of the three-digit low-, moderate-, and high-tech industries. In this case we accepted the null hypothesis and rejected the model without variables in the β -vector. Table 4 reports the results of all low-, moderate- and high-tech industries. We included those variables in the β -vector (lower part of the Table), which were found to be significant in the α -vector (upper part of the Table).

As already mentioned in the previous section, a negative effect in the α -vector shifts the maximum to the right and lowers it. Of the three low-tech industries a strong negative effect of the scale economies is found for the apparel industry, whereas the effect remains moderate for the mills/wood industry. In contrast, the risk tends to be higher for new establishments in the printing/publishing industry indicating an earlier and shorter adolescence. Start-up size exerts a negative effect on all three industries but the strongest effect is in the apparel industry indicating a shift to the right. For the industry growth variable the effect is positive and the strongest effect is found in the mills/wood industry. This suggests a higher risk and an earlier

Table 4: Regression results for three-digit, low-tech, moderate-tech and high-tech industries including variables in β -Vector^a

Independent Variables	Low-Tech			Moderate-Tech			High-Tech					
	Apparel	Mills/Wood	Printing/Publishing	Clay Pottery Concrete	Abrasive Asbestos Minerals	Fabricated Metals	Construct. Mining Machinery	Metal-working Machinery	Refrig., Misc. Equipment	Electrical Household Wiring Audio	Vehicle Aircraft Ship Parts	Measuring Analyzing Instruments
α : Constant	-0.951 (-6.15)	-2.449 (-6.11)	-2.473 (-5.71)	-2.044 (-13.85)	-10.384 (-3.46)	-1.715 (-13.79)	-1.35 (-2.87)	-2.971 (-10.61)	-3.832 (-6.52)	-1.224 (-6.69)	-1.551 (-9.27)	-0.633 (-0.92)
Minimum Efficient Scale	-0.642 (-2.72)	-0.093 (-0.21)	0.028 (2.53)	-0.08 (-0.39)	-0.234 (-3.25)	0.167 (0.83)	0.036 (1.85)	0.168 (1.56)	-0.021 (-1.10)	0.015 (2.18)	0.004 (1.04)	-0.109 (-2.62)
Start-up Size	-0.009 (-4.17)	-0.001 (-0.40)	-0.0004 (-0.56)	-0.003 (-1.1)	0.007 (1.58)	-0.002 (-0.93)	-0.008 (-1.63)	-0.014 (-1.74)	-0.002 (-1.67)	-0.002 (-1.19)	-0.008 (-1.69)	-0.011 (-1.65)
Growth	0.575 (0.46)	10.069 (2.55)	2.209 (0.13)	7.110 (2.11)	4.112 (1.10)	1.175 (0.56)	0.611 (0.23)	13.15 (3.27)	-1.80 (-0.37)	-6.224 (-1.86)	0.753 (1.97)	-0.908 (-0.27)
R&D / Sales	-0.60 (-1.08)	2.582 (1.62)	1.314 (1.50)	0.473 (3.02)	7.177 (2.83)	-0.167 (-2.51)	-0.332 (-1.22)	0.232 (1.17)	1.633 (3.34)	-0.336 (-2.39)	-0.121 (-1.31)	-0.132 (-0.84)
	β-Vector											
β : Constant	0.425 (6.99)	0.327 (4.50)	0.294 (4.15)	0.101 (0.93)	2.063 (0.64)	0.238 (3.62)	0.369 (2.96)	-0.004 (-0.03)	-0.049 (-0.18)	0.384 (2.57)	0.492 (6.24)	0.524 (3.97)
Minimum Efficient Scale	0.002 (0.01)	-	0.007 (1.28)	-	0.072 (0.93)	-	0.001 (0.21)	-	-	0.004 (0.72)	-	-0.065 (-2.53)
Start-up Size	-0.001 (-1.01)	-	-	-	-	-	0.001 (0.22)	-	-	-	-0.004 (-1.43)	-0.002 (-0.49)
Growth	-	-1.141 (-0.42)	-	-	-	-	-	6.017 (1.57)	-	0.159 (0.05)	-0.187 (-0.87)	-
R&D / Sales	-	-	-	0.379 (3.08)	-1.335 (-0.50)	-0.007 (-0.14)	-	-	0.259 (1.14)	-0.035 (-0.31)	-	-
Log of Likelihood	-1521.3	-943.4	-888.8	-494.0	-234.4	-878.7	-288.2	-597.4	-1502.3	-561.3	-712.2	-460.6
No. of Observations	685	432	410	236	110	415	132	331	742	261	324	230

^a T-values in Parentheses

maximum. The sign of R&D intensity varies between the three low-tech industries. Now, if we look at the estimates in the β -vector we observe for the apparel industry that the effect of the minimum efficient scale is positive and insignificant, whereas the effect of start-up size is found to be negative but insignificant. This suggests a moderate shape effect for both variables. Similar behavior is also observed for the two remaining industries.

For the remaining moderate- and high-tech industries we observe a strong negative effect of the minimum efficient scale on new establishments in the abrasive/asbestos/minerals and measuring/analyzing instruments industries. This suggests a longer adolescence and shift to the right. In almost all industries (except abrasive/asbestos/minerals) a moderate negative effect of the start-up size variable is found indicating a shift to the right. The coefficient of the industry growth variable tends to change its sign across all the industries. R&D intensity exerts a much stronger negative effect on the fabricated metals and electrical/households/wiring/audio industries. Now, if we look at the shape effect of the variables we observe a much stronger positive effect of industry growth and R&D/sales in the clay/pottery/concrete industry. In contrast, a significant negative shape effect of the minimum efficient scale variable is found in the measuring/analyzing/instruments industry.

VI. Conclusions

Based on a visual inspection of transformed survivor plots we found that the log-logistic model among other models fit the data significantly. Using the longitudinal data base of newly founded businesses, we found that the hazard rate follows an inverted U-shaped pattern. The estimated log-logistic rate showed consistency with the theoretical assumptions of the liability of adolescence argument. Rates reached a maximum for all low-, moderate-, and high-tech industries. As the adolescence ends, afterwards, they showed a monotonic decline. We found a difference in the length of adolescence across two and three digit industries, which was found to be longer for new establishments in three-digit industries. Brüderl (1991) found that adolescence lasts not much longer than one year. In order to test the resources arguments of liability of adolescence we estimated the influence of market structure variables, i.e., scale economies, initial start-up size, industry growth and technology, on the new plant hazard rate. Further, we examined whether the influence of these variables differ within the low-, moderate- and high-tech industries as well as across two and three-digit industries. The finding of this paper suggests that the hazard rate tends to be reduced in three-digit moderate- and high-tech

industries in the presence of scale economies. In all other remaining two-digit industries the risk exposure remains elevated. This suggests that desegregation matters for a number of three-digit industries.

The influence of the start-up size tends to be similar between all two and three-digit low-, moderate- and high-tech industries indicating a strong support of the hypothesis. This suggests that better resource endowments should protect new firms from failure, so that the hazard rate should be lower for new firms with more resources. Further, its role is found to be less significant for quite a large number of three-digit moderate-tech industries. The influence of market growth on the hazard rate is found to be not much different between the two and three-digit low-, moderate-, and high-tech industries. Finally, the effect of the R&D/Sales ratio on the hazard rate confronting new establishments is found to be alternating within the two and three-digit low-, moderate- and high-tech industries. In this paper we did not separate branches and subsidiaries opened by existing firms from independent firms, but the effect of the ownership structure in determining the risk confronting any given plant plays an important role.

Notes:

¹ For the arguments, as to why some studies found monotonically declining rates, whereas others found inverted U-shaped rates. see Brüderl (1992a).

² For a description and application of other theories relevant to start-up research, such as human capital, social network and transaction cost theories, see Williamson (1975,1981), Granovetter, M. S. (1983), Aldrich, H. E. et al.(1987), and Aldrich and Wiedenmayer (1990).

³ For other parametric distributions, such as the Weibull, Log-Normal and Sichel, see Blossfeld and Rohwer (1995). For a three parametric generalization of the Log-Logistic Model, see Brüderl (1991).

⁴ This measure should show the importance of technology in the industry. Acs and Audretsch (1990) studied 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 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.

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