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Firm Survival in the German Automobile Industry

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Abstract

In this paper methods of duration analysis are applied to investigate determinants of firm survival in the German automobile industry during 1886-1939. Therefore a new comprehensive data set has been assembled in order to reach a data basis comparable to data sets for the US automobile industry. Our results show that the forces that shape the survival pattern of firms over the life cycle are quite similar in both countries, i.e. early entry in the life cycle and prior experience are associated with lower risk of exit. This result holds equally when parametric, semiparametric and nonparametric methods are applied.

JEL classification: L10, L62, O33, C41

keywords: firm survival, experience, automobile industry, hazard rates

1. Introduction

The concept of the industry life cycle is concerned with the analysis of regular patterns in the evolution of an industry. One central indicator used in the life-cycle literature to describe this evolution is the number of firms that produce a certain product (Gort and Klepper (1982)). Based on the development of the number of firms different stages of an industry life cycle can be distinguished: a birth stage with an increasing number of firms which is frequently followed by a shakeout that is defined as a rapid decline in the number of firms. Finally, a mature stage in which the number of firms at market stabilizes can be identified.

What are the forces that shape such a characteristic development of the number of firms? For answering this question we have to consider determinants of the market entry of firms and the possible causes of exit which together determine their duration at the market. Hence, an improved understanding of the industry life-cycle can be gained in the first instance by focusing on the investigation of the factors that influence the duration of survival of the firms at the market. A mathematically equivalent representation of the duration of survival is the probability of exit faced by firms that survive up to a particular point in time. This is the technical definition of the so-called hazard rate which is in a certain sense the work-horse of empirical life-cycle analysis. It allows us to focus on the question why some firms have to exit while others survive without having to dwell on the determinants of entry, although these are interesting in their own right.

There already exists quite a number of empirical studies that use statistical methods of survival analysis to investigate aspects of industry life cycle models. These studies attempt to determine the effects that technological or economic variables exert on the hazard rates of the firms. They find that the sophistication of the technological environment in which the firms operate affects the hazard of exit, although the studies differ even in the sign of this effect. Whereas the level of technological activity lowers the hazard rate in Agarwal (1996) and Agarwal and Gort (1996, 2002), the R&D intensity and the innovation rate used in Audretsch and Mahmood (1994, 1995) tend to raise the hazard rate.

Variables related to the economic environment are investigated by Audretsch and Mahmood (1994, 1995) and by Mata and Portugal (1994), among others. They find that the minimum efficient scale and the intensity of competition generally increase the hazard rate, but the growth of the market tends to reduce the risk of exit. Among the specific firm characteristics which are related to the hazard rate in various studies are the capital intensity, ownership status and the initial endowments of the firms. Quite robust across the studies is the negative effect of start-up size on the hazard rate. Audretsch and Mahmood (1995) also consider the effects of macroeconomic variables in the context of their hazard regressions.

If it is not just the aim to investigate the survival of firms at an arbitrary stage of the life-cycle of an industry but to track the survival of firms from the birth stage of the life-cycle onwards the information about firm and environment characteristics becomes much more scarce. In his investigation of four industries over the whole life-cycle Klepper (2002a) is restricted to data about the year of entry, the year of exit (which may be right-censored) and information about the heritage of the founders including the type of experience at his/her disposition.

In this paper we take up this line of research and focus on the experience (comprising technological knowledge and market know-how) of a firm and its influence on the duration of survival of firms in the market. Related to the study of Klepper (2002a) we analyse the influence of the experience that firms already have at the time of entry (pre-entry experience) and the experience they accumulate during their operation in the market (post-entry experience) on their risk of exit. By this we presume that firms which are endowed with more experience in the form of technological know-how, managerial capabilities, access to capital markets, customer relations, new marketing techniques and distribution networks (see Agarwal, Sakar and Echambadi (2002) as well as Helfat and Lieberman (2002)) tend to have a higher probabilities of survival and therefore lower hazard rates. Our investigation is based on data for the German automobile industry from 1886 to 1939. We find that (i) the earlier the date of entry the lower the hazard rate, (ii) experienced entry gives an additional advantage and (iii) thereby our results confirm the findings for the US automobile industry reported in Klepper (2002a).

We proceed as follows. In section 2 the general patterns of firm survival that can be observed for the German automobile industry are presented. Sections 3 and 4 contain the econometric survival analyses performed with the Gompertz model and the Cox regression. Section 5 summarizes the central findings and outlines directions for further research.

2. General Patterns

To investigate the determinants of the hazard of exit we have compiled a unique comprehensive dataset of the German automobile industry. This dataset has been assembled using a multitude of historical sources and covers the period starting in 1886 and ending in 1939 because thereafter major structural breaks changed the economic system in Germany. For further details of the data of the German automobile industry and the construction of the variables we refer to the appendix.

The data allow us to analyze the effects that pre-entry and post-entry experience of firms have on their probability of survival. Pre-entry experience is quantified by a dummy variable that is equal to unity in the case of firms that have former experience in the production of automobiles or other products at the time of entry and therefore are classified as experienced firms, all other firms are treated as unexperienced (see also the appendix for details). We assume that post-entry experience is associated with the date of entry which we operationalize by the division of the firms into entry cohorts, as well as by the duration of survival.

We first turn to the influence of pre-entry experience. Figure 1 shows the survivor curves of firms with and without pre-entry experience on a log scale, respectively. The survivor curves are estimated by the nonparametric Kaplan-Meier estimator (Kaplan and Meier (1958)) which accounts for censoring. The absolute value of the slope of the survivor curves represents the hazard rate. It is evident that experienced entrants have a lower probability of exit than unexperienced ones.

The validity of these differences of the survivor curves can be substantiated by a statistical test. We use the family of tests proposed by Harrington and Fleming (1982) which are designed to test the null hypothesis that two survivor curves that have been estimated by the Kaplan-Meier estimator are equal to each other. The particular version we apply is the log-rank test which is more sensitive to later differences between survivor curves. For the curves in figure 1 the test outcome shows that the differences between the curves are not only visually apparent but also statistically significant by all means. Thus, experience at the time of entry is an important factor that lowers the risk of exit at any time.

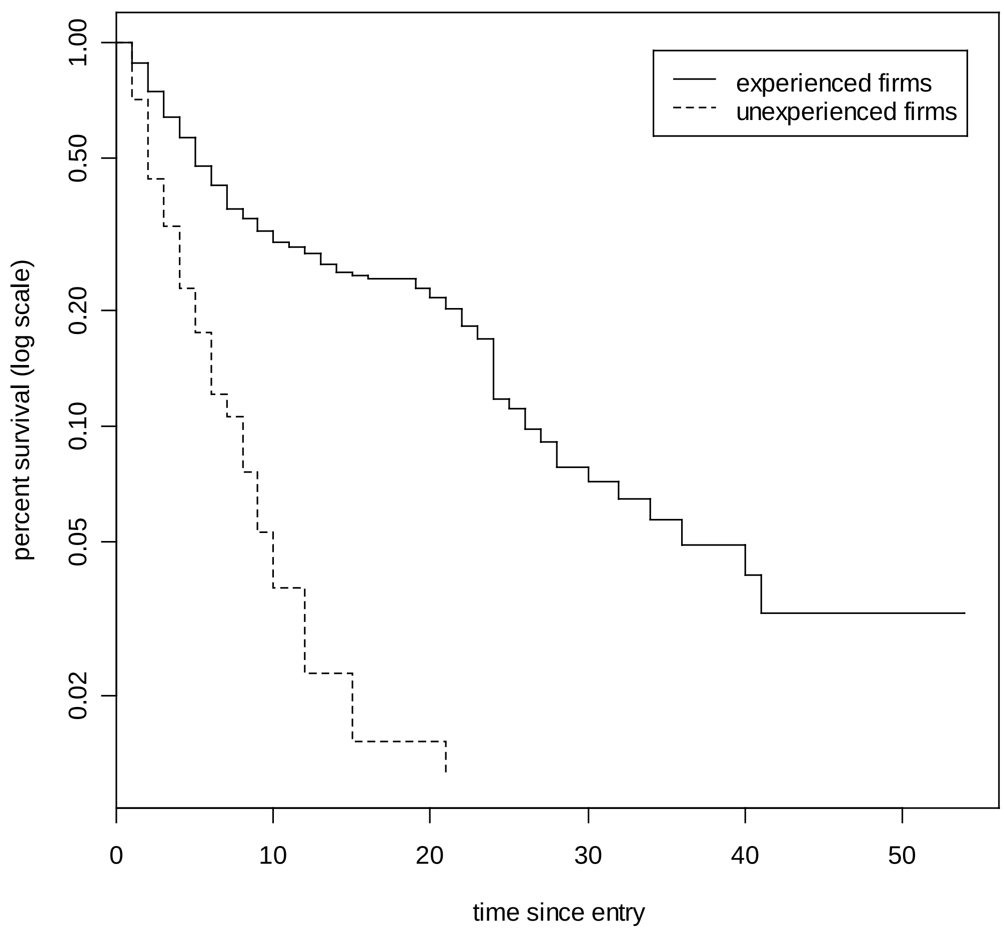

Figure 1: Kaplan-Meier Estimates (pre-entry experience)

In a second step we explore the issue of post-entry experience. Specifically, we examine whether early entry is accompanied with a lower probability of exit compared to later entry. For that figure 2 shows the respective survivor curves. It is notable, that the survivor curve of the first entry cohort is less steep compared to the survivor curves of the other cohorts. This means that the firms that entered early are faced with a lower probability of exit especially at later ages. In contrast to that, the exit hazard of the firms that entered later is higher as can be inferred from their steeper survivor curves.

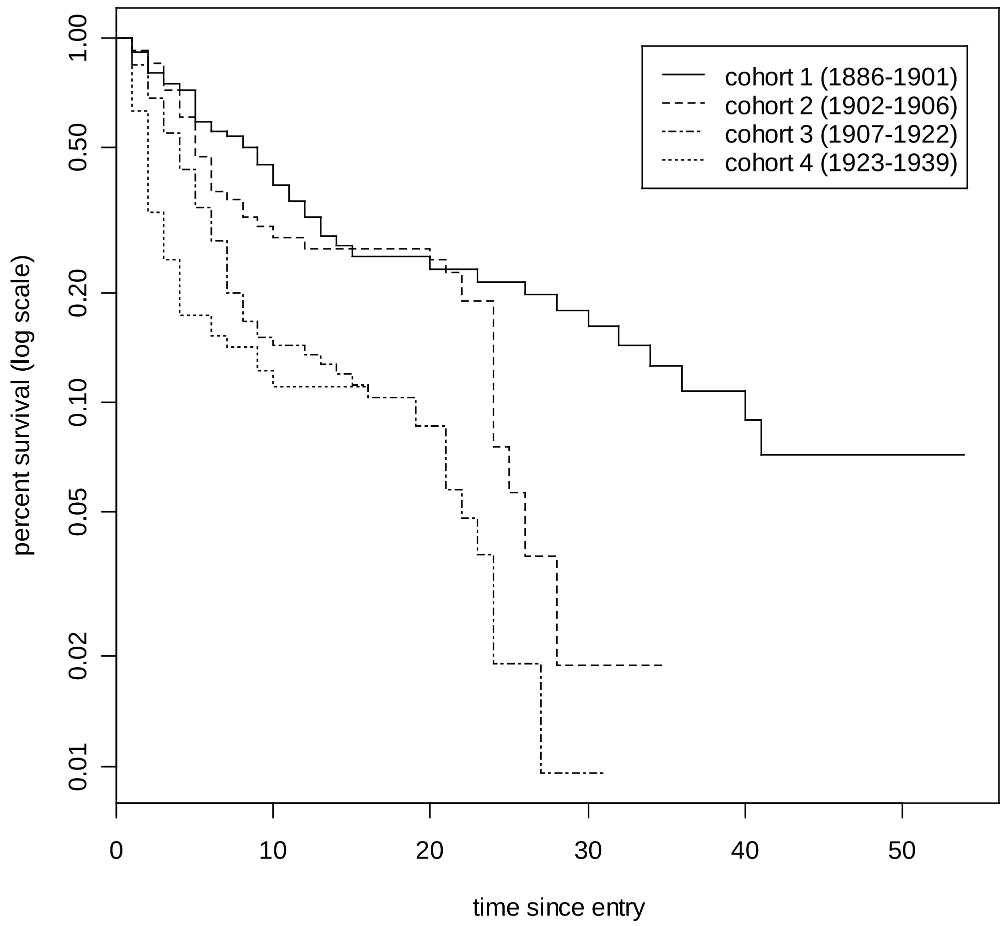

Figure 2: Kaplan-Meier Estimates (post-entry experience)

When we subject these survivor curves to the Harrington-Fleming test we find a p-value equal to 0.0683 in the case of testing the null hypothesis that the survivor curves of the first and the second entry cohorts are equal. The p-values for the null hypotheses that the survivor curve of the first equals that of the third entry cohort and that the survivor curve of the first equals that of the forth entry cohort are both essentially zero.

In sum, we find significant differences of the survivor curves not only with respect to pre-entry experience but also with respect to post-entry performance. These findings are similar to the results of Klepper (2002a) for the US automobile industry. In order to sharpen our comparison to Klepper in a more quantitative fashion we now turn to econometric duration analyses of the German data in the next two sections. We start with the fully parametric estimation of the Gompertz model and then proceed to the semiparametric Cox regression.[1]

3. The Gompertz Model

Klepper (2002a) estimates hazard rate models based on the Gompertz distribution for the length of time t_i a particular firm i stays in the market. The Gompertz distribution is associated with the following functional form of the hazard rate:

$$h(t_i) = \exp(\beta_0 + \boldsymbol{\beta}'\mathbf{x}_i) \cdot \exp((\gamma_0 + \boldsymbol{\gamma}'\mathbf{z}_i) \cdot t_i) \text{ , } i = 1,...,n .$$

Therein $h(t_i)$ represents the hazard rate of firm i to exit the market t_i periods after entry. The vector $\mathbf{x}_i$ contains the explanatory variables for the ith observation that effect the hazard rate $h(t_i)$ of the ith observation at birth and the vector $\mathbf{z}_i$ contains the respective explanatory variables that account for differential effects of the knowledge accumulated while staying in the market. Thus, the coefficients in the $\boldsymbol{\beta}$ vector indicate the effect of the explanatory variables when $t_i = 0$. In addition, the coefficients in the $\boldsymbol{\gamma}$ vector allow us to make statements about the hypothesis that the explanatory variables have differential effects with increasing duration $t_i > 0$. This influence can alternatively be interpreted as an effect on the rate of change of the hazard rate, since $d \ln h(t) / dt = \gamma_0 + \boldsymbol{\gamma}'\mathbf{z}_i$. The coefficients β_0 and γ_0 represent the respective intercepts.

The main advantage of the Gompertz specification in this application is that the functional form of the hazard rate is more flexible compared to the hazards rates of other duration distributions like the Weibull or the lognormal distribution. It allows to assess the influence of explanatory variables on both parameters of the distribution, which is important for the comparison of the influence that firm characteristics exert on the hazard at birth and at maturity. As we will explain in the next section this is not possible with the Cox regression that is frequently used in the literature (see e.g. Audretsch and Mahmood (1994, 1995)).

[1] See Helsen and Schmittlein (1993), Kiefer (1988) and Wooldridge (2002, ch. 20) for surveys of statistical methods of duration analysis.

The set of explanatory variables we consider consists of dummy variables for the entry cohorts (E_1, E_2, E_3, E_4) and a dummy variable to indicate the presence of experience at birth, *P*. Like Klepper (2002a) we estimate four models via maximum likelihood using the program TDA (Transition Data Analysis; see Rohwer and Pötter (2002)). The results are reported in table 1.

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	-1.6702 (0.0000)	-1.2188 (0.0000)	-0.6812 (0.0000)	-0.8040 (0.0000)
E_1		-1.1647 (0.0000)	-1.1810 (0.0000)	-1.3700 (0.0118)
E_2		-0.8796 (0.0000)	-0.8670 (0.0000)	-1.1270 (0.0137)
E_3		-0.4690 (0.0005)	-0.6198 (0.0000)	-0.6379 (0.0148)
P			-0.9307 (0.0000)	
$E_1 \cdot P$				-0.5344 (0.3439)
$E_2 \cdot P$				-0.8852 (0.0813)
$E_3 \cdot P$				-0.7086 (0.0064)
$E_4 \cdot P$				-0.3855 (0.1708)
Intercept	-0.0442 (0.0000)	-0.0236 (0.0066)	-0.0029 (0.7417)	0.1119 (0.1350)
$E_1 \cdot t$				-0.0246 (0.8144)
$E_2 \cdot t$				0.0151 (0.8872)
$E_3 \cdot t$				-0.1020 (0.2022)
$E_1 \cdot P \cdot t$				-0.0993 (0.1854)
$E_2 \cdot P \cdot t$				-0.1028 (0.1923)
$E_3 \cdot P \cdot t$				-0.0103 (0.7640)
$E_4 \cdot P \cdot t$				-0.2557 (0.0049)
Log L	-963.0331	-938.2154	-880.4236	-870.6283
n	351	351	335	335

Note: p-values in parentheses below the coefficients

Table 1: Estimates for the Gompertz Model

In model 1 we neglect all explanatory variables except the intercepts. The estimate of γ_0 is significantly negative which means that the hazard of exit declines with the age of the firm and may be interpreted as capturing a learning effect that originates from the post-entry accumulation of experience.

In model 2 we include dummy variables for the first three entry cohorts. Consequently the average effect of being a member of the fourth entry cohort shows up in the intercept β_0. Thus the coefficients pertaining to the cohort dummies E_1 to E_3 capture the additional reduction of the hazard rate beyond that of the fourth cohort. The estimates of this model imply that the exit hazard is largest for the last entry cohort and lowest for the first entry cohort with the other cohorts in between. These differences between the entry cohorts are not only significant in the statistical sense, but also economically important. With respect to the last cohort the hazard rate is 69% lower in the first cohort, 59% in the second cohort and 37% in the third cohort. The respective figures computed by Klepper (2002a, p.50) for the US automobile industry are 38%, 32% and 7%. This means that the differences in the hazard rates are larger for German data caused by higher risk in the last cohort for the German firms. Despite these differences the estimate of γ_0, and thus the effect of post-entry experience, is quite similar to the US case. Remarkably, once the dummy variables for the entry cohorts are included this coefficient is driven towards zero but still remains statistically significant. This supports our interpretation of the entry cohort dummy variables as capturing the advantage (disadvantage) of accumulating post-entry experience earlier (later). In addition, the advantage of being a member of an earlier entry cohort seems to be higher that the advantage of a longer survival and thus more experienced within a given entry cohort.

Interpreting the estimation results of model 2 in terms of the knowledge advantage firms acquire because of being an earlier entrant implicitly invokes the assumption that all firms have the same experience at birth. However, our data set allows us to differentiate between two different types of entry. We can distinguish completely unexperienced firms from firms that possess pre-entry experience in various forms. In the regression for model 3 we represent that type of knowledge by the dummy variable *P* which is equal to unity for experienced firms and zero otherwise.

The coefficient estimate for the experience dummy is significantly negative which implies that experience at birth reduces the hazard rate at birth by 61% beyond the effects of the entry cohorts E_1 to E_3. This is again much larger than Klepper's estimate of 28% for the US automobile industry. The coefficients pertaining to the intercept and the third entry cohort differ somewhat from the estimates of the second model but the general pattern of the results is not affected. This holds despite the fact that 16 observations drop out of the sample because of lacking information about their experience. Interestingly, once the experience dummy is included the estimate of γ_0 becomes close to zero and insignificant, implying that part of the post-entry experience effect that is evident in the first and second model disappears.

Model 4 extents the specification in two ways. First, the experience dummy is now interacted with the dummy variables for the entry cohorts. Second, all variables are now also included in the second factor of the hazard rate (i.e. in the vector $\mathbf{z}_i$). Regarding the first extension the estimates imply a lower hazard rate for the second and the third entry cohort, at least on a 10% level of significance. Again we observe a declining pattern of coefficient estimates (in absolut values) for the cohorts two to four. This shows that later entry cohorts benefit less from pre-entry experience in terms of the reduction of the hazard rate. With respect to the second extension we find all coefficient estimates besides one exception to be insignificant. The exception being the coefficient for experienced firms in the last cohort interacted with age. This finding is in contrast to Klepper where several coefficients show up significant. Consequently, assuming that the variables in the vector $\mathbf{z}_i$ represent effects of post-entry experience, whether the firm posseses pre-entry knowledge or if it entered early in the market does not exert further influence on the hazard rate in later years. This kind of knowledge seems not to be essential in the German case, whereas it shows up statistically significant in the US case.

4. Cox Regression

The Gompertz model estimated in the previous section is essentially a proportional hazard model in which the baseline hazard rate has been specified depending on regressor variables $\mathbf{z}_i$ in addition to the regressors $\mathbf{x}_i$. Since the former set of regressors shows up predominantly insignificant in model 4 it appears to be the case that the specification of the baseline hazard rate is of minor importance. Thus, we check our results using the Cox (1972) regression which specifies the hazard rate as

$$h(t_i) = \exp(\beta_0 + \boldsymbol{\beta}'\mathbf{x}_i) \cdot h_0(t_i) \text{ , } i = 1,...,n$$

and thereby allows to estimate hazard models without requiring to estimate the baseline hazard rate $h_0(t_i)$ which gives the procedure a semiparametric flavor. The results obtained by maximizing the partial loglikelihood function for the models 2 to 4 are reported in table 2. In this partial likelihood function the terms associated with the intercept cancel out and thus it is not possible to identify the parameter β_0 with the consequence that model 1 could not be estimated at all.

Variable	Model 2	Model 3	Model 4
Intercept			
E_1	-1.4901 (0.0000)	-1.5247 (0.0000)	-1.4073 (0.0000)
E_2	-1.0903 (0.0000)	-1.1228 (0.0000)	-1.1451 (0.0000)
E_3	-0.6507 (0.0000)	-0.8374 (0.0000)	-1.0411 (0.0000)
P		-0.9522 (0.0000)	
$E_1 \cdot P$			-1.2342 (0.0001)
$E_2 \cdot P$			-1.0537 (0.0000)
$E_3 \cdot P$			-0.7186 (0.0000)
$E_4 \cdot P$			-1.1091 (0.0000)
R^2	0.2060	0.3340	0.3400
Log L	-1669.4155	-1548.5047	-1546.9659
n	351	335	335

Note: p-values in parentheses below the coefficients

Table 2: Estimates for the Cox Regression

Regarding the coefficient estimates of the cohort dummies we observe no qualitative differences to the Gompertz model. Again the coefficients show a rising pattern with the time of entry implying a lower risk of exit for earlier entrants. Throughout the coefficient estimates and the p-values are smaller than those obtained with the Gompertz model. Once we account for differences in the pre-entry experience of the entrants by the inclusion of the variable *P* the fit of the model (measured by R^2) increases considerably from about 0.21 to 0.33. The respective coefficient estimate for *P* in model 3 is close to the one obtained with the Gompertz model. Major differences can be observed in the case of model 4. In contrast to the Gompertz model the coefficients for the experienced entrants in all cohorts are now significant. The relative magnitudes of the coefficients give rise to the conjecture of a U-shaped pattern. This implies that the additional hazard reduction originating from pre-entry experience is largest in the first and the last cohorts. This pattern appears to be reverse to the one found in the case of the Gompertz model, although the coefficients are not statistically significant there.

Overall, the results of the Cox regressions confirm the conclusions we have obtained from the Gompertz model above, at least as far the semiparametric nature of the Cox approach permits. Therefore we can be quite assured of the robustness of our estimates. Regarding the statistical significance the results are even sharper.

5. Conclusion

To summarize, our contribution is twofold. First, our results show that the forces that shape the industry life cycle work quite similar in different countries. So the main findings of Klepper (2002a) for the US automobile industry that firms that entry early in the life cycle and firms whose founders possess some form of experience prior to their entry hold as well in case of the German automobile industry. This implies that knowledge, either already present at the time of entry or accumulated during the engagement in production and market activities, is a factor that reduces the exit hazard statistically significant and economically important. Related similarities between the US and the UK televisions and tires industries have been reported by Simons (2001). Although life cycle phenomena such as survival patterns are not universal across all products or industries as recognized by Klepper (1997, p.174) they seem to be more similar across countries in the case of products or industries to which the life cycle pattern of evolution has been found to apply.

Second, the results from the Cox regressions strengthen our confidence in the robustness of these findings. This semiparametric approach allows us to investigate determinants of the hazard rate without having to be concrete about the specification of the duration dependent part. Quite surprisingly, our variables for the time of entry and experience are able to explain more than 30 percent of the variation of the hazard rates.

Admittedly, these variables are reasonably crude representations of the underlying phenomena and the estimated coefficients by that may pick up influences from other economic and technological determinants. Our further research efforts will therefore concentrate on the more detailed exploration of such determinants. In a first step we will consider the patenting activity of the firms in our sample to gain a deeper understanding of the role of innovations in the industry life cycle.

Appendix: Data Description

The data are collected from a lot of different origins, i.e. yearbooks, historical and statistical journals and books about veteran cars. The most important are listed below:

Doyle, Gerorg R., Georgano, Georg N. (1963), The World's Automobiles 1862-1962, London.

Flik, Reiner (2001), Von Ford lernen?, Automobilbau und Motorisierung in Deutschland bis 1933, Cologne.

Köhler, Volkmar (1966), Deutsche Personenwagenfabrikate zwischen 1886 und 1965, in: Sonderdruck aus Tradition, Zeitschrift für Firmengeschichte und Unternehmensbiographie 3/1966, pp. 127 - 151, Munich.

Kubisch, Ulrich (1983), Deutsche Automarken von A-Z, Mainz.

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Schrader, Halwart (2002), Deutsche Autos 1885-1920, vol. 1, Stuttgart.

von Fersen, Hans Heinrich (1967), Autos in Deutschland 1920 - 1939, eine Typengeschichte, 2nd ed., Stuttgart.

von Fersen, Hans Heinrich (1968), Autos in Deutschland 1885 - 1920, eine Typengeschichte, 2nd ed., Stuttgart.

von Seherr-Thoss, Hans Christoph Graf (1979), Die deutsche Automobilindustrie, eine Dokumentation von 1886 bis heute, 2nd ed., Stuttgart.

The history of the German automobile industry started in 1886 with the inventions of Gottlieb Daimler and Karl Benz, who worked independent from each other. We identified 443 firms, that produced automobiles at some time between 1886 and 1939. The data we gathered pertain to the year of entry, the year of exit, the location(s) and the type of entry. Complete observations exists for 351 firms for which the analyses in this paper are performed.

The classification of the entry cohorts is based on Klepper (2002a). He defined the cohorts so that there are at least 15 firms in every cohort, which survived to age 15. This procedure resulted in four entry cohorts, the first from 1886 to 1901 with 56 firms, the second from 1902 to 1906 with 53 firms, the third from 1907 to 1922 with 126 firms and the fourth from 1923 to 1939 with 116 firms. In the fourth cohort there are just 11 firms that survived for at least 15 years.

The classification of the type of entry is implemented according to Klepper (2002b). He distinguished experienced firms (firms that diversify into the production of automobiles originating from other industries), experienced entrepreneurs (de novo firms whose founder headed and typically owned a part of another firm before), spinoffs (de novo firms whose founder worked in the automobile industry before) and unexperienced firms. Firms, that produced automobiles more than once, are treated as different firms. When they entered the market a second time, they are classified as spinoffs.

As in Köhler (1966), those firms, that exit the market as a cause of world war one, get assigned 1915 as the year of exit. All firms that survive past 1939 are treated as censored observations in the statistical analyses of this paper.

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