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Product Quality Selection and Firm Survival

Evidence from the British Automobile Industry, 1895-1970

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This paper proposes an additional determinant of firm survival. Based on a detailed examination of firm survival in the British automobile industry between 1895 and 1970, we conclude that firm's selection of submarket (defined by quality level) influenced survival. In contrast to findings for the US automobile industry, there is no evidence of first-mover advantage in the market as a whole. However, we do find evidence of first-mover advantage after conditioning on submarket choice.

Keywords: *Firm survival, product differentiation, product quality, submarkets.*

JEL Classification: L11

I: Introduction

The theory of the "industry life cycle" is concerned with the analysis of recurrent patterns in the evolution of an industry. Previous studies on the life cycle theory have focused attention on the number of firms present in any particular industry producing a certain product (Gort and Klepper, 1982). The literature puts forth a very general pattern regarding the development of the number of firms in an industry over time. This pattern can be divided into the following general stages: (1) the birth stage, characterized by an increasing number of entrants; (2) the "shake-out" stage, which sees a severe and rapid decline in the number of firms; and (3) the maturation stage. It is in this final stage that a certain number of firms will survive—some industries evolve into oligopolies and others remain atomistic.

The aspiration of profit-seeking is the underlying cause to both the potential entrants thinking about entering a market and for those existing firms who decide to exit a market. One aspect of the theory which we need to investigate further is the influences which affect the duration of survival time of those firms in any particular market. In a formal representation, the duration of survival for a firm is the probability that a currently existing and participating market player will exit its market. This probability of firm exit is what we term the "hazard rate."

Numerous empirical studies have employed sophisticated statistical methods of survival analysis in order to investigate differing characteristics of the industry life cycle model. These studies have attempted to pinpoint, or at least to vaguely identify, the various factors affecting a firm's—or an industry's—hazard rate. They find that the level of technological activity, the degree of R&D intensity, the innovation rate, ownership

status, geographic location, initial endowments of the firms, *et cetera*, all have statistically significant effects in regressions on the hazard rate.

Klepper (2001,2002a,2002b) has developed a series of papers on market evolution. By investigating the U.S. automobile industry, he studies how both the background of firms and the timing of their entry affect their performance. This, in turn, affects not only the evolution of the industry's market structure, but also its geographic distribution of activity. Similarly, Boschma and Wenting (2004) performed Klepper-style tests using Great Britain automobile data. Their results are quite similar to Klepper's conclusions. However, a second look at the Great Britain automobile industry structure shows us an interesting fact. After the shake-out of the industry, Great Britain continued to have a high number (about 35) of car manufacturers in the market. This is very different from the result in the U.S., Germany, and France [Hannan et al., (1995); Klepper, (2002a)]. In Boschma and Wenting (2004), this seemingly contrary outcome is explained as the result of small producers filling market niches with the production of high-priced, high-quality cars. This leaves us with an unanswered question: does the choice of product quality matter in determining a firm's survival time—especially for small players?

The purpose of this paper is to investigate that question more deeply. Specifically, what is the relationship between a firm's product quality choice (high-quality versus low-quality) and its probability of being forced to exit an industry? To make the analysis simple, we call firms that produce high-quality goods as "firms in the high-end." The opposite are those "firms in the low-end." The intuition I want to develop is that profits are more sensitive to cost shocks for firms in the low-end. Therefore, when facing the same level cost shock, firms in the high-end are more likely to survive.

This paper presents the results of a particularly simple test of this idea. It uses a newly constructed dataset incorporating product quality of the British automobile industry. The dataset covers the period 1895-1970. These product quality data are combined with the entrants' background and the time of each firm's entry into the market. This will help predict the propensity to exit—the hazard rate. Our main result will show that product quality does affect the hazard rate of exiting firms.

The layout of the paper is as follows. The history of the industry is reviewed in Section 2. The economic model demonstrating the relationship between product quality and profit is presented in Section 3. A detailed description of the data and the criteria used to determine product quality is in Section 4. The formal econometric analysis used to test the predictions is found in Section 5. Finally, implications of my findings are discussed in Section 6, which also includes concluding remarks.

II: History of the British Automobile Industry

We compile a comprehensive dataset of the Great Britain automobile industry. It incorporates a multitude of historical sources and covers the period 1895-1970. After the year 1970, the market has been fairly stable and there is little entry/exit in the market.

Figure 1: The number of Automobile Manufactures, Entrants and Exits in Great Britain, 1895-1970
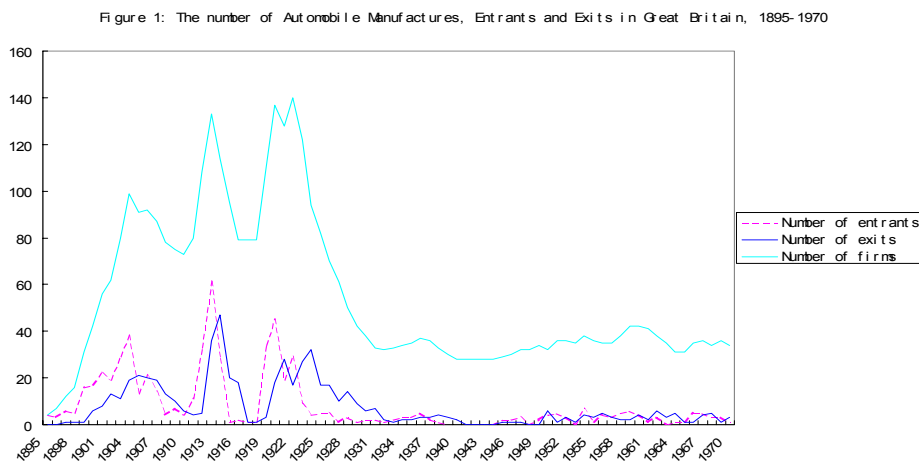
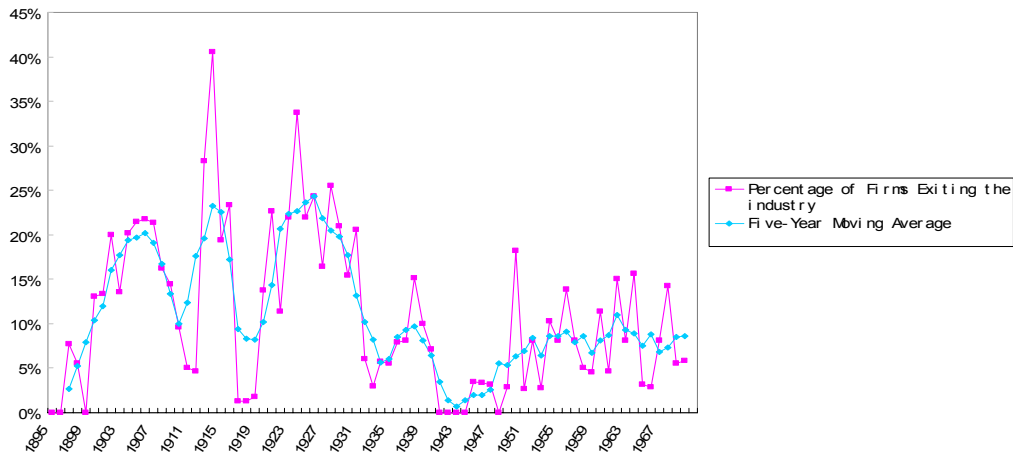Figure 2: Percentage of Firms Exiting the market and the 5-Year moving average

Figure 1 depicts the number of automobile firms (including the number of entrants and exits) in Great Britain during the relevant period. Figure 2 plots the percentage of firms exiting the industry on an annual and five-year moving average basis. The density pattern of Britain falls between the French and German. Its industry started relatively late, but the number of new entrants grew steadily beginning in 1895. The industry seems to reach the first peak around the year 1907. We see from Figure 1 that the automobile industry experienced three significant fluctuations during the relevant window, but overall the number of firms remained very high until after the early 1920s [Hannan, et al., (1995)]. After the shake-out phase (circa 1930), the industry more or less stabilized. Noticeably, the number of entrants into the market reaches its peak during the same period as that of the number of firms exiting the market. Note also that the number of exiting firms reaches its peak behind those of the number of firms and the number of entrants. However, the year that the highest percentage of firms exited the industry did not occur around 1930, but rather around 1913—the second peak of the industry. The shake-out phase appears after the three moderate peaks of the exits. There are very few occurrences of entry and exit during World War II. Even after WWII, the low number of

entry and exit keeps the number of firms around 40. At the end of the period, the number of automobile firms in Great Britain has fallen to 34.

For analysis purposes, we group the firms into four cohorts. Instead of adopting Klepper's (2002a) classification of entry cohort, we follow the industry phase made by Foreman-Peck, Bowden, and McKinlay (1995). The first phase of the industry runs from 1895-1914; the second phase from 1914-1939; third phase from 1939-1945; and the last phase from 1945-1970. Each phase has a defining characteristic. The second phase sees a rapid advance of the motor industry and the emergence of the basic market structure. The automobile industry is stabilized in the third phase by war contracts. The industry served a crucial and central role in supplying the armed forces. The fourth phase occurs with the after-war boom, but without significant changes in the established market structure. Notice that phases are separated by both World Wars. We see that there are no entrances during Cohort 3. This can easily be ascribed the breakout of World War II.

As we examine the industry structure cohort by cohort, we immediately notice that in the first stage of development the density of firms rises steeply. The number of firms reaches its apex until 1907, at which time a general liquidity crisis causes a "slump" that affects all British industries. Afterward, however, the number of firms continues to grow. That is, up until 1914 when the outbreak of the First World War halts the development of the whole industry. The most striking growth occurred during the closing years of the nineteenth century and the first years of the twentieth century. For instance, Great Britain had only 17 firms in 1898; however, five years later, that number had increased to 79 firms. The number of entrants into the industry shows the same pattern.

In the second stage of the industry, "the car became standardized, new location patterns of production emerged, and economies of scale began to dominate product characteristics" [Foreman-Peck, Bowden, and McKinlay, (1995)]. During this period, we readily notice the postwar boom combined with a significant shake-out process around 1922. The result was a steep decline in the number of automobile manufactures. This critical period saw the emergence of a new market structure for the automobile industry. The competitive landscape changed from one characterized by a large number of small, extremely competitive firms with high mortality rates to an oligopoly setting. The industry was dominated by three British companies: Morris Motors, Austin, and Singer. These three giants accounted for approximately 75 percent of total automobile production in Britain during this time [Maxcy, (1958)]. Furthermore, the number of car manufactures in Great Britain is more or less stable in this cohort. For instance, in 1922 the number of car manufactures in the British industry was 138. Five years later, only 58 remained in the market. Compare this figure with France, Germany, and the United States, and one will see that this number of manufacturers remained rather high (29 manufacturers were still present in 1939) [Hannan, et al., (1995); Klepper, (2002a)]. We have already attributed this outcome to the high number of surviving small producers of high-priced, high-quality cars that were filling market niches [Brschma and Wenting, 2004]. We find similar comments about the high-quality producers of British automobiles in *The Beaulieu Encyclopedia of the Automobile*,

> …the Frazer Nash [model] (1924-1957) was a peculiarly British phenomenon—an unconventional and in some ways old-fashioned car made in tiny quantities which capture the imagination of sports car enthusiasts all over the world.

As we begin to examine the characteristics of the third period, demand from the armed forces plays perhaps the most important role in shaping the industry. On examination of the number of firms, the number of entrants, and the number of exits, we immediately notice that there is almost no entry or exit at all during the war period. Instead, the motor industry becomes almost entirely devoted to war production. The advantage to this comes from war contracts planting the seeds of improvement for the British automobile industry after the war. This is due to the focus on demand for tanks and military vehicles which sets off a race for improvements and innovations in the industry.

The domestic and international economic environment of the motor industry drives a moderately active period of firm entry and exit during the last stage compared to the previous period of war. The market structure remains relatively similar as the industry grows out of the third stage. Specifically, it is characterized by a few leading companies dominating the industry alongside a number of small players.

III: The Model

A simple economic model will help us to demonstrate the story. We first specify the form it takes, and then we discuss the implications for how product quality can affect a firm's hazard rate.

III.A. Specification of the Model

We set up a model containing various simplifications designed to isolate the role of product quality. The model is specified so that in one period a firm is faced with the

decision of either entering or not entering a market. They have only one opportunity to make this decision. Upon deciding to enter the market, the firm decides which submarket they should participate in. Here, we allow for two submarkets only: the high-end submarket and the low-end submarket.

Consumers are free to choose from a whole range of products (automobiles) according to their individual budget constrains. They face two differing quality levels in the products: high and low. We further assume two types of consumers in this market. We have high-end consumers and low-end consumers. The products in the high-end submarket are more differentiated than their counterparts in the low-end submarket. This should be a reasonable assumption since high-end products are able to distinguish themselves through some unique features. This, of course, is not the case in the low-end submarket.

Suppose we have n_q producers in submarket q, $q = h,l$. Let x_{iq} denote consumption of variety i in submarket q. The Dixit-Stiglitz utility function of a representative consumer in each submarket is given by:

$$U = (\sum_{i=1}^{n_q} x_{iq}^{\frac{\sigma_q - 1}{\sigma_q}})^{\frac{\sigma_q}{\sigma_q - 1}}, \tag{1}$$

where σ_q is the elasticity of substitution. An important assumption here is that the elasticity of substitution for low-end goods is greater than for high-end goods (i.e., $\sigma_h < \sigma_l$). The reasoning is that products are more differentiated in the high-end submarket, so that competing products are poorer substitutes. It then follows that consumers in the high-end submarket will be less price-sensitive.

Let the consumer's budget constraint be

$$\sum_{i-1}^{n_q} p_{iq} x_{iq} = 1 \tag{2}$$

Equations (1) and (2) yield the following system of demands:

$$x_{iq} = \frac{p_i^{-\sigma_q}}{\sum\limits_{i=1}^{n_q} p_{jq}^{1-\sigma_q}} \tag{3}$$

Profits are given by

$$\underset{p_{iq}}{Max} \ \pi_{iq} = (p_{iq} - \alpha_{iq})x_{iq} - k_q, \tag{4}$$

where α_{iq} is the marginal cost of firm i in submarket q, and k_q is a fixed cost common to all firms in submarket q. Maximizing (4) subject to (3) yields an optimal price of $p_{iq} = \sigma_q \alpha_{iq} /(\sigma_q - 1)$, and profits of

$$\pi_{iq} = \frac{\alpha_{iq}^{1-\sigma_q}}{\sigma_q \sum\limits_{j=1}^{n_q} \alpha_{jq}^{1-\sigma_q}} - k_q \tag{5}$$

Entry decisions are made before a firm's costs are realized. Hence, entry is made upon the basis of an average cost draw $\overline{\alpha_q}$. Substituting $\overline{\alpha_q}$ into (5) and setting profits to zero yields $n_q = 1/k_q \sigma_q$, and hence equilibrium profits are

$$\pi_{iq} = \frac{\alpha_{iq}^{1-\sigma_q}}{\alpha_q^{1-\sigma_q}} k_q - k_q \tag{6}$$

It is now easy to show that profits are more sensitive to cost shocks when σ_q is large. Differentiating (6) and evaluating at the mean, $\alpha_{iq} = \overline{\alpha}_q$, yields

$$\frac{d^2 \pi_{iq}}{d\alpha_{iq} d\sigma_q} \bigg|_{\alpha_{iq} = \overline{\alpha}_q} = -\frac{k_q}{\alpha_q} < 0 \tag{7}$$

Hence, positive cost shocks induce larger losses for low-end firms than they do for high-end firms. [*]

IV: The Data

IV.A. Description

To test our model, we compile a new dataset of the British automobile industry. The dataset is constructed from *The Beaulieu Encyclopedia of the Automobile*; additional information comes from *The Complete Catalogues of British Cars 1895-1975* and Internet resources. The dataset we use contains company name, major makes, first and last location, production volume (when available), the background of firms, date of entry/exit, circumstances of exit, and a critical index that classifies relevant statistics such as body type, number of cylinders, and horsepower. This helps to separate the data into high-quality and low-quality products. When data specifications contradict each other—for example, location, date of entry or exit, *et cetera*—we take the data from *The Beaulieu Encyclopedia of the Automobile*.

One final clarification that needs to be mentioned is why we choose 1970 as the cut-off point for our data. After the industry shake-out phase occurred, entry and exit activity slowed down significantly. We will see that the average rate for entry/exit hovers around four to five firms per year. Notably, in 1970, there is no entry at all and only two firm exit. It is reasonable to assume that the British automobile industry is

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[*] Of course, favorable cost shocks induce larger gains for low-end firms. We are implicitly assuming that good years in the past cannot offset a bad cost draw today. For example, excess profits in the past may have been distributed to shareholders as dividends. An unfavorable cost shock today may make the firm unable to pay its suppliers, leading to forced bankruptcy.

completely stabilized by this time. In addition, the globalization of the economy makes foreign direct investment (FDI) closely related to the domestic industry during this time. This may affect our analysis of the evolution of the British domestic industry and gives us another reason to end our data sample by 1970. After 1970, it will be too difficult to separate the domestic industry from the international industry.

We identify approximately 800 firms that produced automobiles between 1895 and 1970. Since car manufactures are identified by the models they produce, we must pay close attention to the possible cases where different models may be owned by the same firm, or where models have been acquired by different manufactures. We categorize firms as still in the market if new cars are marketed under the same model name after the ownership change. Similarly, we categorize firms as no longer in the market if new cars cease to be marketed under the old model name after an ownership change. Furthermore, if a firm changes its production so that it no longer produces automobiles, it is considered to be out of the market. Regardless of whether the choice was voluntary or forced, the model will no longer exist in the market (Dougill and Firefly are good examples here).

We carefully select our representative firms from the available dataset which, in total, contains information for 612 firms. We select our representative firms as followers. First, we omit firms and production models that fail to demonstrate any serious market activity (such as Holroyd-Smith and International). The reasons behind low volume or a lack of production in any given model may vary. Sometimes models have a limited run (fewer than ten produced), or appear only in car shows and collector catalogues. As another example, consider the Whiteclock-Aster model. Its production can be ascribed

primarily to owners' interest, and thus no serious production efforts are undertaken. A similar case applies to firms that, like some commercial vehicle manufactures, take automobile production as a tangential component of their overall business enterprise. These firms can conceivably continue their car production even after exiting the automobile market. Since they do not show serious automobile production, we omit them from our data sample (such as Bayley). In all these cases, we cannot adequately determine the market's response from such limited production. We therefore exclude all these situations from our analysis.

Second, since we are ultimately interested in answering how product quality affects the hazard rate faced by firms, we omit any models whose quality classification (high-end or low-end) could not be sufficiently determined from the available resources. The most obvious example in this case is when automobile producers provide a vast range of different quality automobiles under the same model name. This makes it almost impossible to determine the appropriate quality level of the model. This situation arises most commonly for the older, larger market participants (such as Morris). A good example of this case is Daimler, one of the earliest British car builders which still exists today under Jaguar's ownership.

Other cases where we had to omit models based on the ambiguity of their quality levels occurred when there was a total reversal of the quality level during the maker's life span. They switch either from low-end to high-end or high-end to low-end. This usually happens after the reorganization of a firm or after a period of war (for example, Alldays, Humber, Riley, and Speedwell). We also had to omit models when they evolved too much with other makers, such as other models are produced under this model's name, or

vice verse. In this case, we can hardly separate one model from the other models (Wolseley-Siddeley and Siddeley).

Our third criterion is that we focus solely on the domestic (British) brands. We are, after all, concerned with the market evolution of the British automobile industry. Therefore, British branches of primarily foreign producers such as Ford and Toyota will necessarily be excluded from the data sample. Additionally, when the car's country of origin is not known for certain, it is omitted from the sample. Examples of this are imported cars claimed as domestic or vehicles constructed from mostly foreign parts (consider Mayfair). This scenario tends to occur when the auto producer is also an agent or dealer.

Lastly, we exclude models designed for special uses. Illustrative examples include Invacar, a vehicle designed for people with disabilities; Pullcar, a cab designed for commercial use; Eclipse, a second-hand car claimed as new; and Bradbury, a tricar. Similarly, models actually produced by other firms will also be excluded from our dataset.

Notice that we distinguish between "exiting the market" and simply being "not in the market." There are some cases where we consider exiting the market as being *censored* instead of simply the demise of the model. For example, firms can discontinue their production plans because of an outbreak of war, or because of the death of the firm's owner. Recall that our data only covers the period 1895-1970. Because of this truncation, we consider those models as censored that are still in production beyond this end date.

IV.B. Classification

The key concept of this paper is determining how the degree of product quality affects the hazard rate of firms. We therefore need clear criteria by which to locate every individual firm in the corresponding submarket. This is the focus of this section.

Because of advances in technology and changes in demand, each phase may have a distinct definition of what constitutes "high-quality" or "low-quality" in the market. We adopt the following guidelines for classifying a model in the high-end category. Most importantly, a model will be considered high-end if it has above-average quality. This can be identified through traits such as a sound reputation, a novel design that attracts consumers' eyeballs, sporty features, or a big engine that satisfies the need for speed. In Cohort 1, for example, cycle cars and light cars are in the mainstream. Even though we would normally locate a cycle car or a light car in the low-end market, it *could* be classified as high-end if its quality "goes above the average." Occasionally these types of cars have unusual features and will therefore qualify as high-end. Pre-1920, four or more cylinders in the engine would be considered a unique, distinguishing feature. After 1920, however, four-cylinder engines became the norm; thus, we do not locate ordinary cars with four cylinders in the high-end. This is especially true for firms entering the market during Cohort 1.

When a car is described by words and phrases such as "sporty features", "luxurious", "distinguished", "large engine", or "stylish design", it gets located in the high-end market. Similarly, when the car's body type, appearance, or engine is referred as "unusual" or "unconventional", the car will be classified as high-end. We do not maintain this distinction for an automobile's components such as the radiator, stroke, *et*

cetera. The reason for this is that we assume the customer has only limited knowledge on the technical parameters of the automobile. They are not able to tell the difference between cars with such unusual components and those without.

An automobile qualifies for the low-end submarket if its model is conventional, standardized, or has a small engine. This is the situation of the aforementioned cycle cars and light cars. For specificity, when a model is described as "conventional", "typical", cycle car, light car, micro-car, mini-car, three-wheeled car, *et cetera*, it is categorized as a model in the low-end. However, keep in mind that small cars are not necessarily the same as low-end cars. As a consequence of our "limited knowledge" assumption on the part of the consumers, even if some conventional models do distinguish themselves by unique components, they will still be located in the low-end market. Additionally, if the model is based on an assembled car with nothing special about its performance marketed, if it is made in a family-based location such as a garage, if no precise standard for the model is stated, or if the model does nothing more than replicate a famous model (a Model T Ford, for example) to market at a lower price, it is then classified as a low-end model.

We have one last issue on classification—how to handle the over-priced car. For over-priced cars that are small, we locate them in the low-end. We do this strictly judging from size. For medium and large cars, we treat them as high-end. This is also a direct consequence of our "limited knowledge" assumption. Since consumers are not able to judge the quality of a car simply by inspecting its technological parameters that it bear, the size of the car serves as an important signaling feature.

V: Econometric Analysis

In this section, we introduce our main explanatory variables in the estimation model and we present our empirical results. We then proceed to estimate Cox regressions, in the hope of finding the factors that influence the survival time of car industry participants during the period 1895-1970.

V.A. Submarket Choice

To begin, consider Figure 3 which graphs survival rate estimates for the different submarkets. The survival time of each car manufacturer has been determined as follows. We use the entry and exit year of each manufacturer and count the number of years of its existence. In other words, the survival time equals the difference between its date of entry and date of exit, plus one. In this way, we avoid possible confusion if a firm enters and exits the market during the same year. We additionally clarify our treatment of firms who re-enter the market after wars. We take its first entrance into the market as the entry date, and its last date of production as the exit date. We subtract the years when they temporarily leave the market. Since we treat the survival time of firms who enter and exit the market in one year as a duration of one year, we use *log (1.1)*—as opposed to simply *log (1)*—as the survival time of these firms. This helps to avoid the appearance of erroneously missing sample observations. We see that firms in high-end production tend to have a higher survival rate than those in the low-end submarket, as predicted.

Firms choose their quality level submarket when they first enter the industry. We want to investigate the consequences of this choice on the firm's future performance. We expect to find that firms in the high–end submarket have a higher survival rate than those in the low-end. The underlying reason can effectively be explained by differentials in the

price-cost margin in the different submarkets. In general, high-end producers will have a higher price-cost margin than those in the low-end. Therefore, when a cost shock occurs that reduces the prevailing market price, the leading firms in the high-end can more ably resist the shock than those in the low-end. As Figure 3 depicts, the Kaplan-Meier survival estimates of different quality groups supports the theory that firms in the high-end submarket have a higher survival rate.

Figure 3:

Kaplan-Meier survival estimates, by qualitycode
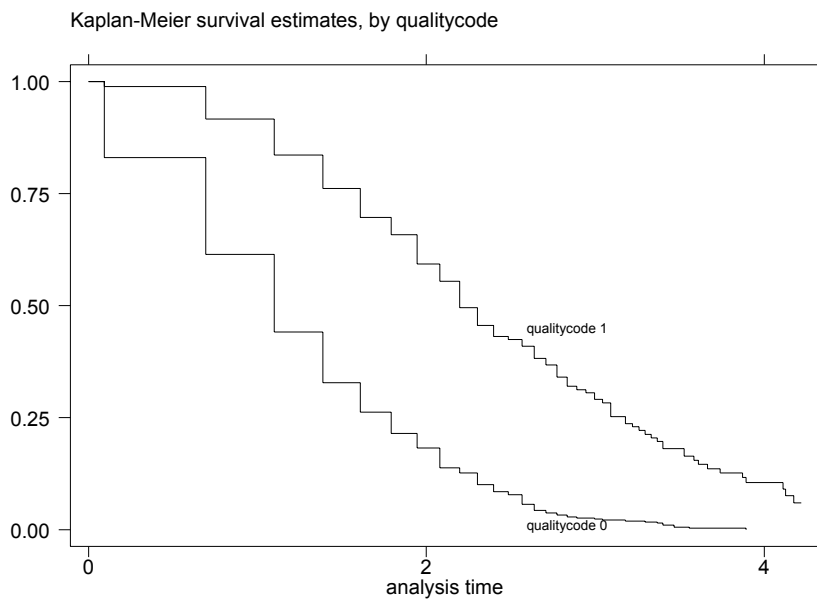
Quality code 0=Low-end product
Quality code 1= High-end product
Survival times in log form

When we separate the firms by submarkets, we find something interesting. Figures 4 and 5 depict the market evolution of the automobile industry in the low-end and high-end submarkets, respectively, using the same scale as Figure 1. The number of firms, the number of entrants, and the number of exits in the low-end submarket share a similar pattern to that of the overall industry. In contrast, the number of firms in the high-end submarket evolves rather smoothly when compared with its counterpart. There

are no large fluctuations of entry and exit. The number of firms increases smoothly until it reaches 40 around 1907. The industry reaches its peak around 1920, which is followed by a smooth decrease. Thereafter, the number of firms is more or less stable. Unlike the firms in the low-end market (which are characterized by almost no entering or exiting of firms after World War II), the high-end firms are relatively active—experiencing approximately five entry/exits per year.

Figure 4: The Number of Automobile Manufactures in High-end submarket,
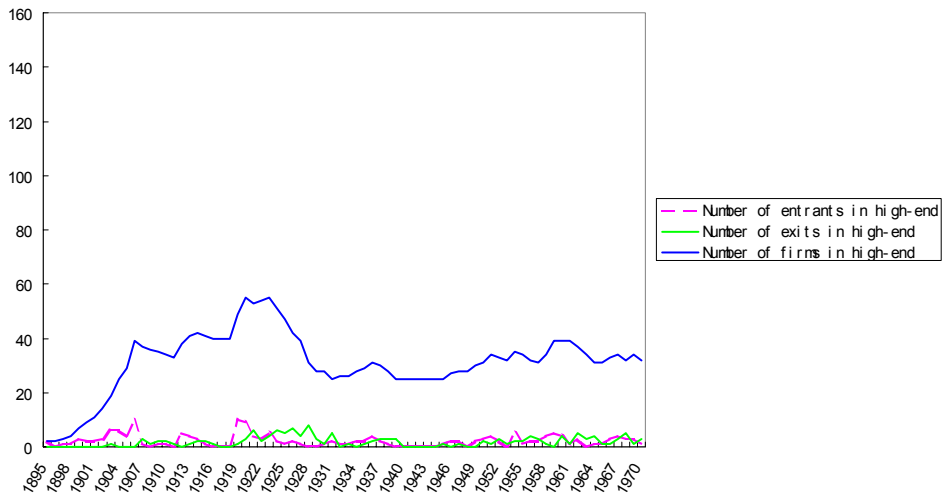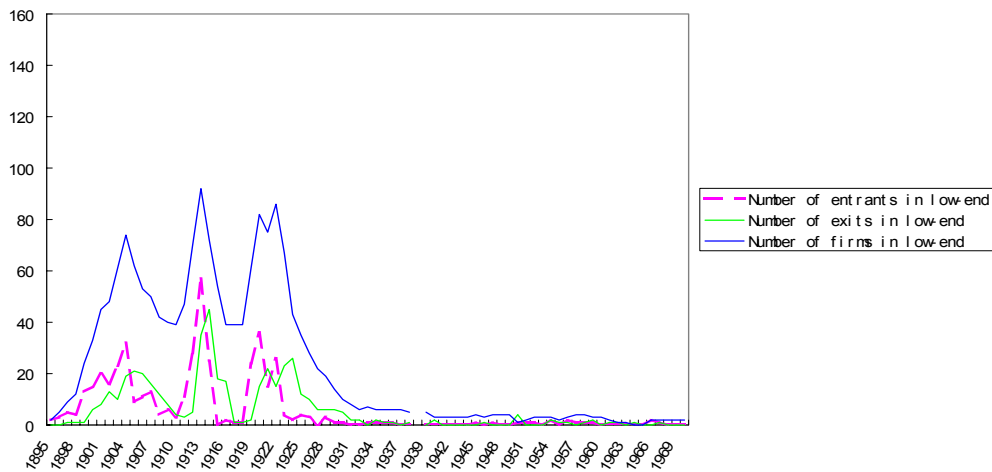Entrants and Exits in Great Britain, 1895-1970

Figure 5: The number of Automobile Manufactures in Low-end Submarket,
Entrants and Exits in Great Britain, 1895-1970

The slow rise in the density of the high-end submarket can be traced all the way from the industry's beginning in Great Britain. Britain was widely regarded as the world's most powerful and richest industrial country in the mid-nineteenth century. The concentration of population—coupled with a sophisticated rail and tramway network—may have reduced the demand for a related and possibly far more important industry; namely, the motorcar. As has been recorded, "the essential advances in motor vehicle designs were made in France, Germany, and Austria, not in Britain; and France, not Britain, dominated the European motor industry before 1914" (Foreman-Peck, Bowden, and McKinlay, 1995). As a consequence, during the first phase of the industry (the period before 1914), British demand for cars was "dominated by wealthy and leisured buyers." These buyers preferred higher quality foreign cars. But as improved designs and thorough workmanship of English-made bodies become more recognized and appreciated, buyers were increasingly inclined to buy British made motorcars.

As we see in the graph, the number of firms in the high-end submarket increases until 1907. The number of firms becomes stabilized—both in the high-end and low-end submarkets—after the shake-out phase. However, unlike the first three stages of the industry, the high-end submarket is very active during this period. Firms entering and exiting the market comprised the biggest part of the industry's behavior. This can be attributed to the fact that economies of scale allowed fewer manufacturers with larger plants to produce more and more vehicles at lower unit cost. The result is that there is no chance for a new entrant in the low-end submarket to compete with the already

established oligopoly players. New entrants can only find market niches in the high-end submarket.

V.B. Time of Entry

According to Klepper (2002a), when it comes to survival rates, early entrants have an advantage over late entrants. Klepper ascribes this phenomenon to earlier entrants facing a higher price-cost margin than those who arrive late to the game. The mechanism runs as follows: in the early stages of development, early entrants to the industry make high profits which they allocate to research and development (R&D). This enables them to grow at a faster pace than those who enter the industry later. This implies a lower hazard rate (i.e., a lower probability of being forced to exit the market) for the earliest entrants. The implication holds at every stage of the industry life cycle.

To investigate whether the timing issue is important not only to the evolution of the British automobile industry, but also for each of the submarkets, we analyze the survival rate in each cohort.

Figure 6 shows the Kaplan-Meier Survival Estimates of the whole industry by cohorts. Notice that in the third cohort, the number of firms is stabilized because of war contracts. When using our dataset, we see no new participants entering during this period. Therefore, Cohort 3 does not appear in the graph. This result is not expected. Firms who enter the industry during Cohort 1 should not have any advantage in survival time over the firms in Cohort 2 until they are eight years in the market. Also, firms entering in Cohort 4 have a higher survival rate than older firms. Basically, we see that *firms who enter the industry later have a lower risk of being forced to exit*.

Figure 6

Kaplan-Meier survival estimates, by cohort
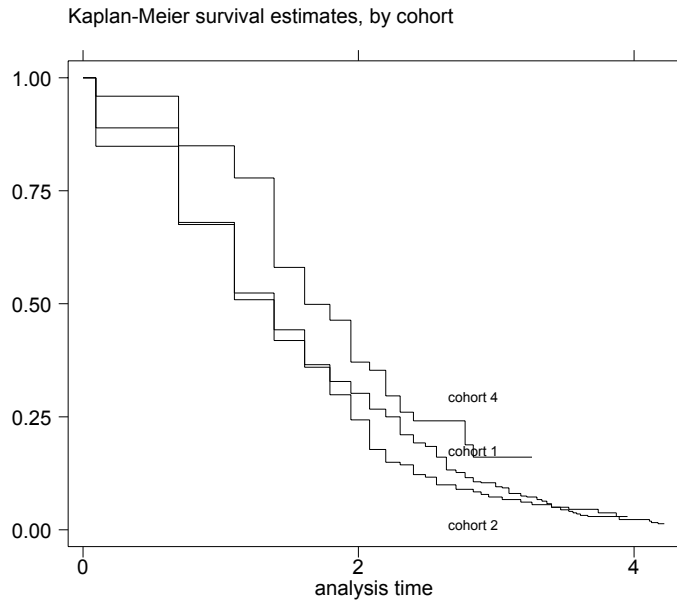
Cohort 1= 1898-1914
Cohort 2= 1915-1938
Cohort 3= 1939-1944
Cohort 4= 1945-1970
Survival times all in log form

We propose two alternative explanations about cohort-specific survival times that relate to the different submarkets. The first explanation is depicted in Table 1 below. Here we list the number of firms both in the high-end submarket and in the low-end submarket for each cohort. From Table 1, we see the percent of firms entering the low-end submarket (i.e., choosing to produce a low quality product) decreases over time and the percent of firms entering the high-end submarket increases over time. This is especially evident in Cohort 4 where the degree of increment and decrement is pronounced. Once again we attribute this fact to firms located in the high-end submarket having larger profit margins. This advantage outweighs the benefit accruing to early entrance. It does seem logical, then, that later entrants will have the benefit of high survival rates.

Table 1: Entrants by submarket and cohort

Time of entry	Number of entrants	Number of firms in high-end (percentage)	Number of firms in low-end (percentage)
Cohort 1	355	55 (15%)	300 (85%)
Cohort 2	181	54 (30%)	127 (70%)
Cohort 4	74	59 (80%)	15 (20%)

The second explanation follows from how we define each cohort. As compared with Boschma and Wenting (2004) [who arrive at the same results regarding time of entry as Klepper (2002a)], we classify the inter-war period as a distinct cohort. We do this since this period is characterized by some firms exiting the market—even if no firms entered it. This causes the survival time of firms in the cohorts that include inter-war periods to be pulled down. This, of course, contributes to why we get conclusions that contradict what one may initially expect about survival rates.

A simple way to verify the first explanation is to re-plot the Kaplan-Meier survival estimates in another way. Figures 5 and 6 detail survival estimates of low-end production and high-end production, respectively, separated by cohorts. We see that in the low-end submarket, firms located in Cohort 4 tend to have higher survival rates only when the firms are young (i.e., less than three years). For those firms located in the high-end submarket, the advantage of early entry is obvious.

The obscurity of survival time in Cohort 4 in the low-end submarket may hint at the second explanation. By separating the data into submarkets, we see the advantage to early entry as stated by Klepper.
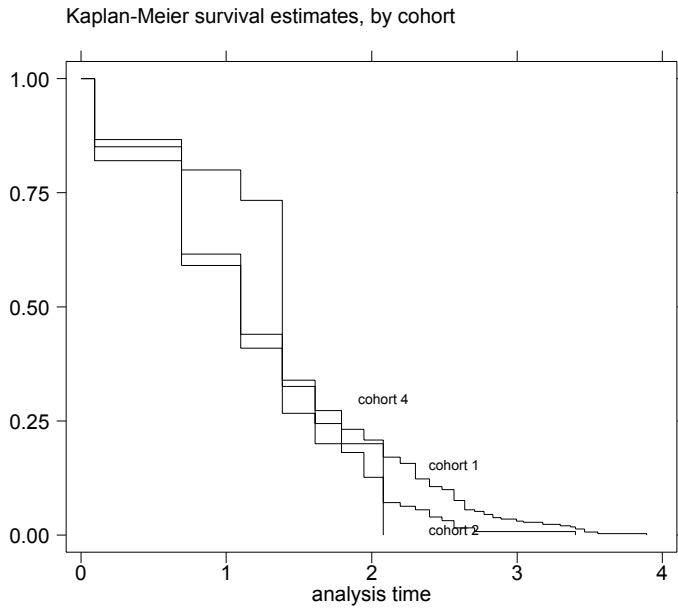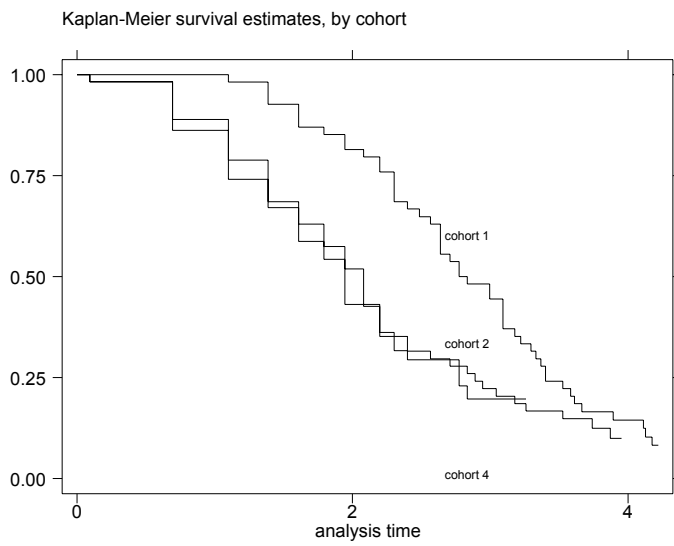
Figure 7:

Kaplan-Meier survival estimates, by cohort

Figure 8: High-end submarket

Kaplan-Meier survival estimates, by cohort

Survival times in log form

V.C. Background of the Manufacturers

In Klepper's model, the pre-entry background of the entrants is considered essential because it incorporates both management's capabilities and the potential technology that the new entrants could bring. Klepper (2002a) differentiated between firm types by appealing to the diversity of their entrepreneurial backgrounds. But the main purpose of this paper is not to scrutinize the importance of any particular entrant's background. Therefore, we simply separate firms into two groups: those who are "experienced", and those who are "inexperienced". Instances of the former are those firms with expertise in the bicycle industry or engine manufacturing industry (this is Klepper's definition of "experienced firms"), firms whose owners have management or technical background accrued from other industries (his definition of "experienced entrepreneurs"), and when employees of automobile firms start up their own independent firm (his definition of "spin-offs").

Figure 7 below depicts Kaplan-Meier survival estimates for both experienced and inexperienced firms using the log of survival time. As expected, the experienced firms have a higher survival rate than the inexperienced firms.

Figure 9

Kaplan-Meier survival estimates, by backgroundcode
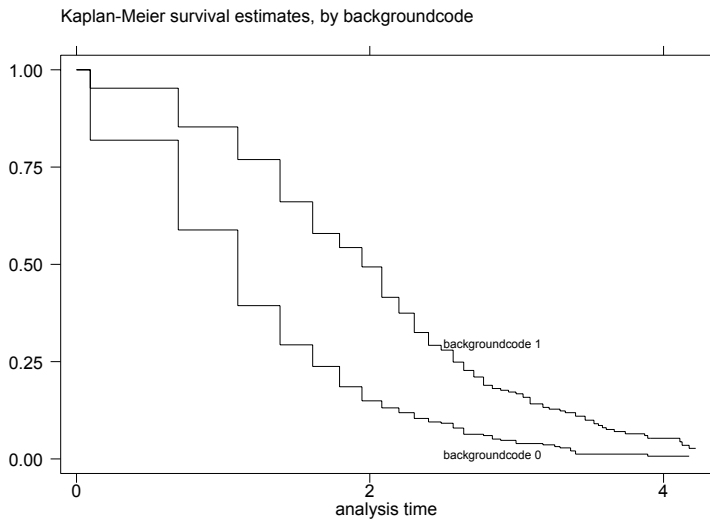
Code 0 = Inexperienced firms
Code 1 = Experienced firms
Survival times in log form

V.D. Further thoughts

We examine the fact that product quality choice will affect the survival time of the firms. A further question that would arise here is: given the information that firms in the high end would have a relatively lower hazard rate, would the experienced firms have more propensity to enter the high end submarket?

Table 2: Number of firms entering the high-end according to background/cohort

	Experienced firms entering high-end (% of experienced) [% of all the firms]	Inexperienced firms entering high-end (% of inexperienced) [% of all the firms]
Cohort 1	40 (29.2%) [11.3%]	15 (6.9%) [4.2%]
Cohort 2	34 (41%) [18.8%]	20 (20.4) [11%]
Cohort 4	26 (81.25%) [35.1%]	33 (78.6%) [44.6%]

As we see from table 2, despite an increasing trend of firms entering the high-end submarket for firms with or without experience, a greater percentage of experienced

firms enter the high submarket. Clearly, experienced firms do have a higher propensity to enter the high-end submarket than inexperienced firms.

V.E. Results

We employ a hazard model in order to determine whether quality can explain the survival rates found in our data of the British automobile industry. We estimate Cox regressions to assess the effects of submarket choice, experience background, and time of entry on the survival rate. The linear Kaplan-Meier estimates of (log) survival time suggest that by refitting the data into a Weibull regression, we may end up with a better fit.

Hazard Model (A)

The dependent variable in our model is the survival rate. It serves as an indictor of firms' performance. By construction of the dataset, we can determine the year of entry and exit for each automobile firm in Great Britain during the period 1895-1970. Since 1970 is the cut-off date for data observations, we are left with 34 car manufacturers who continue to participate in the market. These firms are defined as being *censored* (refer to Section IV.A for the classification criterion).

We utilize a simplified version of the Cox proportional hazard regression model:

$h(t) = [h_0(t)]e^{\beta x}$.

Here, x is a covariate, β is the regression coefficient, and $h_0(t)$ is the baseline hazard function when x is set equal to 0 (i.e., the expected risk with no covariate term). As with any multi-variate linear regression, the Cox regression framework can be expanded to include more than one covariate:

$$h(t) = [h_0(t)]e^{\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n}$$ (8)

where $x_1, x_2, \ldots x_n$ are the covariates. For multiple level variables, e^{β} estimates the percent change in risk with each unit change in the covariate. The model serves to determine the influence of a predictor variable (such as submarket type, experience, or time of entry) on the dependent variable (the survival rate of the firms). We focus our attention on the hazard ratio which takes the form $HR(t, x_i, x_i') = e^{\beta(x_i - x_i')}$. A hazard ratio of one implies the corresponding covariate has no effect on the baseline hazard. A coefficient less (greater) than one indicates that an increase in the value of the covariate will lower (raise) the probability of being forced out of the market. In our model, we incorporate three variables: quality level, experience background, and the time of entry. We investigate how these affect the survival time of firms. Additionally, we want to find out if submarket choice affects the survival times of firms who have similar backgrounds and dates of entry. In other words, do firms in the high-end submarket truly face a lower hazard rate?

Table 3 presents the results of the Cox proportional hazard regression. Notice we use Cohort 1 as the basis for Cohorts 2 and 4. We estimate four regression models, with QUALITY LEVEL as the only parameter in the first model. We then subsequently add additional variables to note changes in statistical significance.

The key result is the estimated hazard ratio for firms who enter the high-end submarket. The model returns a ratio for QUALITY LEVEL of 0.334, less than one. Entering the high-end submarket reduces the hazard rate by approximately two thirds relative to entering the low-end. When we add more variables, the evidence in favor of QUALITY LEVEL is still strong.

Table 3: Hazard Ratio of the Cox regression (s.e.)

	Model 1	Model 2	Model 3	Model 4
Quality Level	.334 (0.0353)*	.302 (.035)*	.362 (.039)*	.331 (.039)*
Cohort 2	---	1.266 (.12)*	---	1.335 (.127)*
Cohort 4	---	1.4 (.228)*	---	1.294 (.213)
Experience Background	---	---	.543 (.048)*	.535 (.048)*

denotes significant at 5% level
Cohort 1 as basis; it is a dummy variable

Similarly, the experience background of entrants plays a role in reducing the hazard ratio. An experienced firm with any kind of background has the advantage of reducing its hazard rate by half.

Lastly, a hazard ratio with respect to time of entry greater than one indicates that the value of the covariate raises the exiting hazard. This is consistent with what we expected. Early entrants have an advantage over late entrants because of their higher profit margins. This gives them the benefit of a lower hazard rate than the late entrants. Notice in Model 4 that the hazard ratio of Cohort 4 is no longer significant. This result leads us to a new question. Does the decision regarding submarket choice (high-end or low-end) eliminate the effects of the decision on when to enter the market?

Hazard Model (B)

Recall that the convex shape of the (log) survival time with respect to different variable groupings is consistent with the fact that the hazard rate is decreasing in firm age. Although not always the case in our paper, it reminds us to try Weibull accelerated failure

time regressions to see if they provide us with a better fit with the data. We formulate the

hazard function as $h(t,x,\beta,\lambda) = \dfrac{\lambda t^{\lambda-1}}{(e^{\beta_0+\beta x})^{\lambda}}$, where $\lambda = 1/\sigma$. The parameter σ is a

variance-like parameter on the log time scale, and the parameter $\lambda = 1/\sigma$ is commonly

referred to as a shape parameter. The proportional hazard form for the function is

obtained as follows. If we let $h(t,x,\beta,\lambda) = \lambda t^{\lambda-1} e^{-\lambda\beta_0} e^{-\lambda\beta x}$, and if we

define $\gamma = \exp(-\beta_0/\sigma) = \exp(\theta_0), \theta_1 = -\beta_1/\sigma$, then we obtain the familiar proportional

hazard form:

$$h(t,x,\beta,\lambda) = h_0(t)e^{-\theta_1 x} . \tag{9}$$

In this case, the baseline hazard function is $h_0(t) = \lambda\gamma t^{\lambda-1}$. This form leads to a hazard

ratio interpretation of the parameter θ_1 .

Table 4 gives the results. In this Weibull model, an improvement over the simpler

exponential model (for a given set of covariate values) is evaluated through testing the

hypothesis $\sigma = 1$. In each case, we reject the exponential formulation.

We start with the single covariate model. In Model 1, where QUALITY LEVEL

is the only covariate, we get a statistically significant result. Model 2 controls for

QUALITY LEVEL and takes the cohort classification into consideration. The coefficient

on COHORT 4 is no longer significant. Examining each model one by one, we find that

when we control for QUALITY LEVEL, the coefficient of COHORT 4 loses its

significance. This implies that submarket choice affects the cohort. The advantage

(disadvantage) to time of entry is affected—perhaps even disappearing—for firms who

enter the high-end submarket.

Table 4: Weibull Regression—the Accelerated Failure-Time Form

	Model 1	Model 2	Model 3	Model 4
Quality Level	.673(.066)*	.703(.07)*	.588(.064)*	.606(.068)*
Cohort 2	----	-.123(.0614)*	----	-.146(.059)*
Cohort 4	----	-.129(.105)	----	-.064(.102)
Experience Background	----	----	.382(.055)*	.387(.0552)*
Constant	.306(.033)*	.347(.038)*	.153(.038)*	.195(.0417)*
-ln(sigma)	.41(.0348)	.418(.035)	.451(.035)	.46(.035)
Sigma	1.506(.052)	1.519(.053)	1.57(.0545)	1.584(.055)
1/(Sigma)	.664(.023)	.658(.023)	.637(.0221)	.631(.0221)

Denotes significance at a 5% level

VI: Conclusions

In this paper, we attempt to utilize a firm's choice of submarket production (high-end or low-end) to explain the evolution of the British automobile industry. Similar to the United States automobile industry, the British industry underwent a rapid expansion at its start. This was characterized by numerous entrances and exits of market participants. After an industry-wide shake-out phase, the number of market players in the automobile industry more or less stabilized. Unlike the U.S. automobile industry—which was left with very few firms after its industry shake-out—the British industry maintained a relatively high number of firms in its market.

We theorize that this difference in outcomes between the two countries is due to firms' choice of which submarket to participate in. If firms producing in the high-end submarket have higher markups over marginal cost than their low-end counterparts (which we assume to be true), a negative cost shock has a more negligible effect. They are more able to survive this shock. This results in the lower hazard rate of firm exit that we expect to see from the high-end manufacturers.

We tested our hypothesis using the Cox proportional regression, adding two additional regressors in order to make the model more complete. These variables are the time of firm entry and the new entrant's background. Previous studies indicate that early entrants should have a lower hazard rate than later entrants [Klepper, (2002a)]. The Kaplan-Meier survival plot shows the opposite result. We see late entrants characterized by higher survival times than early entrants. After sorting firms by submarket type and omitting the inter-war period in our survival estimates, we arrive at similar results as those in Klepper. Likewise, we find similar results in the British automobile industry relating to entrant background and how it influences the hazard rate. This suggests the hypothesis regarding early entrants does indeed hold after conditioning on submarket type. It is conceivable that other factors can mitigate or rule out completely the early-entrant advantage, and it is worth further investigation to examine the extent to which early-entrant advantage might be crowded out.

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