Heterogeneity in Oligopoly: Theories and Tests

Rickard Sandin

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by

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Stockholm, December 1996

Rickard Sandin

To the reader

This dissertation consist of five separate chapters, of which the three first are empirical and the last two are theoretical. The notation in the chapters is not necessarily the same, but there are some overlaps between the two first chapters on driving schools, and between the two theoretical chapters.

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Competition in Interrelated Markets: An Empirical Study*

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Abstract

This paper studies competition in small, concentrated, and interrelated markets. Our data set consists of price information from 543 driving schools in 250 local markets in Sweden, which gives a large sample to test hypotheses on how market structure influences competition. The results show that if prices in nearby markets are low, and the distances to them are short, it reduces prices, as suggested in models of spatial competition. Moreover, we find that prices in closely located markets are interdependent. It is also shown that prices are increasing in firm concentration within a market, as most theories of oligopoly predict.

Keywords: Spatial competition; interrelated markets; oligopoly; driving schools.

JEL specification: C24; C31; D43; L13; L84; R32

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1. Introduction

Although oligopoly theory has been successful in generating hypotheses on factors that may affect the intensity of competition, few of them are easy to test empirically. A set of models that have received little empirical attention, despite the fact that they yield testable implications, and for which data are relatively easy to find, are spatial models of competition. In these models the intensity of competition among firms is partly determined by the geographical dispersion of firms, which is easy to observe. Many of the industries where these models are applicable also have relatively homogeneous goods and prices that are readily observable. Our study uses data from a large number of concentrated markets within the same industry to test how prices in nearby markets, and the distance to them affect competition in a given market. At the same time we test how firm concentration within a market affect the intensity of competition.

The theory underlying this approach goes back to the early work of Kaldor (1935) who recognised that firms within a market compete not only with each other, but also, to a lesser extent, with firms in other nearby markets, which has been referred to as "overlapping oligopolies". However, most of the recent theoretical work on spatial competition focus on the interaction between firms at different locations. Factors that have been emphasised are the entry and locational decision of firms, and the distribution and travel cost of consumers. For surveys of this large literature, see Eaton and Lipsey (1989) and Martin (1993).

There are relatively few empirical studies on spatial models of competition. Johnson and Parkman (1983) studies the cement market and finds no significant support for the hypothesis that profitability falls with the geographical concentration of firms. In Cotterill's (1986) study of the retail food industry in Vermont, the distance between warehouses have negligible effects on the price level. Claycombe and Mahan (1993) study beef pricing, but finds no significant effects of commuting distances on prices. Fik (1988), however, finds that the distance to the nearest competitor has a significant effect on price when it is the only explanatory variable in a linear regression. A common feature of these studies is that only distances to, and not prices in nearby markets are considered to influence competition. An exception is Haining (1984), who finds some support for price clustering among neighbouring outlets in urban gasoline retailing. Slade (1986) on gasoline prices, and Horowitz (1986) on prices of meat, use time series data on price differences between markets to detect those that are part of the same geographical market. Even though we feel that this line of research is very interesting, it does not address the same questions as this study. For example, no measure of firm concentration within a market is included, and there is no measure of geographical distance between markets, as suggested by theories of spatial competition.

Much more attention have been assigned to factors that may affect the intensity of competition within a market. There exists a literature which focuses on competition in regional markets within the same industry. Examples of such studies are Geithman, Marvel, and Weiss (1981), and Koller and Weiss (1989) for the case of cement, and Marvel (1989) on gasoline. These studies mostly deal with the relation between prices and market concentration, and typically find a positive relation, Schmalensee (1989 p. 988).

Our choice of industry and market sample permits tests of competition both between and within markets. The results of our study of driving schools in Sweden show that the distances to other closely located markets and, in particular, the prices there play a significant role in explaining the price level in a given market. Moreover, we conclude that prices in nearby markets are endogeneously determined. Our results also show that prices increase with firm concentration within the market.

2. The data

To undertake a study as outlined in the introduction, we searched for an industry where the product is fairly homogeneous and sold in many markets. We argue that an industry which meets these requirements is driving schools, with the product being a single driving lesson. One might argue that the quality of a lesson varies across firms (vertical product differentiation), but price differences are small within markets in our sample, which one would not expect if there were substantial quality differences. Furthermore, it appears that quality differences between teachers within the same firm are as common as any quality differences between firms, which again might explain the small price variation within markets. The product is horizontally differentiated to consumers at different locations, but probably quite homogeneous to consumers at similar location, as indicated by the low advertising intensity in the industry.

2.1 Markets

In this study a market is defined as a municipal. There are 288 municipals in Sweden of which 250 are included in our sample. We excluded Stockholm, Gothenburg, and Malmoe with surrounding suburb municipals because these three cities are much larger than the rest, and which may each consist of many local markets.[1] Furthermore, it was indicated that these markets had different cost and demand characteristics, as discussed in the Appendix. The markets in our sample differ in size as shown in Table 1. In 1993, the smallest market has a total population, *POPTOT* of only 2.865 while the largest market has a population of 178.011. The distribution is skewed towards smaller markets.

Although total population may describe the size of a market, the most important consumer group for the study of driving schools is the population of age 16-24, which is measured in hundreds, and denoted *POP1624*. We included the number, in hundreds, of students in the gymnasium (≈ high-school), *STUDENTS* as a separate measure of market size. This variable was chosen because there are municipals where there are no gymnasium, and where students must travel to other municipals, where it is likely that they take their driving lessons.

Municipal data on average personal wage income in 1993, *PINC* is used to control for differences in wealth levels that may affect demand. In Table 1 it is measured in SEK hundreds of thousand.[2]

[1] In the municipal of Stockholm, for example, the total population in 1993 was almost 700.000 and there are more than 50 driving schools, which should be compared to the mean population and number of firms in our sample which are 24.930 and 2.2 respectively.

[2] We are referring to the Swedish currency throughout the paper and we omit SEK from now on. In June 1, 1995, one US dollar equals SEK 7.35.

Table 1.– Sample Characteristics

Variable	mean	stand. dev.	min	max	median	number of observations
POPTOT	249	264	28.6	1780	143	250
POP1624	28.9	33.6	2.73	238	15.4	250
STUDENTS	8.29	11.8	0	65.8	3.39	250
PINC	1.23	0.0840	1.03	1.53	1.23	250
DIST1	27.0	17.1	6.00	119	21.6	250
DIST2	37.6	21.9	9.60	144	32.4	250
FIRMS	2.18	2.40	0	13	2	250
MCARS	5.30	6.69	0	33	3	250
FCARS	2.44	1.36	1	9	2	543
MPRICE	5.90	0.529	4.53	8.00	5.92	196
STDEV MPRICE	0.163	0.162	0	0.593	0.125	126
MPRICENEAR1	5.94	0.565	4.53	8.00	5.97	237
MPRICENEAR2	5.93	0.517	4.53	7.14	5.97	235
OFFICEVAL	3.03	0.595	2.23	5.81	2.87	24
WAGE	13.1	0.270	12.6	14.1	13.1	24

As mentioned, we study markets which are not necessarily isolated. In order to account for interdependency of markets we measured the distance (as straight lines) from the central town in each market to the nearest central town of the two closest markets, conditional on there being at least one firm in each of these markets.[3] This gives us two distance variables, *DIST1* and *DIST2*, measured in kilometres. As is evident from Table 1, the range between the minimum and maximum distance is large, identifying the fact that some markets are isolated while others are not.

2.2 Firms

The study contains all driver schools, 543 firms, in our market sample as of June 1995. Driving schools are generally small, family owned businesses with a median of two cars and two employees. From a membership list of the interest organisation (covering approximately

[3] In each municipal there is usually only one central town where the large majority of the population live in and where, with few exceptions, the firms are located. In most cases these towns also lie in the centre of the municipal.

95% of the firms) we checked if a firm was part of a group of firms under common ownership/control.[4] Apart from a about ten firms, and a group of four firms (scattered across the country) owned by a petrol company (OK Petroleum Inc.), the owners controlled only one firm. Each firm was asked about the price per driving lesson, and how many minutes it lasted. We also asked about the number of cars (including brand, model, and vintage) and the number of teachers in the school working full-time as well as part-time. We deliberately restricted the number of questions to the above, since we believed that more questions would negatively affect the responding frequency. All except one firm answered all our questions, which is also explained by the fact that we did not ask questions on profitability or costs, but on features that are easily observed by any competitor.

Table 2 shows the distribution of markets with different number of firms where the number of firms in a market is denoted *FIRMS*.. As one can see, there is a span of market structures ranging from zero to thirteen firms. In our sample, 207 out of 250 markets contain three firms or less, which by any standard are concentrated markets.

Table 2.—Market Size and Price, Related to the Number of Firms in the Market

FIRMS	*No. of markets*	*Mean POP1624*	*Mean STUDENTS*	*Mean MPRICE*
0	54	9.74	0.612	-
1	70	13.4	2.10	5.95
2	50	21.6	6.17	5.82
3	33	32.9	11.4	5.87
4	13	43.4	15.8	5.88
5	9	61.6	20.9	5.78
6	4	80.1	27.2	6.02
7	4	97.8	31.4	6.12
8	4	134	43.2	5.72
9	2	104	38.9	6.64
10	3	123	43.3	5.92
11	2	148	50.1	6.01
12	0	-	-	-
13	2	162	49.7	5.87

[4] The criteria we used were if 1) the companies had similar names e.g. Axelssons Trafikskola Köping and Axelssons Trafikskola Västerås 2) names of the contact person in the membership list were the same.

We use the number of cars in a market, *MCARS*, as a measure of total capacity and the number of cars in a firm, *FCARS* as a measure of firm size. From these variables a Herfindahl concentration index is defined as

$$HERFINDAHL_i = \sum_{k=1}^{FIRMS_i} \left(\frac{FCARS_{i,k}}{MCARS_i} \right)^2 .$$

Figure 1 shows a plot of the square root of the Herfindahl index as a function of market size measured by *POP1624*. The figure reveals a strong negative relation between market size and concentration, which could be even stronger if we had accounted for differences in personal income, distances to the closest markets, and other factors that affect demand. In the framework of Sutton (1991), the lower bound of concentration seems to be strictly decreasing in market size, and markets lie relatively close to this bound. This pattern is more likely to obtain when the product is homogeneous, supporting our argument that driving lessons do not differ much between firms and markets.

2.3 Prices

The price and duration of a single driving lesson varies among the firms in our sample. Some firms use second degree price discrimination, where they offer a package of several lessons (usually 5 or/ and 10 lessons) bundled with theory lessons, which gives a slightly lower price per lesson. We choose the price of a single lesson because it is very difficult to compare these packages, and more so because single lessons are most important quantitatively.

We use several different price variables in the paper. The mean market price per minute is denoted *MPRICE* and varies from 4.53 to 8.00, as shown in Table 1. However, there is almost no variation within a market, which is seen by the small standard deviation of *MPRICE* within markets with more than one firm, *STDEVMPRICE*. This can also be illustrated by the high correlation (0.85) between duopolists' prices within a market. There are relatively small differences in mean *MPRICE* for markets with different number of firms, as illustrated in Table 2. This is not surprising, because we have not adjusted for other factors, such as market spill-over effects and cost differences etc. Since prices in closely located markets are expected to influence competition in the market, we include the mean market price per minute in the closest and second closest market where there exists at least one firm, denoted by *MPRICENEAR1*, and *MPRICENEAR2* respectively. Table 3 shows the correlation between our price variables.

Table 3.– Correlation between Price Variables

Variable	*MPRICE*	*MPRICENEAR1*
MPRICENEAR1	0.557	1
MPRICENEAR2	0.423	0.320

As expected, *MPRICE* is more correlated with the price in the closest market, than with that in the second closest market. Moreover, both of these correlations are higher than between *MPRICENEAR1* and *MPRICENEAR2*, which may be on different sides of the market, and thus further away from each other.

2.4 Costs

The principal costs for driving schools are wages for the teachers, the cost of cars, gasoline, traffic insurance, and office and parking space. Wage costs are dominating. There is a central agreement on the wages of the teachers who are unionised, but according to their trade union, some regional differences exist primarily between Stockholm, Gothenburg, and Malmoe, and the rest of the country although there are no available data on this. Since these cities are excluded from our sample, regional differences are probably less important.

Moreover, wage levels are traditionally quite compressed in Sweden. Still, to track potential wage differences in our sample we use county level data on monthly salary of skilled employees in the trade and commerce sector, measured in thousands, *WAGE*, as a proxy.

In order to account for cost differences in the use of office and parking space, we used the average assessed value of per square metre non-residential floor space in 1994, measured in thousands, *OFFICEVAL*. Again, only county level data are available, which means we cannot measure possible differences among municipals within a county. The remaining cost variables were excluded in our regressions because regional differences are very small.[5]

3. Econometric model

In the preceding section we informally discussed specificities considered to be important for competition in this particular industry. To reiterate, we expect the product - a single driving lesson - to be relatively homogeneous across firms within a market. However, the product is horizontally differentiated to consumers at different locations, who have the possibility to travel to nearby markets if prices there are significantly lower, and distances are short. Cost structures of firms and across markets are similar, and some fixed costs exist. There are many theoretical models that can be used to describe these features, but much of the insights can be found in a simple spatial model with three firms, serving consumers who are uniformly distributed on a line (see Eaton and Lipsey (1989) and Martin (1993) for discussions and references). Let Firm 1 and Firm 2 be Firm 0's closest neighbours, located L_1 and L_2 away, and let C_0 be its constant marginal cost, and t be the unit travel costs of consumers. It is a standard exercise to solve the first order condition for Firm 0 to obtain the best response function (under certain assumptions to guarantee existence)

$$P_0 = \frac{P_1 + P_2 + C_0\left(2 - \frac{dP_1}{dP_0} - \frac{dP_2}{dP_0}\right) + t(L_1 + L_2)}{4 - \frac{dP_1}{dP_0} - \frac{dP_2}{dP_0}} \qquad (1)$$

[5] See Appendix for detailed motivations.

Firm 0's price is increasing in the other firms' prices, the distance to them, and its own marginal cost. However, the magnitude is dependent upon the assumptions about the derivatives of dP_i / dP_0, which are the conjectural variation parameters (e.g. $dP_i / dP_0 = 0$ is Cournot conjectures and $0 < dP_i / dP_0 < 1$ are less aggressive conjectures).[6] The price P_0 can be reinterpreted as the collusive price for firms in market 0, given the prices in nearby markets and equal marginal costs, C_0. However, from static and dynamic oligopoly theory we know that this need not be the price in markets with more than one firm. For example, it may not be sustained in an infinitely repeated game, where more firms may lead to lower prices (see e.g. Tirole (1992)). We model this by introducing the number of competitors and concentration in the market, as independent variables.

As a general matter of specification, it can be argued that it is more appropriate to estimate a reduced form for the equilibrium price (the Nash equilibrium), rather than an equation based on (1). However, in a model with many markets located on a line, the equilibrium price in a market is a function of the all characteristics of all markets. This is clearly impossible to estimate.

The first point to note in the econometric specification, is that there are no firms in 54 out of 250 markets. It is unlikely that this is a random sample, as these markets may be small, lie close to other markets, or have high costs. To correct for this sample selection we use a Tobit II model (see Amemiya (1985)), which is estimated by the two-stage procedure of Heckman (1979). In the Tobit II model, the latent variable $FIRMS^*$ determines where there exists at least one firm through the selection mechanism

$$
\begin{aligned}
&FIRMS_i^* = \gamma W_i + \mu_i . && && (2)\\
&FIRMSPOS_i = 1 && \text{if} && FIRMS_i^* > 0,\\
&FIRMSPOS_i = 0 && \text{if} && FIRMS_i^* \leq 0,
\end{aligned}
$$

[6] It is well known that conjectural variation models can be criticised on several grounds, but they still provide a useful method to analyse different degrees of oligopolistic competition in a unified framework, see e.g. Dixit (1986).

where γ is a vector of parameters to be estimated and W is a vector of exogenous variables. In the data, *FIRMSPOS=1* if there is at least one firm in the market, and *FIRMSPOS=0* if there are no firms. The mean price per minute, *MPRICE*, is determined by the regression model

$$MPRICE_i = \beta X_i + \varepsilon_i \qquad \text{if} \qquad FIRMSPOS_i = 1, \tag{3}$$

where β is a parameter vector and X are explanatory variables. The distribution of the error terms, μ and ε, is assumed to be bivariate normal, $\mu,\varepsilon \sim BVN(0,0,1,\sigma^2_\varepsilon,\rho)$. The expected price, conditional on there being firms in the market, is[7]

$$E[MPRICE_i \,|\, X_i, FIRMSPOS_i = 1] = \beta X_i + \sigma IMR_i, \tag{4}$$

where *IMR* is the inverse Mills ratio equal to

$$IMR_i = \frac{\phi(\psi_i)}{\Phi(\psi_i)}, \qquad \psi_i = \gamma W_i, \qquad \sigma = \rho\sigma_\varepsilon, \tag{5}$$

and where $\phi(.)$ ($\Phi(.)$) is the (cumulative) normal density function.

In the first stage we use a Probit model to estimate the probability that there exists at least one firm in the market. In the second stage we estimate prices, using only the markets which have at least one firm, with the estimated *IMR* as an independent variable. For markets with at least one firm we use the specifications[8]

$$\begin{aligned} &MPRICE_i = \beta_0 + \\ &\beta_1 MONOPOLY_i + \beta_2 DUOPOLY_i + \beta_3 TRIOPOLY_i + \beta_4 QUADROPOLY_i + \\ &\beta_5 MPRICENEAR1_i + \beta_6 MPRICENEAR2_i + \\ &\beta_7 DIST1_i + \beta_8 DIST2_i + \beta_9 DIST1SQR_i + \beta_{10} DIST2SQR_i + \\ &\beta_{11} PINC_i + \beta_{12} WAGE_i + \beta_{13} OFFICEVAL_i + \sigma IMR_i + \varepsilon_i, \end{aligned} \tag{6a}$$

and

[7] For derivations see e.g. Greene (1993) or Amemiya (1985).

[8] We also experimented with a measure of capacity utilisation. This variable was constructed as the number of cars in a market (which is a relatively fixed factor) minus the number of teachers (which can be hired on a part time basis to cover high demand periods), normalised with the former. However, this variable was too crude to yield any effect in our regressions.

$$
\begin{aligned}
&MPRICE_i = \beta_0 + \\
&\beta_1 HERFINDAHL_i + \\
&\beta_2 MPRICENEAR1_i + \beta_3 MPRICENEAR2_i + \\
&\beta_4 DIST1_i + \beta_5 DIST2_i + \beta_6 DIST1SQR_i + \beta_7 DIST2SQR_i + \\
&\beta_8 PINC_i + \beta_9 WAGE_i + \beta_{10} OFFICEVAL_i + \sigma IMR_i + \varepsilon_i.
\end{aligned}
\tag{6b}
$$

It is likely that the *MPRICENEAR* variables are endogenous. For example, if the price in market *1* is increased, it will lead to a higher price in market *0*, which in turn leads to an even higher price in market *1*, and an additional increase in price in market *0*, and so forth. A least squares (LS) estimator does not account for this interdependence, why we use a two-stage least squares (2SLS) estimator. With this 2SLS estimator we avoid the impossible task of specifying the full system of equilibrium prices, and need only to find instrumental variables for the prices in the nearest markets. If e.g. markets j and k are the nearest, we use all exogenous variables which correspond to (6a) in these markets (e.g. $HERFINDAHL_j$, $HERFINDAHL_k$, $PINC_j$, and $PINC_k$,) as instruments for the price variables.

4. Results

Table 4 presents the results from the regressions with *FIRMSPOS* and *MPRICE* as dependent variables. As expected, the Probit regression shows that firms are less likely to operate in small markets (low *POP1624* or few *STUDENTS*), where *PINC* is low, and where *WAGE* is high. However, the distance to the nearest market had no significant effect, and the same holds for *OFFICEVAL*.[9] The predictive ability of the model is satisfying (83.2% compared to the naive 78.4%). The absence of firms in some smaller markets indicates the existence of some fixed cost, which need to be covered in equilibrium.

The LS and 2SLS regressions are based on 181 markets, where neither of the two closest markets are suburbs to Stockholm, Gothenburg, or Malmoe. The coefficients in the LS and 2SLS estimators are similar except for *MPRICENEAR1* and *MPRICENEAR2*. To test for

[9] We also experimented with the number of firms in the nearest markets, and the distance to the closest markets where there are no firms, but these variables had no explanatory value.

endogeneity of these variables we conducted a Hausman-Wu test, which showed that endogeneity could not be rejected at the 10% level (P-value 0.085 and 0.070 in (6a) and (6b) respectively). We therefore focus on the 2SLS estimates in discussing the parameters.

The results support the hypothesis that competition between firms in different markets is important. *MPRICENEAR1* and *MPRICENEAR2* are positive and highly significant in all specifications, and the point estimates are high. Thus, if prices in the nearest markets are high, this will tend to increase the price in a given market. Moreover, the sum of the two coefficients is higher in the 2SLS than in the LS (0.96 and 0.72 respectively). The LS underestimates the full effect of price competition, since it does not account for the fact that prices are interdependent. For example, if prices rise by $1 in both the nearest markets, the direct effect is an increase in price by $0.72. However, this induces a further increase in price by firms in the nearest markets, and so forth, to give a total price increase of $0.96. It must be noted that there is an alternative explanation to why the coefficients of *MPRICENEAR1* and *MPRICENEAR2* are positive and significant in the LS. If there are significant cost differences between markets, which are not captured by the included cost variables, then it is possible that the *MPRICENEAR* variables work as proxies for these left out variables. If unmeasured costs are high in the three closely located markets *1*, *2*, and *3* and low in markets *4*, *5*, and *6* also lying close to each other, then prices will naturally be higher in the first three markets. The coefficients of the *MPRICENEAR* variables will then be positive since they capture the effect of costs differences on prices. However, we argue that this is not the main effect.[10] First, in a regression where we included regional (county) dummies, and market type dummies (e.g. urban, farm area, less densely populated area), the coefficients of *MPRICENEAR1* and *MPRICENEAR2* were similar, and the restriction that all dummies are zero could not be rejected (pseudo F(27,143)=0.907 with P-value 0.600, Startz (1983)). We find it plausible that these regional, and market type characteristics are much more influential in determining costs

[10] An anonymous referee also suggested that common ownership of firms may lead to correlation of prices across markets. This is can certainly be relevant in many industries, but driving schools are in general small, family owned businesses where the owner control only one firm as mentioned in Section 2.2. In our sample only about ten firms are part of a group of firms (and then not always in nearby markets), such that this interpretation is likely to be of little importance in this industry. We believe, however, that this point is relevant for future empirical research in industries such as petrol, and banking

than very local variations that affect only a small region. Discussing the matter with the main interest organisation of the firms, they clearly indicated that such very local variations are likely to be uncommon, and small in magnitude where they exist. Moreover, this would be an exogenous effect, but our Hausman-Wu test rejected that *MPRICENEAR1* and *MPRICENEAR2* are exogenous. The strong effect we find of prices in nearby markets raises questions on previous studies, where these variables are omitted e.g. Cotterill (1986), Koller and Weiss (1989), and Marvel (1978). If markets in these studies are not isolated, there may be a serious omitted variable bias, making the interpretation of the results difficult. Studies where markets were explicitly selected to be isolated, as in Bresnahan and Reiss (1991), are not sensitive to this criticism.

In the reported specifications we excluded *DIST2* and *DIST2SQR* because they were highly collinear with *DIST1* and *DIST1SQR*. The distance measures are neither individually, nor jointly significant. However, this test may not be the most interesting. A better way would be to test if the distance variables can be restricted both as regressors and as instrumental variables. We are not aware of any such formal test, but if distance variables are redundant, they will not have any explanatory power in a reduced form regression with *MPRICE* as dependent variable and all exogenous variables as explanatory variables. Even though this is not a formal test, the restriction that all distance variables are zero is strongly rejected (F(6,152)=3.75 with P-value 0.002). Based on this we conclude that the distance variables are important to include as explanatory variables in the regressions.[11] A robust finding in all our regressions is that the point estimate of *DIST1* is positive and *DIST1SQR* is negative, implying a concave effect of geographical distance on price, and not a linear effect as suggested by (1). Hence, the further away the nearest market is - the higher the price, but the effect decreases more than proportionally with distance. As a numerical example of the magnitude of the distance effect in (6a), a market where the closest market is 40 km away has about 0.07 higher price compared to a market where it is 10 km away (the effect of distance in *IMR* is negligible). This is comparable to the quadropoly coefficient of 0.06. Other studies

[11] Moreover, when the distance variables were excluded both as regressors and instruments, the 2SLS estimates of the other variables appeared to be quite different from those reported in Table 4.

that have included a measure of geographical distance find a positive, although not always significant effect on prices or profits, e.g. Cotterill (1986), Collins and Preston (1969), Fik (1988), and Johnson and Preston (1983).

In (6a), *MONOPOLY* is positive and highly significant in both the LS and the 2SLS regressions. The coefficients of the dummy variables are decreasing in the number of firms, as expected from theory. We tested restrictions on the market structure parameters, as shown in Table 5. It can be rejected that all market structure coefficients are equal, and that monopolies, duopolies, and triopolies have the same effect on price. It can not, however, be rejected that monopolies and duopolies have the same coefficient.

Many previous studies have used some measure of concentration and found it to be positive and significant in explaining price, (see Schmalensee (1989 p. 987-8) for references). This also holds in (6b) where we use *HERFINDAHL* as a measure of concentration.[12] Much of its significance is due to the effect of monopolies, but it is significant even when monopolies are excluded.[13] The conclusion from (6a) and (6b) is that even though prices tend to be lower in markets with more firms, and in less concentrated markets, they are not decreasing steeply. Of course, this is consistent with many theories of oligopolistic behaviour, and we do not make any strong statement on which of these that is the most plausible.

The cost variables *WAGE* and *OFFICEVAL* are insignificant, and the former even has a negative sign. Again, it is an indication that costs differentials are not very important in determining prices. On the other hand, *PINC* is positive. As noted above, *PINC* can be interpreted either as a cost parameter or a demand parameter, and it is not possible to distinguish between them a priori. We favour the latter interpretation, since it is positive and significant in the Probit regression, where it should have been negative if it had measured costs.

Although insignificant, *IMR* is negative in both (6a) and (6b). This means that prices tend to be lower in markets where it is unlikely to observe a firm, but where there exists at least one firm. Failure to use information about markets where there are no firms, may bias

[12] The same holds if we instead use the square root of the Herfindahl index. The coefficient is then 0.543*** (0.206), and the coefficients of the other variables are essentially the same as in (6b).
[13] Based on the 114 observations with two or more firms the coefficient is 0.563* (0.333).

the estimated parameters of the other variables. For comparison we report a regression with *IMR* excluded both as a regressor, and as instruments. The significance levels for the coefficients of *MPRICENEAR1*, *MPRICENEAR2* and *MONOPOLY* are lower, whereas *PINC* is significant. The point estimates also differ for most coefficients, suggesting the importance of including *IMR* in the specification.

To get another look at the price-concentration relation we estimated (6b) for different subsamples, based on the number of firms in the market. The results in Table 6 reveal that there is no effect of *HERFINDAHL* if we look only at markets with a given number of firms. This is due to the small variation in the variable (for a given number of firms), since firms are of roughly the same size. *MPRICENEAR1* remains significant, and the point estimate is high. Even though *MPRICENEAR2* is positive in all subsamples, it is significant only for triopolies. *DIST1* is positive and *DIST1SQR* is negative in all subsamples, as in Table 4, but point estimates are largely insignificant. One further point to note is that adjusted R^2 are higher for markets with three or more firms. The very poor fit for duopolies partly explains why *DUOPOLY* did not show up significant in (6a). There is no obvious explanation to why it is much easier to estimate the price level in markets with three firms or more, than in duopoly markets.

5. Concluding remarks

Our sample of small firms, who provide a relatively homogeneous product in local, but not isolated markets is close to the textbook example of spatial competition. The econometric model used in this paper did not explicitly test any specific theory, but rather the main implications of spatial oligopoly models. The reason for this is simply that in the wide array of models, many of the results are dependent on specific, but unobservable, details e.g. whether travel costs are linear or quadratic, or if the pattern of entry is sequential or simultaneous. However, the general conclusion is that our results give support for the main hypotheses in this set of theories. We showed that high prices in nearby markets give a higher price level, and that prices in closely located markets are interdependent. Moreover, there is some support for the hypothesis that geographical distance between markets affect price levels.

Our future work in this area will be to use time series, as well as cross sectional data, to test more specific theories about spatial oligopoly. As a part of this extension we will use the accounting rates of return for the companies in the sample, to study the relation between prices and profitability. Although we feel that cost differences between firms and local markets in this study are small, there is scope for improvement. A challenge for future research is to find firm level cost data for some markets that fits into the spatial oligopoly framework.

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Appendix

Data employed in statistical analysis

1. *Market variables*

1993 data on the total population of age 16-24 across municipals are collected from the Association of Local Authorities. Source: Kommunförbundet. Municipal data on the average number of students in the gymnasium for the academic years of 92/95 were collected from the National Agency for Education. Source: Skolverket, 1995, Skolan - Jämförelsetal för skolhuvudmän, Skolverkets rapport nr 73, table 2, Solna.

Municipal data on yearly average personal wage income in 1993 was collected from Statistics Sweden. Source: Statistiska Centralbyrån, 1995, Inkomst- och skattestatistik 1993, Statistiska meddelanden, Be20 SM 9501, table 14. We also used municipal data on average personal capital income in 1993, which was collected from the same source. The variable did not turn out significant in any of our regressions, and we therefore excluded it.

In addition to the variables measuring the distance to the closest markets conditional on there being at least one firm, we also measured the distance to the three closest markets unconditional on there being any firms. However, these variables are not included in our final regressions.

2. *Firms*

The firms were initially located from local phone books (yellow pages). A member list from the main interest organisation of the companies, the Swedish Association of Driving Schools, completed our set. Source: Sveriges Trafikskolors Riksförbund, 1995, Matrikel. Phone calls to all firms were made from the beginning of June to the middle of August in 1995. We reached about 95% of the firms within the first two weeks. The remaining firms were harder to reach, hence explaining the relatively long period of data collection. Our sample of 543 firms includes a few firms that are branches of firms in other nearby markets. A branch is counted as a separate entity if it uses different cars and teachers than the main school. If the same cars and teachers are used, the school is placed in the municipal where, according to the company, the principal operation is located, unless it is possible to divide the entity into separate entities on the basis of share of demand. Hence, a firm operating in two separate markets with three cars and three employed teachers altogether, is divided into two separate entities containing two and one car(s)/teacher(s) respectively if the firm stated that one of the markets accounted for approximately 67% of its total demand. It should be noted that this question of definition is relevant to less than ten firms.

3. *Costs*

i) Wages

There are no data available on wages for teachers employed in driving schools. Regional wage differences may exist, but is of less importance when Stockholm, Gothenburg, and Malmoe are excluded. Through the central agreement between the employer and employee unions, wage differentials are recommended on basis of education and the number of years of experience of the employee. It states that the wage should be increased by approximately SEK 300 every third year of employment. Data on skills levels in each firm has not been collected in this study. There are no clauses on regional wage differences. County level data on monthly salaries for skilled employees in the trade and commerce sector in 1990 were used as a proxy for the wages of the employed teachers. This is the last year for which a complete survey of wages and employment in the private sector was undertaken. Data was collected from Statistics Sweden. Source: Statistiska Centralbyrån, 1991, Löner och sysselsättning i den privata sektorn 1990, table 9.

Another possibility would be to use the income variable *PINC* as a wage proxy. However, there are reasons to believe that the correlation between these variables is less strong due to the fact that markets differ in the composition of industries. Some municipals are heavily dependent on a few industries (e.g. mining and forest industries in the northern part of Sweden). Furthermore, using the income variable as a wage proxy at the same time as it is used to predict consumer demand is less suitable, since a high income simultaneously corresponds to high costs and high demand, which affects the number of firms in the market in an ambiguous way.

ii) Office and parking space

County level data on the average assessed value of non-residential floor space per square metre in 1994 was collected from Statistics Sweden. This includes space used not only for driving schools. Source: Statistiska Centralbyrån, 1995, Rikets Fastigheter 1994 (1), Statistiska meddelanden, Bo 38 SM 9501, table 7a.

iii) Cars

Firms use different cars and one would therefore expect cost differences among firms. We collected data on the cars each firm used, including model and vintage. We ordered them in three classes according to their cost or present value, as stated by the Swedish variant of the "Blue Book", published by the Swedish Automobile Association. The three classes were used as dummy variables in our regressions, but did not have any explanatory power. The interest organisation of the firms claim that these cost differences are of minor importance, which was another reason for why we decided to drop them from our final regressions.

iv) Traffic insurance

The amount of traffic insurance paid for cars differs depending on how expensive the car is and whether the firm is located in a large town or not. Insurance companies also provide bonus systems, giving a higher bonus to companies who have a low degree of injury. Information from a major insurance company indicate that possible differences among the firms are negligible, mainly because fees are very low (they vary from SEK 1 200 to 2 300 per year and car). We therefore omitted the variable.

v) Gasoline

Gasoline cost vary across the country and over time. It is generally cheaper in large cities than in non urban areas. However, the difference in list prices of a major chain is at most 0.02 per litre. Since during a lesson of 40 minutes one rarely drives more than 20 kilometres, the difference between the firms per lesson is negligible. Even at a widely exaggerated price difference of 1 SEK per litre, the cost difference is only about 2 SEK out of a price of 240 SEK. We therefore chose to omit this cost variable from our regressions.

4. State regulation

Current regulation state that one can start practising driving at the age of 16 and receive licence not before the age of 18. Taking driving lessons in a school is not the only way driving can be practised. A person can take lessons privately from a person who is not an authorised teacher. The only requirement of this non authorised person is that he/she is of age 25 or older and has had the driving license for at least 5 years. These lessons are quite common and are thereby a source of competition. The share of these lessons vary across the country, although it seems to be more common in large towns. The quality of these lessons are much lower compared to lessons offered by schools. This can be seen in statistics on driving exams provided by the Swedish National Road Administration, which show that the percentage failing is 30 percent on average by students taught in schools, while the corresponding number for students taught by non authorised persons is more than 60 percent. Source: Vägverket.

Table 4.—Regression Results

Variable	Probit *FIRMSPOS*	LS[a] *MPRICE*	2SLS[a] *MPRICE*	2SLS[a] *MPRICE*	2SLS[a] *MPRICE*
CONSTANT	7.03	2.45	1.34	1.87	1.34
	(7.11)	(1.71)	(2.35)	(2.42)	(2.38)
MONOPOL		0.311***	0.329***	0.262**	
		(0.111)	(0.121)	(0.105)	
DOUPOL		0.194*	0.196	0.164	
		(0.109)	(0.127)	(0.136)	
TRIOPOL		0.0915	0.105	0.120	
		(0.0960)	(0.0949)	(0.0932)	
QUADROPOL		0.0616	0.0568	0.0721	
		(0.121)	(0.131)	(0.137)	
HERFINDAHL					0.375***
					(0.145)
MPRICENEAR1		0.453***	0.468**	0.380	0.465**
		(0.0720)	(0.199)	(0.231)	(0.193)
MPRICENEAR2		0.267***	0.492**	0.581*	0.508**
		(0.0744)	(0.243)	(0.323)	(0.231)
DIST1	0.0114	0.959 E-02*	0.564 E-02	0.545 E-02	0.505 E-02
	(0.0279)	(0.538 E-02)	(0.546 E-02)	(0.590 E-02)	(0.527 E-02)
DIST1SQR	0.211E-04	-0.103 E-03**	-0.679 E-04	-0.588 E-04	-0.613 E-04
	0.301E-03	(0.470 E-04)	(0.511 E-04)	(0.555 E-04)	(0.470 E-04)
POP1624	0.0813**				
	(0.0366)				
STUDENTS	0.187**				
	(0.0804)				
PINC	4.65**	0.882*	0.781	1.02*	0.673
	(2.07)	(0.510)	(0.524)	(0.527)	(0.459)
WAGE	-1.12*	-0.175	-0.188	-0.258	-0.185
	(0.585)	(0.139)	(0.172)	(0.173)	(0.172)
OFFICEVAL	0.306	0.0334	0.0443	0.0658	0.0451
	(0.255)	(0.0584)	(0.0754)	(0.0787)	(0.0718)
IMR		-0.218	-0.197		-0.208
		(0.167)	(0.189)		(0.178)
Number of observations	250	181	181	181	181
adj. R^2		0.380	0.361	0.334	0.368
Log *L*	-81.3				
Percent correct predictions[b]	83.2				

Standard errors in parenthesis.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.
a Numbers in parenthesis are heteroskedastic consistent standard errors.
b Percent positive observations in sample is 78.4.

Table 5.—Joint Tests on Market Structure Variables (p-values)

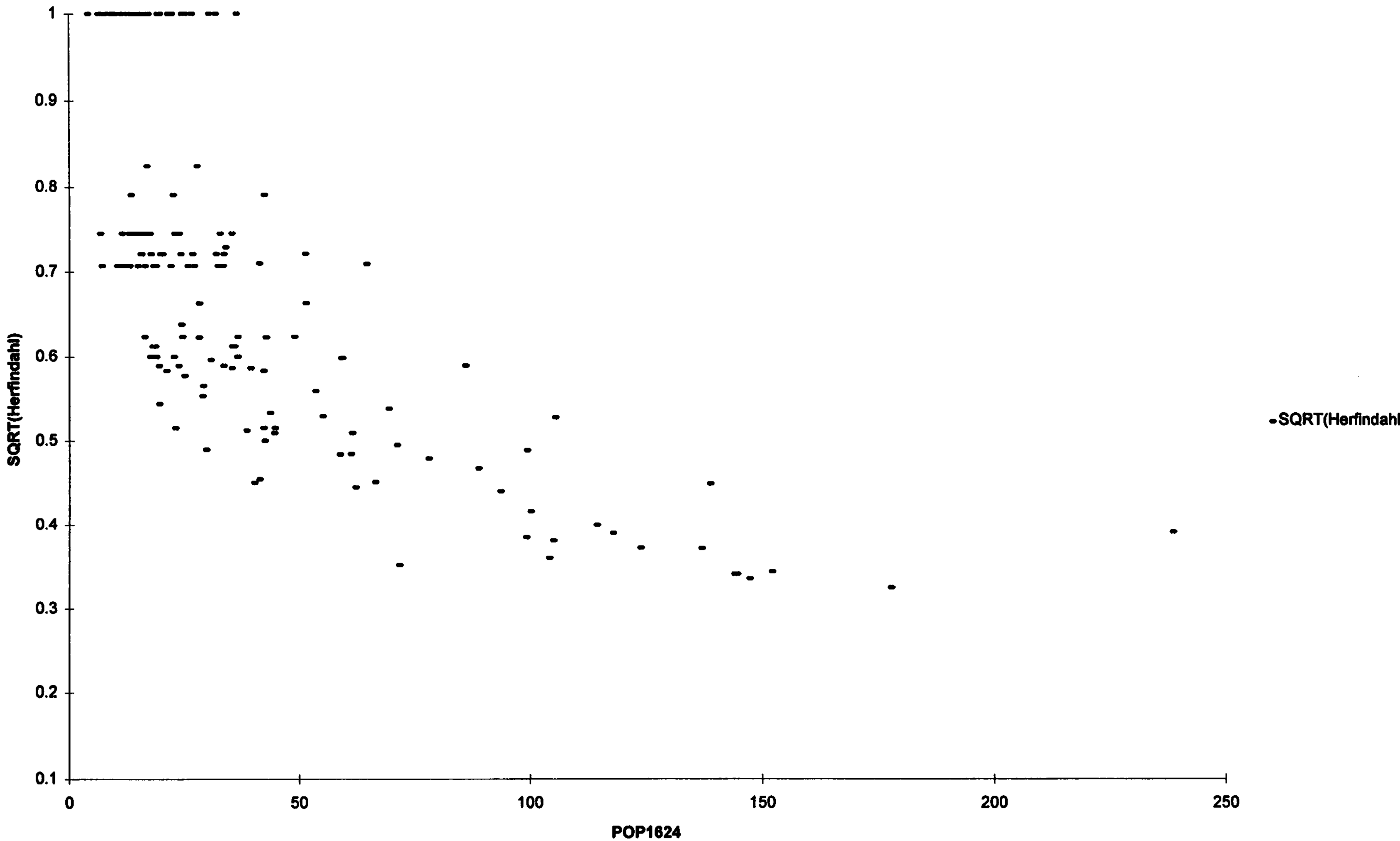
MON = DOUP	0.191	*MON = TRIOP*	0.058	*MON = QUAD*	0.093
DOUP = TRIOP	0.422	*DUOP = QUAD*	0.371	*TRIOP = QUAD*	0.756
MON = DUOP = TRIOP	0.051	*DUOP = TRIOP = QUAD*	0.302	*MON = DUOP = TRIOP = QUAD*	0.032

Table 6.—Regression Results for Subsamples

	2SLS			
Variable	*MPRICE* (FIRMS=1)	*MPRICE* (FIRMS=2)	*MPRICE* (FIRMS=3)	*MPRICE* (FIRMS≥4)
CONSTANT	0.907	0.440	-3.01	-1.19
	(1.54)	(2.22)	(1.35)	(1.60)
HERFINDAHL		-0.171	-0.590	-0.159
		(1.72)	(1.30)	(0.965)
MPRICENEAR1	0.407**	0.498**	0.536***	0.750***
	(0.181)	(0.203)	(0.0882)	(0.187)
MPRICENEAR2	0.113	0.819E-02	0.638***	0.131
	(0.260)	(0.164)	(0.117)	(0.208)
DIST1	0.0227	0.357E-02	0.0129	0.0165
	(0.0170)	(0.0148)	(0.0104)	(0.0179)
DIST1SQR	-0.230E-03	-0.386E-04	-0.263E-03*	-0.287E-03
	0.185E-03	(0.114E-03)	(0.134E-03)	(0.256E-03)
PINC	1.15	2.48**	2.37***	1.05
	(0.783)	(1.10)	(0.912)	(0.939)
OFFICEVAL	0.0627	-0.171	-0.325***	0.103
	(0.0765)	(0.109)	(0.114)	(0.0847)
Number of observations	67	46	32	36
adj. R^2	0.298	0.129	0.774	0.504

Numbers in parenthesis are heteroscedastic consistent standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Figure 1. Concentration and Market Size



Estimating the Number of Firms and Capacity in Small Markets*

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Abstract

Many oligopoly theories predict that there will be a positive correlation between market size and the equilibrium number of firms, and some also imply that competition is more intense in larger markets. We test these predictions with a sample of 535 driving schools in 249 markets. With an ordered Probit, a Tobit, and a Poisson model we estimate the relation between the number of firms, capacity, and market size. We find a strong positive correlation between market size and the number of firms. The results show that the per firm market size is increasing in the number of firms in the market. The market size per capacity unit is smaller in large markets. Since the industry produces a fairly homogenous good, we argue that this is evidence that competition is increasing in market size.

Key words: Industry structure; capacity; entry thresholds; count data; driving schools.

JEL specification: C24; C25; D43; L11; L13; L89; R32.

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1. Introduction

Many oligopoly theories predict that the number of firms is positively correlated with market size. If firms need to cover exogenous sunk costs with variable profits, then the demand in some small markets may be insufficient to support any firm. At some larger market size the demand will be sufficient for one firm, and for still larger markets there may be room for two or more firms. The exact relation between the number of firms (or concentration) and market size will in general depend on the magnitude of sunk costs, and the intensity of competition once firms have entered. Studies which compares concentration in a given industry between countries (≈markets) tend to find that concentration is higher in small countries, Caves (1989 p. 1230-5), but see discussion in Curry and George (1983). Even though the negative relation between market size and concentration can be expected to hold for markets with exogenous sunk cost, a non-monotonic relation may be found in markets with differentiated products and endogenous sunk cost investments in advertising or R&D, Sutton (1991).

An econometric model that relates market size to the number of firms in homogenous goods industries is proposed by Bresnahan and Reiss in a series of papers (1988, 1990, and 1991). They suggest that one can draw inferences on the intensity of competition from the relation between the number of firms in the market and market size. The general idea is that if competition is increasing in the number of firms, then the minimum per firm market size, denoted per firm entry threshold, has to be increasing for firms to cover fixed cost. For example, if the smallest market size necessary to support one firm is equal to S, then the market must be greater than $2S$ to support two firms if competition reduces profits. Bresnahan and Reiss (1991), henceforth BR, find that estimated per firm entry thresholds are increasing in the number of firms for several retail and professional industries in the United States.

Our sample consists of information on 535 driving schools in 249 markets in Sweden. This is a "simple" industry where firms generally produce only one, relatively homogenous product, with the same technology. It is therefore reasonable to compare markets with respect to the number of firms, and to estimate the per firm entry thresholds, as in BR. In addition, the data includes information about firm capacity, measured by the number of cars in each firm. We extend the analysis of BR by estimating per capacity unit entry thresholds, defined as the minimum market size per car. The conjecture is that if competition is more intense, and prices are lower in larger markets, the market size per capacity unit will be smaller in those.

Several econometric techniques are used to estimate entry thresholds. In general, we find that estimated entry thresholds are insensitive to the applied econometric specification. Results show that per firm entry thresholds are increasing in the number of competitors. Together with the finding that per capacity unit entry thresholds are decreasing in the number of capacity units (at least for small markets), we argue that competition intensifies with market size. Since we reached a similar conclusion in Asplund and Sandin (1995a), where we instead used market price as the dependent variable, we argue that information on the distribution of firms across markets, and their size distribution, can be used to predict competition, at least in homogenous goods industries.

2. The data

Our study of the driving school industry consists of 535 firms located in 249 markets, where a market is defined as a municipal. The four largest cities (Stockholm, Gothenburg, Malmoe, and Uppsala) with surrounding suburb municipals are excluded from our sample because they are substantially larger than the rest, which makes it likely that each of them consists of many local markets. Definitions and summary statistics of our variables are presented in Table 1 and Table 2. We use total population of age 16-24, denoted *POP*, as our primary measure of market size, and also a dummy variable for whether the number of students in the gymnasium (≈ high-school) is greater than 50, *STUDENTSDUM*.[1] We focus on the 236 markets where $POP < 100$.[2] Yearly average personal wage income, *PINC* is used to

[1] We use a dummy variable because in some smaller markets there are no gymnasium, and students go to school in a nearby municipality, where it is likely that they take driving lessons. However, the number of students is highly correlated with *POP* for larger markets.

[2] Markets with $POP>100$ may for at least two reasons be different. First, larger municipals usually have a university to which people in the age group of 18-24 move from smaller municipals, where they may already

represent the wealth level in a market. Competition is likely to be more intensive the closer markets are to each other, and we therefore include the distance variables *DIST1* and *DIST2*.

The cost structure in the industry will obviously affect the number of firms and capacity in markets. The principal costs are wages for teachers, the cost of office and parking space, cars, traffic insurance, and gasoline. We expect differences in costs of firms within a market to be small (since production functions are essentially the same), but there may be larger differences across markets. There exists no disaggregated data on wages for driving schools, and we therefore use the monthly wage of skilled employees in the trade sector, *WAGE* as proxy. Table 2 shows that the wage spread across counties is small, which is a common feature in Sweden with a generally compressed wage distribution across firms, industries, and regions. The cost of office and parking space is represented by *OFFICEVAL*. Remaining cost variables are excluded in our regressions because regional differences are small, as indicated by the main interest organisation of the firms.[3]

have taken their driver's licence. Second, large municipals typically have better public transport, which tend to reduce the demand for driving lessons.

[3] See Asplund and Sandin (1995a) for detailed motivations.

Table 1.- Variables Definitions

Variable	Definition
POP	Total population of age 16-24 in the municipal measured in hundreds. Data from 1993 was collected from the Swedish Association of Local Authorities.
STUDENTS, *STUDENTSDUM*	The average number of students in the gymnasium (high school) for the academic years 92/95 in the municipal, as stated by the National Agency for Education. From this we define the dummy variable to be one if there are 50 students or more, and zero otherwise. Source: Skolverket, 1995, Skolan - Jämförelsetal för skolhuvudmän, Skolverkets rapport nr 73, Solna.
PINC	Yearly average personal wage income in 1993 in the municipality, measured in hundreds of thousands of SEK.[4] Data was collected from Statistics Sweden. Source: Statistiska Centralbyrån, 1995, Inkomst- och skattestatistik 1993, Statistiska meddelanden, Be20 SM 9501, table 14.
DIST1, *DIST2*	Distance in kilometres to the nearest and the second nearest market where there exists at least on firm. Distances are measured as straight lines between central towns in each municipal.
WAGE	Average monthly wage measured in thousands of SEK in 1990 of skilled employees in the trade sector. County level data were collected from Statistics Sweden. Source: Statistiska Centralbyrån, 1991, Löner och sysselsättning i den privata sektorn 1990, table 9. Later statistics are not available.
OFFICEVAL	Average assessed value of office space per square metre in 1994, measured in thousands of SEK. This includes office space used not only by driving schools. County level data are provided by Statistics Sweden. Source: Statistiska Centralbyrån, 1995, Rikets Fastigheter 1995 (1), Statistiska meddelanden, Bo 38 SM 9501, table 7a.
FIRMS	Number of driving schools in the municipal. All operating driving schools were located from local phone books (yellow pages) and a member list from the main interest organisation, the Swedish Association of Driving Schools where about 95% of the firms are members. With this information we are confident that the data includes all active firms in the markets. See Asplund and Sandin (1995a) for the definition of a firm.
FCARS	Number of cars in the driving school. This information was collected by telephone interviews with each firm. All firms answered this question.
MCARS	Number of cars used by driving schools in the municipal.

The number of firms in a market is denoted *FIRMS*. We have information on the number of cars in each firm, *FCARS*, which gives the number of cars in the market, *MCARS*. The number of cars is reasonable to use as a measure of capacity, since a car can be used by several teachers working different hours, and because teachers can be hired on a part time

[4] In June 1, 1995, one SEK equalled 0.136 US dollars.

basis to cover high demand periods, whereas cars generally can not.[5] Conversely, in periods with low demand, cars are retained, but the hours worked by the teachers are adjusted. If one could assume that capacity utilisation were relatively constant over time and markets, *MCARS* would measure the quantity produced in a market. Even if this can not hold strictly when capacity is lumpy (as are cars), it provides a rough approximation to the produced quantity.

Table 2.– Sample Characteristics

Variable	mean	stand.dev.	min	max	median	no. of observations
POP	28.0	30.9	2.73	177	15.4	249
STUDENTSDUM	0.651	0.478	0	1	1	249
PINC	1.23	0.0836	1.03	1.53	1.22	249
DIST1	27.1	17.2	6.00	119	21.6	249
DIST2	37.6	22.0	9.60	144	32.4	249
WAGE	13.1	0.270	12.6	14.1	13.1	24
OFFICEVAL	3.03	0.592	2.23	5.81	2.87	24
FIRMS	2.16	2.39	0	13	1	249
MCARS	5.24	6.62	0	33	3	249
FCARS	2.44	1.36	1	9	2	535

Table 3 shows the distribution of the number of firms and average per firm capacity across markets. The span of market structures ranges from zero to thirteen firms, of which 207 out of 249 markets contain three firms or less. It reveals a strong positive correlation between the number of firms and market size.

[5] Cars used in driving schools have specific equipment, e.g. brakes that can be controlled by the teacher.

Table 3.–Distribution of Firms, Capacity and Market Size

FIRMS	*Number of Markets*	*Mean POP*	*Mean FCARS*
0	54	9.741	-
1	71	13.44	1.99
2	49	21.56	2.32
3	33	32.90	2.23
4	13	43.35	2.60
5	9	61.58	2.84
6	4	80.12	2.97
7	4	97.84	2.83
8	3	106.8	2.62
9	2	103.8	2.50
10	3	123.4	2.40
11	2	147.7	2.70
12	0	-	-
13	2	161.9	2.38

Table 3 further indicates that per firm capacity increases with the number of firms in the market for the 233 markets with less than seven firms, but for markets with more than seven firm there is a negative relation. The results from the least squares regression reported below confirms this.

$$FCARS = 1.78 + 0.261 FIRMS - 0.0171 FIRMS^2$$
$$(0.169)\ (0.0679)\qquad (0.00517)$$

Adjusted $R^2 = 0.029$ no. of obs. $= 535$

(Standard errors in parenthesis.)

As discussed below, we have no other explanation to why the average firm size is decreasing in markets with more than six firms, than that the estimates are based on few observations. Figure 1 gives a more complete picture on the size distribution of firms across markets with different number of firms. The important fact to note is that there are only a few large firms, indicating the absence of great economies of scale.

3. Econometric models

As noted in the introduction, Bresnahan and Reiss (1991) argue that if the per firm market size increases with the number of firms, it indicates intensified competition. This concave relation between the number of firms and market size implies an increase in average firm size, which is borne out in Table 3 (at least for markets with fewer than seven firms). More interestingly, it implies a convex relation between produced quantity and market size. That is, if a concave relation between the number of firms and markets size corresponds to lower prices in larger markets, then the per capita demand will be increasing in market size.[6] Now, let one car be the capacity unit, and let the entry threshold per capacity unit be the minimum market size necessary to support each car. As an alternative indicator of intensified competition, we then expect these entry thresholds to be decreasing in market size, since each capacity unit will be used to satisfy a smaller share of demand.

Similar methods are employed to estimate firm and capacity entry threshold levels. We begin by setting up an alternative specification of the econometric model in Bresnahan and Reiss (1991),[7] and suggest three other methods to estimate the relation between the number of firms and market size. In our specification it is assumed that each firm in market i, with N firms, has an unobservable profit function

$$\Pi_{i,N} = \frac{S(X_i^S, \beta^S)}{N} V_N(X_i^V, \alpha^V, \beta^V) - F_N(X_i^F, \alpha^F, \beta^F) + \varepsilon_i. \tag{1}$$

$S(.)$ is the size of the market, which is a function of a vector of demographic variables, X^S. $V_N(.)$ is the per capita variable profit, which is a function of market specific demand characteristics and variable costs, defined by the vector X^V. $F_N(.)$ is the fixed costs function,

[6] A concave relation between the number of firms and market size need not necessarily correspond to lower prices, since it may also be associated with higher fixed costs per firm. For an industry such as driving schools, the latter explanation seems less likely, since there is little advertising, and because the supply of workers, cars, and office space tend to be quite elastic.

[7] The alternative specification is applied, since that used by BR has a different interpretation to the one they suggest, as discussed in footnote 8 below.

determined by a vector of market specific fixed cost, X^F. The α's and β's are parameter vectors to be estimated. The error term ε is assumed to be normally distributed as

$$\varepsilon_i \in N(0,\sigma^2), \qquad E\varepsilon_i X = 0, \qquad \text{and} \qquad E\varepsilon_i\varepsilon_j = 0 \qquad \text{if} \qquad i \neq j. \tag{2}$$

In an equilibrium with N identical firms in a market, the net profit of each these firms is non negative, while the profit would be strictly negative for at least one of $N+1$ firms. Given the assumptions about the error term, the probabilities that there are N firms in market i are

$$\begin{aligned}&\text{Prob}(FIRMS_i = N) = \\ &\begin{cases}\text{Prob}(\Pi_{i,1} < 0) = 1 - \Phi(\overline{\Pi}_{i,1}) & \text{if} \quad N = 0 \\ \text{Prob}(\Pi_{i,N} \geq 0 \quad \text{and} \quad \Pi_{i,N+1} < 0) = \Phi(\overline{\Pi}_{i,N}) - \Phi(\overline{\Pi}_{i,N+1}) & \text{if} \quad 0 < N < \hat{N} \\ \text{Prob}(\Pi_{i,\hat{N}} > 0) = \Phi(\overline{\Pi}_{i,\hat{N}}) & \text{if} \quad \hat{N} \leq N,\end{cases}\end{aligned} \tag{3}$$

where Φ(.) is the cumulative normal distribution function, and $\hat{N}$ is defined below. From the assumptions about the error term, the model is an ordered Probit, and can be estimated by maximum likelihood techniques. The per firm entry threshold for this specification (defined by $\overline{\Pi}_N = 0$) is

$$s_N = \frac{\overline{F}_N}{\overline{V}_N}. \tag{4}$$

The per firm entry threshold will depend upon values of the market specific variables in V_N and F_N. For comparison, these are evaluated at their sample means. We follow BR closely and assume the following functional forms of S, V_N, and F_N

$$S(X_i^S, \beta^S) = POP_i + \beta_1^S STUDENTSDUM_i, \tag{5}$$

$$V_N(X_i^V,\alpha^V,\beta^V)=\alpha_1^V-\sum_{n=2}^{N}\alpha_n^V+\beta_1^V PINC_i+\beta_2^V WAGE_i+ \beta_3^V DIST1_i+\beta_4^V DIST1SQR_i, \tag{6}$$

and

$$F_N(X_i^F,\alpha^F,\beta^F)=\alpha_1^F+\sum_{n=2}^{N}\alpha_n^F+\beta_1^F OFFICEVAL_i. \tag{7}$$

We denote the dependent variable *FIRMS#* and define it as

$$FIRMS\#_i=\begin{cases} FIRMS_i & \text{if} \quad 0\le FIRMS_i<\hat{N} \\ \hat{N} & \text{if} \quad \hat{N}\le FIRMS_i. \end{cases} \tag{8}$$

In our sample we let $\hat{N}=5$, since there are insufficient number of markets with more than five firms in the sample to permit estimation of higher entry thresholds. Hence, all markets with five or more firms are pooled into one category.

The market size is normalised with the population in the age group 16-24 years, *POP*. The coefficient of *STUDENTSDUM* is expected to be positive in that a significant student population will increase market size and thereby gross profits. The coefficient of *PINC* is expected to be positive if it measures the wealth level of the consumers, and if the demand is less elastic in markets where the wealth level is high. *WAGE* is expected to have a negative coefficient, since it reduces the price-cost margin. It is likely that price-cost margins are lower if the distances to the closest markets are short, but the relation is not necessarily linear. Due to multicollinearity problems, we use only the distance to the closest market, *DIST1*, and its square term, *DIST1SQR*. Market specific fixed costs are represented by *OFFICEVAL*, which is expected to have a negative effect on profits, and therefore a positive coefficient. If per firm fixed costs are increasing with the number of competitors, then α_n^F, for $n=2,..,\hat{N}$, are positive. In $V_N(X_i^V,\alpha^V,\beta^V)$, α_n^V for $n=2,..,\hat{N}$, are positive if more firms lead to more intensive competition and lower price-cost margins.[8]

[8] The specification used in BR is

$$\Pi_{i,N}=S(X_i^S,\beta^S)V_N(X_i^V,\alpha^V,\beta^V)-F_N(X_i^F,\alpha^F,\beta^F)+\varepsilon_i$$

The results of the ordered Probit model are compared to a Tobit model and a Poisson model for count data. The Tobit model (see e.g. Amemiya (1985) or Greene (1993)) captures the fact that the dependent variable is non negative. The latent variable $FIRMS^*$ is assumed to be

$$\begin{aligned} FIRMS_i^* = {} & \beta_0 + \beta_1 POP_i + \beta_2 POPSQR_i + \beta_3 STUDENTSDUM_i + \beta_4 PINC_i + \\ & \beta_5 OFFICEVAL_i + \beta_6 WAGE_i + \beta_7 DIST1 + \beta_8 DIST1SQR_i + \varepsilon_i . \end{aligned} \tag{9}$$

In the data we observe

$$FIRMS_i = \begin{cases} FIRMS_i^* & \text{if} \quad FIRMS_i^* > 0 \\ 0 & \text{if} \quad FIRMS_i^* \leq 0. \end{cases} \tag{10}$$

The error term in (9) is allowed to be heteroskedastic[9] and normally distributed as $\varepsilon_i \in N(0,\sigma_i^2)$. We found that a good representation of the heteroskedasticity is obtained by setting

$$\sigma_i = \sigma \mathrm{Exp}(\gamma_1 POP_i + \gamma_2 POPSQR_i + \gamma_3 STUDENTSDUM_i). \tag{11}$$

The square of the population variable, *POPSQR*, is included in (9) to capture the possibly non-linear relation between the number of firms and market size.[10] The drawback of the Tobit model is that it does not use the information that *FIRMS* is a positive, integer variable, i.e. a count.[11] As a second alternative, we therefore apply the most commonly used count data

The *V* function is then the *variable per capita profit of each firm*, which obviously will be decreasing in the number of firms, even if price-cost margins are the same for all market structures. It can therefore not be concluded, as in BR, that if the *V* function is decreasing in the number of firms, it implies lower variable profits *per capita*. However, the two specifications yield very similar estimates of the per firm entry thresholds.

[9] If not accounted for, heteroskedasticity may give inconsistent estimates of the coefficients in the standard Tobit model, although the direction and magnitude of the bias is ambiguous, see Greene (1993 p. 698-700).

[10] We also experimented with other transformations that can give convex or concave functions, but this formulation gave the best fit. However, the other functional forms generally supported a concave relationship between the number of firms and market size, similar to the results shown below.

[11] It has been noted that this may lead to inconsistent estimates of the parameters, but the magnitude of the bias is unknown, see Stapleton and Young (1984). Since our primary concern is not the estimated values of any individual coefficient, but rather the predicted values, we use this model as one among other specifications.

model, the Poisson model. It is reasonable to use this distributional assumption on our sample given the data illustrated in Table 3, where the distribution of firms across markets roughly resembles a Poisson distribution. The probability that there are exactly N firms in market i is

$$\mathrm{Prob}(FIRMS_i = N) = \frac{\mathrm{Exp}(-\lambda_i)\lambda_i^N}{N!} \quad \text{for } N=0,1..,\infty, \tag{12}$$

where we specify λ by

$$\begin{aligned}\lambda_i = \mathrm{Exp}(&\beta_0 + \beta_1 POPSQRT_i + \beta_2 POP_i + \beta_3 STUDENTSDUM_i + \beta_4 PINC_i + \\ &\beta_5 WAGE_i + \beta_6 OFFICEVAL_i + \beta_7 DIST1 + \beta_8 DIST1SQR_i).\end{aligned} \tag{13}$$

Note that we include the square root of *POP*, *POPSQRT* to allow for a concave relation between the number of firms and market size.[12] Apart from the specific functional form imposed on the distribution, a well known problem with the Poisson model is the implicit assumption that λ is both the conditional variance and the conditional mean. If this restriction is violated, the coefficients are consistent but their standard errors are inconsistent (see e.g. Cameron and Trivedi (1990)). As a final check of our results, we make a regression model of (13) by substituting *FIRMS* for λ and adding an error term. This model is estimated by non-linear least squares (NLS), ignoring the information that the dependent variable is a positive integer.

To estimate market capacity we only use specifications (9) and (12), where we substitute *MCARS* for *FIRMS*, and use the same explanatory variables. The ordered Probit model described above is not directly applicable to the problem of estimating the market capacity.

Before turning to the results there are a few general points to note when we compare the models. First, if the specification of the ordered Probit model is correct, it provides valuable information about structural parameters in the profit function. If not, then the parameters of

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Moreover, it is in some instances better to have an inconsistent estimator with small variance, than a consistent estimator with large variance, see e.g. Greene (1993 p. 94-95).

[12] The motivation for not using *POP* together with *POPSQR* is that markets with many firms get very large weights, since λ is defined by $\lambda = \mathrm{Exp}(\beta X)$.

the misspecified model have no such interpretation. The other models do not run this risk, since these do not attempt to estimate a profit function, but merely to describe the relation between the number of firms and the exogenous variables. For example, in the ordered Probit specification it is implicitly assumed that the profit function for all firms *within* a market is the same, but that it differs *between* markets. [13] This is a restrictive assumption, which assumes away the possibility that firms within a market may have different profit functions. However, for an industry such as driving schools it may not be unreasonable, since firms are of roughly the same size, use the same technology, and because the product is relatively homogenous.[14] Second, the ordered Probit model is associated with a considerable information loss, since estimation required pooling of markets with five or more firms into one category. Finally, the number of firms in different markets is not only a ranking order, but also a count, that is, two firms are not only more than one, but it is exactly one more. The other models use this information and do not pool the markets into different groups, but the Tobit model may give inconsistent parameter estimates.[15]

4. Results

The results reported in Table 4 are for the subset of 236 markets with *POP*<100, (the results for the full sample (249 markets) are shown in the Appendix). In the ordered Probit model, most of the coefficients have the expected signs. Higher wage levels and office values decrease profits, while higher income levels, and the distance to the closest markets increase profits. However, only a few of them are individually significant, which is similar to the findings in BR. Likelihood ratio tests of joint restrictions on the cost and distance variables are

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[13] In Bresnahan and Reiss (1990), more elaborate specifications were applied to markets with one or two firms, where profit functions could vary across firms in a market. However, these become impossible to estimate when there are more than four firms in the market, since they require integration of multidimensional normal distributions.

[14] However, to use this as a general assumption seems too strong, since the size distribution of firms tend to be skewed (see e.g. Schmalensee (1989 p. 994)), and thus firms may have different profit functions even if they operate within the same market.

[15] See Cameron and Trivedi (1986) for more comparisons between count data models, least squares estimators, and ordered Probit models.

shown in Table 5. It is not possible to reject (the critical value at the 5% level is $\chi^2 = 5.99$) the hypothesis that costs differences have no effect on profits. Likewise, we can not reject the hypothesis that the profit is independent of the distance to the closest market. The α^F's are positive as expected, which suggests that fixed cost increase with the number of competitors. However, α_2^V is negative and significant, which suggests that duopoly firms have higher variable per capita profits than monopolies. Moreover, α_3^V and α_5^V, are negative (although insignificant). All these negative coefficients seem unreasonable, in particular when set in relation to the results in Asplund and Sandin (1995a), where estimated prices in duopoly markets were lower than in monopoly markets. The most obvious explanation is that the profit function (1) is too restrictive, such that there is little meaning in interpreting the coefficients as parameters in a profit function. Despite this question of interpretation, it is interesting to study the estimated per firm entry threshold levels. Before that we look at the alternative estimators.

Results reported for the Tobit model in Table 4 are robust to heteroskedasticity, which was present in a standard Tobit model. The most important finding is that the coefficient of *POP* is positive whereas *POPSQR* is negative, which implies a concave relation between the number of firms and market size. Both measures of costs, *WAGE* and *OFFICEVAL*, are negative as expected, but they are not jointly significant at the 5% level, as seen in Table 5. This is also true for the distance measures. As in the ordered Probit, markets with high average personal income tend to fewer markets with no firms, but the effect is not significant.

Finally, the signs of the comparable coefficients in the Poisson and NLS models are similar to the ordered Probit and the Tobit model. As noted in Section 3, a well known problem with the Poisson model is the implicit assumption that the conditional mean and variance are equal, something that is often inconsistent with count data which usually display overdispersion. We tested for mean-variance equality using methods of Cameron and Trivedi (1990) and found *under*dispersion. Therefore our parameter estimates may be consistent, but their tests statistics are not, and we therefore refrain from discussing their significance levels.[16]

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[16] We have also estimated an extended Poisson model (WZ-Poisson) of Mullahy (1986), which allows for a specific form of underdispersion. However, the specified form of underdispersion did not fit our data well, and the model was highly sensitive to specification, why we report the original Poisson model. Results from the WZ-Poisson model are available upon request.

A point worth commenting on are the low significance of the cost variables, which potentially could be explained by the fact that these are measured at county level. The bias this may cause is probably of minor importance for the wage variable, since wage differences generally are small across regions in Sweden, as indicated in Table 2. However, we had expected to find *OFFICEVAL* more significant, since it has greater variation across regions.

Table 6 shows the estimated per firm entry thresholds. The market size necessary to support N firms in the Tobit model is defined by the value of *POP* that satisfies $FIRMS^{*}=N$, and for the Poisson and NLS by $\lambda=N$ and $FIRMS=N$ respectively, for $N=1,..,5$. The per firm entry threshold is obtained by dividing this value of *POP* with N. For all thresholds, the other variables are evaluated at their sample means, and for $STUDENTSDUM=1$. By inspection, the general conclusion must be that the different econometric techniques give similar estimates of the threshold values. The differences between the models are small, e.g. for monopolies (duopolies) the implied per firm entry threshold varies between 895 and 1150 (1120 and 1200) people in the age group of 16 to 24 years old. It is interesting to note that all specifications (with the exception of s_5 for the ordered Probit and s_1 in the Tobit) support the hypothesis that the per firm minimum market size is increasing with the number of firms.

The results for the regressions with *MCARS* as the dependent variable are shown in Table 7. As in Table 4, the most significant variables are those measuring market size, while the remaining variables generally are insignificant, and some even have a perverse sign. Table 8 shows the estimated per capacity unit entry thresholds. As expected, the market size of each capacity unit is decreasing in market size, at least for eight or fewer capacity units. For more capacity units the market size increases in the Poisson model, which is an effect of the non-monotonic relation found in Table 3. Up to this level, each capacity unit satisfies a smaller share of the consumer demand. This finding provides complementary evidence for that competition is increasing in market size. It is interesting to note that the capacity unit entry threshold for the first car in the Poisson (Tobit) model is slightly (much) lower than the monopoly entry threshold. One interpretation is that per firm entry thresholds for these models are for the average firm, which may not be the smallest possible firm. For example, the average monopoly has 1.99 cars, but there are several monopolies with only one car, and these may have an opportunity to enter at markets sizes smaller than those estimated.

The different econometric specifications gave broadly similar predicted values of entry thresholds for firms and capacity. As noted in section 3 all specifications have drawbacks, and the questions about model selection naturally arise. We weakly prefer the Poisson model to the alternatives. This is motivated by the count data nature of the dependent variables, which also had distributions that resembled the Poisson, and by the computational simplicity of the model. The ordered Probit model seemed to impose too much structure on our data, which gave unreasonable results. However, we still believe that it can work well on another sample.

5. Concluding remarks

For industries with homogenous goods and absence of large barriers to entry, it is not unreasonable to assume that the relation between market size and the number of firms provides information about how fast competition is increasing with the number of firms. When entry is relatively easy, new firms will establish as the market expands, and if this leads to intensified competition with lower profits, the per firm market size needs to be larger in order for firms to cover fixed costs. This study showed that per firm entry threshold is increasing in the number of firms, which is similar to the results in Bresnahan and Reiss (1991). This finding was remarkably robust to all our econometric specifications. In addition we showed that capacity unit entry thresholds are decreasing in market size. Together these results indicate that competition is more intense in larger markets. This conclusion is broadly consistent with the findings in Asplund and Sandin (1995a), where we used price information from firms in this industry, and showed that prices were significantly decreasing in the number of firms in the market.

Although the method of estimating the relation between market size and the number of firms, or capacity, is useful for homogeneous goods industries, it is less clear that it can be used for industries with differentiated products. For example, Sutton (1991) shows that the relation between market size and the number of firms (or more correctly - concentration) could be non-monotonic due to endogenous investments in R&D or advertising. Extending the analysis to deal with differentiated products, and to account for the fact that firms within a market can have significantly varying profit functions, seem to be important questions to address in future research.

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Appendix

Table A1.–Regression Results with *FIRMS* as the Dependent Variable (249 markets)

	Ordered Probit	Tobit[a]	Poisson	NLS[b]
Variable	*FIRMS#*	*FIRMS*	*FIRMS*	*FIRMS*
CONSTANT		1.64	-0.678	-0.576
		(4.52)	(4.54)	(1.59)
POPSQRT			0.498***	0.364***
			(0.160)	(0.0731)
POP	≡1.00	0.0745***	-0.0164*	-0.828 E-02**
		(0.0113)	(0.995 E-02)	(0.410 E-02)
POPSQR		-0.461 E-04		
		(0.777 E-04)		
STUDENTSDUM	4.28*	0.571***	0.397*	0.511***
	(2.46)	(0.182)	(0.218)	(0.135)
PINC	0.0964	2.46**	0.571	0.485
	(0.0947)	(1.18)	(1.18)	(0.444)
OFFICEVAL	0.168	-0.133	-0.0758	-0.112**
	(0.160)	(0.163)	(0.158)	(0.0556)
WAGE	-0.0265	-0.365	-0.120	-0.0778
	(0.0303)	(0.381)	(0.383)	(0.113)
DIST1	0.191E-02	0.814 E-02	0.228 E-02	-0.857 E-03
	(0.133 E-02)	(0.0133)	(0.0120)	(0.426 E-02)
DIST1SQR	-0.213 E-04	-0.864 E-04	-0.536 E-04	-0.432 E-04
	(0.139 E-05)	(0.131 E-03)	(0.125 E-03)	(0.430 E-04)
α_1^V	0.303			
	(0.393)			
α_2^V	-0.0938***			
	(0.0295)			
α_3^V	-0.0333			
	(0.0326)			
α_4^V	0.0133			
	(0.0420)			
α_5^V	-0.0511			
	(0.0445)			
α_1^F	0.432			
	(0.615)			
α_2^F	1.22***			
	(0.358)			
α_3^F	0.590*			
	(0.331)			
α_4^F	0.325			
	(0.434)			
α_5^F	0.704			
	(0.516)			
σ		0.982***		
		(0.160)		
Number of obs.	249	249	249	249
Log *L*	-271.2	-344.8	-340.8	
adjR^2				0.84

Standard errors in parenthesis.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.
a In (11) $\gamma_1 = 0.0152$ (0.639 E-02), $\gamma_2 = -0.706$ E-04 (0.451 E-04), and $\gamma_3 = -0.284$ (0.173).
b Heteroskedastic consistent standard errors.

Table 4.–Regression Results with *FIRMS* as the Dependent Variable (236 markets)

Variable	Ordered Probit *FIRMS#*	Tobit[a] *FIRMS*	Poisson *FIRMS*	NLS[b] *FIRMS*
CONSTANT		1.50	-1.73	-1.93
		(4.57)	(5.06)	(1.77)
POPSQRT			0.770***	0.630***
			(0.275)	(0.104)
POP	≡1.00	0.106***	-0.0394*	-0.0289***
		(0.0176)	(0.0209)	(0.745 E-02)
POPSQR		-0.466 E-03**		
		(0.189 E-03)		
STUDENTSDUM	4.99*	0.449**	0.297	0.366***
	(2.72)	(0.190)	(0.235)	(0.139)
PINC	0.103	2.47**	0.807	0.766
	(0.0929)	(1.19)	(1.22)	(0.490)
OFFICEVAL	0.135	-0.122	-0.0834	-0.111*
	(0.163)	(0.162)	(0.174)	(0.0601)
WAGE	-0.0141	-0.387	-0.115	-0.0608
	(0.0313)	(0.380)	(0.409)	(0.129)
DIST1	0.132 E-02	0.0133	0.614 E-02	0.641 E-02
	(0.131 E-02)	(0.0131)	(0.0127)	(0.513 E-02)
DIST1SQR	-0.162 E-04	-0.115 E-03	-0.751 E-04	-0.917 E-04*
	(0.136 E-04)	(0.128 E-03)	(0.127 E-03)	(0.525 E-04)
α_1^V	0.136			
	(0.401)			
α_2^V	-0.0928***			
	(0.0285)			
α_3^V	-0.0344			
	(0.0321)			
α_4^V	0.0128			
	(0.0428)			
α_5^V	-0.183*			
	(0.0945)			
α_1^F	0.469			
	(0.614)			
α_2^F	1.25***			
	(0.353)			
α_3^F	0.610*			
	(0.336)			
α_4^F	0.333			
	(0.448)			
α_5^F	1.98**			
	(0.956)			
σ		0.964***		
		(0.187)		
Number of obs.	236	236	236	236
Log *L*	-266.8	-316.4	-310.5	
adjR^2				0.69

Standard errors in parenthesis.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.
[a] In (11) $\gamma_1 = 0.0169$ (0.0122), $\gamma_2 = -0.102$ E-03 (0.130 E-03), and $\gamma_3 = -0.298$ E-03 (0.183).
[b] Heteroskedastic consistent standard errors.

Table 5.–Likelihood Ratio Tests

Restriction	Ordered Probit	Tobit	Poisson
DIST1=DIST1SQR=0	5.63	0.58	0.92
WAGE=OFFICEVAL=0	2.29	4.01	2.00

Table 6.–Estimates of Per Firm Entry Thresholds

Per firm entry threshold	Ordered Probit	Tobit	Poisson	NLS
s_1	8.95	11.5	11.2	9.18
s_2	11.2	11.3	12.0	11.2
s_3	12.2	11.8	12.4	12.0
s_4	14.5	12.6	13.3	12.8
s_5	12.8	14.1	16.4	14.0

Table 7.–Regression Results with *MCARS* as the Dependent Variable

Variable	Tobit[a] *MCARS*	Poisson *MCARS*
CONSTANT	10.3	-0.338
	(10.1)	(1.59)
POPSQRT		1.08***
		(0.125)
POP	0.330***	-0.0564***
	(0.0477)	(0.987 E-02)
POPSQR	-0.150 E-02***	
	(0.468 E-03)	
STUDENTSDUM	0.476	0.345***
	(0.424)	(0.110)
PINC	3.32	-0.195
	(3.00)	(0.441)
OFFICEVAL	0.0495	0.840 E-02
	(0.363)	(0.0556)
WAGE	-1.34*	-0.165
	(0.789)	(0.120)
DIST1	0.0103	-0.101E-02
	(0.0342)	(0.547 E-02)
DIST1SQR	0.118 E-03	0.485 E-05
	(0.351 E-03)	(0.600 E-04)
σ	1.39***	
	(0.242)	
Number of obs.	236	236
Log *L*	-477.1	-474.7

Standard errors in parenthesis.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

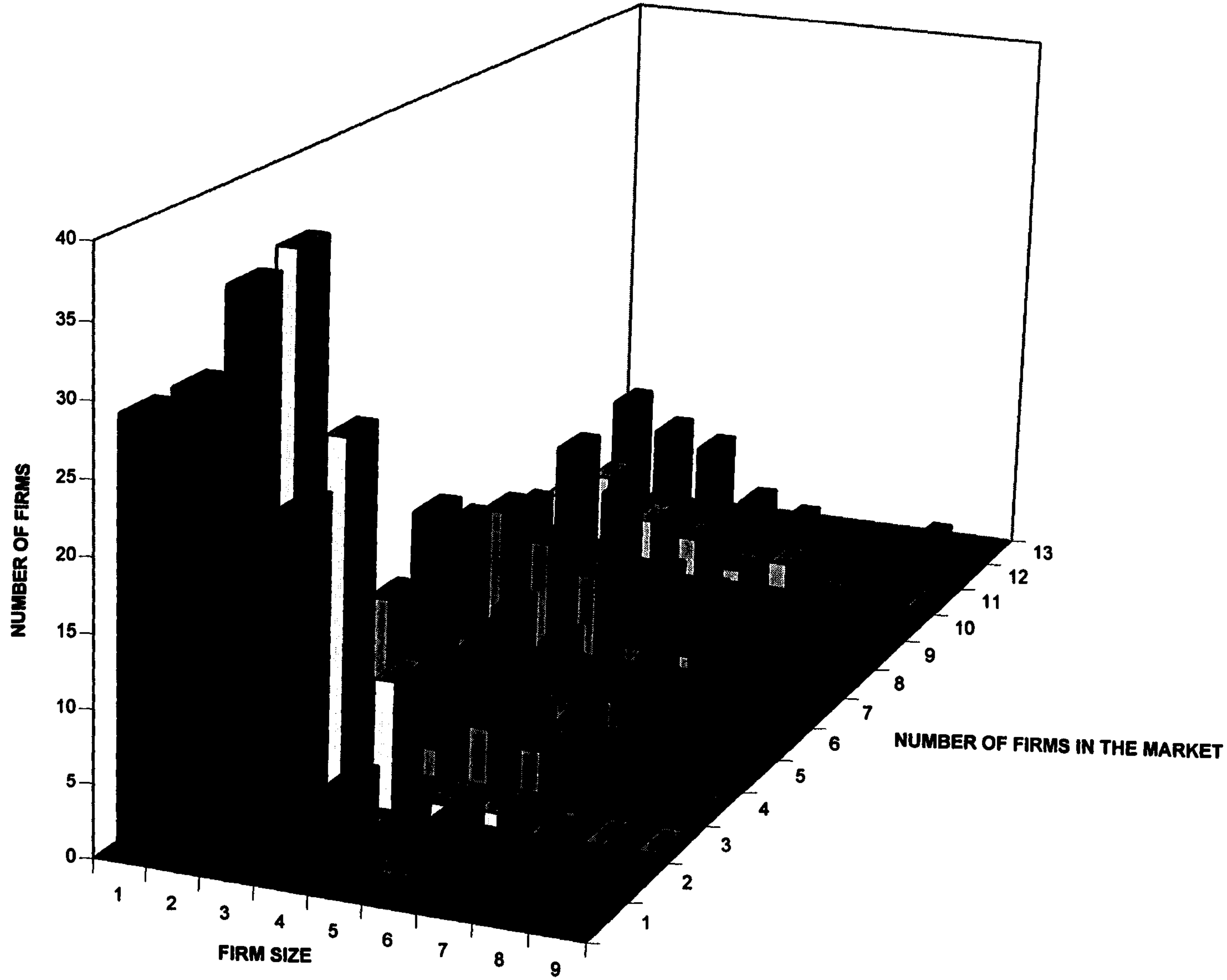
* Significant at the 10 percent level.

a $\gamma_1 = 0.0477$ (0.0136), $\gamma_2 = -0.407$ E-03 (0.156 E-03), and $\gamma_3 = -0.211$ (0.148).

Table 8.–Estimates of Per Capacity Unit Entry Threshold Levels

Per capacity unit entry threshold	Tobit	Poisson
s_1	6.41	9.30
s_2	6.00	6.65
s_3	5.55	5.60
s_4	5.20	5.12
s_5	4.94	4.86
s_6	4.75	4.71
s_7	4.58	4.62
s_8	4.46	4.61
s_9	4.37	4.62
s_{10}	4.31	4.66

Figure 1. - Size Distribution of Firms



The Survival of New Products*

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Abstract

We study the product turnover in an industry and, in particular, the survival of new products. The data set consists of monthly sales of *all* products sold in the Swedish beer market over the time period of 1989-1995. The death rates of newly introduced products are high - out of 199 products an estimated 25 percent were withdrawn within 18 months and 50 percent within approximately 48 months. We use parametric duration models with time varying covariates to estimate survival functions. Our results show that products with low and decreasing market shares have higher hazard rates. Moreover, the hazard rates are dependent on the characteristics of the producer. Products from firms with a large number of other products, and (to a lesser extent) the largest market shares are more likely to be withdrawn.

Keywords: Product survival; multiproduct firms; duration models; beer market.

JEL specification: C41; L13; L66.

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1. Introduction

A common phenomenon in many consumer goods industries is that firms frequently add and subtract from their list of products. At the same time, some other products keep dominant positions for very long periods, several decades in many cases. Although there is a large literature on market shares and lives of the leading or pioneering products in various industries such as Budweiser and Kellogg's Corn Flakes in the U.S. (see for example Golder and Tellis (1993), and Sutton (1991)), few have studied the life of the average product. To provide evidence on this we therefore study the survival of new products and firms' decisions to withdraw products.[1] This is made possible with a new data set containing monthly sales statistics and characteristics on *all* products in the Swedish market for beer during the period 1989-1995. Our results provide insights into markets with horizontal product differentiation where product turnover is typically high and where market shares of most products are small.

The success of products and brands form the basis for firm performance. If a product wins consumer approval, its market share will increase and generate profits to the firm. On the other hand, if its popularity declines the firm may experience a serious cash flow shortage, which may possibly lead to product displacement or even firm exit.[2] When firms invest in a new product or variety there are definitely some stochastic factors that are exogenous to the firm, such as changes in taste and unforseeable introductions of competing products, which determine the fate of the product. While there exist several models of product entry, we are aware of no theoretical model that study the introduction *and* displacement of products in a stochastic setting. The models on brand proliferation pioneered by Schmalensee (1978) argue that incumbent firms introduce new products to deter entry by other firms, but do not discuss the exit process. Raubitschek (1988) on the other hand, suggest that the introduction of new products is a search process for potential "jackpots", i.e. products that will be successful in the

[1] In industries where technological progress is important, new vintages will replace existing ones, so called product life cycles (see e.g. Klepper (1996)). This is certainly important in many industries, but we choose to abstract from these additional complications by looking at a market where there is very little technological progress.

[2] This will in turn affect the variety of products in the market, and the discussion whether the market provides too much or too little variety compared to what would be socially optimal. For references, see e.g. Tirole (1988, Chapter 7) and Beath and Katsoulacos (1991).

future. This is certainly a plausible mechanism for the large number of introductions in consumer goods industries, but the model is not rich enough to deal with learning over multiple periods and the displacement decision.

Even though we do not have a formal theoretical model to use as a framework for the econometric specification, we believe that the following story captures the essence of firms' decision to withdraw products: A firm introduces a new product without knowing the demand for it, as in Raubitscheck (1988). After some time it will become clearer if consumers prefer the new product to the existing varieties, and what the costs are of keeping it in the market. The future demand for the product can (imperfectly) be predicted by its past and current market shares. The costs are on the production side, and may also come from the fact that the product steals sales from the firm's other products in the market (the replacement effect). Over time firms will update their beliefs about all these factors and decide on whether the product should be withdrawn or not. It is then more likely that product withdrawal occurs as a result of low and decreasing sales, rather than the opposite. As an illustration, Figure 1 shows the development of market shares of two products in our sample that were introduced and subsequently displaced when their market shares became too small. This story is analogous to stochastic models of firm entry and exit, of which a well known example is Jovanovic (1982), where firms enter a market without perfectly knowing their costs.[3]

Our main results are the following: First, we find that firms introduce many new products, but that their exit rates are high as well. We estimate that 50 percent of the products have disappeared within four years. This is similar to the results referred to in Raubitscheck (1988), where 60 percent of the newly introduced breakfast cereal products exited within four years. Second, the probability that a product is withdrawn is decreasing in its current market share. We also show that the trend in sales is an important determinant of survival, where products with decreasing sales tend to be withdrawn. Third, we find that products introduced

[3] In that model, a firm whose true costs are high is more likely to receive unfavourable signals about its costs, through low profits, and if (after some time) costs are learned to be very high, the firm's best option may be to leave the market. Hopenhayn (1992) presents a similar model. A more elaborate model is presented by Ericson and Pakes (1995) where firms search for and invest in new opportunities, which also lead to industry dynamics with entry and exit. The earlier literature on the growth of firms is more directed towards explaining the patterns of firm growth by constraints on demand, finance, and managerial capacity (see references in Hay and Morris (1991, 327-374).

by firms with many other competing products and (to a lesser extent) the largest firms have higher hazard rates. We argue that this may be explained by the replacement effect. It is noteworthy that many of our results have counterparts in empirical studies of firm survival, recently surveyed by Geroski (1995).[4]

The paper is organised as follows. Section 2 discusses the econometric specification, a parametric duration model with time varying covariates. Section 3 provides a general description of the market, while section 4 discusses the data collected from the Swedish alcohol retail monopoly. Section 5 gives the econometric results and some numerical simulations, and the last section some concluding remarks.

2. Econometric specification

The econometric model that incorporates the features described in the introduction is a duration model.[5] The duration (or spell) - in our case the number of periods that a product survives in the market - is denoted t and is an observation of the random variable T. Some spells are not completed, i.e. at the time of observation the product is still in the market (right censoring), while for completed spells we know that the product survived for t periods. The random variable T is assumed to have a density function $f(t)$ and a distribution function $F(t)$ which defines the survival function $S(t)=Prob(T\geq t)=1-F(t)$. The survival function shows the probability that the product survives at least t periods. From the survival function one can the define the hazard function $h(t)=f(t)/S(t)$, which shows the rate at which a spell is completed after duration t conditional on that it has lasted until at least t. In this formulation the hazard rate is simply a function of time and can therefore be useful as a description of the data in our sample. However, in our setting, with frequently changing conditions, it is more reasonable to

[4] Cross sectional studies of industries find a significant amount of firm entry, but that survival rates are low for new firms, as in Mata and Portugal (1994) and Wagner (1994). The survival of a firm is highly dependent upon its current size and age, where large old firms have lower failure rates (Dunne and Hughes (1994) and Mata, Portugal and Guimarães (1995)). Mahmood (1995) and Mata, Portugal and Guimarães (1995) find that the entrant's characteristics matter for the prospect of survival.
[5] See e.g. Amemiya (1985), Greene (1995), Kiefer (1988), and Lancaster (1990), who also list numerous of other applications.

assume that the hazard rate is a function of variables that change over periods. The explanatory variables for product i at time j are denoted $\mathbf{x}_{i,j}$. Define the variable λ as

$$\lambda = \exp(-\beta \mathbf{x}_{i,j}). \quad (1)$$

We use the exponential distribution to model the hazard function in period j,

$$h^{E}(j|\mathbf{x}_{i,j}) = \lambda. \quad (2)$$

With time varying covariates and an exponential hazard function, λ gives the constant hazard rate conditional on the values of the covariates.

There is a risk associated with using parametric models in that one has to specify the hazard function. If data does not nicely reveal it, an erroneous model may yield unreliable and inefficient estimates, and possibly generate inappropriately shaped hazard functions, as pointed out in Heckman and Singer (1984). To avoid this problem, the Cox Proportional Hazard Model can be used.[6] The hazard function is then defined as

$$h^{CP}(j) = h_0(j)\exp(\gamma \mathbf{x}_i), \quad (3)$$

where $h_0(j)$ is the baseline hazard rate equal for all products and $\mathbf{x}_i$ are covariates that shift the hazard function proportionally, but are constant throughout the product's life. The model allows estimation of γ without the simultaneous estimation of $h_0(j)$, which is required for parametric models.[7] A problem with this model, however, is that it imposes a strong form of proportionality on the hazard function.

A general problem in the data set (as well as in most other data sets with duration data) is the existence of left censored observations, i.e. some products have already been present in

[6] This is the econometric specification most commonly used in studies of firm survival, e.g. Audretsch and Mahmood (1995) and Mata, Portugal, and Guimarães (1995).

[7] Due to software limitations in LIMDEP we have not yet been able to estimate the Cox Proportional Hazard Model with time varying covariates. In future versions of the paper we intend to include this regression using another software package.

the market for some time before our first date of observation. Without time varying covariates it is possible to account for this using the modifications of the likelihood function described in Amemiya (1985, pp 447-8). However, we are aware of no methods to treat left censored observations with time varying covariates, and we therefore restrict our analysis to new products, which have entered after our first time of observation.

3. The market

There are some institutional factors that make the Swedish beer market particularly attractive for a study of product survival. Before we describe the data it is therefore necessary to make a brief summary of the market and the different segments for beer. In Sweden, there are three classes of beer based on the alcohol content. Class I (low alcohol beer) and Class II (ordinary beer) contain less than 2.25% and 3.5% alcohol by volume (henceforth abv) respectively and are sold in every grocery store. We focus on Class III (medium strong and strong beer) which contain more than 3.5% abv and for which the only retailer is the state owned Systembolaget AB. Our choice of segment is partly motivated by the detailed statistics that are available, but also by the fact that product differentiation and turnover is far greater than in the other segments. Alcohol content not only determines the retail channels and price, but also the restrictions on advertising. Since 1978 advertising is allowed for beer in Class I and prohibited for the other two.[8]

In 1994 the retail monopoly had about 375 stores and at an additional 551 places (mostly on the country side) it was possible to order for delivery the following day. All products are, in principle, available at all outlets at the same price. However, due to space limitations each store only stocks the products for which there is regular demand (usually more than half of the total number of products), but any other product can be ordered at no extra cost. The

[8] The advertising intensity is, by international standards, low in the industry. A rough calculation for 1994 based on a total value of the beer market in Sweden of more than ten billion SEK (Source: Swedish Brewer's Association Annual Report 1994) and advertising by all breweries in all media of about one hundred million SEK (Source: IMU Testologen) gives an advertising to sales ratio less than one percent.

regulation of the retail monopoly forces it to treat all products in a non-discriminatory fashion. The retail price is set through a cost-plus pricing rule, where the mark-up factor is independent of sales volume.[9] This implies that there are no fixed costs for the firms to sell their items through the retail monopoly that could have put small firms at a disadvantage. Of course there may be other fixed costs involved in selling a product that differ across firms and which influence the decision to introduce or displace a product, but the important feature is that all are treated symmetrically at the retail level.

To get a detailed picture of the market for beer it is necessary to divide it into sub segments. According to people involved in the industry beers can be categorised as lager, dark lager, ale, porter/stout, weiss bier, seasonal beer, lambics, and special beers.[10] In the reported regressions only the segments lager and dark lager are used. This is motivated by the fact that the other segments only had a few brands and very low sales until 1992 and have not experienced any serious shakeout yet. Figure 2a and 2b show aggregate monthly sales and the number of products over the period of 1989-1995 for lager and dark lager respectively. Annual sales in the lager segment is roughly constant over the period 1989-1995, whereas total sales of dark lager has declined somewhat. The number of products in each segment, however, has grown steadily, especially in the lager segment.

The advantage with a retail monopoly for our study is that *all* products sold in the market are included in the data set. Hence, it is possible to avoid the serious sample selection bias that would arise if we only had data on products with a large sales volume. The symmetric treatment of large and small products at the retail level also helps to give an unusually clean case to study. The government controlled retail monopoly and the fact that alcohol taxes amount to significant sums of money guarantee a good quality of the data.

[9] Retail price=markup factor*(price paid to the brewer+volume*alcohol tax)*(1+VAT). As of April 1996: VAT = 0.25, alcohol tax = 2.33*abv, and markup factor = 1.18.

[10] Of course other classifications are possible, e.g. based on price, but it is reasonable as a first attempt to estimate survival in the market.

4. The data

We use a new data set compiled from two sources that enable us to study the survival of the average product. The first is sales information obtained directly from the retail monopoly. The data is monthly sold quantity and revenue for each product appearing in price lists from 1989-1995. Additional data is available for the years 1974 to 1985, but the frequency is annual.[11] The second source of data are price lists from the retail monopoly. These have been published in different months during the time period, but with four to six issues yearly and at a somewhat higher frequency in 1994 and 1995. With price lists and sales figures we are able to determine the time of entry and exit of a product, which then provide us with the number of periods that the product is observed in the market, denoted *NPERIOD*.

Descriptive statistics shown in Table 1 apply to products introduced during the period January 1989 to November 1995. The indicator variable *STATUS* is equal to one if the spell is completed and zero if right censored. During the period, 64 out of 199 introduced products where withdrawn from the market. The increase in the number of new products introduced in the market has been high during the end of the sample period, whence the exit rate is probably higher than revealed by above figures.[12]

Several explanatory variables that intuitively may affect survival and hazard rates are included in our regressions. Informally, in a single period setting with no uncertainty a firm keeps a product *i* on the market if

revenue from product i - lost revenue from the producer's other products - production costs of product i > 0. (A)

In a stochastic, multiperiod setting one would need to solve the firm's optimal control problem, and the left hand side of the inequality in (A) can then be viewed as the maximum

[11] Unfortunately the data set is not yet complete for 1986-1988, but in spring 1997 the data will become available and statistics will then have monthly frequency.

[12] We are constantly receiving new monthly data on sales and the number of products in the market, which will allow us to revise our results in future versions of the paper.

expected net present value at the time. Even though it is obviously impossible for us to know all the variables that are relevant in this problem (expected cost changes, cross price elasticities, strategic considerations etc.) our econometric specification attempts to capture some of the expectations of the future. The inequality in (A) is more likely to be violated if expected revenue is low, and it is reasonable that the current revenue contains information about the future. To avoid the problem with seasonal variation in sales our econometric specification uses monthly product market shares in the segment based on revenue, *PMSHARE*, which is appropriate during the period 1989-95 when aggregate annual sales were roughly constant.[13] Another way to capture the expectations about future revenue is to include the trend in revenue. It is more likely that a firm withdraws a product that has had a downward trend and we therefore define the dummy variable *PMSHAREDECR*, which is equal to one if the market share has decreased three months in a row. In the regressions where lager and dark lager are pooled we use the variable *PPROJREV*, which is the projected annual sale for each product, constructed as the product's current market share times the annual sales by all products in the segment. This variable was used instead of *PMSHARE* to take into account that the size of the two markets differ, hence, to correct for the fact that the value of a given market share is different in a large market and a small market. The second term in (A) shows the effect of lost sales of the firm's other products by keeping product i on the market (the replacement effect). If all products are competing symmetrically, then this loss is greater for a firm with a high market share (for single product firms this term is obviously zero). We therefore define the monthly firm market share, *FMSHARE* from adding together the firm's product market shares in the segment. In the regressions including both segments the corresponding variable is denoted *FPROJREV* and is defined as the current firm market share times the annual revenue in the segment. These variables may also capture other differences in strategies between small and large firms. For example, small firms may consider it to be a relatively more important decision to replace a product that has low current sales. It could also be an endogenous choice of large firms to introduce products whose expected payoff is high

[13] If there was a trend in aggregate sales then the value of a given market share would differ over the sample period.

but have a large risk of failure since they are better able to pool the risks.[14] As an alternative way of testing the producer size effect, the dummy variable *MARKLEAD1* determines if the product is produced by the market leader (Pripps) and *MARKLEAD23* if it is produced by the second or third largest firm (Falcon or Spendrups).[15] We also include the number of products offered by the firm, *FNPROD*, to distinguish between firms with the same total market share, either as a result of many small products or a few large ones. Product characteristics, such as type of beer, and country of origin are also included as explanatory variables. The dummy variable *IMPORTED* determines if the product is produced in a country outside Sweden.[16] It attempts to capture the third term in (A) because if imported products face higher costs (e.g. transport, marketing disadvantages), the break even volume may be higher and will therefore yield a different hazard rate. *DARKLAGER* assumes the value of one if the beer is a dark lager.

The average product market share of a product in our sample is 0.62 percent for lager. However, the variable is skewed towards small products as the median has a market share of 0.26 percent. The average firm market share is 11.0 percent, but the median market share is only around 4 percent. Our samples consists to a large extent of products from the three largest domestic firms.

5. Results

Before we estimate survival functions it is informative to look at empirical survival and hazard rates. Figure 3 shows that it takes approximately 18 months until 25 percent of the products have exited the market and 48 months until 50 percent have exited. The shape of the survival function appears to be weakly convex to the origin. However, the hazard rate varies

[14] In terms of (A), large firms may introduce products that have (*ex ante*) different revenue distributions, just as firms choose the riskiness in their R&D portfolios (see e.g. Tirole (1988, p.396-398).

[15] In 1994, Pripps had a market share of 40 percent and Falcon and Spendrups about 17-20 percent each. Remaining breweries are significantly smaller.

[16] Products produced on licence, like for example Carlsberg, and Tuborg, are counted as domestic. Licensed products are almost exclusively produced by the three largest breweries, Pripps, Falcon and Spendrups.

over time and no clear pattern can be detected, which can partly be explained by the rather small sample size in the study and by the fact that we have not conditioned on the time varying covariates.

Table 2 presents the results of the exponential model for the lager segment only, while Table 3 also includes the dark lager segment.[17] In regressions Ia-c product market share, *PMSHARE* positively affects product duration, as expected. In addition, the coefficients of *PMSHAREDECR* reveal that products which have had a decreasing market share over the last three months have higher hazard rates. The estimated coefficients are highly significant. Hence, results show that firms keep "winners" in the market and withdraw products that turn out unsuccessful. Firm characteristics also determine the likelihood of product survival in the market. In regressions Ia-c, the coefficients of the firm variables, *FMSHARE, FNPROD, MARKLEAD1* and *MARKLEAD23*, are all negative indicating that products from large firms have a higher hazard rate. However, their individual significance are generally low, which is explained by multicollinearity (e.g. the correlation between *FMSHARE* and *FNPROD* is $\rho = 0.835$). Testing the joint restriction that all firm variables are equal to zero is decisively rejected in all specifications in Ia-c. The finding that *FMSHARE, MARKLEAD1, MARKLEAD23* contributes only to a small extent to the explanatory power of the regression Ia (it can not be rejected that they are all zero at the 10 percent level) suggest that most of the difference across firms is due to the effect of *FNPROD*. However, when *FMSHARE* is excluded in regression Ic, the joint restriction that *MARKLEAD1* and *MARKLEAD23* are zero can be rejected at 10 percent level of significance. Thus, if there is any (albeit small) effect of firm market share it stems from the three largest firms. The difference is also found if we only look at the means of *PMSHARE* between products from *MARKLEAD1* or *MARKLEAD23* and the others in the period before withdrawal (0.0006 and 0.0003 respectively with standard deviations 0.0009 and 0.0003). In Ia and Ic we do not reject (at 10 percent level) the

[17] We also estimated a Weibull model (not shown). The log-likelihood values were almost identical and it was not possible to reject the hypothesis that the hazard rate is constant over time conditional on the values of the covariates. In addition we experimented with market characteristics variables, such as the number of competing brands at the time of entry and at each time. However, neither of the variables turned out significant in any of our regressions, so we omitted them. In firm studies, entry conditions (e.g. phase of the business cycle) do play a significant role in the determination of firm survival, see Mata and Portugal (1994) and Audretsch and Mahmood 1995.

hypothesis that the hazard rate is equal for the market leader and the second or third largest company.

In Table 3 the dark lager segment is included. The coefficient on the variable *PPROJREV* is positive in all regressions, which means that higher projected revenue of the product decreases the hazard rate. The coefficient on *MSHAREDECR* is negative and significant, again implying that products with a negative trend are exposed to a higher degree of withdrawal. That the firm size variables are now significant is explained by the fact that the regressions do not include the *FNPROD* variable, which they are highly correlated with.[18] The coefficient on *DARKLAGER* is negative and significant, indicating that withdrawal decisions are different in the two market segments (products have higher hazard rates in the dark lager segment). A speculative interpretation is that the option value of keeping a product in large market is greater. The argument is that, conditional on its current market share, things may change unexpectedly and the product may become popular in the next period. If so, it will get a larger increase in revenue in absolute terms and the firm therefore keeps products longer. The coefficients of the other variables are similar to those in regression Ia-c.

We have done some numerical simulations of the estimated survival functions based on the coefficients in regression Ic. Figure 4 shows experiments with different values of *PMSHARE* and *FNPROD* with the other variables set to *MARKLEAD1=1, MARKLEAD23=0, IMPORTED=0*. The bold line is the survival function where *PMSHARE=0.001* and *FNPROD=8*. With the lower product market share 0.0001 we obtain the survival function shown by the line. The fact that it lies considerably below the former is evidence of the effect of product market share on survival. However, in these two cases the product market share is held constant over the simulation. As an alternative, the dashed line gives the survival function of a product whose market share , starting at *PMSHARE=0.001*, is decreasing by three percent every period. For this set-up the survival function is decreasing more rapidly in the later periods when its market share becomes very small. Finally, we set *FNPROD=1*,

[18] *FNPROD* can not be used in regression IIa-c since there is no natural way in which one can adjust for the big difference in the number of competing products between the segments.

holding the product market share constant at 0.001. The survival function is again below the "base case", and the difference is quite substantial.

6. Concluding remarks

This paper is, as far as we know, the first attempt to study the survival of new products. Throughout the paper we have hinted at the analogy between the survival of new products and the survival of new firms. We have argued that the uncertainty a firm meets upon introduction of a new product is similar to the uncertainty that a new firm faces upon entry into a market. It takes time before firms learn about the consumers' perception of the product. Likewise, after some time new firms learn about their relative ability, which will affect the decision to remain in the market. The econometric analysis showed that product survival had similar determinants to firm survival. In particular, the results pointed at the importance of the current market share of the product *and* the trend in its sales. Products with low and decreasing sales have a significantly greater risk of being withdrawn. An interesting finding that may spur some theoretical work is that large firms seem to have a faster product turnover than the smaller ones. The simplest explanation is that a product steals sales from the firm's other products, whence firms with a greater market share face a larger negative externality than others. It could also be due to an incentive to introduce products whose reception by the consumers is more uncertain, but if successful are the great jackpots. Other explanations may be related to economies of scale and scope or that large firms wish to pre-empt new entry by repeatedly introducing new varieties to the consumers, as suggested by Schmalensee (1978). We have not been able to distinguish between these hypothesis in this study, but we hope to come back to this issue in our future work.

There are a number of extensions to this paper that one would like to pursue. First, in the present paper we only looked at one market. Hence, unlike the empirical studies of firm survival that study several industries, we are not able to show how different industry and market characteristics affect the survival of new products. Undoubtedly the costs of introducing a new product, such as advertising expenditures, and product development costs, play a significant role in explaining the survival of new products. However, the task of collecting appropriate data for many industries is probably considerable bearing in mind that this would require information on all products during a specific time period. When data from cash registers become more widely available this will certainly be a worthwhile question to address. It will then give us the opportunity to compare product survival in markets with high advertising intensity, such as ready eat cereals, soft drinks, detergents, and ice cream, to markets where advertising expenditures are relatively minor. Some casual evidence from telephone interviews with firms producing ice cream in Sweden suggest that products have shorter expected lives, since a very large fraction (about 50 percent) of new products survive only one season and very few more than five years. Second, in the paper we included variables that were intuitively reasonable in the determination of product survival. Clearly, there may be other explanatory variables that would merit attention. As of today, there is no economic theory, to our knowledge, that models product entry and performance as well as exit in a stochastic setting. Although a complicated task, work in this direction would surely be beneficial to the study of competition in differentiated goods markets.

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Appendix

Table A1. Descriptive Statistics, 1974-1995 (excluding 1986-1988).

Variable	Mean	Std. Dev.	Minimum	Maximum	Median	Nobs.
NPERIOD						
lager	34.9	36.7	3	217	22.5	224
dark lager	30.4	29.2	2	33	23.0	31
STATUS						
lager	0.380	0.486	0	1	0	224
dark lager	0.484	0.508	0	1	0	31
IMPORTED						
lager	0.371	0.484	0	1	0	224
dark lager	0.387	0.495	0	1	0	31
MARKLEAD1						
lager	0.138	0.346	0	1	0	224
dark lager	0.125	0.340	0	1	0	31
MARKLEAD23						
lager	0.241	0.429	0	1	0	224
dark lager	0.354	0.486	0	1	0	31

Table 1. Descriptive Statistics, jan. 1989 - nov 1995.

Variable	Mean	Std. Dev.	Minimum	Maximum	Median	Nobs.
NPERIOD						
lager	22.9	18.3	3	83	17	174
dark lager	26.1	24.2	2	83	22	25
STATUS						
lager	0.316	0.466	0	1	0	174
dark lager	0.360	0.490	0	1	0	25
IMPORTED						
lager	0.391	0.489	0	1	0	174
dark lager	0.440	0.507	0	1	0	25
MARKLEAD1						
lager	0.144	0.352	0	1	0	174
dark lager	0.040	0.200	0	1	0	25
MARKLEAD23						
lager	0.224	0.418	0	1	0	174
dark lager	0.360	0.490	0	1	0	25
PMSHARE						
lager	0.0062	0.00870	0.867 E-06	0.0972	0.00262	3990
dark lager	0.0410	0.0354	0.515 E-03	0.156	0.0319	652
PMSHAREDECR						
lager	0.477	0.500	0	1	0	3990
dark lager	0.362	0.481	0	1	0	652
*FMSHARE**						
lager	0.110	0.116	0.148 E-05	0.397	0.0372	3990
dark lager	0.322	0.350	0.515 E-03	0.867	0.0831	652
*FNPROD**						
lager	7.75	5.91	1	19	8	3990
dark lager	2.46	1.97	1	6	1	652
PPROJREV						
lager	19.9	28.2	0.0029	323	8.27	3990
dark lager	8.31	7.83	0.0970	35.2	6.14	652
*FPROJREV**						
lager	354	372	0.0049	1141	124	3990
dark lager	65.0	72.9	0.0970	212	16.5	652

* Includes all products of the brewery, i.e., even left censored products.

Table 2. Exponential Hazard Model.
Regressions are based on 174 products (3990 observations) in the lager segment.

Variable		Ia	Ib	Ic
CONSTANT	*(1)*	12.3***	12.0***	12.5***
		(2.10)	(1.97)	(1.82)
PMSHARE	*(2)*	0.651***	0.669***	0.645***
		(0.0743)	(0.0792)	(0.0732)
PMSHAREDECR	*(3)*	-2.25***	-2.28***	-2.24***
		(0.612)	(0.610)	(0.611)
FMSHARE	*(4)*	-0.0310	-0.0874	
		(0.125)	(0.128)	
FNPROD	*(5)*	-0.469	-0.523	-0.550
		(0.742)	(0.660)	(0.649)
MARKLEAD1	*(6)*	-0.962*		-1.01*
		(0.559)		(0.537)
MARKLEAD23	*(7)*	-0.437		-0.462
		(0.603)		(0.601)
IMPORTED	*(8)*	-1.26	-1.30	-1.24
		(1.37)	(1.25)	(1.37)
Log L		-195.1	-197.2	-195.2
h_0: (4)=(5)=(6)=(7)=0		-200.1**		
h_0: (4)=(6)=(7)=0		-197.5		
h_0: (4)=(5)=0			-200.1*	
h_0: (5)=(6)=(7)=0		-197.8		-200.1**
h_0: (6)=(7)		-196.0		-196.2
h_0: (6)=(7)=0		-197.2		-197.5*

PMSHARE, *FMSHARE*, and *FNPROD* are in log form.
Standard errors in parenthesis.
The numbers in the bottom five rows correspond to the log likelihood values under the restrictions, and the *s denote their level of significance from likelihood ratio tests.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 3. Exponential Hazard Model.
Regressions are based on 199 products (3990+652 observations)
in the lager *and* dark lager segments.

Variable		IIa	IIb	IIc
CONSTANT	*(1)*	7.03***	6.93***	6.64***
		(0.739)	(0.740)	(0.653)
PPROJREV	*(2)*	0.680***	0.706***	0.654***
		(0.0627)	(0.0679)	(0.0622)
PMSHAREDECR	*(3)*	-2.64***	-2.67***	-2.61***
		(0.609)	(0.600)	(0.607)
FPROJREV	*(4)*	-0.0828	-0.148*	
		(0.0820)	(0.0773)	
MARKLEAD1	*(5)*	-1.10**		-1.34***
		(0.505)		(0.461)
MARKLEAD23	*(6)*	-0.538		-0.731
		(0.486)		(0.468)
IMPORTED	*(7)*	-0.888	-0.775	-0.474
		(0.630)	(0.598)	(0.445)
DARKLAGER	*(8)*	-0.939**	-1.03**	-0.742*
		(0.450)	(0.442)	(0.416)
Log L		-224.8	-227.4	-225.4
h_0: *(4)=(5)=(6)=0*		-230.1**		
h_0: *(5)=(6)*		-225.9		-226.7
h_0: *(5)=(6)=0*		-227.4**		-230.1***

PPROJREV and *FPROJREV* are in log form.
Standard errors in parenthesis.
The numbers of the bottom three rows correspond to the log likelihood values under the restrictions, and the *s denote their level of significance from likelihood ratio tests.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 4. Cox Proportional Hazard Model.
Regressions are based on 199 and 255 products (199 and 255 observations) in the lager *and* dark lager segment.

Variable		1989-1995 (199 products)	1974-1995 (255 products)
MARKLEAD1	*(1)*	1.13***	0.653**
		(0.452)	(0.317)
MARKLEAD23	*(2)*	0.640	0.254
		(0.425)	(0.289)
IMPORTED	*(3)*	0.779*	0.146
		(0.409)	(0.287)
DARKLAGER	*(4)*	0.153	0.255
		(0.372)	(0.285)
Log *L*		-290.2	-464.1
h_0: *(1)=(2)*		-291.0	-465.0
h_0: *(1)=(2)=0*		-293.5	-466.2

Standard errors in parenthesis.
The numbers of the bottom two rows correspond to the log likelihood values under the restrictions, and the *s denote their level of significance from likelihood ratio tests.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Figure 1. Market shares of two withdrawn products (PB Privat, Long Strong)

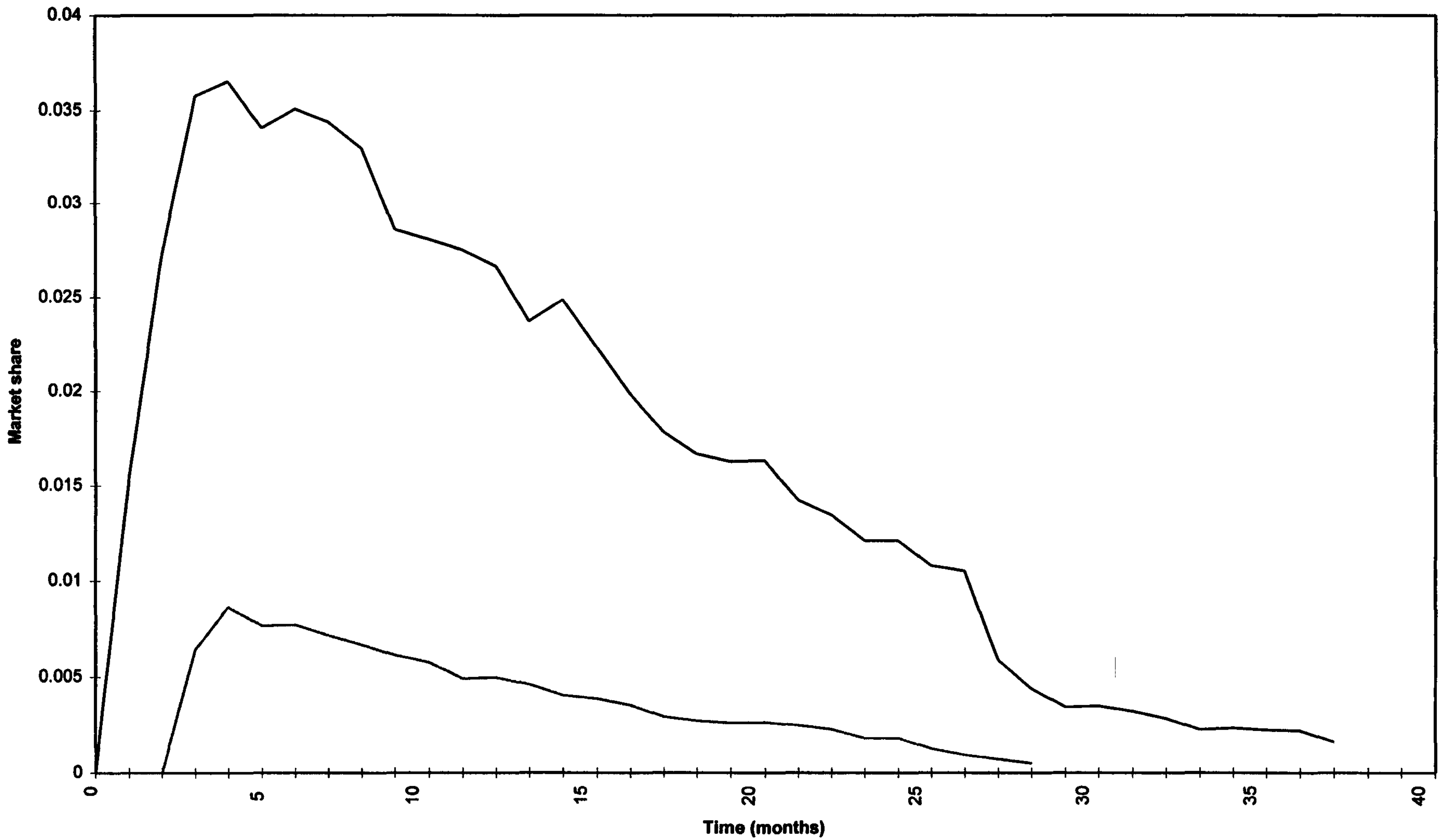


Figure 2a. Number of Products and Aggregate Monthly Revenue, Lager Segment

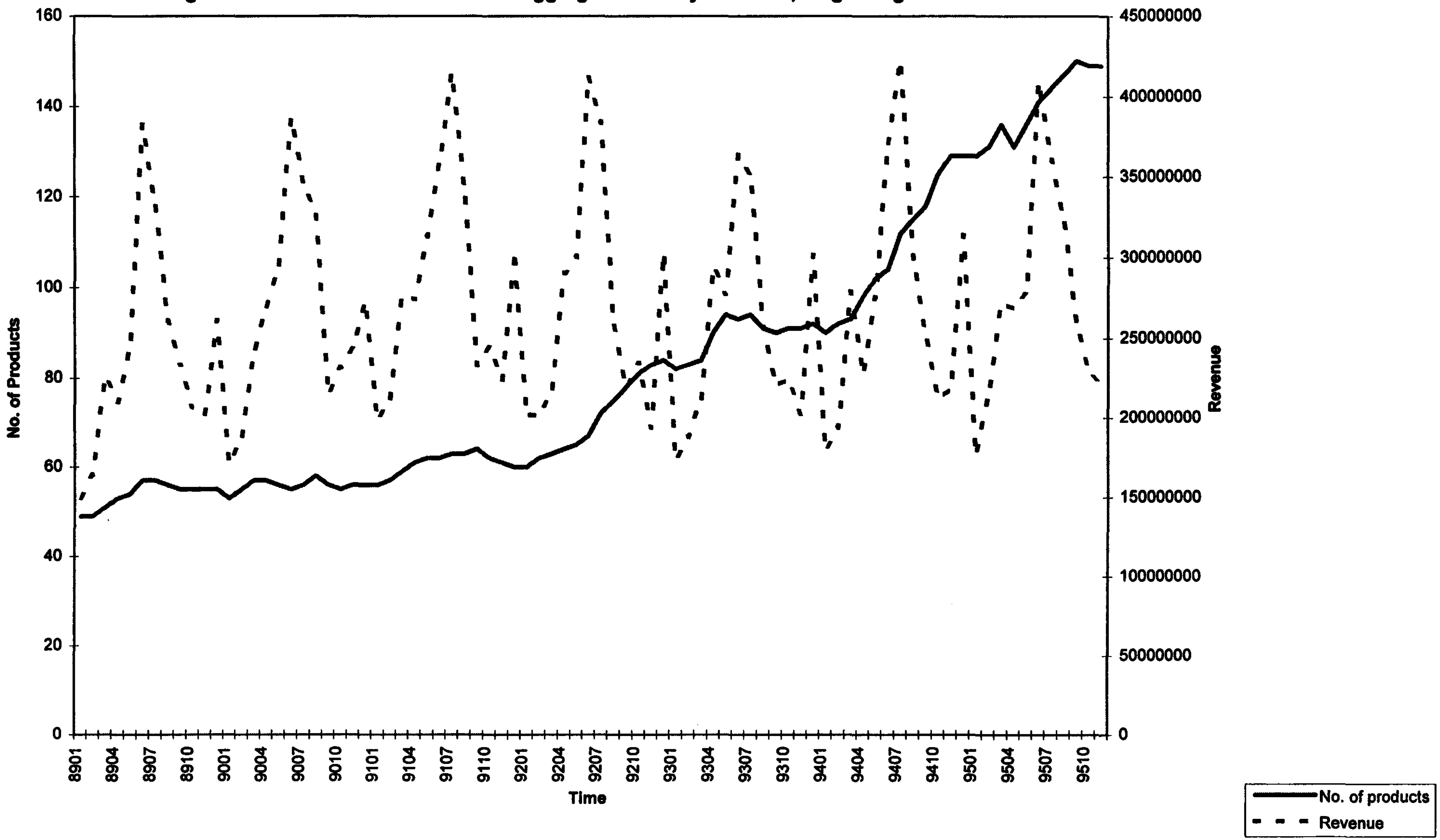


Figure 2b. Number of Products and Aggregate Monthly Revenue, Dark Lager Segment

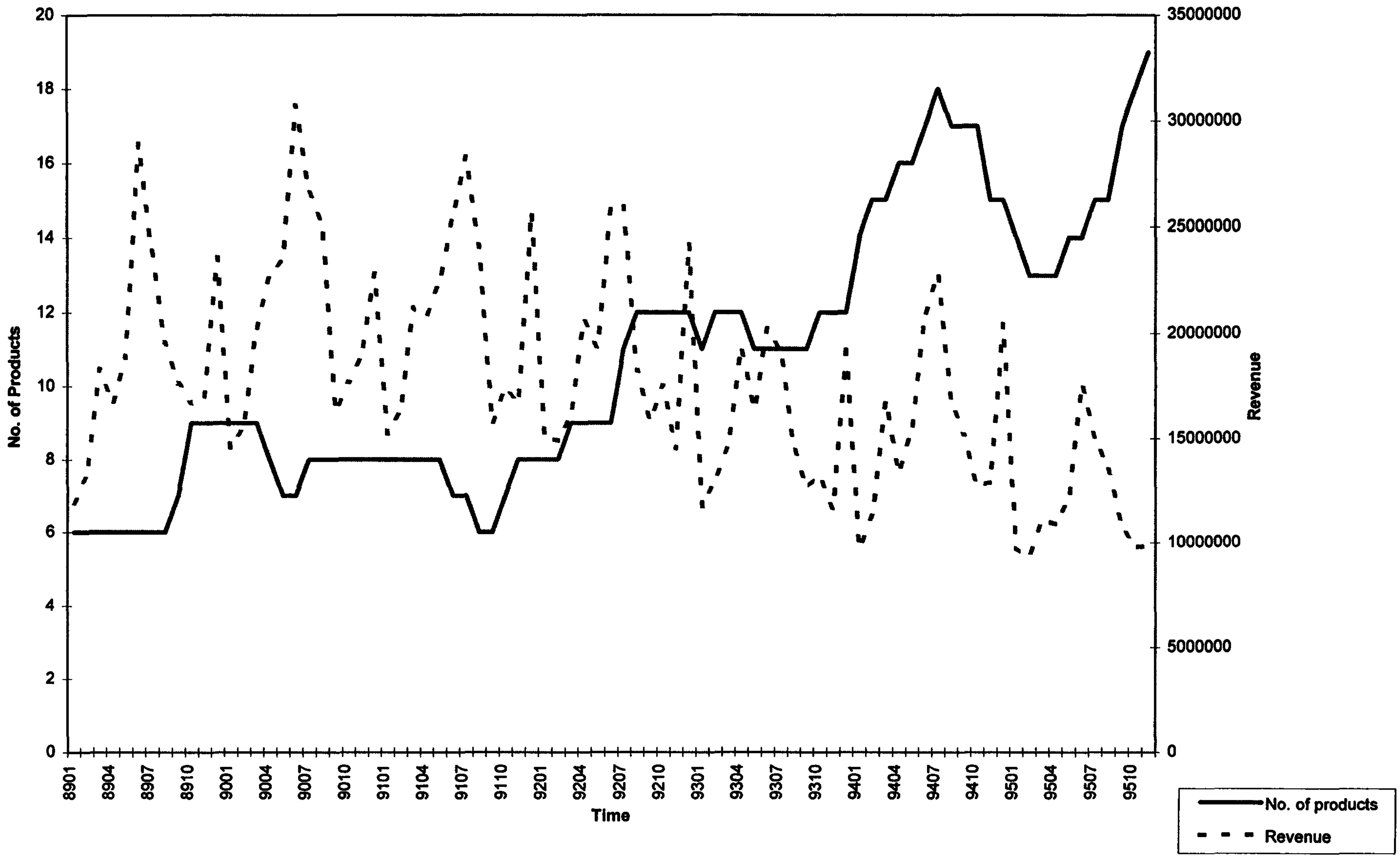


Figure 3. Empirical Survival Function and Hazard Rates

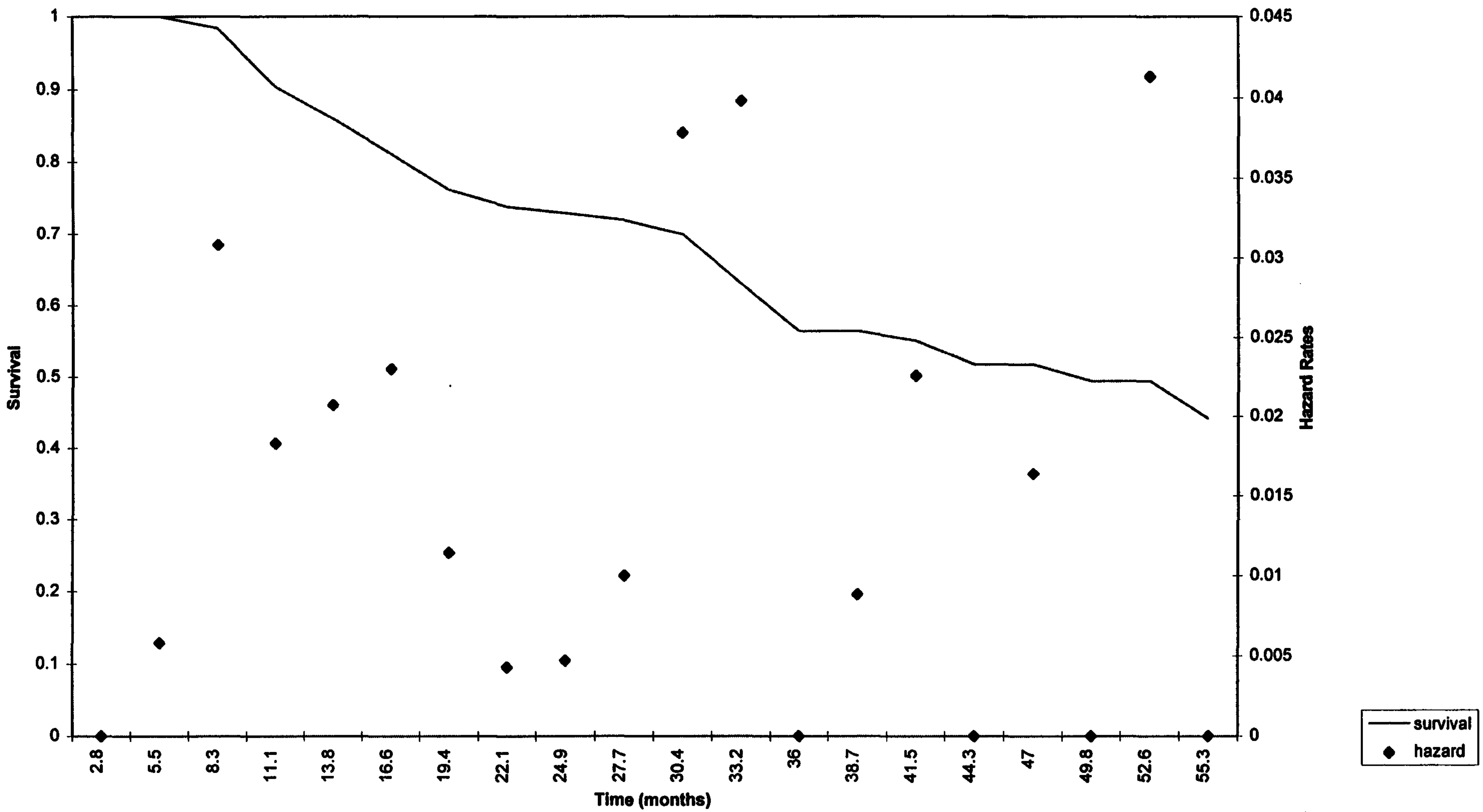
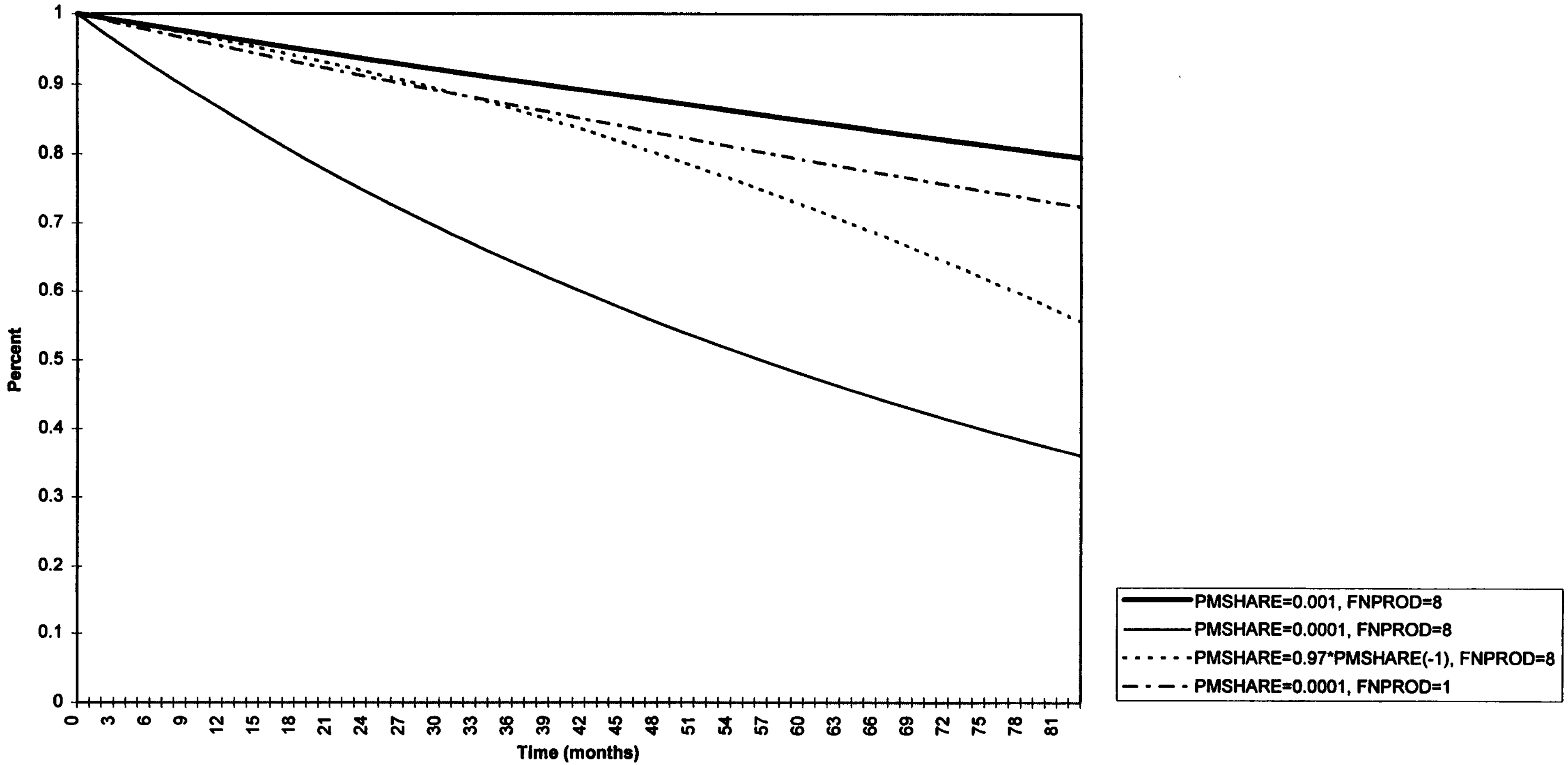


Figure 4. Simulated Survival Functions



Uniform Subsidy Reductions in International Oligopoly*

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Abstract

This paper studies the effect of production subsidies used as strategic instruments by two rivalling countries whose firms differ in production efficiency. In particular, it examines the welfare effects of a uniform subsidy reduction from the Cournot-Nash equilibrium under different assumptions regarding technology and taste. It is found that the net exporter (usually the efficient country) gains while the net importer (usually the inefficient country) loses from a uniform subsidy reduction. Results show that a non-linear demand function or marginal cost functions with different slopes across countries is necessary to obtain an increase in total welfare.

Keywords: Cournot oligopoly; heterogeneous countries; production subsidies.

JEL specifications: D43; F12; F13; H20; L13.

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1. Introduction

Since the end of the II World War considerable efforts have been put into the liberalisation of world trade. To promote free trade, the use of a number of important protectionistic or otherwise discriminatory trade policy instruments - most notably, the import tariffs - have been abolished or significantly restrained through negotiations and legislation. The GATT agreements have been a major contributor in this process, as have the several formation of free trade areas and customs unions (Kowalczyk and Davies (1995)). As a result of reform policies, reductions of trade distortions have been accomplished or are expected in the future.

Although, the process has been successful by rendering growth in world trade and national income (Bhagwati (1988)), there are still discriminatory policies in use that have a significant economic impact. Production subsidies is one example which has been targeted in recent negotiations. Evidently, governments often use subsidies to support domestic industries that compete on the world market. One explanation proposed by Brander and Spencer (1985) is that subsidies are beneficial for exporting countries whose firms compete in imperfectly competitive markets. A large literature has followed this article.[1]

A common denominator in many papers on the subject is that the noncooperatively chosen level of subsidies is suboptimal. Subsidies of this kind, although to the benefit of all consumers through lower import prices, simultaneously reduces the profits of foreign firms. Brander and Spencer (1985) show that rivalling countries would gain from a uniform subsidy reduction if they are both net exporters of the good.[2] However, such a policy is hard to implement in cases where there are no other credible instruments restricting opportunistic behaviour. A reduction is easier to implement (perhaps) if countries form a union, where the

[1] Typically, results turn out depending on model assumptions. Eaton and Grossman (1986) show that export taxes are optimal under Bertrand as opposed to Cournot oligopoly. Retaliation and countervailing duties by rivalling countries usually lessen or take away the incentive for subsidies, as proved by Dixit (1988), Collie (1991), and others. A number of authors address the issue of heterogeneous production costs. Dixit (1987) and Keen and Lahiri (1993) find that an efficient country will have a larger subsidy than a less efficient country. This follows from the fact that the efficient country has more to gain from a larger market share than the inefficient country, since the price-cost margin is greater in the former.

[2] In their model there is a third country, which only imports the good.

central concern is the welfare of the region as a whole. In this setting, Keen and Lahiri (1993) analyse the welfare effects of a uniform subsidy reduction in a linear model with two heterogeneous countries. They find that it always benefits the country which firm is more efficient in production at the expense of the other country. This is explained by the fact that the resulting price increase benefits the net exporter, which always happens to be the efficient country, and harms the net importing country, which consequently is the inefficient country.

The present paper studies the welfare effects from a uniform subsidy reduction in a more general model, which allows for non-linear demand and cost functions. It is shown that a uniform subsidy reduction always benefit the net exporting country, while it harms the net importing country. In most case, the efficient country will be the net exporting country. However, exceptions are found in situations where the efficient country has a relatively large demand and the technology yields decreasing returns to scale or where it has a relatively low demand and the technology yields increasing returns to scale. The paper also shows that an improvement in joint welfare is possible only when the demand function is non-linear or when the slope of the marginal cost function differs between the countries.

2. The model

There are two countries in this model, each has its own firm producing a homogenous good in Cournot competition with the other country's firm. The firms differ in efficiency of production and we will refer to them as the efficient country/firm (denoted by subscript *L*) and the inefficient country/firm (denoted by subscript *H*). There are no transportation costs in the model, which means that markets are integrated and that the demand curve is the world demand curve. Both countries have their own consumption represented by a single individual in each country. Preferences are quasi-linear[3] and may vary between the countries.[4] We

[3] A quasi-linear utility function has the form of $U = u(k_i) + m_i$, where k_i is consumption of the homogenous good, and m_i is consumption of a competitive numeraire good in land *i*. This utility function generates no income effects, which simplifies the analysis.

[4] If one country has a higher demand, we assume that this occurs at each given price level.

restrict our attention to situations in which both countries have some production in equilibrium.

In the game under consideration, governments first maximise domestic welfare by choosing the optimal production subsidy level with full information of the industry structure in which its firm competes. Then, firms maximise profits taking the subsidy level as given in their decision problem. We look for a subgame perfect equilibrium.

To formalise the model, let the profit of firm i be given by

$$\pi_i = P(q_i + q_j)q_i - c_i(q_i) + s_i q_i; \qquad i = L,H; \qquad j = L,H; \qquad i \neq j, \tag{1}$$

where $P(q_i + q_j)$ is the inverse demand function, $c_i(q_i)$ is the cost function, which has a quadratic form equal to[5]

$$c_i(q_i) = \alpha_i q_i + \frac{\theta_i}{2} q_i^2 \; ; \qquad \alpha_L < \alpha_H; \qquad \theta_L \leq \theta_H, \tag{2}$$

and s_i is the optimal subsidy level provided by the government in country i. The firms maximise profit by choosing the optimal level of quantity. The first order condition for profit maximisation of firm i is given by[6]

$$P + q_i P' - c_i' + s_i = 0, \tag{3}$$

and the second order condition by

$$2P' + q_i P'' - c_i'' < 0. \tag{4}$$

[5] We are ruling out cases where marginal cost functions cross to avoid the problem of identifying the efficient firm.

[6] From now on we omit the arguments of the demand- and cost functions.

We assume that conditions for stability of a Cournot-Nash equilibrium are satisfied. Hence, reaction curves slope downwards and marginal cost curves are not allowed to fall faster than the demand curve, i.e.[7]

$$P'+q_i P''<0, \tag{5}$$

and

$$c_i''>P'. \tag{6}$$

The latter condition allows us to account for increasing returns to scale, as long as marginal costs do not fall too rapidly.

The effects of subsidies on firm production are obtained by totally differentiating the first order conditions. Hence,

$$\frac{dq_L}{ds_L}=\frac{-1}{D}(2P'+q_H P''-c_H'')>0, \tag{7a}$$

$$\frac{dq_H}{ds_L}=\frac{1}{D}(P'+q_H P'')<0, \tag{7b}$$

$$\frac{dq_L}{ds_H}=\frac{1}{D}(P'+q_L P'')<0, \tag{7c}$$

$$\frac{dq_H}{ds_H}=\frac{-1}{D}(2P'+q_L P''-c_L'')>0, \tag{7d}$$

where

$$D=(2P'+q_L P''-c_L'')(2P'+q_H P''-c_H'')-(P'+q_L P'')(P'+q_H P''),$$

[7] This is standard in the literature, see Hahn (1962), Seade (1980), and Dixit (1986).

and positive by conditions (5) and (6). Equation (7) discloses the externality property of the production subsidy. As is clear, each country's subsidy benefits its domestic firm while it harms the foreign firm, which follows by the second order condition for profit maximisation and by downward sloping reaction curves. The own effect of a subsidy is always greater than the effect on the rivalling country, which follows by condition (6) and is seen by adding the effects of an increase in country i's subsidy, i.e.

$$\frac{dQ}{ds_i}=\frac{dq_i}{ds_i}+\frac{dq_j}{ds_i}=\frac{1}{D}(c_j''-P'). \tag{8}$$

Thus, the effect on total production is positive, and therefore implies a reduction in world price.

We now turn to the choice of the optimal subsidy level. Let the welfare function of country i be given by[8]

$$W_i=\int_P^{\infty}k_i(x)dx+P(q_i+q_j)q_i-c_i(q_i), \tag{9}$$

where k_i is domestic demand. To solve for the optimal subsidy level we totally differentiate the welfare function and set the derivative equal to zero, that is

$$\frac{dW_i}{ds_i}=(P+q_iP'-c_i')\frac{dq_i}{ds_i}+q_iP'\frac{dq_j}{ds_i}-k_i\frac{dP}{ds_i}=0. \tag{10}$$

If we use the first order condition of firm i, $P+q_iP'-c_i'=-s_i$, as well as the fact that $\frac{dP}{ds_i}=\frac{dP}{dQ}\frac{dQ}{ds_i}=P'\left(\frac{dq_i}{ds_i}+\frac{dq_j}{ds_i}\right)$, and substitute these expressions into (10) we obtain an expression for the subsidy in country i equal to

[8] Profits and subsidy costs are redistributed and financed in a lump-sum fashion.

$$s_i = \frac{q_i P' \frac{dq_j}{ds_i} - k_i P' \left\{ \frac{dq_i}{ds_i} + \frac{dq_j}{ds_i} \right\}}{\frac{dq_i}{ds_i}}. \tag{11}$$

Substituting equation (7) into (11), we get

$$s_i = \frac{-P'[q_i(P'+q_jP'') - k_i(c_j''-P')]}{2P'+q_jP''-c_j''}. \tag{12}$$

It is important to note that this is generally not a closed form expression for the optimal subsidy, since non-linearities will make s_i appear on the right hand side of the expression as well. However, regardless of functional forms on demand and cost functions, the optimal subsidy is unambiguously positive.[9]

Before we turn to the welfare analysis of a uniform subsidy reduction it is informative to study the first order condition for welfare maximisation. Rearranging terms in equation (10) to identify the different effects of a reform, it can be written as

$$\frac{dW_i}{ds_i} = (q_i - k_i)P'\left[\frac{dq_i}{ds_i} + \frac{dq_j}{ds_i}\right] + (P - c_i')\frac{dq_i}{ds_i} = 0. \tag{10'}$$

The first is the terms of trade effect, while the second relates to the deviation of price from marginal cost, which occurs because of non-competitive behaviour and due to the presence of subsidies. Since optimal subsidy levels must be set such that all first order conditions are satisfied in both countries simultaneously, it is immediately apparent that the price-cost margin must be positive in the net exporting country and negative in the net importing country. From this it naturally follows that the marginal cost is lower in the net exporting country than in the net importing country.[10] If land L is the net exporting country, then the first term in equation (10') is negative, which follows from equation (8). To satisfy the first order condition, the optimal subsidy must be set to a level where the price-cost margin is

[9] This is consistent with Brander and Spencer (1985). Brown and Lee (1993) show that the optimal subsidy need not be positive if one applies a weaker stability condition.
[10] The exception is the case of autarky, in which price equals marginal cost in both countries.

positive in the country. For land H, which is then the net importing country, the first term in equation (10') is positive and requires that the optimal subsidy is set to a level where the price-cost margin is negative. Since, these requirements together do not violate each other, all equilibrium outcomes are such that the price-cost margin is positive in the net exporting country and negative in the net importing country. The intuition is clear. From the perspective of the net importer it is welfare increasing to subsidise beyond the level where price equals marginal cost. The dead-weight loss is of second order and outweighed by a cheaper import. For the net exporting country, the argument is, of course, the opposite.

3. Uniform reduction of subsidy levels

Since a subsidy in one country imposes a negative externality on the other country through reduced profits, there may be scope for welfare improvements, at least jointly, if subsidies are reduced uniformly from the non-cooperative solution. The latter is of interest if countries form a union and the goal is to maximise overall welfare.

Proposition: A uniform subsidy reduction unambiguously improves (reduces) welfare in the net exporting (net importing) country.

Proof: Consider a uniform subsidy reduction in both countries. Since we start from the sub-game perfect equilibrium, where the own welfare is already maximised, a subsidy reduction in one country only affects the welfare in the other country, that is

$$dW_i = \frac{\partial W_i}{\partial s_i} ds_i + \frac{\partial W_i}{\partial s_j} ds_j = 0 + \frac{\partial W_i}{\partial s_j} ds_j = \frac{\partial W_i}{\partial s_j} ds_j. \tag{13}$$

The welfare change in country i from a subsidy reduction by the government in country j is therefore equal to

$$\frac{dW_i}{ds_j} = -k_i \frac{dP}{ds_j} + q_i P' \frac{dq_j}{ds_j} - s_i \frac{dq_i}{ds_j}. \tag{14}$$

Since $\frac{dP}{ds_j} = P'\left(\frac{dq_L}{ds_j} + \frac{dq_H}{ds_j}\right)$, equation (14), using equation (7) and the expression for the subsidy in equation (12), becomes

$$\frac{dW_i}{ds_j} = \frac{-(q_i - k_i)}{D}(1 - A)(2P' + q_i P'' - c_i'')P', \tag{15}$$

where

$$A = \frac{(P' + q_L P'')(P' + q_H P'')}{(2P' + q_L P'' - c_L'')(2P' + q_H P'' - c_H'')}.$$

Conditions (5) and (6) imply that $A \in (0,1)$. From equation (15) it is clear that a subsidy reduction, which results in a price increase, unambiguously benefits the net exporting country, while it harms the net importing country. *Q.E.D.*

In general, it is not possible to determine who is the net exporter solely on the basis of relative production efficiency, since we also have to consider relative demand. The only exceptions are those when both demand and cost functions are linear. As mentioned before, the fact that the price always lies in between marginal costs, then, unambiguously makes the efficient country the net exporter of the good, regardless of relative demand.[11] In all other cases, one can easily construct situations in which the efficient country is the net importing country. We leave this exercise to the numerical analysis below.

To obtain the effect on total welfare, denoted Ψ, we add equation (15) for $i = L, H$ and use market clearing (which implies that $q_L - k_L = -(q_H - k_H)$), so that it becomes:

[11] This contradicts the statement in Keen and Lahiri (1993) that one can not identify the net exporting and net importing country on the basis of relative cost efficiency when, as a special case of their model, consumption taxes are set to zero (see their footnote 14 on page 70).

$$\Psi = \frac{dW_L}{ds_H} + \frac{dW_H}{ds_L} = \frac{1}{D} P'(q_L - k_L)(1 - A)[c_L'' - c_H'' - (q_L - q_H)P'']. \tag{16}$$

The terms of trade effects cancel out and we are left with reallocation and dead-weight loss effects. Generally, we can not determine the sign of the effect on total welfare, because we do not know if the efficient country is the net exporter. However, all cases where demand is linear ($P''=0$) and marginal cost functions are parallel to each other ($c_L''=c_H''$) give no effect on total welfare, since the expression in the last bracket is zero then. Hence, in all these cases there are no welfare gains (or losses) obtained through reallocation of production or changes in dead-weight losses. The absence of gains through reallocation is explained by the fact that firms, in equilibrium, are equally sensitive to cost perturbations, that is, they reduce quantity by the same amount to restore their first order conditions. Thus, the contraction in total production is shared equally among the firms. This furthermore implies that the decrease in dead-weight loss in the net importing country, following the price increase, exactly offsets the increase in dead-weight loss in the net exporting country.[12]

To obtain an increase in total welfare we need either a non-linear demand function or a marginal cost function with a different slope in each country. Only then will firms differ in their sensitivity to cost perturbation, so that welfare gains can be obtained through production reallocation, and only then can we obtain reductions in total dead-weight loss. To explain in which way non-linearities in demand and cost may increase total welfare we treat them separately.[13] We start by assuming that the demand function is linear ($P''=0$) and that $c_L'' < c_H''$, in which case the change in total welfare equals

$$\Psi = \frac{dW_L}{ds_H} + \frac{dW_H}{ds_L} = \frac{1}{D} P'(q_L - k_L)(1 - A)(c_L'' - c_H''). \tag{17}$$

[12] If we set the first order condition for welfare maximisation given by equation (10) equal to zero and equate them across the countries, it is easily seen that the equilibrium price lies exactly halfway between marginal costs.
[13] Unfortunately, it does not seem possible to separate reallocation gains from gains in reducing total dead-weight loss.

The sign of (17) depends on whether the efficient country is the net exporter. If so, (17) is positive, implying that a uniform subsidy reduction lowers total welfare. Hence, the loss in total welfare occurs due to a reallocation of production from the efficient to the inefficient country. The intuition behind this result is the following: When $c_L'' < c_H''$ the efficient firm is more sensitive to cost perturbations than the inefficient firm and therefore needs to adjust quantity by more to restore its first order condition.[14] This implies that the contraction in total production is borne to a larger extent by the efficient firm. Since marginal cost is lower in the efficient country from being the net exporter, this reduces total welfare. The effect on total welfare is reversed when the efficient country is the net importer, because it then produces at a higher marginal cost. The larger contraction in production by the efficient firm, then, improves total welfare.

A non-linear demand function also makes the firms differ in sensitivity to cost perturbations. Now, the firms are profit maximising on a different part (slope) of the marginal revenue curve. If we set $c_L'' = c_H''$, the effect on total welfare equals

$$\Psi = \frac{dW_L}{ds_H} + \frac{dW_H}{ds_L} \quad = -\frac{1}{D} P'(q_L - k_L)(1 - A)(q_L - q_H)P' \tag{18}$$

The sign of (18) depends on whether the efficient country is the net exporter, whether it produces more than the inefficient country, and whether the demand function is concave or convex. We do not know the sign of (18) unless we specify the demand and cost functions more specifically. However, to show the way in which the curvature of the demand function effects the change in total welfare, consider the special case when the efficient country is the net exporter and that it produces more than the inefficient firm. A subsidy reduction will then increase total welfare if the demand function is concave $(P'' < 0)$ and reduce total welfare when the demand function is convex $(P'' > 0)$. With a concave demand function the efficient firm is less sensitive to cost perturbations, since it, in equilibrium, is located on a steeper part of the demand curve than is the inefficient firm. Hence, the contraction of total production is

[14] When the demand function is linear, a lower slope of the marginal cost function for the efficient firm automatically makes it more sensitive.

borne to a larger extent by the inefficient country. Since the marginal cost is higher in the inefficient country, this improves total welfare. The opposite holds for a convex demand function.[15]

4. Numerical analysis

Results from the general analysis do not generally convey which is the net exporting and net importing country, since it depends on the impact of relative cost and demand asymmetry. Therefore, we can not always answer the question if the efficient country gains from the subsidy reduction and whether total welfare is improved or not. To do this we need to specify functional forms of demand and cost functions and run numerical analysis. The aim of this section is to identify the net exporter. It is then left to the reader to verify that the results of the numerical analysis, shown in Tables 1-5, illustrate the findings of the theoretical analysis above.

The numerical analysis is based on the inverse demand function

$$P = 1 - \beta(q_L + q_H)\,; \qquad \beta = \frac{b_L b_H}{b_L + b_H}, \tag{19}$$

and is obtained by adding the demand in each country, which has the form

$$k_i = \frac{1-P}{b_i}. \tag{20}$$

In this setting, $b_L < b_H$ implies that the efficient country has a relatively larger demand. The cost function of firm i has the quadratic form given by (2). Note that this model is a special

[15] This is similar to the intuition provided in Dierickx, Matutes and Neven (1988), who studies the effect of taxation *within* a country where firms differ in production efficiency.

case of the general model studied above. Therefore, results from the numerical analysis must be in line with the ones from the general analysis.

In Tables 1-5 we have varied demand and cost parameters to analyse the impact of relative demand and cost asymmetry on which is the net exporting and net importing country respectively. To understand the way in which demand and cost asymmetry affect results it is informative to treat them separately and compare them to the benchmark solution - autarky - for which equilibrium values are shown in Tables 1-3, column I.[16] We start by assuming that demand is symmetric and that firms differ in production efficiency. Then, it is clear that the efficient country is the net exporter, as is illustrated in Tables 1-3, column II. To consider the impact of demand asymmetry we let the firms be equally cost efficient. It is found that the country which has a relatively higher demand (lower b) is the net importer when marginal cost are increasing (see Table 2, column III) and a net exporter when marginal cost are decreasing (see Table 3, column III). The explanation is similar to the one given in models of monopolistic competition, where a large home demand allows the country to exploit increasing returns to scale.[17]

If we allow for both demand and cost asymmetry, many different cases can be constructed, even those where the efficient country is the net importing country. However, when cost asymmetry is comparably large to demand asymmetry, the efficient country will be the net exporting country regardless of whether it has a lower demand or not (see column IV and V in each table). To obtain outcomes where the efficient country is the net importer, cost asymmetry needs to be comparably small to demand asymmetry. Then, the efficient country is the net importer if marginal costs are increasing and it has a relatively high demand (see column VI in Table 2 and Table 4) or if marginal costs are decreasing and it has a relatively small demand (see column VI in Table 3 and Table 5). In the latter case, the efficient country is too small compared to the inefficient country to become the net exporter in spite of being able to exploit increasing returns to scale.

[16] There is no autarchy solution in the presence of cost asymmetry, which explains why there is no such column in Tables 4-5.

[17] See Krugman (1989) for a survey of this literature.

5. Concluding remarks

We have studied the welfare effects of a single reform in two competing countries - a uniform subsidy reduction from the Cournot-Nash equilibrium. It was found that the net exporter (usually the efficient firm) always gains from the reform, while the net importer (usually the inefficient country) always loses. To obtain an increase in total welfare, specific characteristics of the demand and cost functions must be satisfied, which shows the importance of these features in negotiations of subsidy reductions. This is somewhat promising, since the information is not too hard for policy makers to obtain. It can readably observed who the net exporter and the net importer is respectively, and it is not too difficult to collect information on the costs structure in each country. However, the results in the paper also show that there is a clear winner and loser which may makes it difficult to agree on the implementation of the reform. In real life, on the other hand, negotiations between countries seldom cover just a single reform. Typically, it is easier to carry through a reform package in which all countries have something to gain and lose, and from which no country will stand as the clear loser.

In the paper, each government maximises a welfare function where consumers and producers are given the same weight. However, it is more likely that producer interest are given a higher priority, because they are usually more successful than consumer in lobbying for their own interests. Although we do not model this feature in the paper, in the extreme case where consumers are given no weight, a uniform subsidy reduction from the Cournot-Nash equilibrium would benefit the producers in each country, since they both gain from the resulting price increase.

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Table 1. Numerical analysis, constant marginal costs ($\theta_L = \theta_H = 0$)

	I	II	III	IV	V	VI
Parameters values						
α_L	0.2	0.19	0.2	0.1	0.1	0.19
α_H	0.2	0.2	0.2	0.2	0.2	0.2
θ_L	0	0	0	0	0	0
θ_H	0	0	0	0	0	0
b_L	0.6	0.6	0.6	0.65	0.6	0.4
b_H	0.6	0.6	0.65	0.6	0.65	0.8
Equilibrium values						
P	0.2	0.195	0.2	0.15	0.15	0.195
MC_L	0.2	0.19	0.2	0.1	0.1	0.19
MC_H	0.2	0.2	0.2	0.2	0.2	0.2
$q_L - k_L$	0	0.033333	0	0.320513	0.320513	0.0375
$q_H - k_H$	0	-0.033333	0	-0.320513	-0.320513	-0.0375
dW_L/ds_H	0	-0.020222	0	-0.192875	-0.192875	-0.023222
dW_H/ds_L	0	0.020222	0	0.192875	0.192875	0.023222
Ψ	0	0	0	0	0	0
s_L	0.4	0.4075	0.416	0.458	0.492	0.54167
s_H	0.4	0.3975	0.384	0.392	0.358	0.26333
q_L	1.33333	1.375	1.33333	1.62821	1.73718	2.05
q_H	1.33333	1.30833	1.23077	1.09615	0.987179	0.9687
k_L	1.33333	1.34167	1.33333	1.30769	1.41667	2.0125
k_H	1.33333	1.34167	1.23077	1.41667	1.30769	1.00625
W_L	0.533333	0.546896	0.533333	0.637179	0.688942	0.820281
W_H	0.533333	0.533479	0.492308	0.547276	0.50641	0.400172
π_L	0.533333	0.567188	0.554667	0.827128	0.941551	1.12067
π_H	0.533333	0.513521	0.472615	0.374885	0.304051	0.25026
$s_L q_L$	0.533333	0.560313	0.554667	0.745718	0.854692	1.11042
$s_H q_H$	0.533333	0.520063	0.472615	0.429692	0.35341	0.3895
c_L	0.266667	0.26125	0.266667	0.162821	0.173718	0.19375
c_H	0.266667	0.261667	0.246154	0.219231	0.197436	0.261923

Table 2. Numerical analysis, increasing marginal costs ($\theta_L = \theta_H$).

	I	II	III	IV	V	VI
Parameters values						
α_L	0.2	0.19	0.2	0.1	0.1	0.19
α_H	0.2	0.2	0.2	0.2	0.2	0.2
θ_L	0.05	0.05	0.05	0.05	0.05	0.05
θ_H	0.05	0.05	0.05	0.05	0.05	0.05
b_L	0.6	0.6	0.6	0.65	0.6	0.4
b_H	0.6	0.6	0.65	0.6	0.65	0.8
Equilibrium values						
P	0.261538	0.256923	0.259347	0.213056	0.213056	0.264
MC_L	0.261538	0.253105	0.261176	0.172604	0.176489	0.277379
MC_H	0.261538	0.260741	0.257519	0.253509	0.249623	0.250621
$q_L - k_L$	0	0.023636	-0.010911	0.241401	0.218216	-0.092421
$q_H - k_H$	0	-0.023636	0.010911	-0.241401	-0.218216	0.092421
dW_L/ds_H	0	-0.012614	0.005802	-0.128378	-0.116048	0.049613
dW_H/ds_L	0	0.012614	-0.005802	0.128378	0.116048	-0.049613
Ψ	0	0	0	0	0	0
s_L	0.369231	0.374811	0.383564	0.412598	0.440727	0.4794
s_H	0.369231	0.368266	0.357089	0.374346	0.346217	0.2566
q_L	1.23077	1.2621	1.22351	1.45208	1.52979	1.74758
q_H	1.23077	1.21483	1.15038	1.07017	0.992467	1.01242
k_L	1.23077	1.23846	1.23442	1.21068	1.31157	1.84
k_H	1.23077	1.23846	1.13947	1.31157	1.21068	0.92
W_L	0.492308	0.504777	0.492326	0.587823	0.630513	0.73009
W_H	0.492308	0.492393	0.457162	0.501408	0.464703	0.37773
π_L	0.492308	0.51769	0.504482	0.71058	0.788665	0.89076
π_H	0.492308	0.479635	0.445974	0.385955	0.331942	0.298957
s_Lq_L	0.454438	0.473048	0.469294	0.599126	0.674219	0.83779
s_Hq_H	0.454438	0.447378	0.410787	0.400614	0.343609	0.259787
c_L	0.284024	0.279621	0.282127	0.197922	0.211485	0.408391
c_H	0.284024	0.27986	0.263159	0.242666	0.223118	0.228109

Table 3. Numerical analysis, decreasing marginal costs ($\theta_L = \theta_H$).

	I	II	III	IV	V	VI
Parameters values						
α_L	0.4	0.39	0.4	0.3	0.3	0.39
α_H	0.4	0.4	0.4	0.4	0.4	0.4
θ_L	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
θ_H	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
b_L	0.6	0.6	0.6	0.65	0.6	0.8
b_H	0.6	0.6	0.65	0.6	0.65	0.4
Equilibrium values						
P	0.345455	0.34	0.347735	0.29338	0.29338	0.332414
MC_L	0.345455	0.332105	0.344513	0.219817	0.212837	0.359681
MC_H	0.345455	0.347895	0.350957	0.366943	0.373923	0.305147
$q_L - k_L$	0	0.057895	0.022623	0.516552	0.565568	-0.228099
$q_H - k_H$	0	-0.057895	-0.022623	-0.516552	-0.565568	0.228099
dW_L/ds_H	0	-0.040908	-0.015754	-0.359723	-0.393857	0.168054
dW_H/ds_L	0	0.040908	0.015754	0.359723	0.393857	-0.168054
Ψ	0	0	0	0	0	0
s_L	0.327273	0.339474	0.343014	0.426779	0.463357	0.188969
s_H	0.327273	0.320526	0.309251	0.279841	0.243264	0.478617
q_L	1.09091	1.15789	1.10973	1.60366	1.74327	0.606384
q_H	1.09091	1.04211	0.980862	0.661148	0.52154	1.89706
k_L	1.09091	1.1	1.08711	1.08711	1.1777	0.834483
k_H	1.09091	1.1	1.00348	1.1777	1.08711	1.66897
W_L	0.327273	0.338623	0.327329	0.437763	0.480527	0.252818
W_H	0.327273	0.327623	0.300056	0.35653	0.33528	0.518845
π_L	0.327273	0.368698	0.353441	0.738085	0.872189	0.088861
π_H	0.327273	0.298645	0.27612	0.125453	0.078065	0.869723
$s_L q_L$	0.357025	0.393075	0.380653	0.684409	0.807755	0.114588
$s_H q_H$	0.357025	0.334022	0.303332	0.185016	0.126872	0.907967
c_L	0.406612	0.418061	0.413105	0.416805	0.447006	0.227297
c_H	0.406612	0.389693	0.368292	0.253531	0.201816	0.668855

Table 4. Numerical analysis, increasing marginal costs ($\theta_L < \theta_H$).

	II	IV	V	VI
Parameters values				
α_L	0.19	0.1	0.1	0.19
α_H	0.2	0.2	0.2	0.2
θ_L	0.04	0.04	0.04	0.04
θ_H	0.05	0.05	0.05	0.05
b_L	0.6	0.65	0.6	0.4
b_H	0.6	0.6	0.65	0.8
Equilibrium values				
P	0.250963	0.2064	0.206004	0.255664
MC_L	0.242124	0.15993	0.16316	0.262535
MC_H	0.259684	0.252268	0.248293	0.248894
$q_L - k_L$	0.054717	0.277316	0.255676	-0.047464
$q_H - k_H$	-0.054717	-0.277316	-0.255676	0.047464
dW_L/ds_H	-0.02928	-0.147845	-0.136309	0.025563
dW_H/ds_L	0.029738	0.150072	0.138362	-0.026009
Ψ	0.000458	0.002227	0.002053	-0.000446
s_L	0.382095	0.42098	0.449804	0.490438
s_H	0.366824	0.372017	0.343635	0.253999
q_L	1.30311	1.49824	1.579	1.81338
q_H	1.19368	1.04535	0.965855	0.977883
k_L	1.24839	1.22092	1.32333	1.86084
k_H	1.24839	1.32267	1.22153	0.93042
W_L	0.513027	0.598981	0.642874	0.745852
W_H	0.492759	0.504205	0.467423	0.376799
π_L	0.543392	0.745247	0.827758	0.942656
π_H	0.463081	0.368259	0.314379	0.278908
$s_L q_L$	0.497912	0.630728	0.710242	0.889348
$s_H q_H$	0.437869	0.388888	0.331902	0.248381
c_L	0.281553	0.194718	0.207765	0.410308
c_H	0.274357	0.236389	0.216493	0.219483

Table 5. Numerical analysis, decreasing marginal costs ($\theta_L < \theta_H$).

	III	IV	V	VI
Parameter values				
α_L	0.39	0.3	0.3	0.39
α_H	0.4	0.4	0.4	0.4
θ_L	-0.05	-0.05	-0.05	-0.05
θ_H	-0.04	-0.04	-0.04	-0.04
b_L	0.6	0.65	0.6	0.8
b_H	0.6	0.6	0.65	0.4
Equilibrium values				
P	0.345515	0.297651	0.297009	0.341865
MC_L	0.329829	0.218864	0.212255	0.353694
MC_H	0.360873	0.374864	0.380069	0.330325
$q_L - k_L$	0.112621	0.542182	0.583239	-0.096539
$q_H - k_H$	-0.112621	-0.542182	-0.583239	0.096539
dW_L/ds_H	-0.07743	-0.367768	-0.395617	0.068963
dW_H/ds_L	0.078838	0.374175	0.402509	-0.070389
Ψ	0.001408	0.006407	0.006892	-0.001427
s_L	0.345342	0.427501	0.462773	0.205463
s_H	0.308814	0.273273	0.238525	0.45296
q_L	1.20343	1.62272	1.75489	0.726129
q_H	0.978187	0.628399	0.498286	1.74188
k_L	1.09081	1.08054	1.17165	0.822668
k_H	1.09081	1.17058	1.08152	1.64534
W_L	0.33963	0.441476	0.483572	0.248943
W_H	0.322799	0.35466	0.333798	0.500846
π_L	0.398267	0.755733	0.883857	0.127422
π_H	0.267918	0.115307	0.0725	0.748419
$s_L q_L$	0.415595	0.693714	0.812115	0.149192
$s_H q_H$	0.302077	0.171725	0.118854	0.789
c_L	0.433131	0.420985	0.449476	0.270009
c_H	0.372138	0.243462	0.194349	0.636068

Subsidies in Oligopoly Markets: A Welfare Comparison between Symmetric and Asymmetric Costs*

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Abstract

This paper studies welfare effects of uniform production subsidies in oligopoly markets, comparing cases of symmetric and asymmetric costs. Cost asymmetry reduces the welfare impact relative to the symmetric-cost case if the demand function is concave and magnifies the impact if demand is convex. The welfare difference increases with the degree of market power and the cost differential in the industry.

Keywords: Oligopoly; cost asymmetry; production subsidy; welfare.

JEL specifications: D43; H20; L52.

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1. Introduction

Oligopolistic industries generally produce less than is socially desirable. As a result, the use of production subsidies is often suggested as a means of raising production toward the efficient level in imperfectly competitive markets. In cases where firms are equally efficient in producing the good, the common is a policy of uniform subsidisation of firms, as suggested in for example Besley (1989).[1] When firms in an industry differ in efficiency, however, uniform subsidisation involves subsidising inefficient firms in the same manner as efficient firms. Consequently, uniform policy may be undesirable from a social perspective, particularly when the price-cost margins of inefficient firms are small.

In a market in which firms are characterised by differences in efficiency, one might ideally like to subsidise only the most efficient firm(s) and perhaps tax or even exclude inefficient firms from the market. However, in many situations treating rival firms in an industry differently is politically infeasible. When regulators are constrained to implement a single uniform subsidy (tax) rate in an asymmetric-cost industry, the welfare change created by the policy is likely to diverge from the case of equal cost efficiency. Different welfare implications are likely to arise because changes in regulatory structure can affect the market shares of firms in an asymmetric-cost industry (Dierickx et al. (1988), and Kimmel (1992)), which is not the case in an industry with symmetric firms. Therefore, in an asymmetric-cost oligopoly, the effect of taxes and subsidies on productive efficiency must also be included in the policy analysis.

Several papers in the public finance literature have addressed the issue of tax incidence on the rivalry and profitability of firms in oligopoly markets. Katz and Rosen (1985) show in a conjectural variations model with symmetric firms that a uniform tax on production can lead to an outcome with larger after-tax profits for all firms. This result is also supported by Seade (1985), Dierickx, Matutes and Neven (1988), and Kimmel (1992) for the case when cost

[1] Besley's optimal policy also includes a fixed fee for entering the market, in order to prevent excessive duplication of fixed costs.

efficiency of firms differs. However, few of these papers directly analyses the industry profit and social welfare effects of a change in the tax or subsidy program.

The present paper identifies relevant implications for tax policy by comparing welfare changes in the asymmetric-cost case to the benchmark case of symmetric costs. It is shown that, relative to the symmetric-cost case, non-convex demand functions give lower impact on welfare in the asymmetric-cost case, while the opposite is true for convex demand. The greater the cost asymmetry is, and the more collusive firms are, the greater is the difference in welfare impact.

2. The model

Consider a traditional conjectural variation model with two firms producing a homogenous good.[2] The profit of each firm in the asymmetric cost industry, where L and H denote the low- and high-cost firm respectively, is equal to

$$\pi_i = P(Q)q_i - c_i(q_i) + tq_i; \qquad i = L, H. \qquad (1)$$

$P(Q)$ is the inverse demand function, $Q = q_L + q_H$, $c_i(q_i)$ is the cost function of firm i, and $t > 0$ is a production subsidy.[3] The cost function is quadratic and has the form

$$c_i(q_i) = \alpha_i q_i + \frac{\theta}{2} q_i^2; \qquad \alpha_L < \alpha_H; \qquad i = L, H, \qquad (2)$$

where the parameter θ is identical for both types of firm, which means that the difference in productive efficiency between firms can be characterised entirely by the level effect.

[2] The conjectural variation model is not to be understood as a dynamic model, but merely as a way to quickly analyse different degrees of oligopolistic competition in a unified model. The conjectural variation model has been investigated extensively by Seade (1980), Dixit (1986), and Stern (1987).

[3] We are analysing production subsidies here, but the analysis apply equally well for production taxes $(t < 0)$.

Differentiating expression (1) with respect to q_i gives us the first-order-condition of firm i in the asymmetric cost industry:

$$P(Q)+(1+\delta)q_i P'(Q)-c_i'(q_i)+t=0, \qquad i=L,H \qquad (3)$$

and the second-order-condition:

$$2(1+\delta)P'(Q)+(1+\delta)^2 q_i P''(Q)-\theta<0, \qquad i=L,H \qquad (4)$$

where δ denotes the firm's conjectural variation parameter. We assume that the marginal cost curve of each firm does not fall faster than its perceived demand curve, that is,

$$\theta>(1+\delta)P'(Q). \qquad (A1)$$

Since we allow for concave cost functions in our analysis, assumption (A1) limits the allowable degree of concavity and is a common stability condition in the literature on oligopoly.[4] In the following analysis we compare welfare implications of a subsidy in the asymmetric-cost industry to that in a symmetric-cost industry. In order to establish a benchmark, we assume for comparative purposes that the sum of marginal cost intercept values are equal between the asymmetric- and the symmetric- cost case, that is,

$$\alpha_L+\alpha_H=2\alpha_S; \qquad \alpha_L<\alpha_S<\alpha_H, \qquad (A2)$$

where S denotes the symmetric firm. Assumption (A2) calibrates firms in the symmetric-cost case with the average level of cost efficiency in the asymmetric-cost case, which allows us to reference a meaningful benchmark case of homogeneous firms. What we bring about by the properties of the cost functions are parallel shifts of the marginal cost curves of the high and the low cost firm (up and down, respectively) from the symmetric case without affecting

[4] See Hahn (1962), Seade (1980), and Dixit (1986).

industry output. We do so because we are comparing welfare changes in the same industry under the two different cases. In the next section, we derive the effect of a uniform production subsidy in an asymmetric-cost industry and compare the results to the case of an industry with symmetric firms.

3. Effects of a production subsidy

A production subsidy placed in an oligopoly industry will affect welfare for both consumers and producers. We first focus on the effects on producers, since changing production incentives affects industry output, which in turn alters consumer surplus. For the asymmetric case (denoted by superscript A), a change in the subsidy rate will cause a change in total industry profit, equal to the sum of each firm's profit: [5]

$$\frac{d\Pi^A}{dt}=\frac{d\pi_L}{dt}+\frac{d\pi_H}{dt}=P\frac{dQ}{dt}+Q\frac{dP}{dt}-(\alpha_L+\theta q_L)\frac{dq_L}{dt}-(\alpha_H+\theta q_H)\frac{dq_H}{dt}+t\frac{dQ}{dt}+Q. \quad (5)$$

We now need to derive an expression for $\frac{dq_i}{dt}$. This is done by totally differentiating the first order condition for each firm, as expressed by (3). For a duopoly, this gives us two equations and two unknowns. Writing these out in matrix form yields:

$$\begin{bmatrix} 2(1+\delta)P'+(1+\delta)^2 q_L P''-\theta & (1+\delta)[P'+(1+\delta)q_L P''] \\ (1+\delta)[P'+(1+\delta)q_H P''] & 2(1+\delta)P'+(1+\delta)^2 q_H P''-\theta \end{bmatrix}\begin{bmatrix} dq_L \\ dq_H \end{bmatrix}=\begin{bmatrix} -1 \\ -1 \end{bmatrix}\begin{bmatrix} dt \\ dt \end{bmatrix}. \quad (6)$$

Applying Cramer's rule to the coefficient matrix (6) yields:

$$\frac{dq_L}{dt}=\frac{\theta - (1+\delta)P'+(1+\delta)^2(q_L-q_H)P''}{D^A} \quad (7)$$

[5] The arguments of the demand and cost functions are suppressed from this point onward.

and

$$\frac{dq_H}{dt} = \frac{\theta - (1+\delta)P' + (1+\delta)^2 (q_H - q_L)P''}{D^A}, \tag{8}$$

where D^A (> 0) is the determinant of the system of equations (6). Since we are interested in comparing the difference in total welfare effects of a subsidy between the asymmetric and the symmetric- cost case, we need not sign equations (7) and (8). Our primary concern is the change in industry quantity, which is obtained by adding equations (7) and (8):

$$\frac{dQ^A}{dt} = \frac{2[\theta - (1+\delta)P']}{D^A} > 0, \tag{9}$$

where the inequality holds by condition (A1).[6]

We can plug equations (7), (8) and (9) into equation (5) and calculate the change in profit following a subsidy in the asymmetric-cost industry. However, since our goal is to contrast the effect of a subsidy between the symmetric- and asymmetric-cost case, the analysis can be simplified by recognising that many of the terms in equation (5) are identical. The properties of the quadratic cost function above, in fact, ensure that the movement in industry quantity is independent of the cost structure in the industry when (A2) holds. This result can be seen by adding the first-order-conditions of the low- and high-cost firm:

$$2P + (1+\delta)QP' - \theta Q = 2(\alpha_S - t), \tag{10}$$

[6] This result is consistent with Seade (1985), who compute a negative sign for a unit tax on production in a homogeneous firm oligopoly.

where the substitution $\alpha_L + \alpha_H = 2\alpha_S$ has been made using (A2). Since equation (10) can be expressed strictly in terms of industry quantity, it follows that the movement in total industry quantity is independent of the industry cost structure.[7] Hence, it means that the change in aggregate quantity is the same between the cases. It also implies that the arguments of P, P', and P'' are the same, such that the effect of a subsidy change is evaluated at the same aggregate quantity, and finally that $D^A = D^S$. An alternative proof of this is provided in the Appendix.

From equation (10), the change in market price following a change in the subsidy rate is then independent of industry cost structure, whence the change in consumer surplus is identical in each of the two cases. It also implies that the total subsidy cost to the regulator is the same. Thus, the only difference in welfare between the two cases arises entirely from the profit effect. It is now possible to compare the welfare effect of a unit subsidy in the asymmetric-cost case to the benchmark case of symmetric costs.

4. The welfare comparison

Subtracting the change in profit in the symmetric-cost case from that in the asymmetric-cost case gives the following expression:

$$\Psi = \frac{d\Pi^A}{dt} - \frac{d\Pi^S}{dt} = -\left[(\alpha_L + \theta q_L)\frac{dq_L}{dt} + (\alpha_H + \theta q_H)\frac{dq_H}{dt}\right] + 2(\alpha_S + \theta q_S)\frac{dq_S}{dt}, \qquad (11)$$

where the comparative static's of the symmetric-cost case can be calculated from expressions (7) and (9) using the restriction $2q_S = q_L + q_H$ together with (A2). By substituting in equations (7) and (8) as well as the expression for $\frac{dq_S}{dt}$, equation (11) becomes (after some algebraic manipulation) equal to

[7] We wish to thank an anonymous referee for suggesting this line of reasoning.

$$\Psi = \frac{1}{D}(1+\delta)^2 (q_L - q_H)(c_H' - c_L')P''. \tag{12}$$

Our main results follow directly, recognising that all terms except P'' are unambiguously positive:[8]

Proposition:

i) The welfare effect is smaller (larger) in the asymmetric case when demand is concave (convex). The greater the degree of concavity (convexity), the smaller (larger) is the welfare effect in the asymmetric case. When demand is linear, the percentage change in welfare is smaller in the asymmetric case.

ii) The greater the degree of collusion in the industry, the greater the magnitude of the difference in welfare effect.

iii) The greater the cost difference is between the firms in the asymmetric case, the greater the magnitude of the difference in welfare effect.

The intuition behind *i)* is that when demand is concave, the high-cost firm is on a more elastic portion of the marginal revenue curve than the low-cost firm and thus must change the quantity by more to restore its first-order-condition. It thereby contributes to a greater than 50 percent share of the increase in total industry output.[9] The reverse is true if demand is convex. With linear demand the difference in welfare change from the production subsidy is identical between the two cases, but since initial welfare is greater in the asymmetric case due to the low-cost firm producing more than the high-cost firm, the percentile change is smaller in the asymmetric case. Hence, uniform production subsidies distort market shares in favour of the

[8] Note that $\delta = -1$ does not correspond with a Bertrand equilibrium when firms differ in cost efficiency, whence our comparison cannot include that case, see Shapiro (1989; p 354). Therefore, the lowest admitted value of δ in our analysis is slightly greater than minus one.

[9] Similar intuition is provided by Dierickx et al. (1988).

high-cost firm when demand is non-convex, thus giving a smaller welfare effect in the asymmetric case.[10]

5. Concluding remarks

This paper demonstrated how important it is to account for the industry cost structure when imperfectly competitive markets are subsidised. If firms differ in cost efficiency, the change in welfare from a uniform subsidy is not necessarily the same as in the case of homogeneous firms. The explanation is that firm market shares can be affected by a uniform policy in asymmetric cost industries, while it can not in industries with symmetric firms. Demand conditions are shown to determine the sign as well as to influence the magnitude of the welfare difference, while cost conditions and market power only influence the magnitude. Hence, the policy can lead to a greater or lesser welfare change than expected when cost asymmetry is ignored in the policy analysis.

A direct implication of the results in the paper is that one can draw inferences relating to demand convexity by observing changes in market shares that occur following the imposition of taxes and subsidies.[11] As shown in the model, the market share of the low-cost firm increases in response to a raise in the subsidy rate when demand is convex, while it decreases when demand is convex. This result may allow future empirical research to parameterise demand convexity in oligopolistic industries. More research in this area is needed.

When a subsidy is placed in an industry with asymmetric costs, the resulting distortion of market shares also has legal ramifications. Anti-trust cases, in particular, may have outcomes that are influenced by the imposition of regulatory policy. Our model demonstrates that a uniform subsidy, in all but the most restrictive cases, perturbs the market share of each

[10] Note that the implications are exactly reversed with production taxes, that is, a tax is less welfare decreasing in the asymmetric case, since the high cost firm is decreasing its production by at least as much as the low cost firm.

[11] Generally, it is possible to infer the cost structure of firms based on relative market shares in the industry. Many studies have adopted essentially the inverse approach, calculating market shares in a theoretical model based on relative costs. There are many examples of this approach, including Seade (1985), Dierickx et al. (1988), Shapiro (1989), and Kimmel (1992).

firm in the industry. Thus, in periods when new taxes or subsidies are imposed, using the Herfindahl Index (HHI) as a tool for policy analysis can significantly alter the outcome of anti-trust cases. The effect of tax policy on legally-defined regulatory limits, such as those suggested in current merger guidelines, may, in fact, be determined endogenously in the policy decision.

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Appendix

In this appendix we prove that $\frac{dQ^A}{dt} = \frac{dQ^S}{dt}$.

Proof. We start by calculating $\frac{dQ^S}{dt}$ in the same fashion as we did for the asymmetric case in equation (9). Hence,

$$\frac{dQ^S}{dt} = \frac{dq_S}{dt} + \frac{dq_S}{dt} = \frac{(f-h)+(g-e)}{D^S} = \frac{2[\theta - (1+\delta)P']}{D^S}, \tag{AI}$$

where

$$e = 2(1+\delta)P' + (1+\delta)^2 q_S P'' - \theta \qquad f = (1+\delta)[P' + (1+\delta)q_S P'']$$

$$g = (1+\delta)[P' + (1+\delta)q_S P''] \qquad h = 2(1+\delta)P' + (1+\delta)^2 q_S P'' - \theta .$$

Since assumption (A2) ensures that $Q^A = Q^S$, the arguments of all P' and P'' are the same, because they are evaluated at the same level of industry production. Using equation (9), our claim can be expressed as

$$\frac{dQ^A}{dt} - \frac{dQ^S}{dt} = \frac{2[\theta - (1+\delta)P']}{D^A} - \frac{2[\theta - (1+\delta)P']}{D^S} = 0. \tag{AII}$$

Since the numerators are equal, all that has to be shown is that the denominators of (9) and (AI) are equal. Here:

$$D^A = 3(1+\delta)P'^2 + (1+\delta)^3(q_L + q_H)P'P'' + \theta^2 - 4\theta(1+\delta)P' - \theta(1+\delta)^2(q_L + q_H)P'',$$

and

$$D^S = 3(1+\delta)P'^2 + 2(1+\delta)^3 q_S P' P'' + \theta^2 - 4\theta(1+\delta)P' - 2\theta(1+\delta)^2 q_S P''.$$

Since $Q^A = Q^S$ implies that $q_L + q_H = 2q_S$, the difference between the determinants is zero.

Q.E.D.

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