Entry and exit decisions in differentiated product markets: the Spanish car industry.

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April 18, 2005

Abstract

This paper is aimed at modelling entry and exit decisions in the context of product differentiation. Firms introduce a new product when the expected discounted profit exceeds the sunk cost of development. This is an infinitely repeated game that should be solved using dynamic programming tools. As a first attempt, this paper presents just a two-stage model where firms first choose product characteristics, summarized by an index, and then compete in prices. Firms face fixed costs of entry and constant marginal cost of production. The model is solved for alternative demand specifications to obtain the expected variable profit of entering with a given set of characteristics. This is used to characterize entry decisions: entry takes place when profit exceeds fixed cost. The empirical exercise is carried out using data on the Spanish car industry for the period 1990-2000. Preliminary estimates of the structural model show an inverse relation between entry and fixed cost, and a weak positive relation with variable profits, suggesting the importance of controlling misspecification in the empirical model. Future extensions of the paper will make use of the one-period profit function from the two-stage game to obtain an estimable entry condition in the fully dynamic setting.

JEL classification numbers: L11, L13

Keywords: entry, differentiated product, automobile

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1 Motivation

This paper will focus on product entry and exit decisions. I understand by "entry" the introduction of a new model that then competes against the incumbent models for a stake of the market. This means I am not considering the entry of a firm itself, rather I want to model and describe when and why producers decide to offer a new, possibly differentiated, car model. Common sense indicates that firms are willing to introduce a new product when the expected revenue exceeds the fixed (or sunk) cost of development, which includes for example the R&D costs, plant setup or adaption costs and advertisement costs. The product is differentiated and firms react strategically to their competitors' actions, competing infinite periods. The best approach is a model of dynamic competition where each period firms decide to enter if the sum of expected discounted profits from entering the market is bigger than the sunk cost of entry the firm enters. However, and as a first step, I present here a two-period model where firms first choose the set of characteristics of the product (summarized by an index) and then compete in prices. From this model I able to obtain an expression for the single-period expected variable profits of introducing a new good, given a set of characteristics. The comparison of variable profits an fixed costs gives the rationale for the entry decision.

Demand is determined by utility maximizing consumers that take into account the price and characteristics of each alternative. I shall stick here to the well established literature of discrete choice of product differentiation. Alternative demand specifications are considered for the estimation of market shares taking care of the segmented nature of this market.

The richness of my database allows the identification of decisions of firms so that by using an adequate model I can try to explain why each player behaves as it does up to the randomness derived from the fact that actual realizations might come from a set of possibly different equilibria. There have been many papers addressing the issue of entry but most of them, speacilly in the early literature, focus on the number of firms the market can sustain and how many can enter/exit. The identity of the firms involved either remains undetermined or it is not the focus. For instance, Bresnahan and Reiss (1991b) propose a model that accounts for the number of entrants and where the decision of entry is based on having non-negative profits, however the product is homogeneous and potential entrants are all identical. The focus of their paper is on competition and the evolution of market structure, so they do not consider firm specific analysis of the determinants of entry. Berry (1992) presents a two-stage model where firms first decide to stay or to leave and then they compete and earn profits. He provide conditions under which the equilibrium number of firms is unique but the identities of the entrants remain undetermined (This is similar to Bresnahan and Reiss (1991a) where a given market structure is compatible with several empirical observations). Profits drive the decision of entry, variable profits are function of market characteristics and market structure but do not explixivcely depend on firms' strategies. Mazzeo (2002) is another two-stage differentiated product model where first entry and quality is decided and then
firms compete. Profits are empirically characterized by a set of market demand characteristics and market structure.

This paper presents a structural model of firm behavior that links entry decisions with the observed actions of firms in the product space. The focus is not the number of players but their identity. I want to be able to explain why some firms enter while other do not. The number of firms is not explicitly modeled and market structure is known after all decisions of entry/stay/exit are put together. A similar approach can be found in Ishii (2005) for ATM networks in the banking industry. She presents a model where first the bank chooses the size of the network and then compete in prices (interest rates). The focus is on firms’ behavior and on the determinants of price and network choice. This one is, from the point of view of consumers, an attribute that differentiates banks from one another. In Seim (2004) the source of differentiation is geographic location. Here firms jointly decide whether to enter or not and if yes, their location. Each firm makes its decision based on its expected post-entry profits. These are influenced by the unobserved competitors’ type and the effort is put on obtaining an estimable condition for entry and the probability of entry at each possible location. That condition is the expected profit from getting in being greater than the reservation payoff from staying out of the market.

In order to see the magnitude of the phenomenon of entry I start by describing the industry from the point of view of entry-exit decisions. Section 3 describes the database used. Section 4 presents a preliminary probit analysis describing correlations between entry and some relevant variables. The model is presented in section 5. The empirical implementation and estimation results are in section 6. Section 7 concludes.

2 Introduction: Entry and exit in the Spanish car market during the 90’s

The period 1990-2000 shows an increasing trend in the number of models marketed (Figure 1).

There are two main reasons behind this fact. Firstly, the opening of the Spanish market to foreign producers as a result of becoming a member of the EC. Secondly, there is an increase in the number of models marketed by firms. I look at each one in more detail.

The entry of Spain in the European Community implied a progressive reduction on the tariffs for imported cars in order to converge to the rates applied in the Union. This fostered the entry of many foreign producers, whose cars became cheaper. The evolution of tariffs is shown in Table 1. 1993 is the cut-off point. However, this does not appear to have a striking influence on the number of models marketed. Indeed, Figure 1 shows that 1996 is somehow a breaking point after which the introduction of models speeds up, the main reason being the intensive entry by some (mainly Asian) newcomers. This is clear in Figure 2: I represent, by segment, the percentage of models according to the geographical
origin of the firm: the lowest line represent EU producers (excluding Spain), the next one spanish producers, next are americans and finally asian producers. For example, the gap between lines 3 and 4 represents the presence (in terms of number of models marketed, and not in terms of market share) of asian producers. This presence becomes significantly greater circa 1996, and it focuses in the small-medium range of models. Figure 3 plots the market share by segment according to the geographical origin of the firm (the cross is for european producers, the triangle spanish producers, the square americans and the solid line the asian). The same evidence is obtained by looking at the economic origin of the firms: Figures 4 and 5 represent the proportion of the number of models marketed by domestic firms (crossed-line), europeans (squared-line) and others (solid line), including asian and american producers.

Regarding the total number of entries and exits, it does not appear to follow a clear pattern. Entries take place somewhat regularly along the sample period with just a sharp peak in Jan-97 associated to massive entry from asian producers. Exits behave a bit more regularly along the year (Figure 7). Table 2 displays the gross number of entries and exits per year and the number of models at the beginning of the period.

The average (average by year and brand) proportion of entries per segment\(^1\) in the sample period is between 2% and 8%. Those proportions are computed as follows: I generate a variable "enter" with 2904 obs. (the combination of 8 segments, 11 years and 33 brands) that has a 1 if a brand in a particular year has introduced a model and a 0 otherwise. Then I compute by segment the proportion of ones. This procedure assumes that all the firms of our sample could have made a decision of entry at any moment of the sample. This is not realistic, because that was not possibly the case of most of asian producers. Moreover, following that argument I could consider that any firm with presence or not in the spanish market could have entered, what would have forced us to include all manufacturers in the world. Therefore, a refinement on that procedure is to exclude a firm while it has not entered the spanish market for the very first time. This affects only Subaru, Chrysler, Hyundai, Kia, Daewoo and Galloper, who entered the spanish market for the first time after 1990. But it could also be the case that a firm leaves at all the market and never comes back, then it would not make much sense to include it as potential entrant in each period. This affects Yugo and Lada. The remaining firm are all present in every year in at least one segment. Therefore if I forget about the firms that have not entered yet or who have left definitelly I get a file of 1075 decisions of "enter" "not enter". Computing now the proportions of entry yields a pretty stable number of 15 % (Table 5). The average level of entry in the whole sample is roughly the same for all segments (it goes from the 12.5% in segment 6 to the 16.4% of segment 3. The 28.5% figure of segment 8 is due to the fact this is a really new segment and the process of entry is more intensive). By economic origin domestic firms have a proportion of entries of 10% for a 20% of foreigners.

\(^1\)We consider here the following 8-segment classification: Small-Mini, Small, Compact, Intermediate, High-Intermediate, Luxury, Sports, and Minivan
Domestic firms, already present in most segments, just make a replacement effort and eventually enter new segments. By contrast, foreign firms (especially Asian) enter the Spanish market and also have to undertake model replacement.

Regarding the increase in the number of models marketed by firms a glance at Figure 8 shows that almost all firms maintain or increase the number of models for sale in the sample period. Exception are short-lived brands and Rover. Tables 3 and 4 show how newcomers tend to occupy all "niches" and incumbents tend to reinforce their presence. Indeed, 6 out of 8 firms with no activity up to December 1989 were present in at least 3 segments by the end of 2000. Paradigmatic examples are Hyundai or Kia. Incumbents either maintain or increase the number of models for sale and the segments where they are present with an intensive activity of entry and exit of models. This can only correspond to replacement decisions in most cases (for example Renault, Ford, Peugeot). Moreover, during this period we assist to the born and expansion of new segments. For instance, in 1992 Chrysler introduces its minivan, a new concept of car bridging together the classic familiar tourism and the van. Only Renault was offering a similar concept of car. In 2000 there were 19 firms. The end of the decade witness the consolidation of the "urban car", a pretty small one designed for driving in traffic-jammed cities. Therefore, the expansion or consolidation in the number of segments spurs model proliferation. Behind the "creation" of new segments lies the interest of firms to best fit the needs of some groups of consumers. In some sense, this is just a horizontal differentiation process. The natural question now is, why did it happen at that time? What was the difference that made optimal to increase differentiation? Figure 9 illustrates this process: Segments 3, 4 and 5 are "intermediate" ones, we observe how segments 3 and 5 get more crowded while the number of models in segment 4 decreases. Segment 1 can be identified as the "urban car" segment, and its trend is to increase in size as well.

There are at least two reasons behind the entry and exit decisions of each producer:

On the one hand, replacement decisions. A number of entry decisions, i.e., the introduction of a new model is associated to a correspondent exit, in such a way that the firm just replaces one model with another, maybe with some degree of overlapping.

On the other hand, net entries. These are related to the "creation" of new segments or new bundles of characteristics significantly different from the existing ones. Examples of this are the introduction of minivans (segment 8) or the increasing popularity of the urban cars (segment 1), that has converted them in a segment on its own, different from the small segment (sg 2). By contrast, some segments may become sort of "unpopular" and lose weight in the industry. This seems to be the case of segment 4, whose number of models declines as segments 3 and 5 go up.

A plot of the duration of models by firms shows that behaviour varies considerably among firms. Some of them just offer one model per segment, or at most two due to the overlapping when passing from the old to the new model.
Examples are Saab, Citroen-Peugeot (PSA holding) or Renault. There is another group of firms offering many models in the segments they are present, like Mercedes-Benz, BMW, Rover. They all have in common the specialization in sport or luxe cars, grouped all in segments 6 and 7. Obviously the models are differentiated both horizontally and vertically, but they are classified in the same slot by the industry. The target consumer of those companies usually has a relatively high purchasing power and does not care much about price.

The majority of producers displays a behaviour lying in between those two extreme positions. Some regard is due with the asian latecomers, as I do not have a long enough sample to evaluate their behaviour in replacement, and I can just say something about their "net entry" decisions, i.e., the order in which they introduce models into the spanish market.

3 Data description

I use a unique database of car registrations over the period 1990-2000 disaggregated by model. The price and main characteristics of the car (such as power, speed, fuel consumption, dimension, ABS or air conditioning among others) are available in a monthly basis. The sample is filtered to exclude some particular models or brands with really special features (for example Ferrari and high-top cars affordable only to a minority). In any case the sample represents more than 99% of total registrations during the sample period. Models that are new commercial denomination of an existing model are skipped and assimilated to the original name when there is no change in the basic characteristics, otherwise a new model is added to the sample. Car producers usually offer a number of varieties of each model, for instance different engines, optional characteristics, etc. For each model it is chosen the most popular variety and then all registrations from all varieties are attributed to that one. In particular, all are gasoline models. The sample considers to types of segment classification: 8-segment classification, with Small-Mini (or urban car), Small, Compact, Intermediate, High-Intermediate, Luxury, Sport, and Minivan. The 5-segment classification: Small (equivalent to Small-Mini + Small), Compact, Intermediate, Luxury (includes sport), and Minivan. The off-road segment is excluded because of data unavailability.

4 Descriptive probit analysis

The depiction of the empirical framework can be completed by looking at the correlations among variables that arise in a probit model. The dependent variable will be the probability of entering explained with some basic variables: the average real price of cars, as a proxy or index for the bundle of characteristics, the total number of models of each firm (proxy for variety), the age of the oldest model for each firm (proxy for the incentive to replace old models), the proportion of entries over the total number of models in each period, the ratio
of segment sales over total sales (proxy for the importance of entry in some segments) and the existence of tariffs. I also include dummy variables controlling for year, segment and economic origin of the firm (domestic, European or other). I consider the non-augmented sample (1075 obs.), partially-augmented sample (2584) and the augmented sample (2904), defined as in the previous section. Table 6 reports a brief summary of results.

The best results are given by the parsimonious specifications of Table 6 with no dummies for year or segment, for any of the alternative samples. In these all coefficients are highly significant and moreover robust to several probit specifications.

The remarkable findings are the positive sign for the coefficient of the number of models ("number") and negative sign for the age of the oldest model ("maxage"). This can be interpreted as the existence of a strong correlation or "clustering" in the decisions of entry. The negative sign of "maxage" means that the probability of entering increases as the contemporaneous mean average of the models marketed decreases, this average is computed each period taking into account the age of the "new" models, hence if by some reason many models are introduced at the same time the average will be smaller and at the same time entry is high. If firms do not coordinate or enter at the same time, spreading entries along time, we should not observe a deep fall in mean age nor a significant amount of entries, thus having a pair of uncorrelated variables. This is not the case, as the coefficient appears to be highly significant in all regressions run. This correlation is not surprising if we look at Figure 6, where entries take place intensively in certain peak periods. The positive sign of "number" tells that the more models are in the market the more likely entry is, thus feeding back the stock of models sold. This reflects the fact that entry rates speed up in the sample period. Notice that there could have been an increase in the total number of models as a consequence of smaller exit rates and stable entry rates, the positive coefficient tells us that, no matter what happens with exit, entry is fostered as variety increases.

The other variables have the expected signs: higher real prices are an incentive for entry, European and Asian-American firms enter more intensley and the higher the importance of a segment ("relsales") the more likely is entry. The variable "tariffs" should have a negative impact but it is non-significant most of the times (although when it approaches significance its sign is indeed negative).

5 The model

5.1 Consumer’s behavior

In this part I stick to the well established random utility models (Anderson, de Palma, and Thisse (1992)). Individuals demand either one unit of the good or none. They derive utility from the characteristics a product embodies. Let \( i \) denote the product, \( s \) the segment, and \( l \) the firm, then the utility from consuming segment \( s \)'s good \( i \) of firm \( l \), is given by: 

\[
u_{sli} = k_{sli} - p_{sli} + \xi_{sli}\]

where
\( p_{sli} \) denotes the price, \( k_{sli} \) is some index summarizing all the characteristics of the good (could be interpreted as a "quality index" or as an indicator of location in a "horizontal space"). \( \varepsilon_{sli} \) is an idiosyncratic error term unobserved to the econometrician, the \( \varepsilon'_{sli,s} \) are assumed to be \( iid \) with a double exponential distribution. Denoting by \( M \) the market size, total demand of the good is \( D_{sli} = S_{sli}M \). The analytical expression of market shares and all the details regarding demand specification and the solution of the models are in appendix 1. There I consider three alternative demand specifications: nested logit, multinomial logit (MNL) with multi-product firms and the standard MNL with single-product firms.

5.2 Firms’ behavior

Firms are profit maximizers that compete in an infinite horizon by playing the following stage game: they simultaneously decide at the beginning of each period the location of their product in the space of characteristics, summarized by the index \( k \), which has an associated cost given by \( F(k_{li}) \). Then they compete in prices having observed the results of the first stage. We have to distinguish between the decision of entry and the decision of where to enter. Provided a firm has entered at some point in time, it may well decide to vary the composition or set of characteristics embodied by its product, without introducing a new one. The car market, which is the focus of this paper actually has this property: I define products based on the commercial name for sale and I plot its main characteristics along time then I see how the actual composition of cars is changing \(^2\). Therefore, it sounds reasonable to allow firms for some flexibility at the time of designing and modifying their products. And all of this may have some cost, represented by the function \( F(k_{li}) \), i.e., this is not a production cost, it is the cost associated to the R\&D, design or plant modification needed for obtaining a level \( k_{li} \) of characteristics. Once the product "exists" it can be replicated at some standard production cost given by the function \( C(D_{li}) \).

With all of this the profit function for (multiproduct) firm \( l \) is:

\[
\pi_l = \sum_{i=1}^{N_l} \{ p_{li} D_{li} (\cdot) - [ C(D_{li} (\cdot)) + F(k_{li}) ] \}
\]

where the demand is a function of the prices and characteristics offered by the firm and also by its competitors:

\[
D_{li} (\cdot) = D_{li} (p_{l1}, \ldots, p_{lN_l}, \ldots, p_{m1}, \ldots, p_{mN_m}; k_{l1}, \ldots, k_{lN_l}, \ldots, k_{m1}, \ldots, k_{mN_m})
\]

I can solve backwards the stage game for the asymmetric subgame perfect Nash equilibrium. The details are in appendix 1.

\(^2\)The election of characteristics is not the focus of this paper but the objective of ongoing parallel research. The mentioned plots are available from the author under request.
5.3 Dynamic framework

The resolution of the two-stage game played by firms would give us the equilibrium prices and locations. However, I do not need that if I just want to determine whether the firm should enter or not. The first order condition give implicit equilibrium relationships that allow us to obtain an equilibrium expression of profits. Then I can apply the methodology developed in Pakes, Ostrovsky, and Berry (2004) and obtain an empirical condition for entry relating variable profits and fixed costs. They propose

\[ \Pi(n, z) = 2 - \frac{Z^2}{(1-n)^2} \]

as an empirical profit function.

From my model I can alternatively put forth \( \Pi_i = \mu \frac{S_i}{S} (1 + z) M - F_i \), if I just consider the price competition stage. Considering the first-stage profit functions leads to alternative, more complicated specifications (see the details in appendix 1):

6 Empirical model and estimation (preliminary)

Once the model is set up it is time to put it in practice. The first step is to do a structural analysis of entry based on the comparison of variable profit and fixed costs, whenever the difference is positive a new model comes in:

\[
\text{Pr (entry)} = \text{Pr (} \Pi_i > 0) = \text{Pr (} E(\Pi_i^v) - F(k_i) + \xi > 0) = \\
= \text{Pr (} \xi > -(E(\Pi_i^v) - F(k_i))) = F_\xi (E(\Pi_i^v) - F(k_i))
\]

where the last equality comes from the assumption of a symmetric distribution for \( \xi \). In particular: \( \xi \sim N(0,1) \) so this is the probit model. As a starting point I consider the case of single product firms competing in prices so that the baseline demand model is the standard multinomial logit with price competition (however, recall the variable profit from the price competition stage is the same for all three demand specifications\(^3\)) and I will consider a "firm" to be the combination of car producer and segment (segment-firm, to avoid confusion), for example Renault in the small segment is one firm, and so is Renault in the intermediate segment. Then, the discounted sum of variable expected profits is:

\[
\frac{1}{1 - r} E(\Pi_i^v) = \mu \frac{1}{1 - r} E \left( \frac{S_i}{1 - S_i} \right) M .
\]

The market size, \( M \), is approximated by the number of households per year. \( r \) is the interest rate, assumed to be known and constant. \( \mu \) is a demand parameter to be estimated. More has to be said for the expected market shares: We observe the characteristics and sales of the products that successfully enter then I can assume perfect foresight and consider that the market share expected a priori is the same than the realized a posteriori. What about the "failed entries"? i.e. how can we approximate the expected market share of a model which has not entered? Here we have two possibilities. First, the segment-firm has never been present in the Spanish market, in this case I do not consider as a potential entrant until it enters for the very first time. This is equivalent to assume that the first entry of any firm is always successful and that

\(^3\)See appendix 1
if I have not observed in a particular market is because the firm does not want to do it, whatever the reason (dimension, international presence policy, etc.). If I do not make this assumption I would have to consider as a potential entrant any car producer of the world, and that extreme does not sound reasonable. Second, the segment-firm has entered before, in this case it has already a product for sale and I can assume that had it been able to introduce another product, it would enjoy the same market share share, i.e., the failed entrant is at most (and in the limit equal) as good as the incumbent product. It is worth to note here that I am about to fit a probit model to a panel dataset. This is not the best way to take advantage of the panel structure but it is a first step before estimating the dynamic model. Therefore there are observations for each segment-firm in several years, some of these correspond to entry periods others do not. What I am assuming is that in the periods where there is no entry but still the segment-firm is present, the characteristics and expected share of the failed product were equivalent to those of the product already present. The segment-firm would entry only with a "better" product than the one it is currently offering.

I only have one parameter to estimate from the demand side and it is likely to vary across segments, so I interact $\frac{S_l}{1-S_l}$ with segment dummies to control for that ($x_{1seg1}$ to $x_{1seg8}$).

After the discussion of the demand and variable-profit side of the story I focus on the specification of fixed costs. The model allows for several specifications. A location-dependent fixed cost could be represented by $F(k_l)$ as an increasing (convex) function of the index of characteristics. However, I shall start with a purely fixed cost that only varies through segments. I define a set of segment dummies (seg1 to seg8) that capture this fixed cost. One could think that there are another factors affecting cost structure: I introduce a set of dummies to control for origin (either domestic, european or non-european firm) and a count of the models each segment-firm has per period (to control for synergies between models at the time of entry).

Table 7 presents a summary of the structural probit specification. Column 1 presents the basic model. All the dummies of segment have negative sign which is coherent with the economic interpretation: the greater the cost of entry, the less entry we see. Coefficients are related to the average cost of segment 8 (Minivan), the negative sign is also telling that entry is less likely in all other segments. There could be two reasons justifying these negative signs: they are costs but they are also capturing the excess entry in segment 8 with respect to other segments as if it were a cost advantage (i.e. there would be more entry in the minivan segment because it is cheaper). This second effect is misleading and once I start controlling for diverse factors the cost differential becomes smaller. Columns 3 and 4 of table 7 show the results when we control for the economic origin of the firm (the reference is a domestic firm and I introduce dummies to control for european origin and other non-european origin). The positive signs are consistent with the fact that entry comes mainly from foreign firms. Regarding the segment-specific demand parameters (the $x_{1seg}$’s variables, recall that $\mu * x_{1seg} = \mu * \frac{S_l}{1-S_l} M * segment \ dummy = \Pi_l'$ by segment) positive
signs should be expected: the more profitable is a model the more likely entry is. However, I get positive sign only in segments small-mini, intermediate and sport, in the four specifications provided. Nevertheless, after controlling for economic origin the positive signs become greater and more significant and the negative ones become closer to zero and less significant (columns 2, 3, and 4). This means it is needed to control for factors that can bias variable profit estimates to be able to obtain consistent estimates of the influence of variable profits on entry.

7 Concluding remarks

This paper studies the determinants of entry decisions or introduction of new goods in the context of product differentiation, with an application to the spanish car market. It is common to observe firms regularly introducing new products, while in other occasions entries take place in a massive way. Here is proposed a two-stage model of price competition and election of characteristics that yields a structural equation of profits depending on market shares and cost determinants. This equation provides a rationale for entry decisions: a new good is introduced when the discounted sum of profits exceeds the cost of entry. The two-stage structural equation is estimated for data on entries and characteristics in the spanish car industry in the period 1990-2000. A set of preliminary specifications provide insight on the forces driving entry, though some refinement is still required. In particular, the negative relationship between entry and the cost of entry is confirmed. Also, we see how misspecification leads to biased estimates of the influence of variable profits on the introduction of new products.

Future research will make use of the single-period variable profit function from the two-stage game to estimate a fully dynamic model of entry and exit, taking advantage of the panel structure of the data.
8 Appendix 1: Solution for the firm’s problem with alternative demand specifications

8.1 Nested Logit

8.1.1 Definitions

Let’s adopt the following notation:

- \( s, r, t \): segment indexes
- \( R \): either the total number of segments or the set of segments
- \( l, m \): firm indexes
- \( N \): number of firms
- \( i, j \): product indexes
- \( N_{sl} \): number of goods of firm \( l \) in segment \( s \)
- \( S_{ili} \): market share of product \( i \) of segment \( s \) for firm \( l \)
- \( S_{li/s} \): conditional market share of good \( i \) of firm \( l \), conditional on segment \( s \) being chosen

- \( S_s \): share of segment \( s \) in the set of set of segments \( R \)

Following Anderson, de Palma, and Thisse (1992) [chapter 2], I define:

\[
S_{li/s} = \frac{\exp \left( \frac{u_{ili}}{\mu_2} \right)}{\sum_{m=1}^{N} \sum_{j=1/s}^{N_{sl}} \exp \left( \frac{u_{imj}}{\mu_2} \right)}
\]

\[
S_s = \frac{\exp \left( \frac{A_s}{\mu_1} \right)}{\sum_{r=1}^{\bar{R}} \exp \left( \frac{A_r}{\mu_1} \right)}
\]

where:

\[
A_s = \mu_2 \ln \sum_{m=1}^{N} \sum_{j=1/s}^{N_{sl}} \exp \left( \frac{u_{imj}}{\mu_2} \right)
\]

the expected value of the maximum of the utilities. And:

\[
U_{ili} = k_{ili} - p_{ili} + \varepsilon_{ili} = u_{ili} + \varepsilon_{ili}
\]

where: \( \varepsilon_{ili} \sim F(x) = \Pr(\varepsilon_{ili} \leq x) = \exp \left[ - \exp \left[ - \frac{x - \lambda}{\mu_2} \right]\right] \). \( \mu \) is a scale parameter and \( \lambda \) a location parameter of the type I extreme value distribution. Actually \( \mu \) is a measure of the variance of the \( \varepsilon \)'s as: \( \Var(\varepsilon_{ili}) = \frac{1}{6}\pi^2\mu_2^2 \) [Johnson and Kotz (1970) [ page 278]]. \( \mu_1 \) is a measure of inter-segment heterogeneity and \( \mu_2 \) a measure of intra-segment heterogeneity. With all of this \( S_{ili} \) is shown to be:

\[
S_{ili} = S_s \times S_{li/s} = \frac{\exp \left( \frac{A_s}{\mu_1} \right)}{\sum_{r=1}^{\bar{R}} \exp \left( \frac{A_r}{\mu_1} \right)} \times \frac{\exp \left( \frac{u_{ili}}{\mu_2} \right)}{\sum_{m=1}^{N} \sum_{j=1/s}^{N_{sl}} \exp \left( \frac{u_{imj}}{\mu_2} \right)}
\]
\[ S_{sl_i} = \frac{\exp \left( \frac{1}{\mu_1} \mu_2 \ln \sum_{m=1}^{N} \sum_{j=1}^{N_{sl_i}} \exp \left( \frac{k_{mj} - p_{mj}}{\mu_2} \right) \right)}{\sum_{r=1}^{R} \exp \left( \frac{1}{\mu_1} \mu_2 \ln \sum_{m=1}^{N} \sum_{j=1}^{N_{sl_i}} \exp \left( \frac{k_{mj} - p_{mj}}{\mu_2} \right) \right)} \times \exp \left( \frac{k_{sl_i} - p_{sl_i}}{\mu_2} \right) \] (1)

8.1.2 The problem of the firm

**Second stage** The firm chooses a set of prices such that it maximizes profits:

\[ \max_{(p_{sl_i})_{i,s}} \Pi_t = \sum_{s=1}^{R} \sum_{i=1}^{N_{sl}} [(p_{sl_i} - c_{sl_i}) MS_{sl_i} - F(k_{sl_i})] \]

The FOC’s:

\[ MS_{sl_i} + (p_{sl_i} - c_{sl_i}) M \frac{\partial S_{sl_i}}{\partial p_{sl_i}} + \sum_{j \neq i} (p_{sl_j} - c_{sl_j}) M \frac{\partial S_{sl_j}}{\partial p_{sl_i}} + \sum_{r \neq s, j=1}^{N_{sl}} (p_{rl_j} - c_{rl_j}) M \frac{\partial S_{rl_j}}{\partial p_{sl_i}} = 0 \]

(2)

\[ s = 1, \ldots, R \]
\[ i = 1, \ldots, N_{sl} \]

Then, the next step is to compute the key derivatives:

\[ \frac{\partial S_{sl_i}}{\partial p_{sl_i}} = -S_{sl_i} \left[ \frac{1}{\mu_1} (1 - S_{sl_i}) S_{li/s} + \frac{1}{\mu_2} (1 - S_{li/s}) \right] < 0 \]

\[ \frac{\partial S_{sl_j}}{\partial p_{sl_i}} = -S_{sl_j} \left[ \frac{1}{\mu_1} (1 - S_{sl_j}) S_{li/s} - \frac{1}{\mu_2} S_{li/s} \right] > 0 \text{, recall } \mu_1 \geq \mu_2 \]

\[ \frac{\partial S_{rl_j}}{\partial p_{sl_i}} = -S_{rl_j} S_{sl_i} \frac{1}{\mu_1} = \frac{1}{\mu_1} S_{rl_j} S_{sl_i} > 0 \]

Now substitute all the expressions in (2) and after some algebra:

\[ (p_{sl_i} - c_{sl_i}) S_{sl_i} = \mu_2 S_{sl_i} + \left( 1 - \frac{\mu_2}{\mu_1} \right) S_{li/s} \sum_{i=1}^{N_{sl}} (p_{sl_i} - c_{sl_i}) S_{sl_i} + \]
\[ + \frac{\mu_2}{\mu_1} S_{sl_i} \sum_{s=1}^{R} \sum_{j=1}^{N_{sl}} (p_{sl_i} - c_{sl_i}) S_{sl_i} \]

(3)

\[ i = 1, \ldots, N_{sl} \]
\[ s = 1, \ldots, R \]

The set of equations given by (3) define implicitly the optimal pricing rule, \( p_{sl_i}^* \), and from these we can get the market shares, \( S_{sl_i}^* \), that are now function of all the \( k \)'s: \( S_{sl_i}^* = S(k_{111}, \ldots, k_{11N_1}, \ldots, k_{R11}, \ldots, k_{R1N_R}, \ldots, k_{rlj}, \ldots, k_{RNN_n}) \)
Notice that if I assume different fixed cost functions for each firm and/or segment and/or product we cannot have a symmetric equilibrium. However, the existence of an asymmetric equilibrium is guaranteed because the strategy space and the profit function are "well behaved" [Caplin and Nalebuff (1991)].

Although we cannot solve for the analytical expression of equilibrium prices we still can manipulate the FOC’s and use them to simplify the first stage of the game. So, now sum over \( s \) and \( i \) and introduce the following definitions:

\[
S_l = \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} S_{sli}, \text{ the total market share of firm } l
\]

\[
S_{sl} = \sum_{i=1}^{N_{sl}} S_{sli}, \text{ the market share of firm } l \text{ in segment } s
\]

\[
\Pi_l' = \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} (p_{sli} - c_{sli}) M S_{sli}, \text{ the variable profit of firm } l
\]

Then:

\[
\Pi_l' = \frac{\mu_1 \mu_2}{\mu_1 - \mu_2} M S_l + \frac{\mu_1 - \mu_2}{\mu_1 - \mu_2} M \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} (p_{sli} - c_{sli}) S_{sli} \left\{ \sum_{i=1}^{N_{sl}} S_{li/s} \right\}
\]

Nested logit term

When segments do not provide any source of differentiation (\( \mu_1 = \mu_2 = \mu \)) we are back to the standard multinomial logit and the expression of variable profits is the one we already know. We would like to have the simplest first-stage optimal variable profit function possible. The one above is rather cumbersome. However, the introduction of an assumption can make things much simpler. In particular:

**Assumption 1**: \( N_{sl} = N_{rl} \) \( \forall s, r \in \mathcal{R} \)

**Assumption 2**: \( S_{li/s} = S_{li/r} \) \( \forall l = 1, ..., N \) \( \forall s, r \in \mathcal{R} \)

In words: the market share of a firm in one good (the "first", "second" or whatever, the only thing that matters is that we can give a number or ordering to them) is the same across all the segments where the firm is present, conditioned on that segment chosen.

Alternatively we can assume:

**Assumption 2’**: \( \sum_{i=1}^{N_{sl}} S_{li/s} = \sum_{i=1}^{N_{rl}} S_{li/r} \) \( \forall s, r \in \mathcal{R} \)

This is just saying that the market share of a firm conditioned to certain segment is the same across segments. Every firm has the same degree of efficiency in all the segments it is present. For example: the market share Citroen can enjoy conditioned we are in the small-mini segment is the same than what it has in the intermediate segment. The shares of each model within segments are allowed to the different, i.e \( S_{li/s} \neq S_{lj/s} \) in general, and this implies that we can have \( S_{sli} \neq S_{sld} \), but also \( S_{sli} \neq S_{sli} \) because although \( S_{li/s} = S_{li/r} \) still
$S_s \neq S_r$. Yet another possible interpretation is the following: consumers consider that all firms have the same degree of "efficiency" (i.e. the relation between $k$ and $p$) in all segments. This is not completely true in the real world, for instance it is plausible that Mercedes-Benz is relatively better than Citroen when producing luxury cars. However, it does not seem unreasonable to consider that both Citroen and Renault are, from the point of view of consumers (what in the end determines demand and market shares), similar in all segments. Therefore, this assumption is sensible if we keep in mind that most brands are "generalistic", in the sense that they pretend to serve all the market, and not to specialize in particular segments.

Moreover, assumption 2' simplifies things a lot, as we can take $\sum_{i=1}^{N_{si}} S_{li}$ out when summing over $s$ to obtain the final expression for profits:

$$\Pi^v_i = \mu_2 \frac{S_l}{1 - S_l} M$$

as in the standard multinomial logit. Therefore I can state that the optimal profit function from price competition is the same for the multinomial logit and for the nested logit plus assumption 2'.

**First stage** Given the optimal pricing behavior in the second stage and the associated variable profit function I can write the problem of the firm in the first stage as:

$$\max_{(k_{sit})_{s,i}} \Pi_t = \mu_2 \frac{S_l}{1 - S_l} M - \sum_{s=1}^{\Re} \sum_{i=1}^{N_{si}} F'(k_{sit})$$

the FOC’s:

$$\mu_2 M \frac{1}{(1 - S_l)^2} \frac{\partial S_l}{\partial k_{sit}} = F''(k_{sit})$$

$$i = 1, \ldots, N_{sl}$$

$$s = 1, \ldots, \Re$$

where:

$$\frac{\partial S_l}{\partial k_{sit}} = \frac{\partial S_{sl}}{\partial k_{sit}} + \sum_{j \neq i} \frac{\partial S_{sj}}{\partial k_{sit}} + \sum_{r \neq s} \sum_{j=1}^{N_{sj}} \frac{\partial S_{rj}}{\partial k_{sit}}$$

We need these three derivatives. We compute them

After some algebra and using assumption 2' we obtain:

$$\frac{\partial S_l}{\partial k_{sls}} = \frac{1}{\mu_2} S_l R - \frac{1}{\mu_1} S_{sls} S_{sl} + \frac{\mu_2 - \mu_1}{\mu_1 \mu_2} S_l S_{sls} + \frac{1}{\mu_2} S_{sls} - \frac{1}{\mu_2} R_l$$

where:
$$R = \sum_{r=1}^{\mathcal{R}} \sum_{m=1}^{N} \sum_{j=1}^{N_{rm}} S_{rmj} \frac{\partial p_{rmj}}{\partial k_{slj}}$$

$$\bar{R} = \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} R = \sum_{m=1}^{N} \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} \sum_{j=1}^{N_{rm}} S_{rmj} \frac{\partial p_{rmj}}{\partial k_{slj}}$$

$$R_{l} = \sum_{r=1}^{\mathcal{R}} \sum_{j=1}^{N_{rl}} S_{rlj} \frac{\partial p_{rlj}}{\partial k_{slj}}$$

Then the FOCs become:

$$\frac{M \mu_{2}}{(1 - S_{l})^{2}} \left[ \frac{1}{\mu_{2}} S_{l} R - \frac{1}{\mu_{1}} S_{sl} S_{sl} + \frac{\mu_{2} - \mu_{1}}{\mu_{1} \mu_{2}} S_{l} S_{ali} + \frac{1}{\mu_{2}} S_{ali} - \frac{1}{\mu_{2}} R_{l} \right] = F'(k_{sl})$$

$$i = 1, \ldots, N_{sl}$$

$$s = 1, \ldots, \mathcal{R}$$

and profits:

$$\frac{1}{(1 - S_{l})^{2}} \Pi' \left[ \frac{1}{\mu_{2}} - \frac{1}{\mu_{2}} \frac{1}{S_{l}} \sum_{s=1}^{\mathcal{R}} \sum_{j=1}^{N_{sl}} R_{l} - \frac{1}{\mu_{1}} \frac{1}{S_{l}} \sum_{s=1}^{\mathcal{R}} S_{sl}^{2} + \frac{1}{\mu_{2}} \bar{R} + \frac{\mu_{2} - \mu_{1}}{\mu_{1} \mu_{2}} S_{l} \right] = \sum_{s=1}^{\mathcal{R}} \sum_{i=1}^{N_{sl}} F'(k_{sl})$$

### 8.2 Multinomial Logit with multiproduct firms

We reproduce here the analysis of the previous section for the MNL demand specification. We keep all definitions presented above and just drop the segment index, $s$.

#### 8.2.1 Second stage

The firms solve:

$$\max_{(p_{i1})_{i=1}^{N_{l}}} \sum_{i=1}^{N_{l}} (p_{i1} - c_{i1}) M S_{i1} - F(k_{i1})$$

FOC’s:

$$MS_{i1} + (p_{i1} - c_{i1}) M \frac{\partial S_{i1}}{\partial p_{i1}} + M \sum_{j \neq i} (p_{ij} - c_{ij}) \frac{\partial S_{ij}}{\partial p_{ij}} = 0 \quad i = 1, \ldots N_{l}$$

And as before:

$$\Pi' = \mu M \frac{S_{l}}{1 - S_{l}}$$
8.2.2 First stage

\[
\max_{\{k_{li}\}_{i=1}^{N_l}} \Pi_l = \mu \frac{S_l}{1 - S_l} M - \sum_{i=1}^{N_l} F(k_{li})
\]

FOC’s:

\[
M \mu \frac{1}{(1 - S_l)^2} \frac{\partial S_{li}}{\partial k_{li}} = F'(k_{li}) \quad i = 1, \ldots, N_l
\]

Where:

\[
\frac{\partial S_{li}}{\partial k_{li}} = \frac{\partial S_{li}}{\partial k_{li}} + \sum_{j \neq i} \frac{\partial S_{li}}{\partial k_{li}}
\]

These derivatives are obtained as before and the profit function is now:

\[
\frac{1}{1 - S_l} \Pi^*_l \left[ \frac{1}{\mu} - \frac{1}{\mu} \sum_{i=1}^{N_l} \sum_{j=1}^{N_l} S_{lj} \frac{\partial p_{lj}}{\partial k_{li}} - \frac{1}{\mu} \sum_{i=1}^{N_l} S_{li}^2 + \frac{1}{\mu} \sum_{m=1}^{N_l} \sum_{i=1}^{N_l} \sum_{j=1}^{N_m} S_{mj} \frac{\partial p_{mj}}{\partial k_{li}} \right] = \sum_{i=1}^{N_l} F'(k_{li})
\]

8.3 Multinomial logit with single-product firms

8.3.1 Second stage

We already know that the result of this stage is:

\[
\Pi^*_l = \mu M \frac{S_l}{1 - S_l}
\]

8.3.2 First stage

\[
\max_{k_l} \Pi_l = \mu \frac{S_l}{1 - S_l} M - F(k_l)
\]

FOC:

\[
M \mu \frac{1}{(1 - S_l)^2} \frac{\partial S_l}{\partial k_l} = F'(k_l)
\]

and by doing the algebra:

\[
\frac{1}{1 - S_l} \Pi^*_l \left[ \frac{1}{\mu} - \frac{1}{\mu} \frac{1}{S_l} S_l \frac{\partial p_l}{\partial k_l} - \frac{1}{\mu} \frac{1}{S_l} S_l^2 + \frac{1}{\mu} \sum_{m=1}^{N_l} S_m \frac{\partial p_{ml}}{\partial k_l} \right] = F'(k_l)
\]
8.4 Summary: alternative profit function specifications

We have computed the expression of (Nash) equilibrium profit of the two stage game as a function of equilibrium market shares and the implicit derivatives. These are:

- Nested logit:

\[
\frac{1}{(1 - S_i)} \Pi_i^n \left[ \frac{1}{\mu_2} - \frac{1}{\mu_2} \frac{1}{S_i} \sum_{s=1}^{N_{sl}} S_{sl} \left( \frac{1}{S_i} \sum_{i=1}^{N_{sl}} R_i - \frac{1}{\mu_1} \frac{1}{S_i} \sum_{s=1}^{N_{sl}} S_{sl}^2 + \frac{1}{\mu_2} \frac{\mu_2 - \mu_1}{S_i} S_i \right) \right] = \sum_{s=1}^{N_{sl}} \sum_{i=1}^{N_{sl}} F'(k_{sl_i})
\]

Where:

\[
R = \sum_{r=1}^{N} \sum_{m=1}^{N_{rm}} \sum_{j=1}^{N_{rm}} S_{rmj} \frac{\partial p_{rmj}}{\partial k_{sl_i}} = \sum_{l=1}^{N} R_l
\]

\[
R = \sum_{s=1}^{N_{sl}} \sum_{i=1}^{N_{sl}} R = \sum_{m=1}^{N} \sum_{s=1}^{N_{sl}} \sum_{i=1}^{N_{sl}} S_{rmj} \frac{\partial p_{rmj}}{\partial k_{sl_i}}
\]

\[
R_l = \sum_{r=1}^{N} \sum_{j=1}^{N_{lj}} S_{rlj} \frac{\partial p_{lj}}{\partial k_{sl_i}}
\]

\[
S_l = \sum_{s=1}^{N_{sl}} S_{sl} = \sum_{s=1}^{N_{sl}} S_{sl}
\]

\[
S_{sl} = \sum_{i=1}^{N_{sl}} S_{sl_i}
\]

- MNL: multiproduct firms (no segments)

\[
\frac{1}{1 - S_i} \Pi_i^n \left[ \frac{1}{\mu} - \frac{1}{\mu} \frac{1}{S_i} \sum_{i=1}^{N_{lj}} \sum_{j=1}^{N_{lj}} S_{lj} \frac{\partial p_{lj}}{\partial k_{li}} - \frac{1}{\mu} \frac{1}{S_i} S_i^2 + \frac{1}{\mu} \sum_{m=1}^{N_{m}} \sum_{i=1}^{N_{m}} \sum_{j=1}^{N_{m}} S_{mj} \frac{\partial p_{mj}}{\partial k_{li}} \right] = \sum_{i=1}^{N_{lj}} S_{lj}(k_{li})
\]

Where:

\[
S_l = \sum_{i=1}^{N_{lj}} S_{lj_i}
\]

- MNL: single-product firms (no segments)
\[
\frac{1}{1 - S_l} \prod_i \left[ \frac{1}{\mu} - \frac{1}{\mu} S_l \frac{\partial p_l}{\partial k_l} - \frac{1}{\mu} S_l^2 + \frac{1}{\mu} \sum_{m=1}^{N} S_m \frac{\partial p_m}{\partial k_l} \right] = F' (k_l)
\]

The three expressions involve similar terms, except for the nested logit, which has an additional term that vanishes when \( \mu_1 = \mu_2 = \mu \). The market shares are observed, and the \( \mu \)'s are parameters to be estimated. What about the derivatives? Their expression in case 3 is computable (see appendix 2). They become cumbersome and analytically unmanageable in cases 1 and 2. However, the structure of the terms containing derivatives is the same. Actually, they are weighted averages of the derivatives of prices wrt \( k \)'s, such that a proper redefinition of market shares in case 3 allows for replacement of those tricky expression by the simpler ones from case 3. Take for instance the MNL with multiproduct firms and consider the \( S'_l \)'s as "given" weights, i.e. constants when deriving wrt \( k_l \):

\[
\sum_{i=1}^{N_l} \sum_{j=1}^{N_l} S_{ij} \frac{\partial p_i}{\partial k_{li}} = \sum_{i=1}^{N_l} \frac{\partial}{\partial k_{li}} \left( \sum_{j=1}^{N_l} S_{ij} p_{ij} \right) = \sum_{i=1}^{N_l} \frac{\partial}{\partial k_{li}} p_i = \sum_{i=1}^{N_l} \frac{\partial p_i}{\partial k_{li}}
\]

where:

\[ p_i = \sum_{j=1}^{N_l} S_{ij} p_{ij}, \text{ the weighted sum of the prices of the firm, using as weight} \]

the importance of that product among all the products of the firm.

Define also:

\[ k_l = \sum_{j=1}^{N_l} S_{lj} k_{lj} \text{ with similar interpretation} \]

I can say that \( p_i \) is some (unknown to us) function of the \( k_l : p_i (k_l) \). Then if we apply the chain rule:

\[ \frac{\partial p_i}{\partial k_{li}} = \frac{\partial p_i}{\partial k_l} \frac{\partial k_l}{\partial k_{li}} \]

Therefore:

\[
\sum_{i=1}^{N_l} \frac{\partial p_i}{\partial k_{li}} = \sum_{i=1}^{N_l} \frac{\partial p_i}{\partial k_l} \frac{\partial k_l}{\partial k_{li}} = \sum_{i=1}^{N_l} \frac{\partial k_l}{\partial k_{li}} \sum_{i=1}^{N_l} \frac{\partial p_i}{\partial k_l} = \sum_{i=1}^{N_l} \frac{\partial p_i}{\partial k_l} S_{li} = \frac{\partial p_i}{\partial k_l} S_l
\]

This means:

\[
\sum_{i=1}^{N_l} \sum_{j=1}^{N_l} S_{ij} \frac{\partial p_{ij}}{\partial k_{li}} = \frac{\partial p_i}{\partial k_l} S_l, \text{ where } p_i, k_l, s_l \text{ are defined above. Notice we need} \]

to consider the \( S'_l \)'s fixed weights to get the result.
The argument extends to the nested logit specification as well. What this is telling is that the weighted sum of derivatives can be replaced by a much simpler term, a derivative that can be expressed purely in terms of firm market shares, defined as the sum of the shares of all products it sells. The nested logit is equivalent to a MNL where each firm sells just one composite good. This composite good is the weighted average of all products actually made by that firm, using as weights their respective market share. This is important because now I only have to compute a matrix of derivatives of size $N \times N$ instead of one of size $(N \times R \times N_{sl}) \times (N \times R \times N_{sl})$ which simplify the computational burden (just to make an idea, for the automobile industry I just need a $33 \times 33$ matrix instead of a $264 \times 264$ if I just assume one product by segment and firm or $528 \times 528$ if $N_{sl} = 2$ and so on).

In other words, those terms are known. This is useful because the expression for equilibrium profits depends on two demand parameters (nested logit) and the cost parameters (this issue is covered later). And more than that, because the FOC’s of the nested logit can also be simplified their estimation is remarkably simpler as well.
9 Appendix 2: Derivatives of price w.r.t. quality index using implicit function theorem: N monopoduct firms case.

I want to obtain the derivatives of a function such that:

$$F(k_1, ..., k_N; p_1^*, ..., p_N^*, k_1, ..., k_N) = 0$$

Now the expression for computing, say $$\frac{\partial p_i^*}{\partial k_1}$$, will involve the derivatives of $$F$$ wrt $$k_1$$ and $$p_1^*$$ but also the cross derivatives $$\frac{\partial p_i^*}{\partial k_j}$$; $$j = 2, ..., N$$. Hence, I end up with a system on $$N \times N$$ unknowns, that correspond to each of the $$N \times N$$ direct and cross derivatives of the $$N$$ prices wrt the $$N$$ indexes of characteristics, $$k$$.

Generalizing the standard implicit function theorem to the matrix case [Mas-Colell, Whinston, and Green (1995) [Pages 940-943]]:

$$\begin{bmatrix}
\frac{\partial F_1}{\partial k_1} & \cdots & \frac{\partial F_1}{\partial k_N} \\
\vdots & \ddots & \vdots \\
\frac{\partial F_N}{\partial k_1} & \cdots & \frac{\partial F_N}{\partial k_N}
\end{bmatrix}
= - \left( \begin{bmatrix}
\frac{\partial F_1}{\partial p_1} & \cdots & \frac{\partial F_1}{\partial p_N} \\
\vdots & \ddots & \vdots \\
\frac{\partial F_N}{\partial p_1} & \cdots & \frac{\partial F_N}{\partial p_N}
\end{bmatrix} \right)^{-1} \begin{bmatrix}
\frac{\partial F_1}{\partial k_1} & \cdots & \frac{\partial F_1}{\partial k_N} \\
\vdots & \ddots & \vdots \\
\frac{\partial F_N}{\partial k_1} & \cdots & \frac{\partial F_N}{\partial k_N}
\end{bmatrix}$$

I consider here the three single-product firms case for ease of exposition. The logit nature of demand makes the extension to the $$N$$ firms case straightforward.

Call: $$Z = 1 + S_1^2 (1 - S_1 + S_2^2) + S_2^2 (1 - S_2 + S_3^2) + S_3^2 (1 - S_3 + S_4^2)$$ then it can be shown that:

$$\begin{bmatrix}
\frac{\partial p_1}{\partial k_1} & \frac{\partial p_1}{\partial k_2} & \frac{\partial p_1}{\partial k_3} \\
\frac{\partial p_2}{\partial k_1} & \frac{\partial p_2}{\partial k_2} & \frac{\partial p_2}{\partial k_3} \\
\frac{\partial p_3}{\partial k_1} & \frac{\partial p_3}{\partial k_2} & \frac{\partial p_3}{\partial k_3}
\end{bmatrix}
= \begin{bmatrix}
1 - \frac{(1 - S_1)^2}{1 - S_1 + S_4^2} + \frac{S_1^2 (1 - S_1)^2}{Z(1 - S_1 + S_4^2)^2} & \frac{S_1 S_2 (1 - S_1)^2}{Z(1 - S_1 + S_4^2)(1 - S_2 + S_4^2)} & \frac{S_1 S_3 (1 - S_1)^2}{Z(1 - S_1 + S_4^2)(1 - S_3 + S_4^2)} \\
\frac{(1 - S_1)^2}{Z(1 - S_1 + S_4^2)^2} & 1 - \frac{(1 - S_2)^2}{1 - S_2 + S_4^2} + \frac{S_2^2 (1 - S_2)^2}{Z(1 - S_2 + S_4^2)^2} & \frac{S_2 S_3 (1 - S_2)^2}{Z(1 - S_2 + S_4^2)(1 - S_3 + S_4^2)} \\
\frac{(1 - S_1)^2}{Z(1 - S_1 + S_4^2)^2} & \frac{(1 - S_2)^2}{Z(1 - S_2 + S_4^2)^2} & 1 - \frac{(1 - S_3)^2}{1 - S_3 + S_4^2} + \frac{S_3^2 (1 - S_3)^2}{Z(1 - S_3 + S_4^2)^2}
\end{bmatrix}$$

Notice that both the direct and cross derivatives are positive (this is clear for the cross derivatives, for the direct just think of it as $$1 - \frac{(1 - S_i)^2}{1 - S_i + S_4^2}$$, which is positive $$\forall S_i > 0$$, plus something positive).
References


Graphics and tables

Figure 1:

Total number of models by month
Figure 4:

Economic origin of producers (accumulated): all segments

Figure 5:

Economic origin of producers: all segments
Figure 6:

Gross number of entries by month, all segments

Figure 7:

Gross number of exits by month, all segments
Graphs by Identification of manufacturer
Year (1990-2000)

Figure 9:
Number of models per segment: all segments
Table 1: Tariffs on imported cars

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Table 2: Gross number of entries and exits by year

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## Table 3: Entries and exits by firm

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<th>Brand</th>
<th>Initial number of models</th>
<th>Initial number of segments (Sg8 and Sg5)</th>
<th>Initial number of models</th>
<th>Final number of segments (Sg8 and Sg5)</th>
<th>Final number of entries-exits</th>
<th>Total number of models marketed</th>
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Table 4: Entry and exit activity of newcomers

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<th>Brand</th>
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<th>Final number of segments (Sg8 and Sg5)</th>
<th>Total number of entries</th>
<th>Total number of exits</th>
<th>Net balance of entries-exits</th>
<th>Total number of models marketed</th>
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<td>8</td>
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<td>Galloper</td>
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<td>1</td>
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<td>Hyundai</td>
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<td>Kia</td>
<td>1997, Jul</td>
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Table 5: Percentages of entry by segment and nature of firms

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<th>Total</th>
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<tr>
<td>Domestic (%)</td>
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<td>0.065</td>
<td>0.168</td>
<td>0.179</td>
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<td>0.038</td>
<td>0.182</td>
<td>0.163</td>
<td>0.103</td>
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<tr>
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<td>77</td>
<td>74</td>
<td>39</td>
<td>63</td>
<td>52</td>
<td>22</td>
<td>43</td>
<td>397</td>
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<tr>
<td>European (%)</td>
<td>0.167</td>
<td>0.186</td>
<td>0.192</td>
<td>0.149</td>
<td>0.165</td>
<td>0.175</td>
<td>0.12</td>
<td>0.364</td>
<td>0.171</td>
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<tr>
<td>(4 obs)</td>
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<td>43</td>
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<td>47</td>
<td>79</td>
<td>80</td>
<td>50</td>
<td>11</td>
<td>380</td>
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<tr>
<td>Non European (%)</td>
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<td>0.203</td>
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<td>0.19</td>
<td>0.139</td>
<td>0.167</td>
<td>0.405</td>
<td>0.215</td>
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<tr>
<td>(4 obs)</td>
<td>-</td>
<td>37</td>
<td>69</td>
<td>19</td>
<td>58</td>
<td>36</td>
<td>42</td>
<td>37</td>
<td>298</td>
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<td>Total</td>
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<td>0.14</td>
<td>0.164</td>
<td>0.162</td>
<td>0.14</td>
<td>0.125</td>
<td>0.149</td>
<td>0.286</td>
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<tr>
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<td>157</td>
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<td>105</td>
<td>200</td>
<td>168</td>
<td>114</td>
<td>91</td>
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Table 6: Summary of selected probit specifications

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<th>Dependent variable: enter</th>
<th>dF/dx (P&gt;z)</th>
<th>dF/dx (P&gt;z)</th>
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The first number is the marginal effect and the second the probability of the significance test, i.e. the probability to the right of the p-value.
Table 7: Structural probits for price competition MNL demand

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Coefficients and standard errors of the structural probit.
* and ** means significant at a 5% and 1% significance level, respectively.