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AUTOMOBILE DEMAND, MODEL CYCLE AND PRICE EFFECTS*

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Abstract

The purpose of this paper is to explore the models' life cycle in automobile demand, exploiting a newly-constructed data set. In particular, we analyze the characteristics of the cycle of models by means of non-parametric regressions of model shares on model ages (or time of permanence in the market). Then we test for the presence of price effects of the cycle, using techniques of the discrete-choice approach to demand estimation in differentiated product markets. Results show that own-price elasticities vary with age. Elasticities decrease after the introduction of the model and begin to increase when it has been marketed for three years.

JEL Classification: D43
Keywords: model cycle, demand, discrete-choice, differentiated products, automobiles.

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1. Introduction

Car model turnover seems to be an important characteristic of the automobile market. The entry of new models over time and the exit of others are quantitatively important, and the existence of life cycles of models is patent. Even the life of extremely successful models is boosted by producers at certain moments of time, with small changes in the current version.

The presence of very defined patterns in the life cycle of models suggests that the age of a model (time of permanence in the market) is associated to a distinct evaluation from consumers. And this different evaluation according to the age of a model is likely to imply changes in the elasticity of cars with respect to price depending on the time that they have been marketed. Changes in the elasticity over time are important because they can explain differences in the firm's pricing over time in a single market, gaps between the price in two markets in which the phase of the cycle is not the same and, particularly, firms' decisions on the entry and exit of models in their mix of products.

The purpose of this paper consist of exploring the presence of effects of the model life cycle in automobile demand, exploiting a newly constructed data set and using techniques of the discrete-choice approach to demand estimation in differentiated product markets. In particular, we analyze the characteristics of the cycle of models by means of non-parametric regression analysis of model shares on model ages. And next, we test for the presence of price effects of the life cycle in the framework of a logit specification of demand equations.

The discrete-choice approach to demand estimation, developed for differentiated products markets, has been recently enlarged, enriched, and applied extensively to the modelling of several markets, in particular to the automobile market[1]. Bresnahan's (1987) automobile article can be considered a precedent of this type of model. Berry (1994) explains estimation techniques, Berry, Levinsohn and Pakes (1995) (hereafter BLP) develop the method and the estimation techniques in a context of the automobile market; and Goldberg (1995), Feenstra and Levinsohn (1995), Verboven (1996) and Berry, Levinson and Pakes (1998) include automobile demand estimations related to the discrete-choice method[2]. We adopt this framework for the modelling of the demand for car models over time.

This work relies on a newly constructed data set, with data on the Spanish car market that presents an unusual richness in the information on dynamic. Over the seven years 1990-96, we observe the monthly registrations (sales) of a total of 183 models that account for virtually the entire market. Among these models, 42 stay on the market the whole period, 45 are observed exiting during these years, 82 enter the market and 14 enter and exit. This data has been elaborated and matched to a data base on prices and technical and physical characteristics of the models.

The exploration of the life cycle of models shows that they bring on the market with

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[1]For an extensive discussion of the discrete-choice framework applied to the modelling of differentiated products markets, see Anderson, de Palma and Thisse (1992). On the other hand, Caplin and Nalebuff (1991) show the existence of Nash equilibria in this type of model.

[2]Surveys on earlier automobile demand studies may be found in Train (1986) and Hensher *et al.* (1992).

relatively high sales, and reach their maximum market share between 24 and 48 months. Afterwards, their presence on the market tends to decrease steadily, although the degree of heterogeneity in life cycle is important among different types of cars. Our estimation exercises show the presence of price effects of the cycle, that is, elasticities vary with age. In particular, we find that elasticities decrease in the first years of the model life and begin to increase when it has been marketed for three years.

The rest of the paper is organized as follows. Section two describes the data set and defines the variables we use. Section three characterizes the Spanish automobile market in the nineties and describes the dynamics. Section four is devoted to the exploration of the model cycle by means of non-parametric regressions. Section five presents the model and section six shows results of the estimation of logit demands for models including price effects of age. Finally, section seven concludes.

2. A data set on automobile models

This work is based on a newly-constructed data set, created for the analysis of the Spanish automobile market during the nineties[3]. The basic data consists of the breakdown by models of the monthly new car registrations (sales) from January 1990 to December 1996. This data set comes from an administrative source, the *Dirección General de Tráfico*, and has been supplied by *ANFAC* (*Asociación Nacional de Fabricantes de Automóviles y*

[3] Details on the construction of the data set can be found in Moral (1998).

Camiones). This data set has been cleaned, retaining 99% of the registrations, and has been matched to a data base on prices and technical and physical characteristics of the models, collected and elaborated from a specialized review. The data on these characteristics come from *Guía del Comprador de Coches*.

Car producers distinguish models, characterized by a model name, from the versions of these models, which they present as slight variations in the characteristics of the model. Our data set takes models, just as they have been defined by producers, as the elemental units of analysis. Only super-luxury and marginal models have been dropped from the sample, and some similar models with extremely small sales have been aggregated in a single model. On the other hand, to meaningfully fix the date of exit of models, we have selected the month at which the previous six-month movil average of auto registrations goes under 10 units. This leaves a total of 183 car models and 9,299 non-zero observations or total sample size. There is an average of 110 models marketed per month and 50 monthly observations per model (the maximum number of time observations is 7*12=84).

The matching of the model sales data with model attributes has been carried out using, when possible, the characteristics of the model version with the highest sales. Unfortunately, detailed sales per version are not available for imported cars. In these cases, an intermediate version has been selected, sometimes based on fragmentary information on the versions' sales.

The information gathered for each model includes the following variables: prices (list retail price and manufacturer's price), power-related variables (fiscal power, cubic centimeters, horsepower, revolutions per minute, number and positioning of cylinders), performance characteristics (maximum speed and acceleration time), consumption (at 120 km/h, at 90 km/h and in town), size-related variables (length, width, weight and luggage capacity) and, finally, the presence of standard equipment and the availability of options such as air conditioning, central locking, power steering, electric windows, ABS and airbag. Table A.1 in the Data Appendix indicates the content of each item that we use in this work.

An important specific variable for the exercises we want to carry out is the age of each model in a given moment of time (*Age*). This variable measures in months for how long, at time *t*, a model has been marketed on the Spanish automobile market. For the models already existing at the beginning of the sample, the marketing age at the starting observation (January 1990) has been approximated relying on external used cars market information and considering a maximum of 180 months (15 years).

To describe data and perform some exercises, cars have been divided into 6 categories that closely resemble common industry and marketing classifications. The considered classes are: small, compact, intermediate, large, coupé and minivan. The number of models in each segment are, respectively, 32, 40, 53, 32, 16 and 10. This classification is also close to the ones used by Verboven (1996) for European cars (mini and small, medium, large, executive, luxury and sports), and Goldberg (1995) for the American car market (subcompact, compact, intermediate, standard, luxury and sports). The main differences are the aggregation of the share of the luxury and sports cars in a single class of coupé, and the specification of a class for the so-called minivans.

Finally, we will distinguish between “domestic” and “foreign” cars using standard demand (not supply) criteria. In Spain there are seven big (export oriented) multinational manufacturers that produce domestically, but whose domestic output is subject to complex transnational decisions about how to allocate the production of the models geographically. Hence, the cars sold in Spain by these firms can be produced at home or imported depending on the model. It is not even unusual to find that the sales of the same model are being fueled simultaneously by domestic production and imports. In this setting, we will define as domestic the models sold by these brands, neglecting the fact that some of them can really have been produced abroad and imported. And we will define as foreign the cars sold by the firms without any domestic production[4]. Grouping together the models manufactured by the same producer gives a total of 31 firms. Therefore, we have a total of 24 foreign producers.

Models seem to be a basic product category, for both demand and supply reasons. On the one hand, models have a name and an image, and firms invest heavily in models' advertising. This implies that consumers basically choose among models, and that firms incur some demand-rooted sunk costs at launching models. On the other hand, models' life spans are, as we will see below, highly heterogeneous, and they can be spotted by minors modifications in the models' characteristics. In particular, the life of extremely successful

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[4]As Goldberg (1995) points out, cars are usually classified into “domestic” and “foreign” according to different criteria depending on whether the analysis is refers to the demand or supply side. In demand analysis, it is customary to classify the cars according to the character of the brand rather than the location of the production of a particular car (this is, in fact, the criterion employed, for example, by Verboven [1996]). In supply analysis, classification should be by the country of production. The rationale for this distinction is that consumers are not expected to pay relatively much attention to the side of production.

models is boosted by the producer at certain moments with small changes. But models also have some basic attributes that remain fairly stable over time. These seem to be related mainly to size and power characteristics as Table 1 illustrates for our 183 models' sample. This strongly suggests that model launching also implies some technology related sunk costs (design, to start model manufacturing, etc.) that encuorage firms to stick to their living models.

BLP define models in their twenty-year US sample by requiring, in addition to the same name, that the width, length, horsepower or wheelbase do not change by more than ten percent. Comparing our data with BLP data, it turns out that we observe more or less the same cross-sectional average number of models (118 vs. 111), but also that a model lasts on average 4.2 years, while they observe a model lasting only 2.2 years. Of course, our definition of model is not the same (we only rely on the name) but, from Table 1, it can be checked that the adoption of similar criteria to BLP would only reduce our average number of years of observations from 4.2 to 3.3.

3. The Spanish automobile market in the nineties

The data on new car registrations from 1990 to 1996 suggest that it was a period of high variability in automobile demand. Figure 1 depicts monthly registrations, and the first two columns of Table 2 show the total yearly quantities, and an index of registrations with base equal to 100 at the average yearly registrations of the entire period.

As Figure 1 shows, the demand for automobiles is highly seasonal (with June and July being the months with the highest registrations, and August and September the months with the lowest). But, in addition to the acute seasonal fluctuations, Figure 1 reveals a strong drop in registrations by the year 1993 and, to a lesser extent, by the year 1995. The magnitude of these downturns can be checked in Table 2. In fact, fiscal subsidies for car renewal were implemented in 1994 and the first quarter of 1995 as a policy to stimulate demand for new automobiles (*Renove* plans).

Table 2 provides other useful information on the evolution of the market. Firstly, the most relevant change is the increase in the number of marketed models, about 36% in the seven-year period, despite the demand downturns. The net entry of models is especially important in the first half of the period, but continues until the end. Secondly, the sales-weighted price, deflated by the consumer price index, tends to decrease the first years by about 5%, and then tends to rise. This change affects all the car classes, as can be checked in Table A.2 of the Data Appendix, and do not correspond to patterns of change in the sales-weighted averages of the characteristics of the cars sold. Therefore, it suggests that some price competition may have been at work.

Table 3 shows the structure of sales and imports during the nineties. The data must be analyzed taking into account that in the year 1992 tariffs for EEC imports were suppresed, and the tariffs for non-EEC countries were reduced to 10.3 percent which continues today. Two trends are apparent. Firstly, the share of domestic models tends to fall since 1992 while the share of foreign models increases (from 18% to almost 25%).

Secondly, the import share[5] of Asian cars (defined according to the nationality of the parent company) increases steadily from 5% to 20%, mainly at the expense of the import share of domestic producers.

Table 4 summarizes the rich dynamics that underlies the data on models in the market. The year columns report the distribution of models observed during the year according to their age (months in the market). Therefore, every cell equals the former cell on its diagonal minus exit the previous year with the corresponding age. The first row reports entry[6]. Exit can be located, until 1995, following diagonals and looking for jumps in the number of models. Total models observed during the year, entry and exit are given in the last 3 rows. The last column of the table gives the exit of a given age.

The most important facts are the following. Firstly, the entry of models during the whole period is very important. They enter by far more models (104) than the number of models marketed at the beginning of the period (79). Secondly, the exit of models increases in the early nineties. This suggests either an increase of competition or a reduction in the life cycle of the models, or perhaps both things, if part of competition is non-price competition. Thirdly, we can observe in the last column that the exit of models is concentrated along some ages. But these ages go, say, from 4 to 8 years, which means that there is an enormous heterogeneity in the span of the life cycle.

[5]Here we drop for a moment the demand criterion used in sales (see footnote 4), and we define imports including the cars imported by domestic firms.

[6]Including 8 models that entered the market in January 1990. Only 4 of them still were in the market by December 1996.

4. Exploring the model cycle

The data set provides us with rich information on the different phases of the life cycle of models. We observe the entry of models, the market evolution of models that have been marketed for different time intervals, and exit. In this section, we focus attention on the evolution of market shares over the model age, to detect and characterize the properties of the life cycle of models. To do this, we will employ non-parametric regression techniques.

Research on the life cycle of products has been scarce among industrial economists, and the main insights have until very recently come from the tradition in the area of marketing. Classic works tend to indicate the presence of product life cycles, and invariably distinguish the following phases: adoption, maturity and decline. However, these categories have usually been applied to products defined in too broad a way, (e.g. automobiles or computers) neglecting the differences between product and industry cycles. In fact, only the recent study of industry cycles by Klepper (1996) has stressed that product life cycles are different from and depend on the phase of the industry cycle. In any case, here we are interested in the particular aspect of the life cycle of varieties in a product-differentiated industry, more or less mature, that raises the typical current product turnover which characterizes many of these industries. Only very few works have addressed this question from one or another point of view[7].

Firstly, we shall summarize how we will use our data. For each model/month in the sample, we have a market share observation that is associated to the age of the model (on

[7] See, for example, Stavins(1995), Asplund and Sandin (1996) and Burton (1994).

the variable age, see section 2), which gives a total of 9,299 non-zero share-age observations. For each model that exits the sample before December 1996, we complete its observations with the assignment of a zero market share until reaching the maximum age that we will consider (180+84=264 months). For the rest of the models, from their last observation onwards, we have censoring and we may use only the (positive) directly available observations. Notice, in addition, that the early life observations of the models, which were already in the market by January 1990, are also censored. To perform our exercises, we will pool together all the non-censored (positive and zero) observations, jointly and by market classes. This gives a total of 19,528 observations. The density of the non-censored observations is rather uniform along the considered ages (see Figure A.1 in the Data Appendix).

Let s be the market share of any model at a given moment of time (we drop the model and time subindices for simplicity), and let t be its age or time elapsed since the moment that it was introduced on the market. Our first aim is the exploration of model shares as a function of the model age, that is, the expectation of model shares conditional on t, $E(s|t)$. However, the conditional expectation of s may be written by the law of iterated expectations as

$$\begin{aligned} E(s|t) &= P(s>0|t)\, E(s|t,s>0) + P(s=0|t)\, E(s|t,s=0) \\ &= P(s>0|t)\, E(s|t,s>0) \end{aligned} \tag{1}$$

where the second equation follows from $E(s|t,s=0)=0$. This expression highlights that the expected share is the result of two things: the probability of still being on the market for each age, or probability of survival, and the expected share conditional on age and survival. Therefore, to help the interpretation of the expectation of *s* conditional on age, we will also study the survival function $P(s>0|t)$ and the expectation of *s* conditional on age and survival $E(s|t,s>0)$.

Figure 2 shows the result of estimating the expectation of *s* conditional on age by means of the econometric model $s = g(t) + e$, estimated in the entire sample employing a non-parametric regression (using the simple Nadaraya-Watson estimator; see, for example, Wand and Jones [1995]). Figure 3 depicts the results of estimating the two components according to expression (1) of this expectation. Panel A of Figure 3 shows a non-parametric estimation of the survival function, computed as the ratios at each *t* of the number of models with positive shares to the total number of non-censored model observations for this age (see Kiefer [1988]). Panel B of Figure 3 shows the result of estimating the expectation of *s* conditional on age and survival by means of the previous econometric model, now using only the subsample of positive shares[8]. Figures 4 and 5 depict the results of estimating the expectation of shares conditional on age in four car subsamples (small, compact, intermediate and large + coupé) of domestic and foreign models.

The curves show many things about model cycles. Firstly, the expectation functions conditional on age show that models invariably come on the market with relatively high sales, probably due to the advertising campaigns that precede their entry. However, for most models, it takes some time to reach the maximum market share. This time seems to be

[8]Figure A.2 in the Data Appendix depicts the product of the estimates of the two components. It closely resembles Figure 2.

placed between 24 and 48 months, clearly being smaller for foreign cars.

Secondly, according to the survival function, the probability of leaving the market before the first 24 months is negligible, and only 10% of the models exit before the first 48 months. Therefore, the first part of the conditional expectation function must also be considered a good approximation to the own average evolution of the surviving models. Thirdly, the survival function shows that the probability of leaving the market increases steadily from the second to the twelfth year, while the expected share conditional on age and survival tends to increase slightly during the same period. In fact, 50% of the models disappear from the market at the end of the eighth year, and nearly 80% at the completion of the twelfth, but the share of the surviving models, curiously enough, remains the same. In balance, the expectation of shares conditional on age during this interval is dominated by the decreasing probability of survival that curves it down. Fourthly, the small fraction of models that reaches the age of twelve years can endure much longer and reach higher shares (see the respective panels of Figure 3). In fact, some of the expectation functions of shares conditional on age even tend to show some recuperation of shares at high ages of the model (72,120,144 months...). This may be explained by the launching of new versions of a successful model when this model has survived for many years on the market.

As far as the differences between domestic and foreign cars are concerned, there are two main points that are worthy of comment. On the one hand, the sharpest contrast is between the shares reached by the models of domestic firms and the smaller shares reached by foreign models. This was already implicit in the aggregated shares of Table 3. On the other hand, the duration of models of domestic firms is inversely related to size (represented by car classes). Duration of foreign models is, on the contrary, directly related to size measured in this way. Smaller domestic cars and bigger foreign cars last longer on the market than their respective counterparts.

5. Model cycle and price effects

The presence of very defined patterns in the life cycle of models suggests that the age of a model is associated with a distinct evaluation from consumers. And this different evaluation according to the age of a model is likely to imply changes in the elasticity of models with respect to price, depending on the time that they have been marketed. Changes in the elasticity are important because they can explain differences in the firm's pricing over time in a single market. In addition, if the phase in the product cycle is different in two markets, this will induce price discrimination. This can justify part of the puzzling gaps in prices that have sometimes been documented among markets. Moreover, the presence of different elasticities according to the age of the model can be an important factor for explaining the product decisions of firms (the entry, duration, and exit of models)[9].

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[9]The likelihood of changes in the elasticity of products along the product life cycle has been realized traditionally by marketing literature. For a recent example of hypotheses testing in this framework and a summary of the tradition, see Parker (1992). However, no author seems to have focussed on the more specific question of the evolution of the price elasticities in each variant of the product in a differentiated- product industry (e.g. car models or personal computers). But, very recently, the process of entry and exit over time (or turnover) of variants of the product of a differentiated industry has come to empirical attention. See, for example, Stavins (1995) and Asplund and Sandin (1996). Age-varying elasticities are probably a key ingredient for explaining the firms' decisions.

Moral (1998), for example, builds a model in which a multiproduct firm, which sets prices taking into account the cross-elasticities of its marketed products, faces product elasticities declining over time and sunk costs of model entry. In this context, it is in the firm's interest to eventually substitute the oldest products for new ones in order to preserve the maximization of the profitability of the product mix that it sells.

To test for differences in price elasticities, we will use the discrete-choice demand framework, which has recently been extensively applied to differentiated products markets and, in particular, to the automobile market (see the references in the introduction). Firstly, we will argue the necessity of enlarging the theoretical model considering the models' ages and we will comment on some econometric characteristics of the framework. Then we will report our estimation.

As explained in Berry (1994), the discrete-choice approach obtains the demand equations by relating observed market shares with the shares predicted by the utility framework. In general, following Berry[10], a demand equation for model *j* can be written relating a nonlinear transformation of the vector of observed market shares $\boldsymbol{s}$ to the mean utility level for model *j* as[11]:

$$\delta_j(\boldsymbol{s}) = \boldsymbol{x_j}\beta - \alpha p_j + \xi_j \qquad (2)$$

where p_j is the price of the model, $\boldsymbol{x}_j$ is the vector of observed product characteristics, and

[10] For the sake of simplicity, we only take into account the case when the distribution of consumer unobservables is known (see Berry (1994), page 248).

[11] According to the usual linear utility specification.

ξ_j represents the effect on utility of product characteristics unobserved by the econometrician. In particular, if we consider that the utility function is $u_{ij} = \boldsymbol{x_j}\beta - \alpha p_j + \xi_j + \varepsilon_{ij}$, where ε_{ij} is assumed identically and independently distributed across products and consumers with the extreme value distribution function, the market share is equal to probability of a logit model. Then we can obtain the following linear expression,

$$Lns_j - Lns_0 = \boldsymbol{x_j}\beta - \alpha p_j + \xi_j \quad (3)$$

where s_0 stands for the share of the so-called outside good (or alternative of not buying any of the models).

Notice that, both in the general case (2) and in the logit particular case (3), the right hand of the equations may fail to give account to the change over time in the observed shares if the age of the models is not included in some way. In fact, in the standard model, if either the attributes or the prices of a model do not change, there is no reason for the left side of the equation to change. But the evidence presented in section 4 seems to indicate that there are more changes over time in observed shares than would be expected from the changes in attributes and prices. Therefore, we will experiment including our age variable in the mean utility.

In particular, our hypothesis will be that the age of a model influences the price effect over time. Therefore, we will specify a parameter α that varies according to the age of the model (t). In fact, there is nothing in the utility framework constraining to the use of a unique α parameter (see the seminal work of McFadden (1981) and the discussion on the

α parameter in Anderson, De Palma and Thisse [1992, cap. 6]). The variation of α with age may be interpreted as the effect of some model circumstances additional to the observed and the (time invariant) unobserved model attributes, for example, the consumer perception of the degree of update of the design and the fashionability of the model, or the consumer assumption of the degree to which the model embodies current technological standards.

As it is well known, there are two main problems in the specification and estimation of demand equations in the discrete-choice framework (see Berry (1994) and BLP for more extensive discussions). First, the simplest specification (for example, the logit model) places strong parametric restrictions on elasticities that imply unreasonable substitution effects. Second, the unobserved product characteristics are expected to be correlated with prices, and this makes endogenous prices.

A reasonable solution to the first problem is the use of nested logit models (see McFadden [1986]). Nested logits, at the cost of imposing some a-priori patterns of substitution, allow for sensible elasticities among different groups of products and preserve the possibility of applying linear techniques (this is the specification of Verboven (1996) and Goldberg [1995]). The nested logit model gives an equation similar to (3) with an endogenous extra term specifying the effect of the market share of the model with respect to the group of products to which model *j* belongs. More general but also complex solutions, which use the introduction of random consumer coefficients, are proposed by BLP. We will use an estimation simple as well as nested logits.

The second problem has an interesting solution when the number of time observations on each model is high (as is our case). If the unobservable product characteristics can be considered stable over time, they can be modelled by idiosyncratic model effects. This makes OLS estimation consistent, even in the cases of unobserved characteristics correlated with the observed model attributes and even correlated across models. We will follow this approach, using standard panel techniques.

6. Econometric results

In what follows, we present demand estimations, based on the logit and nested logit specifications, which embody price effects over the life cycle of models. To start with, we focus on the assessment of the existence and pattern of these price effects and we keep the rest of the specification and the estimation techniques at the simplest level (non-nested multinomial logit and OLS estimation). Table 5 reports the results.

The dependent variable consists of the (log of the) model monthly share observations minus the (log of the) monthly shares of the outside good. Both shares are computed (as in BLP) taking as the market size the current number of households (collected from the population survey *Encuesta de Población Activa*). All the observations are pooled together. Among the explanatory variables we can distinguish three groups: control variables, common variables and, finally, the attributes and the price of models.

To control for seasonality and unspecified time effects, we include a set of monthly dummies and yearly time dummies respectively. In both cases, the set of coefficients are constrained to add up to zero. On the other hand, to control for the idiosyncratic time invariant effects we have added, after some experimentation, a set of firm or brand dummies (recall that models belong to 31 different firms). All these sets of variables are jointly significant.

We must also take into account the changes over time that can affect all the models or a subgroup of them. This is done by means of the common variables. Firstly, we include a tariff variable that approximates the varying height of tariffs during the period. *Tariff* assigns to each foreign model its corresponding tariff and zero to domestic models. This variable is mainly intended to pickup the effect of parallel non-price barriers to entry, because the price effects of tariffs are likely to be already embodied in the effect of the list retail price. The variable obtains the expected sign but is not significant. Secondly, the variable *NoMod* specifies the number of models in the market. As expected, the number of models is significant and tends to reduce the average share in the market. Thirdly, we include a dummy variable which takes a value of one when the *Renove* plans are working and zero otherwise. We also interact this variable with the foreign models (*RveForeign*). Results show that *Renove* plans stimulated mainly the acquisition of domestic cars.

The specification includes two power attributes of models (*CC/Weight* and *NoCil*), a performance attribute (*Maxspeed*), a consumption attribute (*C90*), and two size characteristics (*Length/Weight, Luggage/Width*). All the signs are as expected, but the two coefficients on the size characteristics are not significant. In Spain, consumers probably value size attributes less than in the American market.

Finally, the equation includes the price variable and a set of age dummies interacting with the price, aimed at pickingup the possible differences in the price effects over the model cycle. The dummies take value one when the model has the age in months that corresponds to the specified intervals and zero otherwise. The age intervals beyond twelve years are unified in a unique longer interval and the excluded dummy is the age of less than twelve months. A sensible pattern of variation of the price effects with age emerges. At the beginning, the (absolute value) price sensitivity tends to decrease and then begins to increase.

The explanatory power of the regression is very high, and the number of inelastic demands is relatively low when compared with the number of observations (less than 12%). These are signs of a sensible estimation[12].

Clearly, the price effects diverge along the life cycle of models and this will influence elasticities. Table 6 gives an idea of the evolution of the own-price elasticities according to age. They are evaluated for each age with the average share and price, according to the multinomial logit expression:

$$ {}_{jj} = - \tilde{\alpha} p_j (1 - s_j) \tag{4} $$

where $\tilde{\alpha}$ is obtained by adding the value of the price coefficient to each interaction coefficient.

[12] For example, in the estimation OLS of BLP more than 67% of the demands are inelastic.

The first columns of Table 6 clearly show that the absolute value of elasticity first decreases and then begins to rise. According this estimate, the elasticity of a model that has been marketed for a long time can be 45-50% higher than the minimum elasticity of the model. This suggest that firms' optimal price may evolve over time, increasing at the beginning of the model life up to the moment the model is established, and then decreasing again.

As we have mentioned before, the multinomial logit models imply unreasonable substitution effects, and a sensible solution for this problem is the use of nested logit models. Next, we apply this type of modelization to our problem. To obtain a nested logit it is necessary that consumers show heterogeneous preferences with respect to the observed characteristic of the models. Thus, the coefficient associated to each attribute *k* is defined as $\beta_k = \tilde{\beta}_k + \quad_k v_{ki}$. BLP show that, with this specification, market share corresponds to a nested logit model. This model implies that consumers first choose the market segment, and next the car model. In sum, the model to estimate is equal to

$$Ln s_j - Ln s_0 = \mathbf{x_j}\beta - \alpha p_j + \quad Ln s_{j/g} + \xi_j \qquad (5)$$

where   is interpreted as the correlation coefficient among products that belong to the same segment, and $s_{j/g}$ is the share of the model *j* conditional to segment *g*.

Using the same set of variables as in the previous estimation, and adding the log of the conditional share (*LnCdShare*), a new estimation by OLS is released. Results are reported in Table 7. Compared with Table 5, most of the variables maintain their relevance, even if there are variables that lost significance, such as maximum speed and number of cylinders.

The estimated coefficient for correlation within the segment is very high (0.8) and significant. In fact, the simple introduction of the corresponding variable causes a powerful improvement in the estimation of demand. Now there are no inelastic demands.

As far as elasticities are concerned, notice that with a nested logit model their expresion is the following,

$$_{jj} = -\tilde{\alpha}\, p_j \left(\frac{1 - \quad s_{j/g}}{1 - \quad} - s_j \right) \qquad (6)$$

where $\tilde{\alpha}$ is obtained by adding the value of the price coefficient to each interaction coefficient. The difference with equation (4) is the role of the conditional share and the correlation coeficient. When we compute the estimated elasticities according to the intervals of the age, we obtain the same pattern of the multinomial case. However, the value of the average conditional share in each interval determines higher values for the elasticities.

At last is, it remains the question of endogeneity of conditional shares. To control for endogeneity biases, we estimate the model by means of IV, using as instruments the share variable lagged 6 to 12 months. The results are almost identical to the results in Table 7.

7. Conclusions

This paper is devoted to exploring the existence of a model life cycle in cars, and the presence of price effects linked to the life cycle. Own-price elasticities varying over the phases of the life cycle of cars is a potential explanation of many factors: different pricing of the same model over time, price gaps across markets in which the same model is at a different marketing phase and, particularly, the entry and exit of models by firms in the form of replacement by cannibalization.

Using a newly constructed data set, where there is a lot of turnover, the paper has firstly analyzed the expectation of market shares conditional on the age of the model, and then checked the presence of price effects of the model age employing the discrete-choice demand framework (which uses model shares as the dependent variable). The results seem both sensible and consistent.

On the one hand, market shares conditional on age show a typical life cycle shape. They increase the years following the launch of the model, a time in which every car has a high probability of survival. But, after two to four years, the survival probability begins to decrease sharply and the expected share falls. Only cars that remain on the market expect to continue increasing their shares at a slower path over following years. After 12 years, only a small fraction of extremely successful models, probably renewed several times, remain on the market.

On the other hand, consumers' valuation shows firstly a decreasing sensitivity to price until the third year, and then a negative price effect that increases (in absolute value) again and forever. This implies own-price elasticities that decrease after the introduction of the model and begin again to increase when the model has been marketed for three years.

These findings strongly suggest that the age of model cars should matter in the pricing decisions of firms. In addition, they suggest that model entry and exit decisions of the multiproduct profit maximizing firms that produce cars, which presumably base their decisions on the relative profitability of models, must be linked to the evolution of price elasticities. Investigating these hypotheses would be an interesting follow-up to this research.

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Table 1: Degree of stability in model characteristics [1,2]

(No. and percentage of models with significant changes)

Characteristics	Extent of the change					
	2%		5%		10%	
Stable:						
No. cil	7	(3.82)	7	(3.82)	7	(3.82)
length	21	(11.47)	7	(3.82)	0	(0.00)
width	16	(8.74)	5	(2.70)	2	(1.09)
Variyng:						
fiscalp	42	(22.95)	29	(15.84)	15	(8.19)
cc	44	(24.04)	39	(21.31)	29	(15.84)
luggage	47	(25.68)	40	(21.85)	29	(15.84)
Very varying:						
hp	77	(42.07)	69	(37.70)	55	(30.05)
rpm	64	(34.97)	49	(26.77)	18	(9.83)
maxspeed	74	(40.43)	38	(20.76)	11	(6.01)
c90	84	(45.90)	65	(35.51)	40	(21.86)
c120	81	(44.26)	59	(32.24)	39	(21.31)
ctown	79	(43.17)	62	(33.88)	38	(20.76)
weight	73	(39.89)	59	(32.24)	25	(13.66)

Notes:

(1) Every column reports the number (percentage) of models that fail to pass the corresponding stability test. The test is passed if the characteristic does not change by more than, respectively, two, five or ten percent in a period of twelve months or less.

(2) Definition of variables is in Table A.1. of the Data Appendix.

Table 2: Basic descriptive statistics

Year	Registrations	Indice[1]	No. of models	Average monthly sales by model	Price[2]
1990	971,466	109.7	98	851	1.976
1991	878,594	99.2	106	712	1.948
1992	973,414	109.9	117	700	1.876
1993	737,938	83.3	120	520	1.928
1994	901,754	101.8	124	616	1.925
1995	829,797	93.7	127	556	1.982
1996	906,444	102.3	133	580	1.986

Notes:

(1) Indice=100 at the time average of registrations.

(2) Sales weighted mean price, in million pesetas of 1992. The weight for each model monthly observations is the average share of the model in the corresponding year.

Table 3: The structure of sales and imports (%)

Year	Sales		Imports[1,2]		
	Domestic models	Foreign models	Domestic firms	European firms	Asian firms
1990	82.0	18.0	53.4	41.3	5.3
1991	80.0	20.0	46.9	44.9	8.2
1992	81.3	18.7	43.4	44.3	11.9
1993	80.2	19.8	45.8	39.0	14.5
1994	78.7	21.3	39.7	44.5	14.8
1995	77.2	22.8	37.1	43.0	18.5
1996	75.2	24.8	39.7	38.0	20.3

Notes:
(1) Imports are here defined including the cars imported by domestic firms (see footnotes 4 and 5).
(2) Some column numbers do not add up 100 because the proportion of American cars is not reported.

Table 4: Entry, age distribution of models and exit.

Age (in years)	1990	1991	1992	1993	1994	1995	1996	Exit[3]: until 1995+1996
age[1,2] ≤ 1	19	10	16	13	13	17	16	
1 < age ≤ 2	3	19	10	16	13	13	17	1
2 < age ≤ 3	7	3	19	10	16	12	13	4
3 < age ≤ 4	18	7	3	18	10	14	11	5
4 < age ≤ 5	5	18	6	3	18	7	13	6 + 2
5 < age ≤ 6	8	4	15	6	3	16	7	3 + 1
6 < age ≤ 7	6	8	4	13	6	3	15	5 + 3
7 < age ≤ 8	5	6	8	3	12	4	2	7
8 < age ≤ 9	6	4	6	6	2	10	3	8
9 < age ≤ 10	4	6	4	4	3	2	7	+ 1
10< age ≤ 11	4	4	6	4	4	3	2	4
11< age ≤ 12	0	4	4	5	2	3	3	2
12< age ≤ 13	1	0	3	3	5	2	3	2
13< age ≤ 14	4	1	0	3	2	5	1	1 + 1
14< age ≤ 15	3	4	1	0	3	2	4	+ 1
15< age ≤ 16	5	3	4	1	0	3	2	
16< age ≤ 17		5	3	4	1	0	3	
17< age ≤ 18			5	3	4	1	0	
18< age ≤ 19				5	3	4	1	1
19< age ≤ 20					4	3	4	1
20< age ≤ 21						3	3	
21< age ≤ 22							3	
No. of models	98	106	117	120	124	127	133	
								Totals:
Entry	19[4]	10	16	13	13	17	16	104
Exit	2	5	10	9	14	10	9	59

Notes:

(1) The first category represents a number of months equal to or less than 12.

(2) Each entry is the number of models of a given age observed during the year.

(3) Exits are equal to the difference between the number of models belonging to the interval of *s* years in *t* and the number of models in the interval *s+1* years in *t+1*.Exits during 1996 cannot be observed in this fashion and we report them separately.

(4) Includes the entry of 8 models in January 1990. Four of them stay until the end of the sample and the other four exit before December 1996.

Table 5: Logit demand with cycle price effects

Estimation by OLS		Dependent variable: **Ln s_j – Ln s_0**	
Sample period: I-1990 to XII-1996		Observations: 9299	No. of models: 183
Variable		Coefficient	t- ratio[1]
Constant		-10.594	-8.15
Price		-0.782	-8.36
CC/Weight		0.918	2.83
Maxspeed		0.014	2.69
NoCil		0.204	2.18
C90		-0.182	-2.44
Length/Weight		0.916	0.49
Luggage/Width		0.020	0.60
Tariff		1.286	0.90
NoMod		-0.027	-6.76
Renove		0.150	3.12
RveForeign		-0.122	-3.70
Price x age [2] :	$1 < age \leq 2$	0.063	2.74
	$2 < age \leq 3$	0.091	3.76
	$3 < age \leq 4$	0.055	2.37
	$4 < age \leq 5$	0.019	0.66
	$5 < age \leq 6$	-0.065	-2.14
	$6 < age \leq 7$	-0.121	-4.35
	$7 < age \leq 8$	-0.110	-3.39
	$8 < age \leq 9$	-0.044	-1.30
	$9 < age \leq 10$	0.060	1.56
	$10 < age \leq 11$	-0.021	-0.57
	$11 < age \leq 12$	-0.035	-0.81
	$12 < age \leq 22$	0.191	6.68
Firm dummies		yes	
Seasonal dummies		yes	
Time dummies		yes	
R^2		0.542	
No. Inelastic demands		1120	

Notes:
(1) White-robust standard errors.
(2) Age interval expressed in years. The excluded category is 0 years, which means a number of months equal to or less than 12.

Table 6: Estimated own-price elasticities according to model age

Age (in years)	Market share(1)	Price(1)	Average elasticity	No. of inelastic demands
0 < age ≤ 1	0.0004	2.482	-2.144	60
1< age≤ 2	0.0005	2.573	-1.849	149
2< age ≤ 3	0.0006	2.493	-1.720	152
3< age≤ 4	0.0006	2.586	-1.880	130
4< age≤ 5	0.0005	2.620	-1.998	92
5< age≤ 6	0.0005	2.686	-2.275	32
6< age≤ 7	0.0006	2.616	-2.361	8
7< age≤ 8	0.0006	2.729	-2.433	25
8< age≤ 9	0.0007	2.832	-2.337	70
9< age≤ 10	0.0006	3.067	-2.215	40
10< age ≤ 11	0.0005	3.067	-2.582	25
11< age ≤ 12	0.0007	3.297	-2.693	83
12< age≤ 22	0.0007	4.160	-2.457	254

Note:

1) Market shares and prices are simple averages among the models that belong to the corresponding age interval.

Table 7: Nested logit demand with cycle price effects

Estimation by OLS		Dependent variable: **Ln s_j – Ln s_0**	
Sample period: I-1990 to XII-1996		Observations: 9299	No. of models:
Variable		Coefficien	t- ratio[1]
Constant		-7.884	-8.10
Price		-0.502	-6.88
LnCdShare		0.813	24.05
CC/Weight		0.880	4.80
Maxspeed		0.005	1.45
NoCil		0.053	0.70
C90		-0.147	-2.69
Length/Weight		3.273	2.72
Luggage/Width		-0.093	-3.79
Tariff		1.945	2.33
NoMod		-0.012	-8.68
Renove		0.005	0.25
RveForeign		-0.001	-0.13
Price x age [2] :	1 < age ≤ 2	0.006	0.33
	2 < age ≤ 3	0.034	1.84
	3 < age ≤ 4	0.040	2.57
	4 < age ≤ 5	0.020	1.21
	5 < age ≤ 6	-0.027	-1.52
	6 < age ≤ 7	-0.055	-3.19
	7 < age ≤ 8	-0.051	-2.93
	8 < age ≤ 9	-0.046	-2.86
	9 < age ≤ 10	-0.002	-0.07
	10< age ≤ 11	0.011	0.66
	11 < age ≤12	0.012	0.64
	12 < age ≤22	0.092	3.40
Firm dummies		yes	
Seasonal dummies		yes	
Time dummies		yes	
R^2		0.851	
No. Inelastic demands		0	

Notes:

(1) White-robust standard errors.

(2) Age interval expressed in years. The excluded category is 0 years, which means a number of months equal to or less than 12.

DATA APPENDIX

Table A.1: Variables

PRICE	Market price in millions of pesetas of 1992. It includes indirect tax, transport and registration cost.
CC	Cubic centimeters
HP	Horsepower
FISCALP	Fiscal power, fiscal horses according to Spanish legislation.
RPM	Revolutions per minute
MAXSPEED	Maximum speed (in km/h)
C90	Consumption (in litres) to cover 100 km at a constant speed of 90 km/h.
C120	Consumption (in litres) to cover 100 km at a constant speed of 120 km/h.
CTOWN	Consumption (in litres) to cover 100 km in town at a constant speed of 90 km/h.
LENGTH	Length in cm
WEIGHT	Weight in kg
WIDTH	Width in cm
LUGGAGE	Luggage capacity in cm^3
AIR	Dummy variable, it is equal to one if air conditioning is standard equipment, zero in the other case.
PSTEERING	Dummy variable, it is equal to one if power steering is standard equipment, zero in the other case.
CLOCKING	Dummy variable, it is equal to one if central locking is standard equipment, zero in the other case.

Table A.2: Sales weighted average attributes by cars classes[1]

	Price	cc/weight	c90	length	width	luggage	air	steering	clocking
Small (32 models)									
1990	1.37	1.55	4.86	365.3	157.8	265.8	0.0	0.0	16.4
1991	1.35	1.53	4.83	365.9	158.1	269.8	0.0	0.0	15.3
1992	1.27	1.54	4.76	366.1	158.3	270.1	0.0	0.0	11.7
1993	1.30	1.55	4.81	366.9	159.2	263.3	0.0	0.0	15.1
1994	1.31	1.55	4.94	367.3	159.8	256.5	0.0	0.0	3.7
1995	1.38	1.53	5.08	368.3	159.3	256.3	0.0	8.3	9.3
1996	1.36	1.47	5.05	370.5	159.0	256.8	7.5	11.0	28.0
Compact (40 models)									
1990	1.92	1.62	5.33	416.4	167.4	445.5	2.0	13.9	42.9
1991	1.89	1.59	5.45	414.3	168.0	422.3	4.2	19.7	47.2
1992	1.82	1.66	5.40	410.6	168.2	381.4	1.5	18.8	64.4
1993	1.90	1.69	5.39	408.7	169.1	386.2	1.2	29.3	65.3
1994	1.90	1.66	5.35	407.5	168.9	388.7	1.2	31.5	53.5
1995	1.96	1.61	5.47	408.7	168.8	364.1	3.2	43.4	62.3
1996	1.96	1.55	5.36	410.4	168.8	366.6	10.6	70.0	78.7
Intermediate (53 models)									
1990	2.75	1.76	5.82	440.8	169.8	525.8	52.2	80.6	88.5
1991	2.55	1.75	5.70	439.8	169.2	509.3	31.9	59.6	69.9
1992	2.36	1.73	5.78	440.0	169.1	494.1	28.4	61.3	55.8
1993	2.42	1.65	5.76	441.4	170.7	488.8	41.1	74.9	64.0
1994	2.53	1.58	5.90	443.8	171.2	482.8	41.2	87.6	78.5
1995	2.56	1.53	5.92	445.0	171.5	497.8	37.5	95.2	80.5
1996	2.55	1.49	5.84	445.6	171.7	495.0	34.2	100.0	74.7
Large and coupé (48 models)									
1990	4.24	1.73	6.47	457.2	173.5	457.1	62.9	80.1	89.1
1991	4.04	1.72	6.47	458.9	173.2	443.1	61.0	84.8	95.5
1992	4.01	1.73	6.61	463.3	174.2	443.9	69.6	92.8	95.1
1993	4.68	1.69	6.20	464.4	174.7	447.6	78.0	94.4	96.6
1994	3.95	1.67	6.75	460.1	174.9	441.2	75.0	91.2	98.0
1995	4.12	1.65	6.77	462.2	177.0	428.1	80.9	98.3	98.3
1996	4.27	1.69	6.96	462.8	176.6	421.5	86.0	97.3	98.8
Minivan (10 models)									
1990	3.84	1.64	6.80	437.0	170.0	910.0	100.	100.0	100.0
1991	3.73	1.64	7.21	439.9	175.2	910.0	41.7	100.0	100.0
1992	2.69	1.69	6.75	433.3	172.0	1317.0	15.5	65.1	65.1
1993	2.21	1.68	6.25	426.7	168.6	1155.4	21.6	45.6	45.6
1994	2.62	1.67	6.88	436.3	173.2	1437.7	41.5	70.5	70.5
1995	3.27	1.61	7.52	447.0	178.7	1414.6	31.7	100.0	100.0
1996	3.30	1.61	7.36	448.5	177.1	1535.1	15.2	97.0	97.0
All classes (183 models)									
1990	1.976	1.62	5.28	401.5	164.1	384.9	14.1	24.2	42.7
1991	1.948	1.61	5.32	403.3	164.7	382.6	11.8	24.2	42.2
1992	1.876	1.64	5.33	404.5	165.3	375.0	11.2	26.4	45.0
1993	1.928	1.63	5.35	404.8	166.2	376.1	14.9	33.7	48.2
1994	1.925	1.60	5.40	402.7	166.2	368.8	13.6	35.0	42.1
1995	1.982	1.56	5.50	403.8	166.2	364.4	13.4	44.3	47.6
1996	1.986	1.52	5.44	405.9	166.2	369.5	17.9	55.9	59.8

Note: 1) Definition of variables is in Table A.1. The weight for each model monthly observation is the average share of the model in the corresponding year.

Figure 1: Monthly Registrations from January 1990 to December 1996.

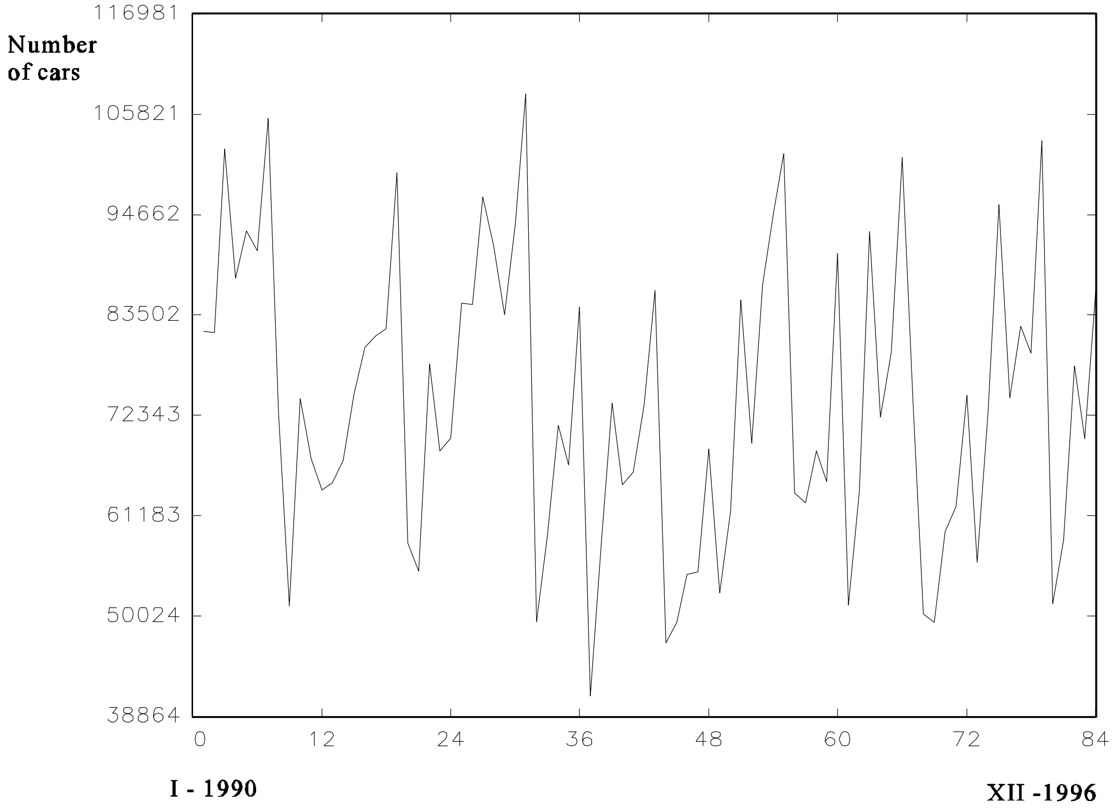

Figure 2: Shares' conditional expectation function.

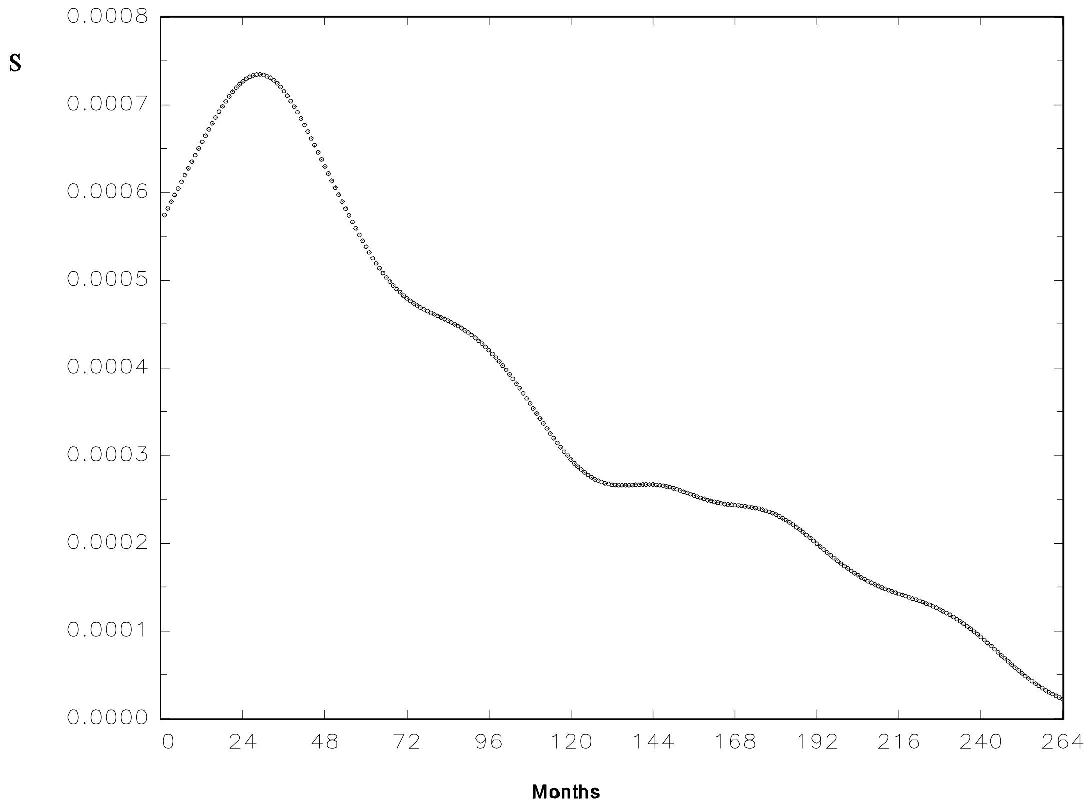

Figure 3.a: Models' survival function.

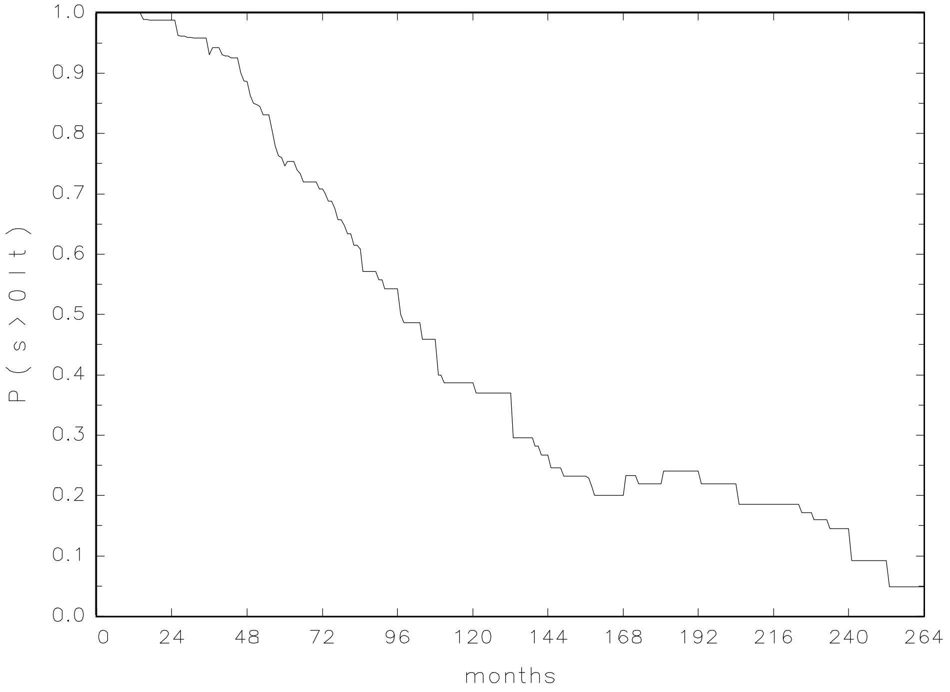

Figure 3.b: Expectation of market share conditional on age and survival

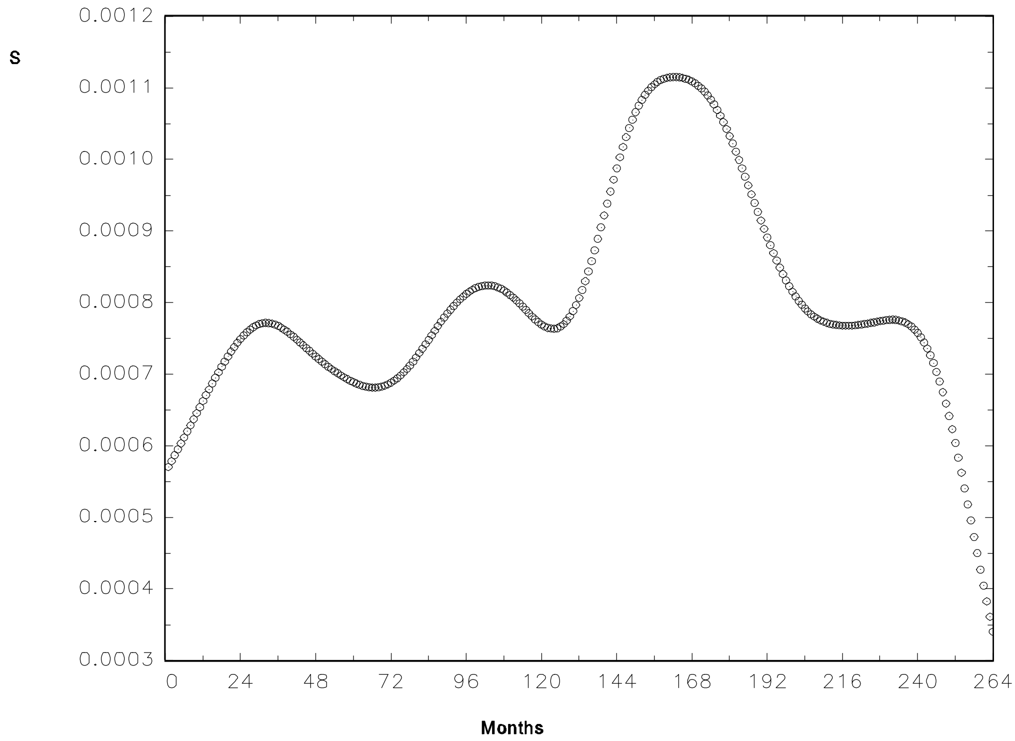

Figure 4: Shares' conditional expectation functions of domestic models.

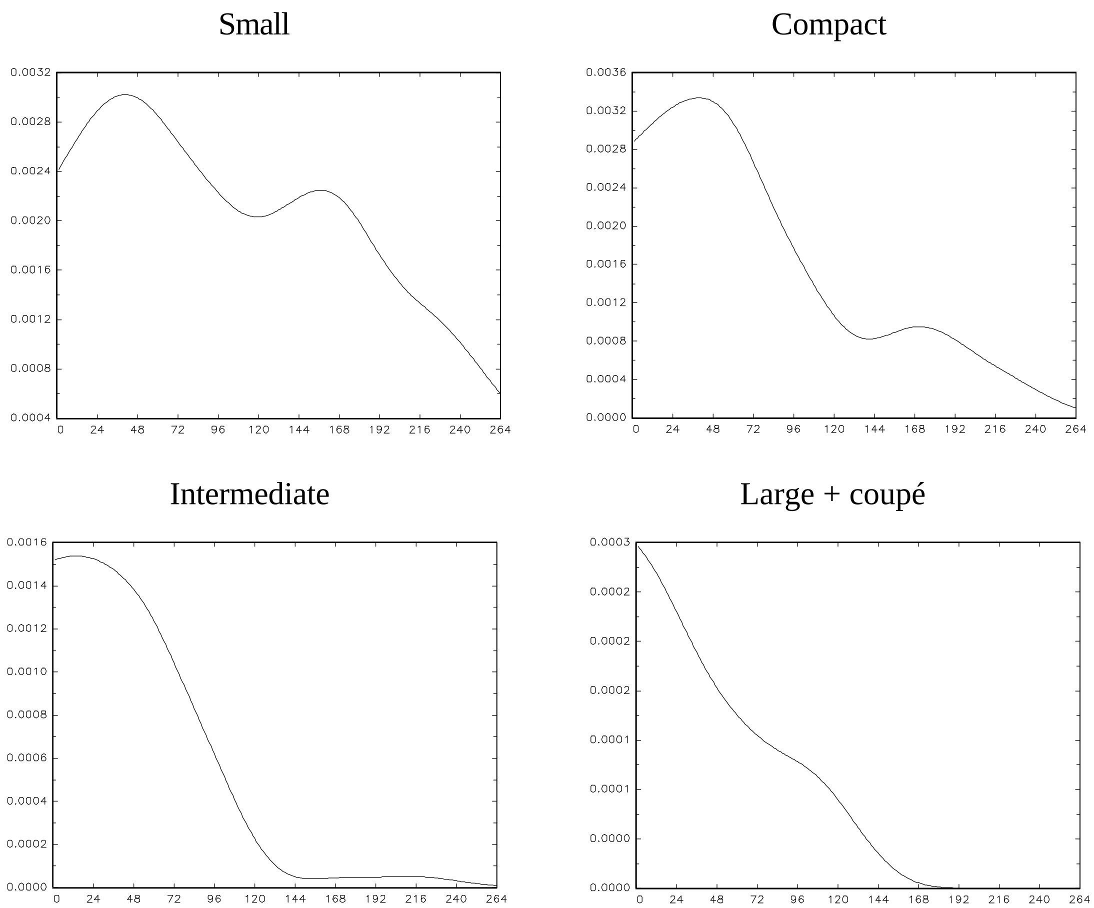

Figure 5: Shares' conditional expectation functions of foreign models.

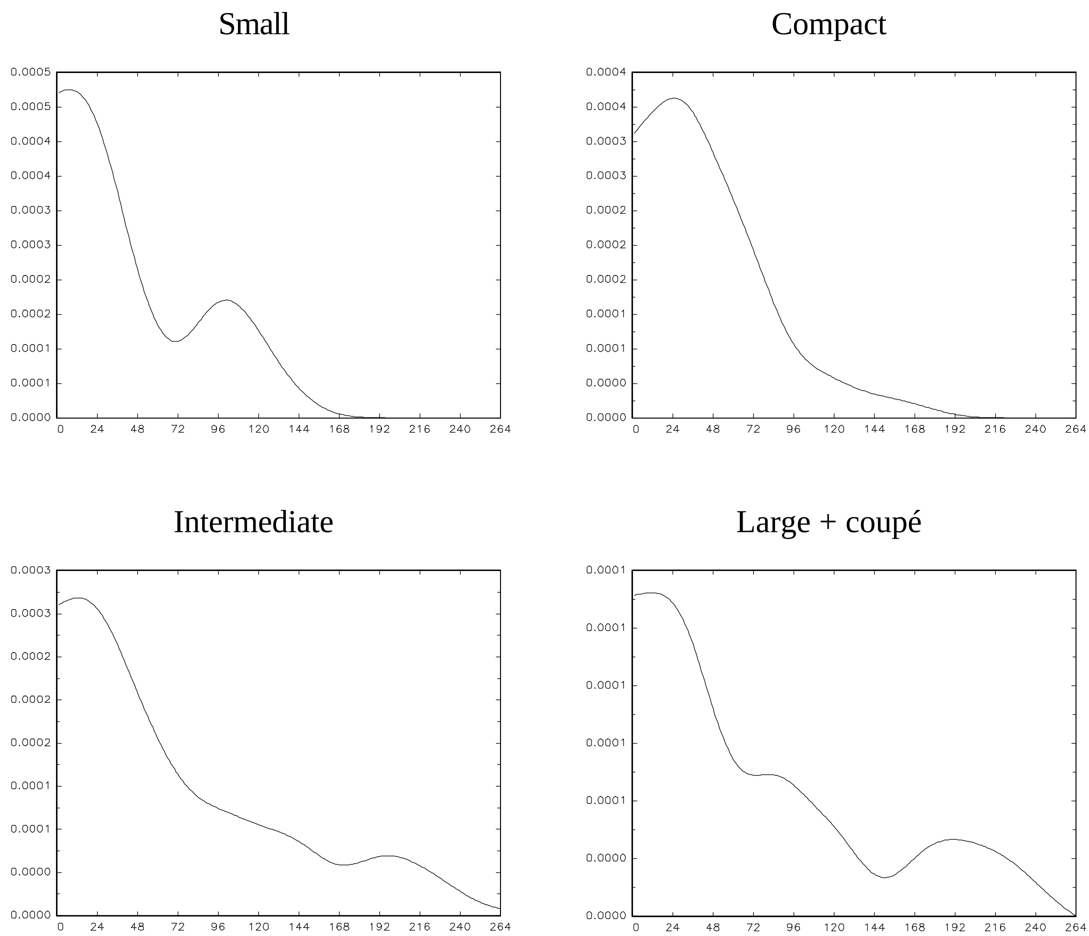

Figure A.1: Frequencies of the non-censured observations.

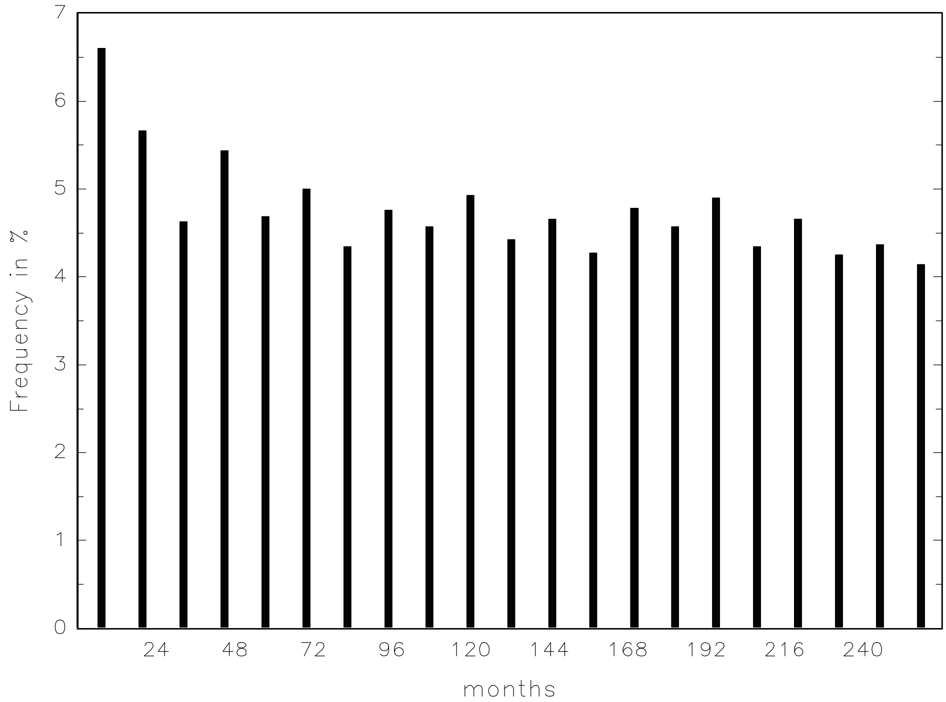

Figure A.2: Product of the estimates of survival function and the expectation of *s* conditional on age and survival.