Identifying changes in behaviour in a multiproduct oligopoly: Incumbents' reaction to tariffs dismantling*

Jordi Jaumandreu[a] and **María J. Moral**[b]

Universidad Carlos III de Madrid | Universidad de Vigo

April 2002

Preliminary and incomplete

Abstract

The Spanish automobile market of the nineties simultaneously experienced a tariff dismantling and a strong demand downturn, with the observed result of an apparently sharpened producer competition, both in products and prices. This paper is aimed at testing whether or not there really was a change in pricing behaviour, using a structural model of competition among oligopolistic multiproduct firms. We understand by behaviour the particular strategies, in the set of well defined market-specific equilibrium concepts, which are sustained at a given moment. To answer that question, we specify and estimate a pricing equation with panel data for the 164 models belonging to 31 firms which competed in the market during this period. The specification includes several equilibriums as alternative (overlapping) estimating models, considering prominently tacit coalitions, by which a group of firms set prices taking into account the cross effects on their demands. The statistical test selects as the best model given the data a switch from collusion to competition of domestic and European producers at the beginning of the nineties.

[a] Dpto. de Economía, c/Madrid 126, 28903 Getafe (Spain). Tel.: 34 91 6245737, Fax: 34 91 6249875.e-mail: jordij@eco.uc3m.es

[b] Dpto. de Economía Aplicada, Facultad de CC. Empresariales de Ourense, Campus Universitario As Lagoas s/n, 32004 Ourense (Spain). Tel.: 34 988368760, Fax: 34 988368923. e-mail: mjmoral@uvigo.es

1. Introduction

At the beginning of the nineties, the Spanish automobile market simultaneously experienced a tariff dismantling and a strong demand downturn, with the observed result of an apparently sharpened producer competition, both in products and prices. Domestic producers (installed multinational firms) and foreign (European and non-European) producers changed car attributes, introduced new models, and engaged in promotional campaigns, at the same time that several signs of price competition appeared. This paper is aimed at testing wheter or not there really was a change in pricing behaviour, using a structural model of oligopolistic multiproduct firms which compete in a product differentiated market.

Obviously, it must be understood that firms continuously adjusted model prices to their environment (entry and changes in characteristics). And all producers, multiproduct firms with a rough average of more than three car models on the market at a given moment, must be assumed internalising optimally the cross effects of their model pricing. The central question is whether, in addition, tariff dismantling induced a change in firms' pricing strategies, modifying their degree of rivalry. We understand by behaviour the particular strategies, in the set of well defined market-specific equilibrium concepts, which are sustained at a given moment.

To answer that question, we specify and estimate a pricing equation with (monthly) panel data for the 164 car models belonging to 31 firms which competed in the Spanish market during the period 1990-96. By developing the underlying theoretical model, the specification is able to include several equilibriums as alternative (overlapping) estimating models. Among these equilibriums we consider prominently tacit coalitions, by which a group of firms sets prices taking into account the cross effects on their demands. In particular, our statistical test selects as the best model a switch from collusion of domestic and European producers at the beginning of the nineties to a whole competition.

Our pricing model employs a discrete choice specification of demand. Discrete-choice models have become a popular alternative for modelling and estimating the

demand of markets with product differentiation (see Nevo 2000, for a list of recent works and discussion). These models, especially under the random-coefficients methodology promoted by Berry (1994), and Berry, Levinsohn and Pakes (1995) –henceforth BLP-, show a number of advantages. In particular, they allow for a reduction of the dimensionality of the problem of estimating demand parameters with many products, give ways to treat the endogeneity of prices, and permit the modelling of consumer heterogeneity. In addition, this methodology has been applied successfully to the treatment of topics this paper is close to (see, for example, Berry, Levinsohn and Pakes (1999) and Goldberg and Verboven (2001)). Here we develop a specific version, in which income effects determine varying marginal utilities, which in turn make possible a simple and realistic full specification of pricing equilibriums.

The rest of this paper is organised as follows. Section two explains in detail the competition changes that took place in the Spanish market and descriptively explores the price data. Section three develops the demand and pricing model, developing the way to specify behaviour. Section four discusses, specifies and estimates the pricing equation.

2. Competition changes

At the beginning of the nineties, the Spanish automobile market was served by three types of car producers: domestic producers, or multinationals with plants installed in Spain during the seventies and the eighties aimed at exporting an important part of production, manufacturing in them some of the car models they sold; European foreign producers, or multinational European producers without manufacturing in Spanish territory; and non-European foreign producers, basically Asian, sometimes possessing an incipient production in European territory.

Domestic producers accounted for seven brands belonging to five groups (Citroen-Peugeot, Ford, Opel, Renault and Seat-VW), which coincided with the most important non-Japanese world producers with the absence of Fiat and Chrysler (recall that Opel is a GM subsidiary). They had dominated the Spanish market during the eighties, and they started the nineties with a joint market share of 82%. At this time the

European foreign producers' supply consisted of 14 brands[1], with a joint share of only 16%, but they sold more than half of the cars of the highest segment. And non-European producers accounted for 9 Asian brands[2] plus Chrysler, which entered the market in 1992, representing all together a market share of 2% (see Table 1 and Figure 1).

Tariff and non-tariff protection made it unprofitable to import cars from abroad during the beginning of the eighties, dampening even the import of the models from domestic producers not produced in Spain. All imported cars in 1985 amounted to only 13% of sales. But this year the Spanish Adhesion Treaty to the EEC, setting the transition framework to full integration in the single market of 1992, firmly established a different perspective. Tariffs on cars imported from the EEC had to be decreased as stipulated from the then-current value of 36,7% to zero by the beginning of 1993. And tariffs on cars imported from third countries had to be reduced from the then-current value of 48,9% to the common EEC tariff of 10%, although import quotas applied to Asian cars remained the same for the moment.

This perspective immediately started a new competition preparing the coming open market, stimulated by a very dynamic demand. Domestic producers enlarged the range of models distributed in the market with models imported from their production in plants abroad, while foreign producers entered new models. Imports had risen to virtually 40% of sales by 1990 (recall that only 18% are imports by foreign producers). At the same time, domestic producers invested heavily in plant productivity improvements. But, the beginning of the nineties, in which demand transitorily experienced a stagnation and then a sharp downturn, triggered a new competition intensity.

Competition during the nineties adopted several dimensions: producers engaged in a sharp increase of advertising expenditures and an enlargement of sales networks, continuously redesigned existing models introducing quality and more equipment, continued the entry of new models, and started an unprecedented price competition which consumers perceived through promotional advertising. The entry of car models,

---

[1] Audi, Alfa-Romeo, BMW, Fiat, Jaguar, Lada, Lancia, Mercedes, Porshe, Rover, Saab, Skoda, Volvo and Yugo.

[2] Daewo, Honda, Hyundai, Mazda, Mitsubishi, Nissan, Subaru, Suzuki and Toyota.

performed with the double target of replacing old models and introducing in the Spanish market models absent until this time, was particularly important and can be followed in detail by means of our data. The year 1990 began with 79 marketed models, while in the following years 104 models entered the market and 59 exited, which implies 123 marketed models by the end of 1996. Asian cars accounted for a disproportionate share of this entry (28 entering models vs. only 15 in 1990), but entry by the European foreign producers (48 entering models vs. 48 in 1990) and domestic producers (28 entering models vs. 35 in 1990) is also important. The role of replacement can be seen by noting that 90% of exits are separated from a model entry by the same brand by less than 48 months.

Among all these competition changes, the focus of this paper is on pricing. In particular, did the dismantling of tariffs change firms' price behaviour? Foreign firms found themselves able to sell at significantly lower prices for the same received prices. Domestic producers experienced the same change for the models which were introduced from abroad and, at the same time, they expected increased competition for all models which included entry and lower rivals' prices. Obviously it is understood that firms must adjust each model price to its new environment (entry and changes in characteristics). And all producers are multiproduct firms, with a rough average of more than three car models in the market at a given moment, which implies that they must be assumed to internalise optimally the cross effects of their models pricing. The central question is whether, in addition, tariff dismantling induced any change in firms' pricing strategies, modifying their degree of rivalry. We understand by behaviour the particular strategies, in the set of well defined market specific equilibrium concepts, which are sustained at a given moment. Testing formally for these changes is the aim of this paper. In what follows we descriptively explore the likelihood of these changes.

To acquire an impression of possible pricing behaviour changes in our sample period, the cost changes induced by quality changes must be disentangled. With this aim, we will use the hedonic coefficients resulting from regressing prices on car characteristics. Let us define the price corrected by quality changes as

$$\tilde{p}_{jt} = p_{jt} - (x_{jt} - x_{j0})\hat{\boldsymbol{b}} \qquad (1)$$

where x_{jt} is the vector of characteristics of model j at moment t, x_0 stands for this vector when the model enters the sample, and $\hat{b}$ represents the cost per unit of characteristic estimated in the hedonic regression[3]. Averages of these quality corrected prices will change with the entry and exit of models, which embody idiosyncratic qualities that shift the mean. To avoid these effects let us define entry and quality change corrected prices as

$$\tilde{p}_t = \frac{1}{N_t}\sum_j \left(p_{jt} - (x_{j0} - \bar{x})\hat{b}\right) \tag{2}$$

where $\bar{x}$ is the sample mean of attributes and N_t is the number of models at date t. Entry and quality change-corrected prices, depicted as indices, give the change in prices which may be attributed to reasons other than quality-induced cost variations. Of course they can show cost changes attributable to other reasons, but they are likely to clearly reflect changes in pricing.

Figures 2, 3 and 4 summarise the results of exploring descriptively price changes. Figure 2 represents simple average monthly prices for the three producer types, deflated by the consumer price index, and the average received prices, that is, the price received by producers after deducting the relevant tariffs. The figure highlights an apparent parallel evolution of European and domestic received prices during the period, at a different level determined by the diverse sales composition, and a sharp decrease of the Asian received prices. Figure 3 represents the evolution of prices differencing out the quality-induced cost variations (normalised to unity the first year), and Figure 4 represents the evolution differencing out the quality composition effects of entry and exit. Both figures stress the same conclusions. Firstly, all prices tend to show a fall during the first three years (1990-92) and some recovery at some point of the following subperiod. This suggests partly procyclical pricing, matched to the demand evolution reported above. Secondly, Asian car prices show a sharp new fall by the year 1993. Asian producers price aggressively when the tariff transitory period reaches its end. Thirdly, domestic producers pricing seems to recover less steadily than the European producers pricing, denoting its likely engagement in downward price competition at least during 1993. Besides the figures, the hedonic corrections denote that quality

[3] We employ the coefficients corresponding to our preferred model (see Section 4), but the exercise produces very similar results using alternative estimates.

increments of marketed cars are introduced at similar pace for all producers, particularly after 1992, and that Asian entry mainly consists of models of lower quality as time goes by.

3. Demand model and firms' pricing

3.1 Demand with varying income marginal utility

(To be summarised from Appendix A)

3.2 Testing firms' behaviour.

3.2.1 *Behaviour*

Suppose J single-product firms. Let the price of the j-th firm be $p_j = \arg\max\left\{\sum_k \boldsymbol{d}_{jk}\boldsymbol{p}_k \mid \boldsymbol{d}_j\right\}$, with $\boldsymbol{p}_k = (p_k - c_k)s_k(p)M$, and where c_k is the marginal cost of product k-th, $s_k(p)$ stands for product k-th market share (a function of the price vector p), and M is (exogenous) market size. Firms' maximisation objectives are determined by specifying the vectors $\boldsymbol{d}_j$. Denote by D the matrix of all price effects $d_{jk} = \frac{\partial s_k}{\partial p_j}$. Two extreme equilibriums, with their corresponding FOC's and the resulting price vector solved in terms of the vector of shares s, are:

a) $\boldsymbol{d}_{jj} = 1 \quad \forall j, \quad \boldsymbol{d}_{jk} = 0 \quad \forall k \neq j$ (Bertrand)

$$(p_j - c_j)\frac{\partial s_j}{\partial p_j} = -s_j \qquad j = 1...J \tag{3.a}$$

$$p = c - (diagD)^{-1}s \tag{3.b}$$

b) $\boldsymbol{d}_{jk} = 1 \quad \forall j, k$ (Full collusion)

$$\sum_{k} (p_k - c_k) \frac{\partial s_k}{\partial p_j} = -s_j \quad j = 1 \ldots J \tag{4.a}$$

$$p = c - D^{-1} s \tag{4.b}$$

Suppose now H mutually exclusive groups of products, with J_h products each ($J = \sum_h J_h$). Let us write the corresponding formulas when profit maximisation is carried out by choosing prices which internalise the cross effects inside the groups. This may be the case if the industry consists of H multiproduct firms or if there are H coalitions of single or multiproduct firms. Let C_h be a (diagonal) selection matrix, with a one in the diagonal if the element corresponds to a product in group h and zero otherwise.

c) $\boldsymbol{d}_{jk} = 1 \quad if \;\; j,k \in J_h, \quad \boldsymbol{d}_{jk} = 0 \quad otherwise$ (multiproduct firms or/and price coalitions)

$$\sum_{k \in J_h} (p_k - c_k) \frac{\partial s_k}{\partial p_j} = -s_j \quad j \in J_h, \quad h = 1 \ldots H \tag{5.a}$$

$$p = c - (\sum_h C_h D C_h)^{-1} s \tag{5.b}$$

3.2.2 *Logit demand specification*

Assume a standard logit industry demand specification with product j utility given by $u_j = x_j \boldsymbol{b} - \boldsymbol{a}_j p_j + \boldsymbol{x}_j$, where x_j represents the vector of characteristics and $\boldsymbol{x}_j$ the impact of unobserved characteristics. Product share derivatives with respect to prices are

$$\frac{\partial s_k}{\partial p_j} = \begin{cases} -\boldsymbol{a}_j s_j (1 - s_j) & if \;\; k = j \\ \boldsymbol{a}_j s_k s_j & otherwise \end{cases} \tag{6}$$

Let $\boldsymbol{a}$ and S be diagonal matrices with elements the $\boldsymbol{a}$'s and the vector of shares respectively, and e a vector of ones. Hence $D = -\boldsymbol{a} S(I - ee'S)$ and

$D^{-1} = -(I + (1/s_0)ee'S)(\alpha S)^{-1}$, where s_0 is the share of the "outside" good. Let us denote by subindices h the subvectors and matrices corresponding to products in group *h*, and let $\Sigma_h = \sum_{k \in J_h} s_k$. Equilibriums are given by the following vector and individual price expressions

- Bertrand:

$$p = c + (diag(I - ee'S))^{-1}(\alpha S)^{-1} s \tag{7.a}$$

$$p_j = c_j + \frac{1}{\alpha_j}\left(1 + \frac{s_j}{1 - s_j}\right) \qquad \forall j \tag{7.b}$$

- Full collusion:

$$p = c + (I + \frac{1}{s_0} ee'S)(\alpha S)^{-1} s \tag{8.a}$$

$$p_j = c_j + \frac{1}{\alpha_j}\left(1 + \frac{s_j}{s_0}\right) + \sum_{k \neq j} \frac{1}{\alpha_k} \frac{s_k}{s_0} \qquad \forall j \tag{8.b}$$

- *H* product groups:

$$p_h = c_h + (I + \frac{1}{1 - \Sigma_h} ee'S_h)(\alpha_h S_h)^{-1} s_h \qquad h = 1...H \tag{9.a}$$

$$p_j = c_j + \frac{1}{\alpha_j}\left(1 + \frac{s_j}{1 - \Sigma_h}\right) + \sum_{\substack{k \neq j \\ k \in J_h}} \frac{1}{\alpha_k} \frac{s_k}{1 - \Sigma_h} \qquad j \in J_h,\ h = 1...H \tag{9.b}$$

3.2.3 *Nested logit*

Assume there are G nests of similar products, indexed $g = 1...G$, presenting a degree of "correlation" or nest-parameter σ, characterised by different marginal utilities of income α_g. Then the relevant price expression for a product j belonging to a group of products *h* becomes

$$p_j = c_j + \frac{1}{\alpha_g}\left[w_{gh}(1 + w_{gh}\frac{\Sigma_{gh}}{1 - w_h}) \right] + \sum_{m \neq g} \frac{1}{\alpha_m} w_{gh} w_{mh} \frac{\Sigma_{mh}}{1 - w_h} \quad j \in J_g \text{ and } J_h \qquad (10)$$

where $w_{gh} = \left[1 + \frac{\sigma}{1-\sigma}\left(1 - \frac{\Sigma_{gh}}{\Sigma_g} \right) \right]$, Σ_{gh} stands for the group share in nest g and Σ_g for the total share of nest g, and $w_h = \sum_g w_{gh}\Sigma_{gh}$. This formula encompasses all the cases of multiproduct firms and coalitions in an environment constituted for nests of similar products.

3. 2.4 *Testing behaviour*.

Mark-ups hence depend on the own and rivals' shares in a specific way according to behaviour, i.e., according to the degree of internalisation of cross price effects. An equation that encompasses all the above behaviours in a simple logit context is

$$p_j = c_j + \sum_k \beta_k f_{jk}(s) \qquad (11)$$

where $\beta_k = \frac{1}{\alpha_k}$ for $k = 1...J$, and f_{jk} are simple transformations of the vector of shares. For instance, if pricing internalises cross effects in H product groups,

$$f_{jk} = \begin{cases} 1 + \frac{s_j}{1 - \Sigma_h} & \text{if } k = j \\ \frac{s_k}{1 - \Sigma_h} & \text{if } k \neq j, k \in J_h \\ 0 & \text{if } k \neq j, k \notin J_h \end{cases} \qquad \text{for } j \in J_h, h = 1...H \qquad (12)$$

If, for a particular equilibrium, we stack transformations f_{jk} in vectors $f_k = (f_{1k},..., f_{Jk})'$, $k = 1...J$, we obtain a set of J variables with coefficients fixed across products. Mark-ups for a particular equilibrium may therefore be written as a linear function of a set of J variables embodying simple transformations of shares. This suggests the use of the econometric model

$$p_j = c_j + \sum_k \boldsymbol{b}_k f_k^E(s) + u_j \tag{13}$$

where E refers to a particular equilibrium and u_j is a zero mean uncorrelated error, to perform the suitable non-nested hypotheses tests to identify behaviour. When products are nested, coefficients $\boldsymbol{b}_k$ are constrained to the same value inside a nest and the summation has only so many terms as the number of nests.

4. Econometric specification, estimation and results.

In this section we discuss, specify and estimate price equations using data on the car models sold on the Spanish market by all the firms with a presence in the marketplace. Taking as a guide the price equilibrium relationships established in Section 3, the final objective of this empirical exercise is to obtain estimates of these relationships and to test their likelihood given the market data. This implies the simultaneous estimation of a nested marginal cost function (that we will base on product attributes data) and the firms' markups.

The optimal pricing expressions developed starting from first order conditions in Section 3 are equilibrium relationships, that is, they relate the endogenous variables prices and shares in equations that include the products cost and demand parameters. They define only implicitly the "reduced-form" for equilibrium prices, in which prices would depend only on the cost and demand parameters. Given the highly non-linear form in which shares depend on prices, explicit reduced-form equations cannot be obtained. Nevertheless, they possess some very useful characteristics. On the one hand, equilibrium prices are additively separable in two components, costs and unit markups. On the other, the specification of demand and behaviour gives structure to the form in which markups depend on observable variables and parameters. The first aspect has been intensively used to estimate the (usually unobservable) marginal costs, usually adopting an "hedonic" approach to the estimation of the cost function[4]. The second

[4] Cost estimations starting from regressions on product characteristics can be called "hedonic" because they use the methodology of the traditional hedonic price regressions (see Griliches (1961), and also Pakes (1997)). Hedonic price equations relate price to product characteristics. They can be theoretically

aspect offers the opportunity to carry out a structural pricing decisions analysis, although it has been not exploited until now.

In this context the estimation of markups raises an endogeneity problem. It is natural to assume that prices are explained by the observed characteristics that determine costs, some additional unobserved cost components, and the markups that depend on shares. But market shares are a function of prices. Hence, shares will be correlated with the cost side unobservable term and the shocks. On the demand side, shares are also influenced by unobserved components of utility that are likely to be correlated with the cost unobserved components. This implies the use of instrumental variables (IV) methods of estimation when we include shares as an explanatory variable.

Markups can change, and the exploration of their changes is a fundamental objective of this exercise. On the one hand, optimal markups change under the influence of factors such as demand changes, rivals prices, entry and so on. In our framework, these changes are embodied in the specification of the relationship between prices and shares according to the theoretically relevant alternative. For example, discrete choice demand models are constructed around the assumption of the presence of an "outside good", whose share is simply the probability of not buying in the analysed market at time t. But this probability is likely to change with the macroeconomic environment. This means that cyclical fluctuations are incorporated in the model through the utility of the outside alternative changing over time. On the other hand, behaviour may take any one of the relevant alternatives (e.g. Bertrand-Nash, collusion through coalitions…) and moreover it can change over time. Our structural price equations are aimed at testing different behaviour hypotheses and their changes over time.

Our estimating equation has the form

$$p_{jt}/(1+tariff_{jt}) = \boldsymbol{h}_j + \boldsymbol{a} + \tilde{x}_{jt}\boldsymbol{b} + \sum \boldsymbol{b}_g f^{E}_{jg}(s) + u_{jt} \tag{14}$$

based on equilibria under the approach of consumer preferences for bundles of attributes and the willingness to pay for these characteristics (Rosen (1974)). Coefficients in hedonic price regressions are thus considered to convey information on preferences, technology, and production costs.

where the dependent variable are received prices, that is, model monthly prices deflated, when relevant, by the tariff. The term $\boldsymbol{h}_j$ is an unobservable individual error, representing cost unobservable advantages or disadvantages, $\tilde{x}_{jt}$ represents the attribute variables (attributes in the form of deviation with respect to the sample mean and squares of these deviations, to approximate cost around its mean $\boldsymbol{a}$), the sum of terms in $f^{E}(s)$ stands for the specification of behaviour according to Section 3, and u_{jt} is a zero mean disturbance. In practice, to control for seasonality, we also will include a set of monthly dummies.

The estimating expression is a linear equation which can be estimated by GMM methods suitable to unbalanced panel data. The GMM estimator exploits the moments $E(Z_j^{'}\boldsymbol{x}_j) = 0$, where Z_j stands for the matrix of instruments and $\boldsymbol{x}_j$ represents the vector of elements $\boldsymbol{x}_{jt} = \boldsymbol{h}_j + u_{jt}$. We employ the estimator $\hat{\boldsymbol{b}} = (M_{zx}^{'}AM_{zx})^{-1}M_{zx}^{'}AM_{zy}$, where $M_{zx} = \sum_j Z_j^{'}X_j$, with the consistent "one-step" choice $A = \left(\sum_j Z_j^{'}Z_j\right)^{-1}$. Three particular aspects of the estimation of the equation deserve, however, particular comments: the identification of markups, the treatment of serial autocorrelation and the instruments to be used.

The sum of variables $f^{E}(s)$ is close to unity by construction, given their theoretical specification. This implies a serious difficulty to separately identifying the average cost and the average level of margins, at least estimating the pricing equation in isolation. Joint estimation with a demand equation, by allowing the imposition of some cross constraints on the coefficients, could perhaps improve the identification conditions. But, for the moment, we will limit ourselves to identifying relative margin differences by constraining the behavioural coefficients to add up to zero. This does not affect the model capacity of discrimination among conducts.

Our data consist of unbalanced panel observations for a rather standard number of individuals (182 models) but with the more unusual monthly data frequency. This is associated with some heterogeneity of the time information content. Monthly data are

likely to contain useful information about prices and shares, which change frequently, but much less about reactions to attributes, which change rarely and have mainly longer term effects. Moreover, monthly market prices contain a lot of short-term movements we are not interested in nor capable of modelling. The time dimension of the data is then important for identifying part of the relationships we are interested in, but is also likely to create problems through autocorrelated errors. To obtain inferences robust to serial correlation, we will use a robust estimate of the variance-covariance matrix.[5] All the statistics are then computed using this robust to heteroskedasticity and serial autocorrelation "two-step" weighting matrix.

To estimate a robust inverse of $E(Z_j^{'}\boldsymbol{x}_j\boldsymbol{x}_j^{'}Z_j)$, we assume that $\boldsymbol{x}_j\boldsymbol{x}_j^{'} = \Omega_j$ are matrices corresponding to conditional homoskedastic errors, and we obtain $\hat{\Omega}_j$ values using the Newey-West Bartlett kernel computations for the autocovariances of individual j. Then we employ the usual "two-step" estimate $A_R = (\sum_j Z_j^{'}\hat{\Omega}_j Z_j)^{-1}$. We use 72 time observations as the maximum lag that we take into account in the Bartlett kernel.

As we have argued above, shares and hence the behavioural variables must be considered variables both correlated with $\boldsymbol{h}_j$ and u_{jt}. The most standard way of treating such a setting is the estimation of the equation taking first differences in order to difference out the individual correlated component, and the use of lags of the endogenous variable to set valid moment restrictions (see, for example, Arellano and Honoré (2001)). In our case, this is an undesirable alternative because T is short in relation to the pace of variation of attributes. The differentiation of the attributes would eliminate crucial information contained in the levels equation and would exacerbate the variance of the disturbances. Instead, we will use as instruments, in a GMM framework, the differences of the shares with respect to their individual time means, $\tilde{s}_{jt} = s_{jt} - (1/T)\sum_s s_{js}$, lagged a number of periods. This instruments shares with their past time variations, avoiding the use of their level variations across models. Instruments of this type were first proposed by Bhargava and Sargan (1983), and moment restrictions of this type have been studied in Arellano and Bover (1995). A

[5] See Newey and West (1987).

recent discussion may be found in Blundell and Bond (1998). As additional instruments, we will employ the set of 31 brand dummies. To test the validity of the employed instruments, we employ the Sargan test statistic of the overidentifying restrictions.

Estimation of the pricing equation is carried out employing as attributes power measure *ratio cubic centimetres to weight* (*CC/Weight*), fuel efficiency *ratio km to litre* (*Km/l*), used in the particular form of the relative efficiency in city driving with respect to 90 Km/h driving, the measure of size and safety *length times width* (*Size*), the *maximum speed in km/h (Maxspeed*) and *air conditioning* (*ac*) “luxury” indicators, and the materials use indicator *weight* (*Weight*). We try to be deliberately close to BLP specification for the sake of comparisons. The use of other characteristics or a more complete list does not change the main results.

We group models into 5 categories that closely follow common industry and marketing classifications. The classes of cars considered are: small, compact, intermediate, and luxury. We separately group minivans, which were at that moment a product beginning their market penetration. The number of models in each segment are, respectively, 33, 37, 56, 47 and 9.

Table 2 presents the results of estimation. All attribute coefficients show the sign expected in a cost function and sensible values (cost is increasing in weight at all the sample values). Moreover they do not change dramatically from estimate to estimate, although some changes are significant.

Estimates of Table 2 implement the three more straightforward specifications of behaviour, and constitute the base for testing behaviour.[6] The first equation assumes that behaviour was Bertrand-Nash all the time and for all players, a common assumption in many models and estimates of this type. The second equation makes the unrealistic assumption that behaviour was collusion of all players all the time. The third estimate makes the sensible assumption that domestic and European producers set prices at the beginning of the period internalising the cross effects of their prices, i.e. they constituted a price coalition, but this coalition broke up at the end of 1991. Domestic and European producers are supposed to switch then to play Bertrand, while

[6] Variables of behaviour are computed using the nested formulas constraints using a $\boldsymbol{s}$ value of 0.8 (the value obtained in an independent demand estimate).

Asian producers are assumed to play Bertrand the entire period. The estimate of a model in which the breaking up of the coalition is assumed at the end of 1992 gives very similar results.

This third estimate is the best in economic and statistical terms. The coefficients of the variables modelling behaviour follow exactly the pattern expected according the theoretical specification, and they are roughly consistent with the coefficients and price elasticities of demand which have been obtained in a demand equation estimated separately (see Tables A.1 and A2). To compare statistically the results of the three models we use a Vuong-type test of selection among non-nested or overlapping models (see, for similar applications, Gasmi, Laffont and Vuong (1992) and Jaumandreu and Lorences (2002). We compute it with the GMM analogous to the likelihood ratio. That is, for every two models we compute the value

$$VT = \frac{N(J_2 - J_1)}{\left[\sum (J_{i1} - J_{i2})^2 - N(J_1 - J_2)^2\right]^{1/2}} \qquad (15)$$

where J_1 and J_2 are the corresponding minimised values of the objective function, J_{i1} and J_{i2} are the individual observation values of the objective function evaluated at the minimum, and N the total number of observations. We expect this statistic to be distributed as a $N(0,1)$. The result says that the Bertrand-Nash competition model is somewhat better than the full collusion model, but that the collusion-Bertrand switching model clearly outperforms statistically both (see Table 2).

Appendix A

A.1 *Consumer choice*

Let $U(m,x_s)$ be the (contingent) utility derived from the consumption of a composite good m and the variant s of a unit demand good characterised by the vector of attributes x_s. Let y be income, p_s the price of good s, and normalise the price of good m to unity. Unconditional indirect utility can be written as $V(y-p_j,x_j)=\underset{s}{Max}\tilde{V}(y-p_s,x_s)$, and Roy's identity holds as $\delta_j=-\frac{\partial V}{\partial p_j}\Big/\frac{\partial V}{\partial y}=1$ for the chosen alternative and $\delta_s=0$ for $s\neq j$ (McFadden, 1981.)

Many empirical analyses specify V as

$$V(y-p_j,x_j)=\alpha(y-p_j)+u(x_j) \tag{A.1}$$

where α stands for constant marginal utility of income, and $u(.)$ is usually taken linear in attributes, i.e., $u(x_j)=x_j\beta$. This specification has the advantage of simplicity and it can be employed to derive straightforwardly an estimable system of demands for differentiated products (Berry, 1994.) It presents, however, the important drawback that it can hardly explain how consumer' income influences decisions, hindering the analysis of a basic dimension of consumer' heterogeneity.

Let us specify utility keeping separability but allowing for a varying marginal utility of income

$$V(y-p_j,x_j)=h(y-p_j)+u(x_j) \tag{A.2}$$

where $h(.)$ is a function with $h(0)=0$, which we will assume to be only monotonically increasing and concave. This specification encompasses expression (1) as a particular case, but shows decreasing marginal utility if $h(.)$ is strictly concave. In order to compare utilities among them, let us write (2) as

$$V(y-p_j,x_j)=h(y)-h'(y-\lambda p_j)p_j+u(x_j)=h(y)-\alpha(y,p_j)p_j+u(x_j) \tag{A.3}$$

where $\lambda\in(0,1)$ and depends on the values of y and p_j. The first equality is obtained applying the mean value theorem. The second establishes that marginal utility of

income α is now a function of y and p_j, with $\frac{\partial \alpha}{\partial y} < 0$ and $\frac{\partial \alpha}{\partial p_j} > 0$. Expression (3) gives consumer utility derived from any consumption in terms, among other things, of the associated marginal utility of income.

For a given consumer $V(y - p_j, x_j) > V(y - p_k, x_k)$, $\forall k \neq j$, if and only if $-\alpha(y, p_j)p_j + u(x_j) > -\alpha(y, p_k)p_k + u(x_k)$ (we will call these last terms utility contributions). As in the standard specification, the consumer can strongly prefer the attributes of k (a high quality version), but be deterred from its consumption by the counterbalancing weight of its higher price. But now this effect may crucially change according to the income that characterises a particular consumer, even if consumers share the same attributes valuation. Some consumers with higher incomes (lower α's) will choose, at the same prices, more expensive varieties.

Let us now represent in Figure A.1 consumer' choices as a function of income, drawing on Bresnahan's (1987) discussion of heterogeneous tastes. To simplify the representation (and only with this purpose), assume a strictly concave function with $h''' = 0$, which implies that $\frac{\partial \alpha}{\partial y} < 0$ is a constant and $\frac{\partial^2 \alpha}{\partial y^2} = 0$. Utility contributions $V - h(y) \equiv u_s$ can be represented in the plane (y, u) by straight lines as:

$$u_s = u(x_s) - \alpha(y, p_s)p_s \tag{A.4}$$

with slope increasing in price ($\frac{\partial u_s}{\partial y} = -p_s \frac{\partial \alpha}{\partial y} > 0$). These lines start from the fourth quadrant[7] and cross the y-axis at the points $\bar{y}_s$ that verify $\alpha(\bar{y}_s, p_s) = \frac{u(x_s)}{p_s}$. Let us take two variants such as $u(x_k) > u(x_j)$ (i.e., the good k is superior in the attributes' valuation), and $p_k > p_j$ in a way that implies $\frac{u(x_k)}{p_k} \leq \frac{u(x_j)}{p_j}$ (i.e., the price of quality increases faster than its valuation.) Then $\alpha(\bar{y}_k, p_k) \leq \alpha(\bar{y}_j, p_j)$ and, as $\frac{\partial \alpha}{\partial p_j} > 0$, this implies $\bar{y}_k > \bar{y}_j$.

---

[7] A consumer will only consider buying the good s at price p_s if he has enough income. If $y = p_S$, he gets utility $u_S = u(x_S) - h(p_S)$, presumably a negative value because of the high marginal utility of income in the absence of other consumption.

The figure illustrates the way in which the choice among the different varieties depends on consumer' income. The consumer will only decide to buy one of the product varieties when his income reaches y^j, even if he had already been able to afford the variety j before $(\bar{y}_j = y^j > p_j)$. At the interval (y^j, y^k) he will buy the variety j and, if $y \in (y^k, y^l)$, he will choose the superior variety k. At higher incomes he will switch his consumption to higher price alternatives. Notice that, with the standard specification (1), this dependence of choices on income is completely missed: contributions to utility are given by horizontal straight lines.

A.2 *Industry demand*

Consider now an industry with differentiated products which are demanded by a population of consumers that, for simplicity, we suppose are endowed with the same V, but with different incomes distributed in $(0, y_{\max}]$. Varieties and their prices are given as the result of previous producers' decisions. Products can be ranked from 1 to n such as $u(x_k)/u(x_j) \leq p_k/p_j$ for any two varieties if $j<k$. It is clear that consumers with different incomes will cluster buying their most satisfactory alternative given their income. For example, consumers with income $y \in (y^j, y^k)$ will buy variety j. Therefore, the simple introduction of varying marginal utility of income in the basic model has been enough to determine an association in consumption between quality varieties and consumers' income[8].

Let us now enlarge the set of products in a direction inspired on the real structure of many markets. We allow for the existence of varieties with the same global valuation and identical price (i.e., their lines are superposed), and we assume that they will share the demand of the corresponding income level. Thus, consumers with incomes belonging to the interval (y^j, y^k) will cluster buying alternative j or any one of the equivalent varieties (class-g varieties.) This agrees very well with the currently assumed consumer taste for variety. In fact, industries consisting of several income-related

[8] Moreover, products present two (perfect information) boundary characteristics. Firstly, a good priced the same as another and characterised by an inferior valuation will not be demanded (its utility contribution is a downward parallel displacement of another). Secondly, a good with a valuation identical to another but with a higher price will not be sold (lines will not cross within the relevant range).

classes of varieties (market segments), in which several varieties compete among them more intensely than with the varieties belonging to other classes, are frequent. In fact, vertical and horizontal differentiation coexist with each other, and tastes rule the choice among the similar varieties while income has a role when comparison involves vertically differenced products. The automobile industry, with products grouped in the standard model categories of small, compact, intermediate and luxury cars, is a good example.

A.3 *Stochastic set-up*

Assume now that an individual's behaviour cannot be completely predicted by any of the usually alleged reasons (see Anderson *et al.*, 1992.) Then some random component must be included in the utility contributions. The simplest specification, which appends to utility an additive random term with zero mean assumed i.i.d. across varieties, is

$$u(x_s) - \alpha(y, p_s)p_s + \varepsilon_s \equiv u_s + \varepsilon_s \qquad \text{(A.5)}$$

If the $\boldsymbol{e}'s$ are distributed as a type I extreme value random variable, the probability of choosing good j for a consumer with income y is now given by the logit formula[9]

$$P(j \mid y) = \frac{e^{u_j}}{1 + \sum_s e^{u_s}} \qquad \text{(A.6)}$$

The lines of Figure 1 and the critical income values y^s now only hold as relations for the average utility contribution (i.e., at the zero mean of the random terms.) But they allow us to easily follow the evolution of probabilities of buying different goods along incomes by looking at the relative values of the utility contributions u_s and thinking of them as arguments of formulas (6). For example, variety j presents the highest probability of being the one chosen by a consumer with an income that belongs to the interval (y^j, y^k), followed by the probabilities of acquiring k and then l. In particular it is clear that the higher the income, varieties with higher prices become the most probable choice.

[9] The alternative of "buying nothing" is indexed by 0 and given null utility contribution.

This model is especially suited to accommodate the existence of the (income level related) classes of varieties. If varieties belonging to a class are identical in price and attributes' valuation, they will exhibit identical income conditional probabilities of choice (they will show the same average utility contribution). But now varieties can even be only "approximately" equivalent, showing minor differences in the total attributes valuation, and they will present similar conditional probabilities of choice.

As far as the probabilities' evolution is concerned, it is easy to show the following

Lemma. $P(0 \mid y)$ is continuously decreasing in y and $P(j \mid y)$ is, for each j, either a continuously increasing function of y or reaches a maximum and then decreases. The alternatives whose probability reaches a maximum are the lowest priced ones, and they reach it at a sequence of y values that reproduce the price ordering.

Proof. See below.

A.4 *Product shares*

Assume a large sample of M consumers, endowed with income-conditional probabilities of buying each alternative of the J product varieties of the industry. Consumer i-th has income y_i and the probability density function $f(y)$ characterises the income distribution among consumers. Given product prices, it turns out that observed market shares will converge in probability to expected market shares that can be approximated by the logit expressions evaluated at sample average utility levels. The average utility level of alternative j is given by u_j valuated at an α equal to consumers' mean marginal utility of income conditional on choosing alternative j.

To see why, note firstly that the number of buyers of product j is the sum of a large sample of Bernoulli independent variables ξ_{ij} with means $E(\xi_{ij}) = P(j \mid y_i)$ and variances $V(\xi_{ij}) = P(j \mid y_i)(1 - P(j \mid y_i))$. The observed share $\hat{P}(j) = \sum_i \xi_{ij} / M$ will converge in probability, by the law of large numbers, to $P(j) = \sum_i E(\xi_{ij}) / M = \sum_i P(j / y_i) / M$, which, using $f(y)$, we will write as $P(j) = \sum_y P(j \mid y) f(y)$.

Associated to this share there is an expected income, or mean income, that buyers of j are expected to exhibit, obtainable by weighting each income by its probability. That is, $y_j = \sum_i y_i \left[\frac{P(x_{ij}=1)}{\sum_i P(x_{ij}=1)} \right] = \sum_y \frac{y_i P(j \mid y) f(y)}{\sum_j P(j \mid y) f(y)}$. Applying Bayes's rule we can write $y_j = \sum_y y\, f(y \mid j)$, where we will call $f(y \mid j)$ the probability density function of income conditional on choosing product j. Similarly, $P(j)$ also has an associated marginal utility of income, or mean marginal utility, that buyers of j are expected to experience, which we can write, by the same reasoning, as $\alpha_j = \sum_y \alpha(y, p_j) f(y \mid j)$.

It is natural to approximate shares as a function of these values. To see how, firstly note that, given prices, (individual) marginal utilities of income $\alpha(y, p_s) = \alpha_s(y)$ can be taken as variables with probability density functions $g_s(\alpha) = f(\alpha_s^{-1}(\alpha)) \mid \alpha_s^{-1}{}'(\alpha) \mid$ and conditional densities $g(\alpha \mid s)$. Then recall that $P(j) = \sum_y P(j \mid y) f(y)$ implies an average across income densities of all marginal utilities of income. Then replace this expectation by the function $P(j \mid .)$ evaluated at the vector of expected income marginal utilities $\alpha = (\alpha_1, ..., \alpha_J)$. Calling this approximation $P(j; \alpha)$, we have

$$P(j) \approx P(j; \alpha) = \frac{e^{u_j}}{1 + \sum_s e^{u_s}} \tag{A.7}$$

where $u_s = u(x_s) - \alpha_s p_s$ and $\alpha_s = \sum_y \alpha(y, p_s) f(y \mid s) = \sum_a \alpha g(\alpha \mid s)$.

We had already established that $\hat{P}(j) \xrightarrow{p} P(j) \approx P(j; \alpha)$. Now it is clear what the contents of the α_s specific price coefficients at expected "aggregated" logit formulas are: expected average utilities of income associated with choosing each alternative. Moreover, given prices and product attributes (and normalising u_0), a unique vector of shares P will correspond to each vector α, and there is only one vector α corresponding to a vector of shares P (see Berry, 1994.) Then, it seems

natural to interpret observed shares $\hat{P}$ as corresponding to average marginal utilities $\hat{\boldsymbol{a}}$ converging to $\boldsymbol{a}$, that is $p\lim \hat{P}(j) = p\lim P(j;\hat{\boldsymbol{a}}) = P(j;\boldsymbol{a})$.

In addition, expected mean marginal utilities will show a very definite pattern with respect to product prices/quality, as the following proposition establishes.

<u>Proposition.</u> With decreasing marginal utility of income, products with higher prices have lower expected average marginal utilities.

Proof. See below.

A.5 *Elasticities*

Replacing sums by the integral sign, in order to simplify notation, the own-price and cross-price elasticities of the expected product j market share $P(j)$ can be written as

$$\boldsymbol{h}_j = -\frac{p_j}{P(j)}\int \tilde{\boldsymbol{a}}P(j\mid y)(1-P(j\mid y))\,f(y)dy \qquad \forall j = 1,\ldots,J \qquad \text{(A.8.a)}$$

$$\boldsymbol{h}_{jk} = \frac{p_k}{P(j)}\int \tilde{\boldsymbol{a}}P(k\mid y)P(j\mid y)\,f(y)dy \qquad \forall j,k \neq j \qquad \text{(A.8.b)}$$

where $\tilde{\boldsymbol{a}} = \boldsymbol{a}(y,p_s)\left[1+\frac{p_s}{\boldsymbol{a}(.)}\frac{\partial \boldsymbol{a}(.)}{\partial p_s}\right] = \boldsymbol{a}(y,p_s)(1+\boldsymbol{g}_s)$. The elasticity $\boldsymbol{g}_s$ of marginal utility with respect to the product price may be considered small if price is not too big with respect to the relevant income. Moreover, in many cases these elasticities can be sensibly assumed to be independent from income. We will assume this henceforth, without loss of generality, in order to simplify notation.

Expressions (A.8) present the general form corresponding to logit elasticities under consumer' attribute-related heterogeneity (see, for example, Nevo 2000). But the focus on income heterogeneity allows us to be more specific. These elasticities can be rewritten as

$$\boldsymbol{h}_j = -\frac{p_j}{P(j)}\left[\tilde{\boldsymbol{a}}_j P(j)(1-P(j)) + Cov\,(\tilde{\boldsymbol{a}}P(j\mid y), P(j\mid y))\right] = -\tilde{\boldsymbol{a}}_j p_j\left[1-P(j)(1+\boldsymbol{w}_j)\right] \qquad \forall\ j \qquad \text{(A.9.a)}$$

$$\eta_{jk} = \frac{p_k}{P(j)}\left[\tilde{\alpha}_k P(k)P(j) + Cov\,(\,\tilde{\alpha}P(k \mid y), P(j \mid y))\right] = \tilde{\alpha}_k\, p_k P(k)(1+\omega_{jk})$$

$$\forall j, k \neq j \qquad \text{(A.9.b)}$$

where $\omega_{jk} = \int (\frac{\tilde{\alpha}P(k \mid y)}{\tilde{\alpha}_k P(k)} - 1)(\frac{P(j \mid y)}{P(j)} - 1) f(y)dy$, ω_j is the corresponding expression for j, the ω factors fulfil the constraint $\omega_j = -\sum_s (P(s)/P(j))\omega_{sj}$, and $\tilde{\alpha}_k$ stands for the mean marginal utility of income associated to product k augmented in the price variation effect, that is $\tilde{\alpha}_k = (\int \alpha f(y \mid k)dy)(1+\gamma_k) = \alpha_k(1+\gamma_k)$.

Elasticities in (A.9) show two important changes with respect to the standard logit elasticities. Firstly, marginal utility parameters α are now product specific. This reflects, as we have shown above, the different average marginal utilities associated with each product. Secondly, cross-price elasticities with respect to the price of product k vary across the substitutes j, in contrast with the uniform effects which characterise the standard logit model. This variation reflects that the model is now distinguishing among products “closer” and “farther” to product k in a very precise meaning, cast in the covariance term. This term shows that a price increase of product k will induce a high substitution by the products that exhibit a high probability of being chosen at the same income levels, and a low substitution by the products that are the typical choices at other income levels.

The differences between the formulas (A.9) and the standard ones is easy to interpret. Let us first examine the conventional logit price effects, given by the first term of the sum in the first part of the equalities 9.a and 9.b. In 9.a we find the share reduction provoked by a price increase of product j, $-\tilde{\alpha}_j P(j)(1-P(j)) = -\tilde{\alpha}_j P(j)\left[P(0) + \sum_s P(s)\right]$, which in case of a price increase of product k will be $-\tilde{\alpha}_k P(k)\left[P(0) + \sum_j P(j)\right]$. In 9.b we find the corresponding increment of all the other market shares $\tilde{\alpha}_k P(k)P(0) + \sum_j \tilde{\alpha}_k P(k)P(j)$, which turns out to be proportional to their relative importance.

It is simply natural to expect and specify such a proportional effect in an individual that we are only able to characterise up to a set of probabilities of buying the alternative products. If one probability is going to be reduced, we expect the

probabilities of all the other alternatives to benefit proportionally from this reduction. But, when we look at the distribution of buyers, we must take into account that this simple change modifies the relative individual probabilities of all buyers. If buyers cluster around alternatives, in the sense that some consumers have higher probabilities of buying some alternatives than others, individual changes will induce expected aggregated changes according to the patterns of substitution given by the clustering. This is what is reflected by the covariance term, raising what can be called “aggregated” elasticities (Ben-Akiva and Lerman, 1985).

A.6 *Nested probabilities*

The present formulation can be combined with the specification of nested logit probabilities. In this case, the nesting must be intended to reflect the structure of the individual preferences and hence probabilities of choice given income. That is, as products to be chosen by any consumer present among them different degrees of “similarity” and “dissimilarity” in attributes, the model avoids the IIA property by grouping together similar alternatives. Then the rest of the model applies.

One particular version of this combination is obtained by assuming that income does not influence the choice among alternatives inside a nest. That is, all products grouped at a nest present conditional probability choices that evolve with income at the same pace as the probability of choosing the group (segment). This corresponds to the simple graphical example of sets of products represented for the same line. It can be regarded as a simplified situation in which income and tastes influence global choice, but only tastes determine the choice inside the segment. This situation is likely to emerge when producers choose to locate products slightly differentiated in nests characterised by the same price.

Formally, let $g = 1,...,G$ index the groups of products and let J_g represent the set of products in group g. We will use the notation $P_g(k \mid y) = P(k \mid y) / P(J_g \mid y)$ for the intra-group share of product k, where $P(J_g \mid y) = \sum_{s \in J_g} P(s \mid y)$. According to the above suggestion assume that $P_g(k \mid y) = P_g(k)$, which is equivalent to

$f(y|k) = f(y|J_g)$. Then, it is easy to check that nested elasticities with consumer income heterogeneity are given by

$$\eta_j = -\tilde{\alpha}_j p_j \left[1 - P(j)(1+\omega_j) + \frac{\sigma}{1-\sigma}(1 - P_g(j))\right] \qquad \forall j \qquad \text{(A.10.a)}$$

$$\eta_{jk} = \tilde{\alpha}_k p_k \left[P(k)(1+\omega_{jk}) + \frac{\sigma}{1-\sigma} P_g(k)\right] \qquad \forall j, k \neq j \quad if \quad j,k \in J_g \qquad \text{(A.10.b)}$$

or $$\eta_{jk} = \tilde{\alpha}_k p_k P(k)(1+\omega_{jk}) \qquad \forall j, k \neq j \quad otherwise \qquad \text{(A.10.c)}$$

Proof of the Lemma

Note that the e^{u_s} are increasing in y. Hence $P(0|y) = 1/(1 + \sum_s e^{u_s})$ is continuously decreasing in y. On the other hand, each $P(j|y)$ will increase if $\frac{\partial P(j|y)}{\partial y} = -\frac{\partial \alpha(y, p_j)}{\partial y} P(j|y)\left[p_j - \sum_s \theta_{sj} P(s|y) p_s\right] > 0$, where the terms θ_{sj} have the form $\theta_{sj} = \frac{\partial \alpha(y, p_s)}{\partial y} \bigg/ \frac{\partial \alpha(y, p_j)}{\partial y} > 0$ and fulfil $\theta_{sj} > \theta_{sk}$ *if* $p_k > p_j$. What we need is the positiveness of the term between brackets. With J varieties ordered according to prices (from the lowest to the highest), the positiveness of conditions from 1 to J form a system of inequalities in which the constraints will be violated in turn as y grows (the constraints are easier to be fulfilled the bigger the price). Then the corresponding probabilities will begin to decrease.

Proof of the Proposition.

We want to show that, if $p_k > p_j$, then $\alpha_k < \alpha_j$. We have

$$\alpha_j - \alpha_k = \int \alpha(y, p_j) f(y|j)dy - \int \alpha(y, p_k) f(k|y)dy = \int (\alpha(y, p_j) - \alpha(y, p_k)) f(y|j) -$$

$$- \int \alpha(y, p_k)(f(y|j) - f(y|k)) = -\int \frac{\partial \alpha}{\partial p_j}(p_k - p_j) f(y|j) - \int \frac{\partial \alpha}{\partial y}(F(y|j) - F(y|k))$$

where the first term of the last equality constitutes a first order approximation and the second is obtained by integration. This expression can be approximated by the integral $-\int \frac{\partial \alpha}{\partial y}(F(y - \Delta p|y) - F(y|k))$. A sufficient condition for this integral to be positive

is the stochastic dominance of the distribution $F(y-\Delta p \mid y)$ over the distribution $F(y \mid k)$. As we are going to see, this is what we must expect when $p_k > p_j$ and prices are not too big with respect to income.

Given the previous Lemma, it is easy to check that the ratio of probabilities of alternative k to j is increasing, that is $\frac{\partial(P(k \mid y)/P(j \mid y))}{\partial y} > 0$. This implies

$$\int \frac{P(k \mid y)}{P(j \mid y)} f(y \mid j)dy < \int_{y}^{y^M} \frac{P(k \mid y)}{P(j \mid y)} \frac{P(j \mid y) f(y)}{\int_{y}^{y^M} P(j \mid y) f(y)} dy \quad \text{or}$$

$\frac{P(k)}{P(j)} = \frac{\int P(k \mid y) f(y)dy}{\int P(j \mid y) f(y)dy} > \frac{\int_0^y P(k \mid y) f(y)dy}{\int_0^y P(j \mid y) f(y)dy}$. Hence, $\int_0^y f(y \mid j)dy > \int_0^y f(y \mid k)dy$ or $F(y \mid j) > F(y \mid k)$. If prices are not too big with respect to income, this will imply the required dominance.

References

Arellano, M. and B. Honorè (2000), *Panel Data Models: Some Recent Developments*, forthcoming in Handbook of Econometrics.

Arellano, M. and O.Bover (1995), "Another look at the Instrumental-Variable Estimation of Error-Components Models", *Journal of Econometrics*, 68, 1995, 29-51.

Anderson, S.P., De Palma, A., and J-F. Thisse (1992), *Discrete Choice Theory of Product Differentiation*, MIT Press.

Ben-Akiva, M. and S.R. Lerman (1985), *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press.

Berry, S.T. (1994), "Estimating discrete-choice models of product differentiation," *RAND Journal of Economics*, 25 (2), 242-262.

Berry, S.T., Levinsohn, J., and A. Pakes (1995), "Automobile prices in market equilibrium," *Econometrica*, 63 (4), 841-890.

Berry, S.T., Levinsohn, J. and A. Pakes (1999), "Voluntary export restraints on automobiles: evaluating a trade policy," *American Economic Review*, 89, 400-430.

Bhargava, A. and D. Sargan (1983), "Estimating dynamic random effects models from panel data covering short time periods", *Econometrica*,Vol. 51, 1635-1660.

Blundell, R. and S. Bond (1998), 'Initial conditions and Moment Conditions in Dynamic Panel Data Models', (with S. Bond), *Journal of Econometrics*, Vol. 87, No.1. November 1998, 115-143.

Bresnahan, T.F. (1987), "Competition and collusion in the American automobile industry: The 1955 price war," *Journal of Industrial Economics*, 35 (4), 457-82.

Cardell, N.S. (1997), "Variance components structures for the extreme-value and logistic distributions with applications to models of heterogeneity," *Econometric Theory*, 13 (2), 185-213.

Goldberg, P.K. (1995), "Product differentiation and oligopoly in international markets: the case of the U.S. automobile industry," *Econometrica*, 63(4), 891-951.

Goldberg, P.K. and F. Verboven (2001), "Market integration and convergence of the Law of One Price: Evidence from the European car market," Discussion Paper 2926, CEPR: London.

Griliches, Z. (1961), "Hedonic price indexes for automobiles: An econometric analysis of quality change," reprinted in Z. Griliches (Ed.) "*Price Indexes and Quality Changes*," Cambridge, MA: Harvard University Press, 1971.

Jaumandreu, J. and J. Lorences (2002), "Modelling price competition across many markets (An application to the Spanish loans market)," *European Economic Review* Vol. 46, 1 (2002) pp. 93-115.

McFadden, D. (1981), "Econometric models of probabilistic choice," in *Structural Analysis of Discrete Data with Econometric Applications*, C. Manski and D. McFadden Eds., MIT Press.

Moral, M.J., and Jaumandreu, J. (2000), "Optimal multiproduct prices. An application in the automobile market," mimeo.

Moral, M.J., and Jaumandreu, J. (2001), "Automobile demand, model cycle and age effects," mimeo.

Nevo, A. (2000), "A practitioner's guide to estimation of random-coefficients logit models of demand," *Journal of Economics and Management Strategy*, 9 (4), 513-548.

Newey, W.K. and K.D. West (1987), "A simple positive semi-definite, heteroskedasticly and autocorrelation consistent covariance matrix," *Econometrica*, 55, 703-708.

Nevo, A. (2001), "Measuring market power in the ready-to-eat cereal industry," *Econometrica*, 69(2), 307-342.

Pakes, A. (1997), "Hedonics and prices indices," mimeo.

Petrin, A. (1999), "Quantifying the benefits of new products: The case of the minivan," University of Chicago, mimeo.

Rosen, S. (1974), "Hedonic price and implicit markets: product differentiation in pure competition," *Journal of Political Economy,* Vol. 82, 34-55.

Shaked, A., and J.Sutton (1982), "Natural oligopolies," *Econometrica*, 51(1), 1469-1483.

Table 1: The Spanish car market in the 90s

Year	Sales	Sales index	Models entry	Models exit	No. of models	Share of domestic producers	Share of European producers	Share of Asian producers
1990	971,466	100.0	19	2	98	82.0	16.0	2.0
1991	878,594	90.4	10	5	106	80.0	16.9	3.1
1992	973,414	100.2	16	10	117	81.3	14.6	3.9
1993	735,993	75.8	13	9	120	80.7	13.9	5.2
1994	897,492	92.4	13	14	124	78.6	15.8	5.3
1995	822,593	84.7	17	10	127	77.0	15.7	6.8
1996	897,906	92.4	16	9	133	75.0	15.8	8.4

Table 2
Results from model estimation and testing

Dependent variable: $p_{jt} / (1 + tariffs_{jt})$
Sample period[1]: I-1991 to XII-1996; Observations[1]: 7,122; Nº of models[1]: 164
Estimation method: GMM[2]

Variable	Coefficient	t-ratio[3]	Coefficient	t-ratio[3]	Coefficient	t-ratio[3]
Constant	2.151	13.74	2.036	11.69	1.985	11.33
Attributes:						
CC/Weight	2.034	7.85	2.068	8.06	1.859	6.89
Maxspeed	1.144	2.26	1.043	2.05	0.832	1.75
Km/l	0.360	0.76	0.364	0.76	1.031	2.17
Size	-0.146	-0.75	-0.162	-0.84	-0.381	-2.05
Weight	3.610	5.41	3.814	5.54	3.908	6.04
Air	-0.085	-0.77	-0.091	-0.80	0.037	0.31
$(CC/Weight)^2$	1.570	3.90	1.560	3.90	1.440	2.70
$(Maxspeed)^2$	3.220	4.21	3.193	4.25	3.589	4.11
$(Size)^2$	0.100	1.82	0.099	1.87	0.088	1.69
Behaviour[4]						
Always Bertrand						
Small	-0.16	-0.09				
Compact	-1.67	-1.55				
Intermediate	3.45	2.80				
Luxury	2.64	1.70				
Minivan	-4.26	-1.69				
Always Collusion						
Small			0.084	0.23		
Compact			-0.219	-0.91		
Intermediate			0.827	3.10		
Luxury			0.667	1.93		
Minivan			-1.358	-2.12		
D+E switch from collusion to Bertrand						
Small					-1.102	-2.22
Compact					-0.952	-1.05
Intermediate					3.013	3.08
Luxury					3.487	3.35
Minivan					-4.445	-2.46
Sargan test[5] (28degrees of freedom)	49.46		50.19		36.22	
Voung-type test[6]						
Always Bertrand			1.20		-8.51	
Always Colusion					-9.21	

Notes:

1. Instruments lagged 12 months imply that models with 12 and fewer observations must be removed.
2. Instruments: differences of segment-shares with respect to their meantime lagged 6 and 12 months, 31 brand dummies.
3. Standard errors are robust to heteroskedasticity and serial correlation.
4. Coefficients of behavioural variables are constrained to add up to zero.
5. Two-step statistic.
6. Computed with the GMM analogous to the likelihood-ratio. A row value above (below) the critical value 1.96 (-1.96) means that the row model can be accepted as better (worse) than the column model.

Table A.1
Results from demand estimation

Dependent variable: $\ln \hat{P}_j - \ln \hat{P}_0$
Sample period[1]: I-1991 to XII-1996
Observations[1]: 7,122
Nº of models[1]: 164
Estimation method: GMM[2]

Variable	Coefficient	t-ratio[3]
Constant	-15.840	-6.70
Attributes:		
CC/Weight	1.332	2.46
Maxspeed	0.034	2.92
Km/l	0.071	1.61
Size	0.651	3.42
Prices:		
Small	-4.916	-2.67
Compact	-3.374	-2.65
Intermediate	-0.931	-3.53
Luxury	-0.593	-2.97
Minivan	-2.575	-3.12
Segment effects[4]:		
Small-domestic	5.152	3.49
Intermediate	-2.831	-1.97
Luxury	-4.969	-3.57
Seasonal effects	included	
Time dummies	included	
Age polynomial	included	
Age-price interactions	included	
s *estimate*	0.842	7.51
Sargan test[5] (25 degrees of freedom)	35.86	

Notes:
1. Instruments lagged 12 months imply that models with 12 and fewer observations must be removed.
2. Instruments: differences of segment-prices with respect to their time mean lagged 6 and 12 months, 20 age dummies (years) and interactions of the age dummies with the price differences lagged 12 months.
3. Standard errors are robust to heteroskedasticity and serial correlation.
4. Small-mini, compact and minivan coefficients constrained to be equal to the average effect.
5. Two-step statistic.

Table A.2
A sample of own and cross-price elasticities[1]
(x100 cross-price cross-segment elasticities[2])

	Small mini			Small			Compact			Intermediate			Luxury		
	Fiat Uno	Seat Marbella	Rover 114	Ford Fiesta	Seat Ibiza	Peugeot 205	Ford Escort	Opel Astra	VW Golf	Citroen Xantia	Ford Mondeo	Opel Vectra	BMW 525	Mercedes 300	Volvo 850
Fiat Uno	**-4.033**	**1.185**	**0.169**	0.421	0.390	0.203	0.279	0.420	0.278	0.019	0.024	0.021	0.007	0.017	0.014
Seat Marbella	**1.396**	**-3.235**	**0.144**	0.417	0.399	0.192	0.278	0.394	0.277	0.037	0.042	0.034	0.007	0.017	0.012
Rover 114	**1.215**	**1.085**	**-6.227**	0.410	0.381	0.167	0.282	0.400	0.266	0.014	0.017	0.038	0.007	0.016	0.013
Ford Fiesta	0.081	0.060	0.010	**-5.776**	**0.913**	**0.455**	0.280	0.405	0.267	0.010	0.012	0.019	0.007	0.016	0.013
Seat Ibiza	0.081	0.060	0.010	**0.949**	**-5.820**	**0.455**	0.280	0.404	0.268	0.010	0.012	0.019	0.007	0.017	0.013
Peugeot 205	0.081	0.059	0.010	**0.949**	**0.913**	**-5.899**	0.280	0.400	0.269	0.009	0.011	0.021	0.007	0.017	0.013
Ford Escort	0.080	0.058	0.010	0.415	0.399	0.193	**-5.294**	**0.909**	**0.616**	0.207	0.231	0.139	0.009	0.018	0.006
Opel Astra	0.044	0.049	0.007	0.387	0.389	0.140	**0.721**	**-5.764**	**0.586**	0.210	0.234	0.081	0.009	0.016	0.005
VW Golf	0.080	0.059	0.010	0.414	0.399	0.193	**0.740**	**0.909**	**-7.030**	0.254	0.285	0.155	0.010	0.018	0.004
Citroen Xantia	0.017	0.045	0.005	0.417	0.430	0.140	0.297	0.361	0.256	**-2.449**	**0.643**	**0.440**	0.011	0.013	0.000
Ford Mondeo	0.019	0.044	0.005	0.414	0.424	0.139	0.294	0.359	0.255	**0.580**	**-2.410**	**0.438**	0.011	0.014	0.000
Opel Vectra	0.076	0.051	0.009	0.422	0.402	0.189	0.280	0.403	0.267	**0.581**	**0.651**	**-2.477**	0.017	0.023	0.000
BMW 525	0.074	0.046	0.008	0.425	0.403	0.186	0.284	0.426	0.253	1.567	1.748	1.021	**-2.631**	**0.545**	**0.433**
Mercedes 300	0.073	0.044	0.008	0.427	0.404	0.185	0.286	0.440	0.243	2.012	2.239	1.201	**0.321**	**-3.258**	**0.433**
Volvo 850	0.032	0.040	0.006	0.403	0.407	0.134	0.273	0.382	0.248	1.206	1.349	0.301	**0.350**	**0.515**	**-2.797**

1. Cell entries *j*,*k* where *j* indexes row and *k* column, give the percent change in sales (or market share) of model *j* with a one percent change in price of model *k*.
2. Cross- price elasticities between models of different segments are multiplied by 100 (the sample includes an average of 110 models/year).

Figure 1

Sales evolution in the Spanish car market

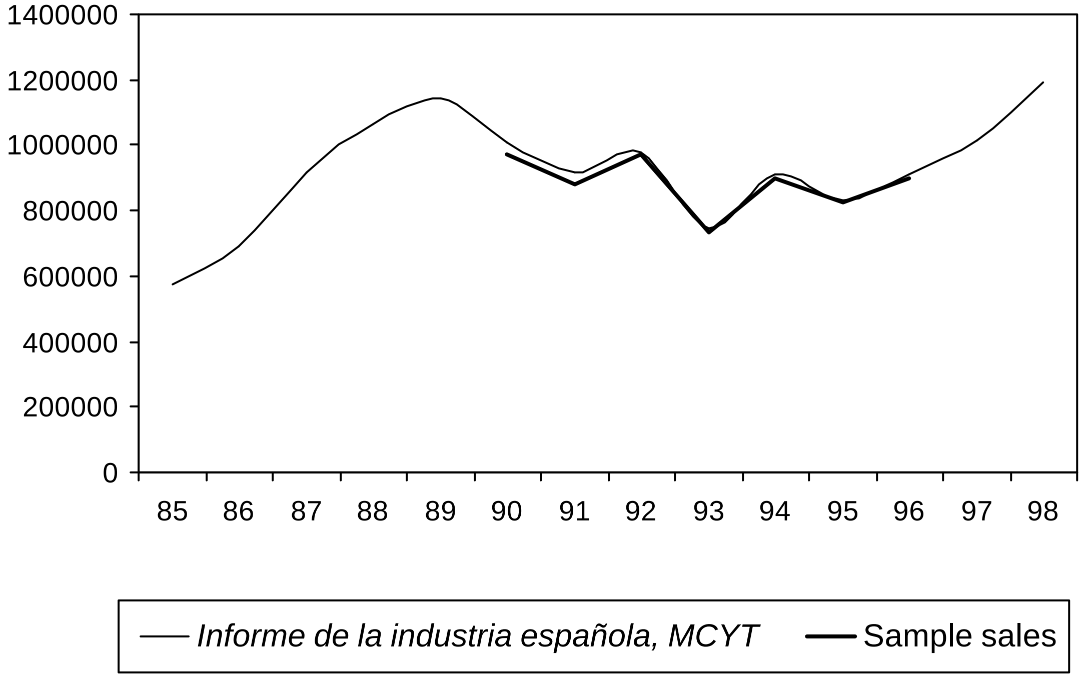

Figure 2: Prices and received prices

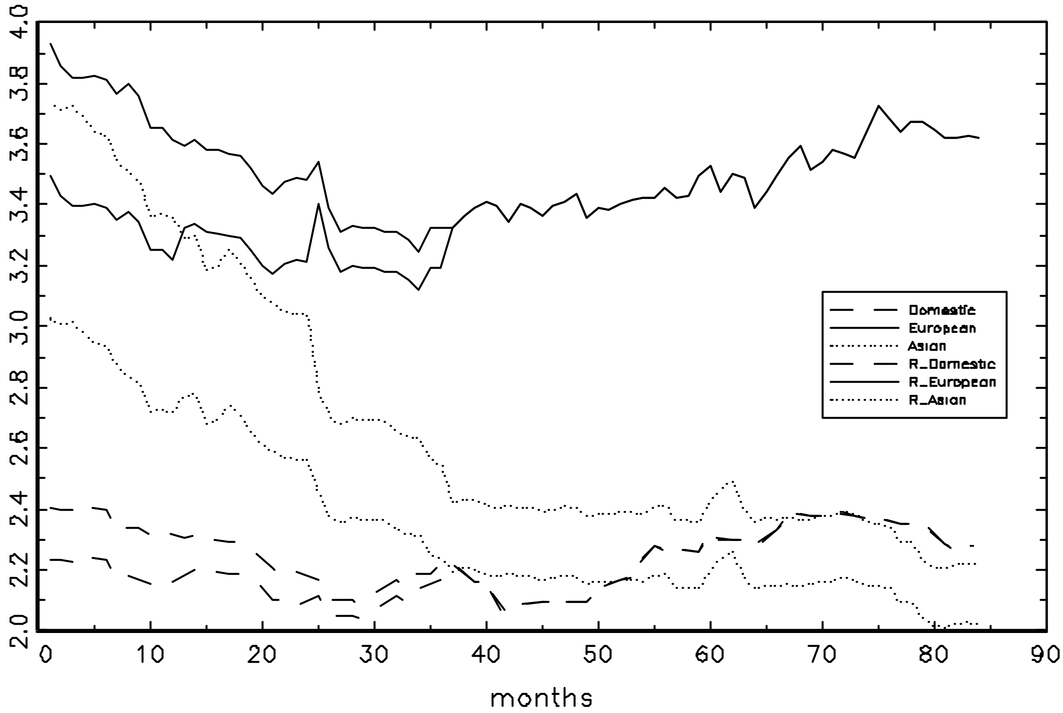

Figure 3: Quality adjusted price index

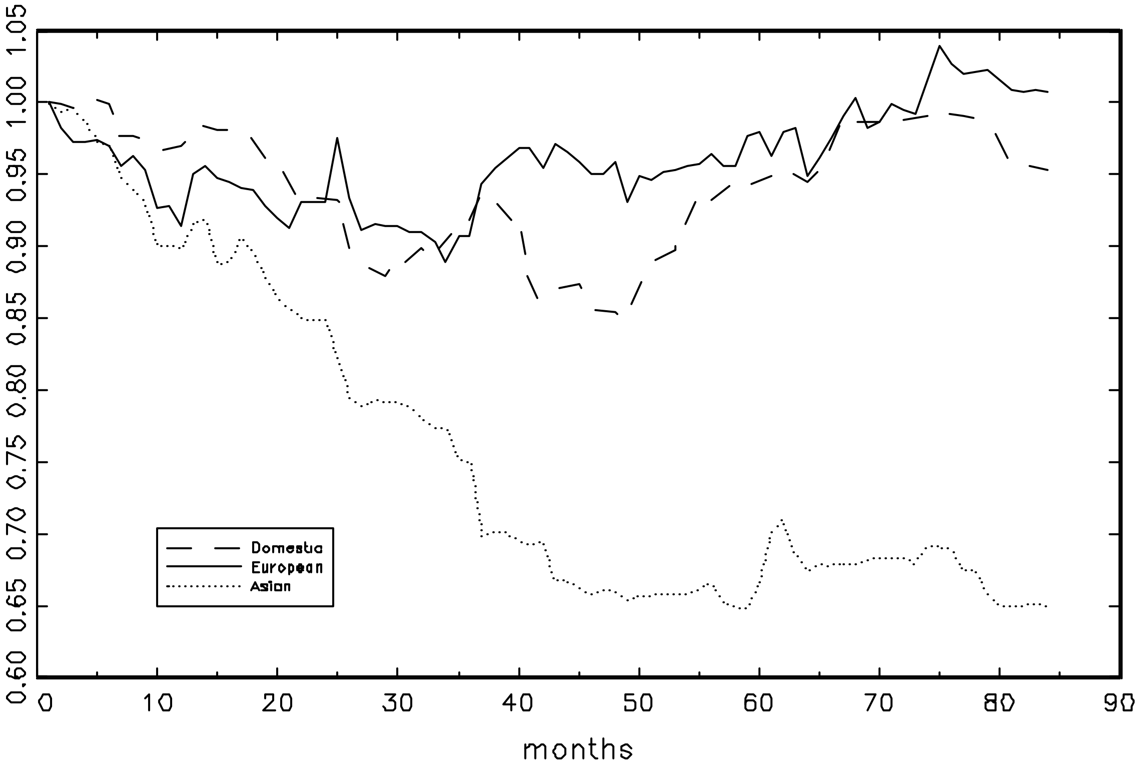

Figure 4: Entry and quality change adjusted price index

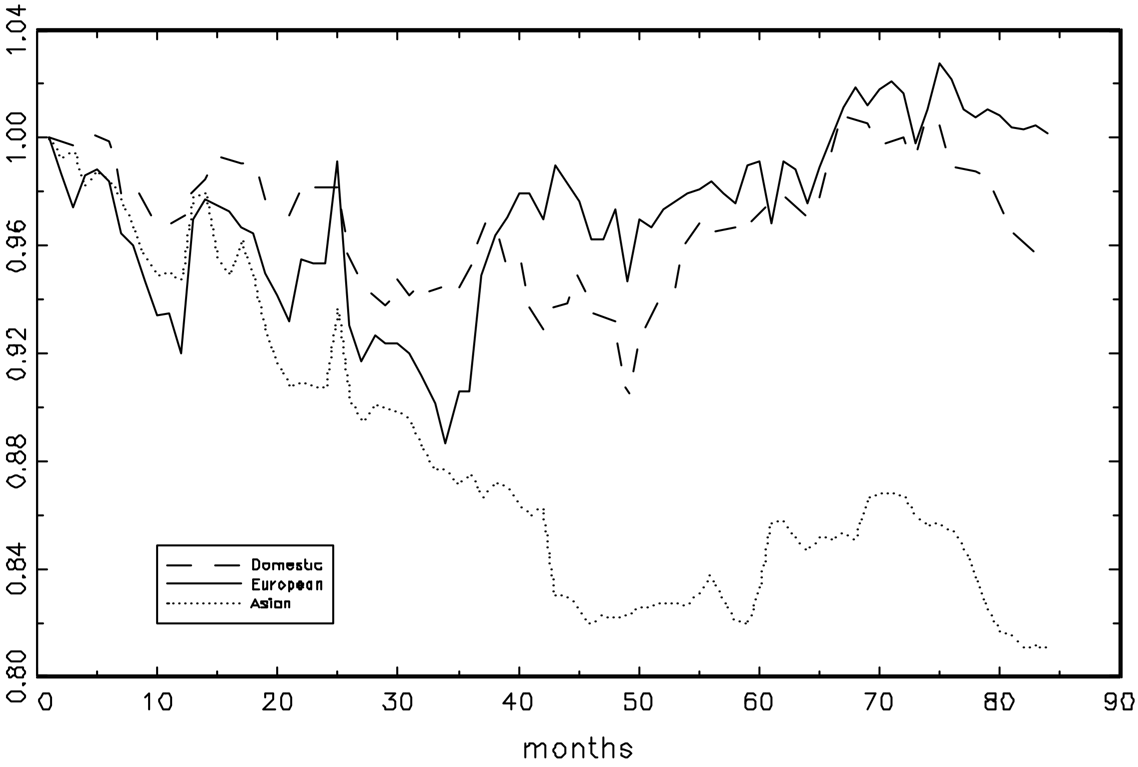

Figure A.1

Utility and choices as a function of consumer' income.