Product lines and price discrimination in the European car market

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Abstract

In this paper we consider a model of oligopolistic competition where firms make a two-dimensional product line decision. They choose a location in style space, thus, inducing horizontal differentiation, and produce different qualities (a product line) of a given good (vertical differentiation), consumed by a population of customers who differ in their income and preference for style. We prove existence of a non-cooperative equilibrium and show that, as the degree of competition increases, prices approach marginal cost. The approach is used to show that European car producers seem indeed to use product lines to discriminate across EU countries.

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1 Introduction

Most consumer product markets are characterized by several firms offering product lines that closely match those of their competitors. The various companies are differentiated not so much by the type of product, but by other factors such as styling, warranties, reputations for reliability, brandname. Most car manufacturers, for example, tend to offer the same range of cars in terms of power, size, engine capacity, speed, etc. The way they vary is to have a styling that is unique to their whole product line (and to their brandname), thus allowing economies of scope in advertising, servicing, etc. Firms seem to work very hard to produce a look that is unique, but not uniformly desired by all consumers (horizontal differentiation), while at the same time they offer products which can vary considerably in quality (vertical differentiation).

This suggests that firms make an essentially two-dimensional product line decision. The first is the choice of a styling, or company practice, that differentiates all of their products in some common way from those of their competitors. In the second stage, each company makes a product line decision which includes the range of products they offer, and the corresponding price schedule. In many markets, firms change their style very seldom and we therefore focus our analysis on product line rivalry for exogenously chosen styles. We show that firms create market power for themselves by differentiating their whole product line to be able to price discriminate among consumers. Therefore, product line rivalry can be viewed as an example of oligopolistic price discrimination.

In our model we assume that firms locate in a point in style space, and produce a product line that varies in quality. Consumers differ in their income and preference for style. In this framework we examine two-part price schedules that include a fixed fee and a markup, and study how price discrimination varies with competition and with consumers’ preferences for style. We prove that a non-cooperative equilibrium exists and show that, as competition increases, prices approach marginal cost. Even though the preferences we use are derived from those of Gabszewicz and Thisse (1979), our model does not lead to their natural oligopoly result.

The empirical part of the paper deals with the car market in five countries of the European Union. For obvious reasons, detailed data on costs as well as

\[1\text{See also Shaked and Sutton (1983).}\]
(in most cases) on volumes are unavailable. There now exist several papers in which authors are able to infer cost and demand parameters (See Berry, Levinsohn and Pakes (1995, 1998) Goldberg (1998) and Verboven (1996) for such examples). Since our focus was different, we did not estimate the structural parameters of the model, and took a shortcut based on the theoretical model, where we derive our results by assuming that the equilibrium price-quality schedules are two-part tariffs, whose coefficients are parametrized with respect to the degree of competition. Here, we directly estimate these price schedules, and find evidence that European producers use product lines to price discriminate.

Before turning to the details of the model, let us note that, as Brander and Eaton (1984) have pointed out in their study of product line rivalry, there is relatively little work on the subject. Their paper centers around the issue of entry deterrence and the choice of scope and has little to say about price discrimination. The earlier literature on product differentiation, has generally assumed that each firm produces a single quality product. More recently, Champsaur and Rochet (1985, 1989) addressed the question of multiproduct oligopolists; however the absence of horizontal differentiation in their model results in each quality being sold by at most one firm. Economides (1986) and Neven and Thisse (1990) study a model in which variety (i.e., horizontal differentiation) and quality choice (i.e., vertical differentiation) of a single product are endogenous; however, they do not examine the case of product line competition. Gilbert and Matutes (1993) focus on the issue of commitment in determining the scope of the firms’ price line offerings in a model with a discrete product space. Rochet and Stole (1999) provide an extensive theoretical framework to address the issue of nonlinear pricing in a multidimensional setting. They show, in particular, that an efficient quality allocation with cost-plus-fee pricing, examined in this paper, emerges as an equilibrium outcome.

The paper is organized as follows. In Section 2 we outline the theoretical model and state our existence and comparative statics results, for which proofs are given in the Appendix. Section 3 deals with our empirical results. Section 4 is devoted to concluding comments.
2 The model

There is a market with differentiated products and there are \( n \) firms, indexed by \( i \in N = \{1, 2, \ldots, n\} \). In contrast to most of the models of spatial competition, that typically deal with one dimensional choice spaces, we assume that firms compete with their product lines. That is, there is an observable characteristic which is common to all products of a given firm. In the case of the car market this might be a firm’s distinctive styling (think, for example, of Mercedes-Benz or BMW who have cars with a distinctive “look”).

It will be assumed that the firms locate symmetrically on the circle \( S^1 \), at locations \( s^1, \ldots, s^n \) (see Salop (1979), Novshek (1980), Horstmann and Slivinsky (1985)). The circumference \( L \) of the circle will provide a measure of potential diversity. While many consumers may wish to buy a product of given style, they will in general also wish to choose among different qualities. Firms therefore offer a range of qualities \( Q = [q_L, q_H] \). Firm \( i \)’s product line is thus defined by \( s^i \times [q_L, q_H] \). The marginal cost of producing a good of quality \( q \) is the same for all firms and takes the form \( c_i(q) = cq \).

There is a continuum of consumers parameterized by their most preferred style and income. The space of consumers is given by \( Y \equiv S^1 \times M \) where \( M \equiv [m_L, m_H] \) and \( m_L \) (\( m_H \)) denotes the lower (upper) bound of consumers’ income. It is furthermore assumed that consumers are uniformly distributed over \( Y \) and, without loss of generality, their total mass is equal to one. Each consumer purchases, at price \( p \), one unit of product of style \( s \) and quality \( q \).

For any consumer \( y = (t, m) \in Y \) the choice over triplets \((s, q, p)\) is made according to the preferences represented by the utility function:

\[
U_y(s, q, p) = -|t - s| + q(m - p),
\]

where \( |t - s| \) is the (arc) distance between two points on \( S^1 \). The first term in (1), \(-|t - s|\), represents the disutility of a consumer whose preferred style is \( t \), but who buys a product of style \( s \). The second term, \( q(m - p) \), represents the utility from consuming one unit of a good of quality \( q \), at price \( p \). This is essentially the functional form used by Gabszewicz and Thisse (1979) and Shaked and Sutton (1982), which guarantees that at given price, consumers with higher incomes put more weight on quality.

Since firms are not able to observe the characteristics of individual consumers and charge a tailor-made price for each of them, they choose price
as a function of quality alone. For reasons of technical tractability and potential empirical applications, we assume that price is an affine function of quality. The firms’ price schedules will therefore be restricted to two-part tariffs. Thus, a typical strategy of firm \( i \) is \( x_i = (a_i, b_i) \in \mathbb{R}_+^2 \) which yields a price \( P_i(q) = a_i + b_i q \) for quality \( q \). When \( b_i \neq c \), the marginal cost for producing quality \( q \), firm \( i \) will discriminate among individuals with different tastes for quality. Customers of firm \( i \) will buy the good of quality \( q \) yielding the highest utility, given by:

\[
V(y, x_i) = \max_{q \in Q} \{ -|s_i - t| + q(m - a_i - b_i q) \}. \tag{2}
\]

Note that the quality of the good chosen by an individual depends only on his income. Therefore, a consumer with income \( m \) will consume a good of quality \( q_i(m) \) and pay a price \( P_i(m) \) where:

\[
q_i(m) \equiv \arg \max_{q \in Q} \{ q(m - a_i - b_i q) \} \tag{3}
\]

and

\[
p_i(m) \equiv P_i(q_i(m)). \tag{4}
\]

We furthermore assume that for each \( P_i, i \in N \) and each \( m \in M \), \( q_i(m) \) is an interior solution, i.e., for all \( m \in M \) and \( i \in N \):

\[
q_L < q_i(m) < q_H. \tag{5}
\]

Equation (5) implies that the price schedules satisfy a non-bunching property: if consumers with different incomes decide to purchase a product from the same firm, they will choose different qualities of the good. This non-bunching property guarantees that \( q_i(m) \) is a strictly increasing function of income, so that a rich consumer will purchase a good of higher quality than a poor one.

We next assume that there exists a positive \( \rho \), satisfying the following inequalities:

\[
2cq_L < mL < (2c + \rho)q_L < q_H < mL < 2cq_H. \tag{6}
\]

This assumption implies that marginal cost pricing is itself a non-bunching strategy and sets upper and lower bounds of the possible range of incomes and qualities.
The functions $V(\cdot,\cdot)$, defined by (2), enable us to derive, for each firm $i \in N$, a market area $I_i(\cdot)$, given by:

$$I_i(x) \equiv \{y \in Y \mid V(y, x_i) \geq V(y, x_j), \forall j \in N\}, \quad (7)$$

where $x = (x_1, ..., x_n)$. In general, this results in market areas overlapping at the boundaries. However, these intersections typically consist of sets of agents with measure zero and therefore do not affect the definition of profits. The profit of firm $i$ is:

$$\Pi_i(x) = \int_{y \in I_i(x)} (a_i + (b_i - c)q_i(m))dy \quad (8)$$

We now consider a non-cooperative game in which firm $i$’s strategy is $x_i = (a_i, b_i)$ and its payoff is given by (8). The parameter $a_i$ represents what is usually called a fixed fee, whereas the difference $b_i - c$ is a markup. (See Gilbert and Matutes (1993), Armstrong and Vickers (1997), Stole and Rochet (1999).)

Since firms are identical we consider only symmetric Nash equilibria and drop the firm index $i$ in what follows. Note that the equilibrium outcomes depend on $n, L$ and the width of the quality and income ranges; however, $L$ and $n$ affect equilibria only via the term $L/n$, which is the width of the market areas $I_i(x)$ at a symmetric equilibrium. Clearly, when $L$ is fixed, the number of firms $n$ represents the level of competition: as $n$ tends to infinity the market approaches perfect competition.

Our first result shows that when the range of incomes (represented by the ratio of the highest to the lowest income $\mu = m_H/m_L$) and the number of firms are large, then a unique Nash equilibrium will exist. Formally,

**Proposition 1**: There are $n^*$ and $\mu^*$ such that for all $n > n^*$ and $m_H/m_L > \mu^*$ there exists a unique symmetric Nash equilibrium.

Since we keep the bounds on consumers’ incomes fixed, we shall denote the firms’ equilibrium strategies by $(a(L/n), b(L/n))$ and the equilibrium price schedules by $P(L/n, q)$. Using (3) and (4), this yields quality and price functions denoted $q(L/n, m)$ and $p(L/n, m)$.

Proposition 2 examines the properties of the equilibrium strategies and price functions.
Proposition 2: There exists $\bar{n}$, such that for all $n > \bar{n}$ and $\frac{m_n}{m}\mu > \mu^*$,

(i) $\lim_{n \to \infty} a\left(\frac{L}{n}\right) = 0$ and $\lim_{n \to \infty} b\left(\frac{L}{n}\right) = c$;

(ii) $a\left(\frac{L}{n}\right)$ is decreasing and $b\left(\frac{L}{n}\right)$ is increasing in $n$;

(iii) The firm’s profit is a decreasing function of income $m$.

The assertions of Proposition 2 are fairly intuitive. Assertion (i) shows that, as the level of competition increases, equilibrium prices approach marginal costs. Assertion (ii) implies that increasing competition generates a decline of the fixed part and an increase of the variable part of the equilibrium two-part price schedule. Assertion (iii) can be explained by the fact that the markup declines with quality, which itself is an increasing function of income. It is important to note, therefore, that since the markup of prices on costs is not constant, product lines are used as a price discriminating device. This suggests the possibility of inferring the degree of competition from examining the equilibrium price schedules.

3 Discrimination in the European car market

Since we shall be discussing price discrimination in Belgium, France, Germany, Italy and the United Kingdom, some comments on the five markets are in order.

Casual observation seems to lend support to the assumption that Belgium is the most competitive market. Indeed, there is no Belgian domestic producer, while the four other countries all have one or several producers enjoying some degree of protection. Belgium is also widely open to Japanese imports. Finally, producer prices are significantly lower in Belgium than in all other countries (see BEUC (1984, 1986) as well as Mertens and Ginsburgh (1985) and Ginsburgh and Vanhamme (1989)). These observations are backed up by the fact that producers complain about Belgian price regulations leading to insufficient profits, or even losses in some cases. On the other end of the spectrum, the United Kingdom is characterized by right-hand driving which isolates the British market and makes it difficult for consumers to import their car from Continental Europe; moreover, a substantial part of “private” cars is owned by companies. France, Germany and Italy are endowed with characteristics which lie between these two extreme cases.
It should also be stressed that there exist exclusive agreements between producers and dealers. This may turn out to impose non-tariff barriers between the various countries and, though it does not completely prevent arbitrage, it makes it rather difficult. An individual consumer from say France, can buy his car in Belgium (differences in regulations tend however to make this quite difficult and time consuming), but dealers can hardly organize arbitrage on a large scale basis, though this is slowly changing over the years.\footnote{The European Court in Luxemburg had to deal with such cases, and ruled against dealers who were not officially selected by producers. In 1999, the European Commission imposed a Euro 102 million fine on Volkswagen who was forbidding Italian dealers to sell cars to Austrian and German customers, since prices in Austria and Germany were much higher than in Italy.}

As was pointed out in the introduction, we did not estimate the structural coefficients of the model, but took the shortcut to estimate the equilibrium price-quality schedules \( P_{ic}(q) = a_{ic} + b_{ic} q_{ic} \) in the various countries \( c \) where producer \( i \) is active and to check whether the coefficients \( a_{ic} \) and \( b_{ic} \) satisfy assertion \((ii)\) of Proposition 2, i.e. whether \( a_{ic'} > a_{ic''} \) and \( b_{ic'} < b_{ic''} \) in a country \( c' \) that is \textit{a priori} – see above – assumed to be less competitive than country \( c'' \). The unique quality \( q \) considered in the theoretical model will be replaced by a vector of characteristics \( z \). The characteristics used are engine capacity, speed and length – which are continuous variables – and a dummy variable which represents the type of fuel used, diesel or gasoline.

For every producer \( i \) selling in country \( c \), the following regression is computed:

\[
\ln p_{ic,jt} = \alpha^0_{ic} + \sum_{l=1}^{2} \alpha^l_{ic} y^l + \sum_{k=1}^{4} \beta^k_{ic} z^k_{ic,jt} + e_{ic,jt}.
\]

Each regression \( ic \) is computed by pooling observations belonging to three years (1988, 1989 and 1990). The variables are as follows: \( p_{ic,jt} \) is the price of make \( j \) sold in year \( t \); \( y^l \) is a dummy variable which takes the value one if observation \((ic, jt)\) corresponds to year \( l = t \) and \( z^k_{ic,jt} \) is the value of the \( k \)th characteristic. The \( \alpha \)'s and \( \beta \)'s are regression coefficients – the intercepts \( a \) and the slopes \( b \) of the theoretical model. Note that the dependent variable in each regression is the logarithm of the price, and not the price itself; this is done to reduce any possible heteroskedasticity. The theoretical model of Section 2, is linear, but nothing there prevents to rescale differently the quality variable(s).
We ran 117 such individual regressions,\(^3\) which makes it impossible to give the detailed results. Table 1 merely reports the distribution of the \(R^2\)s, showing that most adjustments are very satisfactory.

Next, we ran, for each producer \(i\), various hypothesis tests on the (in)equality of the regression coefficients across countries.\(^4\) The resulting F-tests are reported in Table 2 and show that the joint test on equality of intercepts and slopes is rejected in all cases, with the exception of Jaguar-Daimler. This leads us to conclude that the price schedules set by producers for their product lines are significantly different across countries. The joint test on slopes only also rejects equality in most cases.

This seems to imply that producers use characteristics in order to price discriminate, but does not indicate whether assertion \((ii)\) of Proposition 2 holds. To check for this, we have ranked countries according to the values of the intercepts or of the slopes on engine capacity and speed; these are the characteristics that are often used to distinguish a car in a product line – viz. BMW 1600, 1800 or Ford GT, GTI, etc.

The results of these rankings are given in Table 3,\(^5\) which gives the number of times a country is ranked lowest, second lowest, etc. for the intercept of the regressions as well as for each of the slope coefficients corresponding to characteristics (engine capacity, speed). For instance, Belgium has the smallest intercept in 8 cases (out of 20), the second smallest in 11 cases, etc., while it has the smallest slope on engine capacity only once, the second smallest in 3 cases, and the largest in 7 cases. We also compute the mean rank for each country. This shows that Belgium corresponds to the most competitive country (lowest mean rank for intercept and highest for slopes on characteristics),\(^6\) while the United Kingdom corresponds to the

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\(^3\)Five countries times 24 producers, minus 3, since for Ferrari the number of observations was insufficient for Belgium, while Mitsubishi and Toyota were not present on the Italian market.

\(^4\)No hypothesis tests are run on the intercepts across the three years, since this is of no interest in this context.

\(^5\)We only consider producers for whom F-tests have led to conclude that intercepts or slopes were different.

\(^6\)The referee points to another possible interpretation of the result. Assume that producers want to charge higher prices in countries other than Belgium, but that consumers have some possibilities to arbitrage. Then, if arbitrage costs are similar for high and low quality cars, the percentage price premium in other countries than Belgium would decline for more luxurious cars. This could then lead to a higher slope parameter for Belgium.
least competitive (highest mean rank for intercepts and lowest for slopes), which is consistent with the theoretical implications of the model and with the above discussion.

4 Conclusions

In this paper we have considered a model of oligopolistic competition which incorporates both horizontal and vertical product differentiation. Firms choose a location in style space and select a product line of different qualities. We show that a non-cooperative equilibrium exists. We also study the properties of the equilibrium style and product line selections and show that if the degree of competition increases, prices approach marginal cost. The model is applied to the European car market; the results support the theoretical conclusion that producers use product lines to price discriminate across countries.

5 References


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6 Appendix

6.1 Lemmas

In this section we shall state and prove several lemmas which are used to prove Propositions 1 and 2. In order to simply the the notation we set $w = \frac{L}{n}$ the inverse of the degree of market competition. Let $P^*(q) = a^* + b^*(q)$ be a strategy used by each firm $i \in N$ in Nash equilibrium. For any pair of strategies $(a, b)$ we shall denote by $\Pi_i^w((a, b), (a^*, b^*)_{-i})$ the resulting profit of firm $i$ when it adopts strategy $(a, b)$ whereas all other firms choose $(a^*, b^*)$. We shall use the notation $\Pi_i^w(a, b)$ when no confusion arises.

Lemma 1: In equilibrium, the derivatives of the profit functions with respect to $a$ and $b$ are given by:

\[
\frac{\partial \Pi_i^w(a, b)}{\partial a} = \int_{m_L}^{m_H} \left( \frac{w}{2} (1 + \frac{c}{b^*}) - \frac{(m - a^*)}{4b^*} (m + a^* - \frac{c}{b^*} (m - a^*)) \right) dm \tag{9}
\]

\[
\frac{\partial \Pi_i^w(a, b)}{\partial b} = \int_{m_L}^{m_H} \left( wc \frac{(m - a^*)}{2b^{*2}} - \frac{(m - a^*)^2}{8b^{*2}} (m + a^* - \frac{c}{b^*} (m - a^*)) \right) dm \tag{10}
\]

Proof: Let $(a^*, b^*)$ be a symmetric Nash equilibrium. For any $m \in [m_L, m_H]$ there is a marginal consumer with this income who is indifferent between purchasing a product from firms $i$ and $i + 1$. Denote this consumer’s arc distance from $s^i$ by $y_m$. Then $y_m$ is determined by:

\[
q_i(m)(m - p_i(m)) - y_m = q_{i+1}(m)(m - p_{i+1}(m)) - (w - y_m) \tag{11}
\]

where $w$ is the arc distance between symmetrically located firms $i$ and $i + 1$. Assumption (5) implies that

\[
q_i(m) = \frac{m - a}{2b}, p_i(m) = \frac{m + a}{2}, q_{i+1}(m) = \frac{m - a^*}{2b^*}, p_{i+1}(m) = \frac{m + a^*}{2} \tag{12}
\]

Thus (12) yields

\[
y_m = \frac{w}{2} + \frac{1}{2} \left\{ \frac{(m - a)^2}{4b} - \frac{(m - a^*)^2}{4b^*} \right\} \tag{13}
\]

The symmetry of our model implies that the total measure of individuals with income $m$ who purchase from firm $i$ (and thus determine demand addressed
to firm $i$ at this level of income) is $2y_m$ or

$$D_i(m) = w + \{\frac{(m - a)^2}{4b} - \frac{(m - a^*)^2}{4b^*}\} \tag{14}$$

Then the profit of the firm $i$ is given by

$$\Pi^w_i(a, b) = \int_{m_L}^{m_H} D_i(m)(p_i(m) - cq_i(m))\,dm \tag{15}$$

Now by substituting the expressions for $D_i(m)$ and $p_i(m)$, $q_i(m)$ from (12) and (14) into (15) and differentiating the resulting profits with respect to $a$ and $b$, we obtain:

$$\frac{\partial\Pi^w_i(a, b)}{\partial a} = \int_{m_L}^{m_H} D_i(m)\left(\frac{1}{2}(1 + \frac{c}{b}) - \frac{(m - a)}{4b} - \frac{(m + a - \frac{c}{b}(m - a))}{2b}\right)\,dm \tag{16}$$

$$\frac{\partial\Pi^w_i(a, b)}{\partial b} = \int_{m_L}^{m_H} D_i(m)\left(c\left(\frac{m - a}{2b^2}\right) - \frac{(m - a)^2}{8b^2} - \frac{(m + a - \frac{c}{b}(m - a))}{2b}\right)\,dm \tag{17}$$

Now $(a, b) = (a^*, b^*)$ implies $D_i(m) = w$, yielding (9) and (10). \(\Box\)

**Lemma 2**: Set $\rho$ in (6) equal .1. Then there exist $w_1 > 0$ and $\mu_1 > 0$ such that for all $0 \leq w \leq w_1$ and $m_H \geq \mu_1m_L$ the system of equations

$$\frac{\partial\Pi^w_i(a, b)}{\partial a} = \frac{\partial\Pi^w_i(a, b)}{\partial b} = 0 \tag{18}$$

has a unique solution, denoted $a = a(w)$ and $b = b(w)$. Moreover, the function $\Pi^w_i((a, b)(a(w), b(w)_{-i}))$ is strictly concave.

**Proof** We shall prove the assertions of the lemma for an infinite degree of competition, i.e., $w = 0$, as the extension for small values of $w$ can be obtained by a straightforward continuity argument. In fact, perfect competition would yield marginal cost pricing $a(0) = 0$ and $b(0) = c$. We shall show first that there exists $\epsilon > 0$ s.t. for any pair of strategies $(a, b)$ and $(\bar{a}, \bar{b})$ with $1 - \epsilon < c/b < 1 + \epsilon$, the function $\Pi^w_i((a, b), (\bar{a}, \bar{b})_{-i})$ is strictly concave whenever the ratio $\frac{m_H}{m_L}$ is large enough.

We assume, therefore, that $m_L$ is fixed and evaluate the second derivatives of the function $\Pi^w_i(a, b) = \Pi^w_i((a, b)(\bar{a}, \bar{b})_{-i})$ with respect to $m_H$. Denote
\[ \lambda \equiv c/b, \bar{\lambda} \equiv c/b \text{ and, by differentiating (16) and (17) with respect to } a \text{ and } b, \text{ we obtain} \]
\[ \frac{\partial^2 \Pi(a, b)}{\partial a^2} = -\frac{m_H^2}{8b} (3\lambda + 1) + o(m_H^2), \] (19)
which is negative for \( m_H \) large enough. Moreover,
\[ \frac{\partial^2 \Pi(a, b)}{\partial b^2} = -\frac{m_H^4}{16b^4} (3\lambda - \bar{\lambda} - 1) + o(m_H^4). \] (20)
However, since \( \bar{\lambda} \) is close to one and, by (6), \( \lambda > .9 \), it follows that the second derivative of \( \Pi \) with respect to \( b \) is also negative. Furthermore,
\[ \frac{\partial^2 \Pi(a, b)}{\partial a \partial b} = -\frac{m_H^3}{24b^2} (6\lambda - \bar{\lambda} - 1) + o(m_H^3). \] (21)
Finally, we conclude that for \( m_H \) large enough, the sign of the Hessian of the function \( \Pi \) is equal to the sign of the following expression:
\[ K = \frac{(3\lambda + 1)(3\lambda - \bar{\lambda} - 1)}{2} - \left\{ \frac{6\lambda - \bar{\lambda} - 1}{3} \right\}^2. \] (22)
Recalling that \( \lambda > .9 \) and \( \bar{\lambda} \approx 1 \), we obtain
\[ K \geq \frac{1}{6}\left\{ \frac{9}{2}(3\lambda + 1)(3\lambda - 2) - (6\lambda - 2)^2 \right\} > \frac{9\lambda^2 + 21\lambda - 26}{18} > 0, \]
which shows that the function \( \Pi^w((a, b), (\bar{a}, \bar{b})) \) is strictly concave. To complete the proof of the Lemma, observe that the strict concavity of \( \Pi \) in the neighbourhood of the point \( w = 0 \), allows us to invoke the Implicit Function Theorem to guarantee existence, uniqueness and continuity of the solution to (18) for \( w \) small enough. \( \square \)

**Lemma 3**: There exist \( w_2 \leq w_1 \) and \( \mu_2 \geq \mu_1 \), such that \( \frac{m_L}{m_L} \geq \mu_2 \) implies:
(i) \( a(w) \) is an increasing function of \( w \);
(ii) \( b(w) \) is a decreasing function of \( w \),
where \( w_1, \mu_1, a(w) \) and \( b(w) \) are as defined in Lemma 2.

**Proof**: Let the assumptions of Lemma 2 which guarantee existence of the solution of (18) be satisfied. Applying the Implicit Function Theorem to (18) and writing \( \Pi_i \) instead of \( \Pi^w((a, b), (\bar{a}, \bar{b})) \) where the pair \( (a(w), b(w)) \) is a solution of (18)u, we have
\[ \frac{\partial a(w)}{\partial w} = \left[ -\frac{\partial^2 \Pi_i}{\partial a \partial w} \frac{\partial^2 \Pi_i}{\partial b^2} - \frac{\partial^2 \Pi_i}{\partial b \partial w} \frac{\partial^2 \Pi_i}{\partial a \partial b} \right] / H \] (23)
∂b(w) \over \partial w = \left[ - \partial^2 \Pi_i \partial^2 \Pi_i - \partial^2 \Pi_i \partial^2 \Pi_i \right] / H \tag{24}

where $H$ is the Hessian of the function $\Pi_i$ and all the values are taken at the point $(a, b) = (a(w), b(w))$. Since by Lemma 2, $H > 0$, it suffices to evaluate the sign of the numerators of these expressions. Again we do this at $w = 0$ and extend the argument for small values of $w$. Then (9),(10),(19),(20) and (21) yield

$$sgn\{ \partial a(w) \over \partial w \} = sgn\{ \frac{m_5}{48} \} \tag{25}$$

and

$$sgn\{ \partial b(w) \over \partial w \} = sgn\{ - \frac{m_4}{24c^2} \}. \tag{26}$$

Thus $a(w)$ is increasing whereas $b(w)$ is decreasing in $w$. □

6.2 Proofs of Propositions 1 and 2.

**Proof of Proposition 1:** Let $w^* = w_1$ and $\mu^* = \mu_1$, as determined in Lemma 2. A pair $(a^*, b^*)$ constitutes a symmetric Nash equilibrium if and only if it constitutes a solution of the following maximization problem for all $i \in N$:

$$\max_{(a, b)} \Pi((a, b), (a^*, b^*)_{-i}) \tag{27}$$

The first order conditions for a maximum of (27) are equivalent to (18). Lemma 2 implies that for $0 \leq w \leq w^*$ and $\mu \geq \mu^*$, $(a(w), b(w))$ is the unique solution of (18) and, therefore, of the first order conditions of (27). Finally, the strict concavity of the profit function $\Pi((a, b), (a^*, b^*)_{-i})$, guaranteed by Lemma 2, implies that this pair is, indeed, the unique symmetric Nash equilibrium. □

**Proof of Proposition 2:** Let $\bar{w} = w_2$ and $\bar{\mu} = \mu_2$, as determined in Lemma 3. Let also $w < \bar{w}$ and $\frac{\mu w}{m_2} > \bar{\mu}$. Then the Implicit Functions Theorem implies that $\lim_{w \to 0} a(w) = 0$ and $\lim_{w \to 0} b(w) = c$. By Lemma 3, $a(\cdot)$ is increasing whereas $b(\cdot)$ is decreasing in $w$, which, together with assertion (i), implies $b(w) < c$. Since, by (12), $q_i(\cdot)$ is an increasing function of income, it follows that the firm’s markup $P(w, q(m)) - cq(m) = a(w) + (b(w) - c)q(m)$ is declining in $m$. □
Table 1 Distribution of the $R^2$s for individuals producers’ equations

<table>
<thead>
<tr>
<th>Value of $R^2$</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0.95</td>
<td>13</td>
</tr>
<tr>
<td>0.90-0.95</td>
<td>34</td>
</tr>
<tr>
<td>0.85-0.90</td>
<td>28</td>
</tr>
<tr>
<td>0.80-0.85</td>
<td>20</td>
</tr>
<tr>
<td>0.75-0.80</td>
<td>7</td>
</tr>
<tr>
<td>0.70-0.75</td>
<td>6</td>
</tr>
<tr>
<td>0.65-0.70</td>
<td>1</td>
</tr>
<tr>
<td>0.60-0.65</td>
<td>4</td>
</tr>
<tr>
<td>&lt; 0.60</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
</tr>
</tbody>
</table>
Table 2 F-tests on intercepts and slopes

<table>
<thead>
<tr>
<th>Producer</th>
<th>Number of observations</th>
<th>Intercepts and slopes</th>
<th>Slopes only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfa Romeo</td>
<td>239</td>
<td>2.46</td>
<td>2.24</td>
</tr>
<tr>
<td>Audi</td>
<td>341</td>
<td>4.91</td>
<td>3.13</td>
</tr>
<tr>
<td>BMW</td>
<td>383</td>
<td>3.99</td>
<td>4.32</td>
</tr>
<tr>
<td>Citroen</td>
<td>413</td>
<td>5.20</td>
<td>1.95</td>
</tr>
<tr>
<td>Ferrari*</td>
<td>68</td>
<td>2.46</td>
<td>1.05</td>
</tr>
<tr>
<td>Fiat</td>
<td>429</td>
<td>5.94</td>
<td>3.43</td>
</tr>
<tr>
<td>Ford</td>
<td>798</td>
<td>16.41</td>
<td>7.99</td>
</tr>
<tr>
<td>Honda</td>
<td>202</td>
<td>6.70</td>
<td>3.34</td>
</tr>
<tr>
<td>Jaguar-Daimler</td>
<td>115</td>
<td>1.07</td>
<td>-</td>
</tr>
<tr>
<td>Lancia</td>
<td>271</td>
<td>5.36</td>
<td>5.57</td>
</tr>
<tr>
<td>Mazda</td>
<td>233</td>
<td>2.69</td>
<td>1.34</td>
</tr>
<tr>
<td>Mercedes</td>
<td>533</td>
<td>3.60</td>
<td>1.61</td>
</tr>
<tr>
<td>Mitsubishi**</td>
<td>156</td>
<td>2.07</td>
<td>0.43</td>
</tr>
<tr>
<td>Nissan</td>
<td>283</td>
<td>6.43</td>
<td>3.40</td>
</tr>
<tr>
<td>Opel-Vauxhall</td>
<td>695</td>
<td>13.16</td>
<td>6.16</td>
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<tr>
<td>Peugeot</td>
<td>624</td>
<td>9.69</td>
<td>5.60</td>
</tr>
<tr>
<td>Porsche</td>
<td>160</td>
<td>6.49</td>
<td>1.08</td>
</tr>
<tr>
<td>Renault</td>
<td>624</td>
<td>3.77</td>
<td>2.12</td>
</tr>
<tr>
<td>Rover</td>
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<td>8.57</td>
<td>4.85</td>
</tr>
<tr>
<td>Saab</td>
<td>172</td>
<td>2.14</td>
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<tr>
<td>Seat</td>
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<td>1.69</td>
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<tr>
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<td>300</td>
<td>2.57</td>
<td>2.87</td>
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</table>

†In italics: no significant differences.
*Insufficient number of observations in Belgium.
**Not present in Italy.
Table 3 Ranking of countries

<table>
<thead>
<tr>
<th>Country</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean rank</th>
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</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
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<td>3</td>
<td>6</td>
<td>3</td>
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<td>2.6</td>
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<tr>
<td>Germany</td>
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<td>2</td>
<td>8</td>
<td>2</td>
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<td>2</td>
<td>3</td>
<td>12</td>
<td>1</td>
<td>3.4</td>
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<tr>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>4.3</td>
</tr>
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</table>

**Intercepts***

<table>
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<tr>
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<th>3</th>
<th>3</th>
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<td>1</td>
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<td>3</td>
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<tr>
<td>France</td>
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<td>8</td>
<td>3</td>
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<td>3.2</td>
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<tr>
<td>Germany</td>
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<td>6</td>
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<td>1</td>
<td>2.1</td>
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<td>4</td>
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<td>6</td>
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<td>3.1</td>
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</table>

**Capacity slope**

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<th>4</th>
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<th></th>
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<tbody>
<tr>
<td>Belgium</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
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<td>3.6</td>
</tr>
<tr>
<td>France</td>
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<td>4</td>
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<td>3.2</td>
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<tr>
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<td>6</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2.4</td>
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<tr>
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<td>2.1</td>
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</table>

**Speed slope**

<table>
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<tr>
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<th>6</th>
<th>7</th>
<th>12</th>
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<tbody>
<tr>
<td>Belgium</td>
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<td>7</td>
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<td>3.7</td>
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<tr>
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<td>11</td>
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<td>3.4</td>
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<tr>
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<tr>
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<td>7</td>
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<td>2.7</td>
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<tr>
<td>United Kingdom</td>
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<td>10</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

*Gasoline-run engines only. Since the diesel variable is a dummy, a diesel car merely changes the intercept.