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Rosa-Branca Esteves

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Price Discrimination with Partial Information: Does it pay off?*

Rosa-Branca Esteves[†]

University of Minho (Department of Economics) and NIPE

Abstract

This paper investigates the profit effects of price discrimination when firms have partial information about consumer preferences. It shows that price discrimination can boost industry profit if firms have access to the right kind of information about consumer preferences while remaining ignorant of other relevant information.

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1 Introduction

This paper investigates the profit effects of competitive price discrimination in markets where firms have access to partial information about consumer preferences. The paper addresses a two-dimensional Hotelling model where each firm offers a

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[†]Author contacts: Department of Economics, University of Minho, Campus de Gualtar, 4710 Braga, Portugal. Tel: +351253604510. Fax: +351253676375. Email: rbranca@eeg.uminho.pt.

single product. The location of a consumer on the unit square represents his two-dimensional preference for a brand name/product. The model assumes that consumers are heterogeneous because they have different tastes for the different brand names and products. Based for instance on past behaviour, consumers can be more or less loyal to one firm (or brand name) than to the other. However, when consumers are offered two differentiated products, their product preferences do not always coincide with their brand name preferences.[1]

Clearly, in this model, where we have a firm offering a unique product, the distinction between "brand" and "product" preferences may seem somewhat redundant. There are, nonetheless, two reasons why the analysis is worth pursuing.

First, this method of analysis allows us to investigate the profitability of price discrimination when firms have the ability to partially observe consumer preferences. Armstrong (2006) argues that the crucial feature for discrimination to intensify competition and to depress industry profit is best response asymmetry.[2] In a standard Hotelling model, Thisse and Vives (1988) suppose that firms can observe the location of individual consumers on the line and quote personalised prices. In this setting, each firm's strong market is the rival's weak market, so they show that firms are worse off if they can observe all the information of consumers and set prices accordingly.[3] This paper extends the Thisse and Vives model and shows that

[1]This model could embrace other types of two-dimensional heterogeneities (e.g. switching costs/product tastes; geographical location/product tastes).

[2]According to Corts (1998), the market exhibits best response asymmetry when one firm's "strong" market is the other's "weak" market. In the literature on price discrimination, a market is designated as "strong" if in contrast to uniform pricing a firm wishes to increase its price there. The market is said to be "weak" if the reverse happens.

[3]Fudenberg and Tirole (2000) investigate the profit effects of price discrimination in a market where a firm can observe whether a consumer belongs to its turf or rather to the rival's one and set prices accordingly. A similar analysis is carried out by Chen (1997) in a market where firms offer a homogenous product and consumers have switching costs to switch to a different supplier. In both papers the market exhibits best-response asymmetry and price discrimination is bad for industry profit.

price discrimination may boost profits when firms have partial information about consumer preferences.

Second, the analysis is a useful step towards a fuller treatment of the "brand name vs. product" dichotomy. Consider the following example. While some consumers have a preference for the *Coca-Cola* brand over the *Pepsi*, when they consider buying a diet drink, some loyal *Coca-Cola* consumers may prefer *Diet Pepsi Max* rather than *Diet Coke Plus* because *Diet Pepsi Max* contains, for instance, more caffeine.[4]

2 Model

Two firms, A and B, sell competing brands of a differentiated good produced at constant marginal cost c. The total number of consumers in the market is normalised to one. A consumer wishes to buy a single unit either from firm A or B. The consumer's valuation for the product, v, is sufficiently high so that nobody stays out of the market. Consumers are uniformly distributed on the unit square, and the location of a consumer is denoted $(\theta, l) \in [0,1]^2$.[5] Firm A and product A are located at the point of coordinates $(0,0)$, while firm B and product B are located at the point of coordinates $(1,1)$. It is assumed that product A is exclusively offered by firm A and product B is exclusively offered by firm B.

Each consumer is located at a point (θ, l). It is assumed that the consumers' relative preference for products A and B is represented by a parameter θ uniformly distributed in the horizontal line segment $[0,1]$. Assuming that firm A's product is

[4]While the distinction between brand and product differentiation is worth exploring, the contribution of the paper is quite limited in this respect. As said this is due to the one product per firm assumption, where the "brand" dimension can readily be interpreted as just another "product" dimension. This distinction would be better explored in a multi-product setting where the "brand" differentiation would be common to all products while "product" differentiation would be product-specific. Although such an approach is worth pursuing, it would not necessarily contribute much to the main point of this note. Thus, it is left for future research.

[5]A square model is also used for instance by Matutes and Regibeau (1988) and Boom (2001).

located at 0 and firm B's product is located at 1, $t\theta$ is the "transport cost" of choosing product A and $t(1-\theta)$ is the "transport cost" of choosing product B. Additionally, the consumers' relative loyalty for brand names (firms) A and B is represented by a parameter l uniformly distributed in the vertical line segment $[0,1]$. Placing firm A at 0 and firm B at 1, λl is the "transport cost" of buying from firm A and $\lambda(1-l)$ is the "transport cost" of buying from firm B.

When firms can observe the location of a consumer in one of the two dimensions (thereby, the term of partial information) they simultaneously and non-cooperatively choose a personalised price to that consumer. When firms have no information they simultaneously set a uniform price to all consumers.

3 No Discrimination

Suppose firms are not allowed to price discriminate, either because price discrimination is illegal or because firms cannot observe the location of consumers. Both firms charge a uniform price p_i where $i = A, B$. The consumer with preferences (θ, l) is indifferent between buying product A or product B if

$$v - p_A - t\theta - \lambda l = v - p_B - t(1-\theta) - \lambda(1-l).$$

Hence, a consumer located at (θ, l) is indifferent between buying product A or product B if

$$\theta = \frac{1}{2} + \frac{p_B - p_A + \lambda(1-2l)}{2t}. \tag{1}$$

Case I: $\mathbf{t} > \boldsymbol{\lambda}$

When $t > \lambda$, using (1) it is observed that the most loyal consumer to firm A, located at $l = 0$, buys product A whenever $\theta < \overline{\theta} = \frac{1}{2} + \frac{p_B - p_A + \lambda}{2t}$. In contrast, the least loyal consumer to firm A, with $l = 1$, buys product A whenever $\theta < \underline{\theta} = \frac{1}{2} + \frac{p_B - p_A - \lambda}{2t}$.

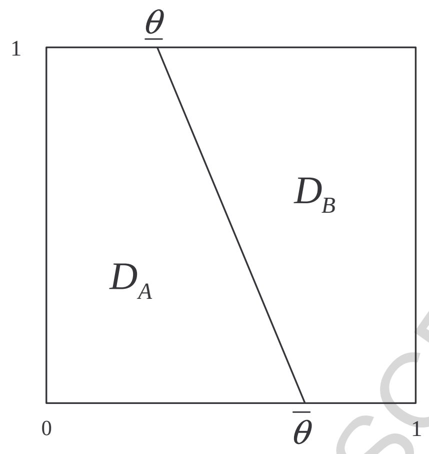

Figure 1: Possible Market Areas when $t > \lambda$

Hence, let $D_i^I(p_i, p_j)$ represent firm i's demand when $t > \lambda$, it follows that:

$$D_A^I(p_A, p_B) = \underline{\theta} + \frac{1}{2}\left(\overline{\theta} - \underline{\theta}\right) = \frac{1}{2} + \frac{p_B - p_A}{2t}, \tag{2}$$

and

$$D_B^I(p_B, p_A) = 1 - D_A^I(p_A, p_B) = \frac{1}{2} + \frac{p_A - p_B}{2t}. \tag{3}$$

Case II: $\mathbf{t < \boldsymbol{\lambda}}$

When $t < \lambda$,

$$D_A^{II}(p_A, p_B) = \underline{l} + \frac{1}{2}\left(\overline{l} - \underline{l}\right) = \frac{1}{2}\left(\overline{l} + \underline{l}\right) = \frac{1}{2} + \frac{p_B - p_A}{2\lambda}, \tag{4}$$

and $D_B^{II}(p_B, p_A) = 1 - D_A^{II}(p_A, p_B)$.

Firm i's profit equals:

$$\pi_i^I = (p_i - c)\left(\frac{1}{2} + \frac{p_j - p_i}{2t}\right), \text{ if } t \geq \lambda \tag{5}$$

or

$$\pi_i^{II} = (p_i - c)\left(\frac{1}{2} + \frac{p_j - p_i}{2\lambda}\right), \text{ if } t \leq \lambda. \tag{6}$$

Proposition 1. *When price discrimination cannot occur the Nash equilibrium (NE) in prices is given by*

$$p_i^* = \left\{ \begin{array}{lll} c+t & if & t \geq \lambda \\ c+\lambda & if & t \leq \lambda \end{array} \right\} \tag{7}$$

with equilibrium profit equal to

$$\pi_i^* = \left\{ \begin{array}{lll} \frac{t}{2} & if & t \geq \lambda \\ \frac{\lambda}{2} & if & t \leq \lambda \end{array} \right\}. \tag{8}$$

In both cases the resulting NE coincides with that obtained when consumers are heterogeneous only on the basis of one dimension. In a Hotelling standard model, the resulting NE in prices is given by the marginal production cost plus the transport cost. Since here the corresponding transport cost is t in the product differentiation dimension and λ in the loyalty dimension, the NE only depends on the relation between t and λ. When t is greater than λ, it can happen that the most loyal consumer to brand B may decide to buy product A if he has a taste parameter that satisfies $\theta < \underline{\theta}$. Thus, all consumers with $\theta < \underline{\theta}$ buy from firm A even if they are strongly loyal to brand B (i.e. with $l = 1$). In this case the cost of a consumer not buying the product that is closer to his tastes is greater than the cost of not buying from his preferred firm. Hence, when $t > \lambda$, firms set their equilibrium prices according to the transport cost associated with the product tastes dimension. Conversely, when $t < \lambda$, it is more expensive for consumers to not buy from their preferred firm than not buy the product that is closer to their tastes. In this case, equilibrium prices are set according to the transport cost λ. Thus, when firms cannot price discriminate they will set prices according to the more differentiated dimension.

4 Price Discrimination with Partial Information

Consider now the case where firms can observe the location of consumers in one of the two dimensions. Suppose, for instance, that based on their data on individuals' past purchasing behaviour firms can observe a consumer brand loyalty degree l but not a consumer product preference θ and then set their prices accordingly. If firms know a consumer's loyalty parameter, they can target a personalised price to that consumer, taking into account, however, that the consumer will be closer or more distant from the firm's product in the tastes line.

Let $p_i(l)$ denote firm i's price for a consumer with brand loyalty degree l. Consider, for instance, the perspective of firm A. The consumer with preferences (θ, l) buys product A rather than product B when

$$p_A(l) + \lambda l + t\theta < p_B(l) + \lambda (1 - l) + t (1 - \theta) .$$

Given the observed value of l, firm A's demand from its p-group is given by

$$D_A(p_A, p_B, l) = \frac{1}{2} + \frac{p_B - p_A + \lambda (1 - 2l)}{2t}, \tag{9}$$

and firm B's demand is $D_B(p_A, p_B, l) = 1 - D_A(p_A, p_B, l)$. Firm i's correspondent profit, $i = A, B$, is $\pi_i(p_i, p_j, l) = (p_i - c) D_i(p_i, p_j, l)$.

The next proposition establishes the equilibrium prices and profits when discrimination is allowed.[6]

Proposition 2. *When firms can observe the brand loyalty degree of each individual consumer and price discriminate, the NE in prices is:*

$$p_A^d(l) = \left\{ \begin{array}{ccc} c + t + \frac{\lambda}{3}(1 - 2l) & if & l < \frac{1}{2} + \frac{3t}{2\lambda} \\ c & if & l \geq \frac{1}{2} + \frac{3t}{2\lambda} \end{array} \right\} \tag{10}$$

$$p_B^d(l) = \left\{ \begin{array}{ccc} c & for & l \leq \frac{1}{2} - \frac{3t}{2\lambda} \\ c + t + \frac{\lambda}{3}(2l - 1) & for & l > \frac{1}{2} - \frac{3t}{2\lambda} \end{array} \right\} \tag{11}$$

and each firm equilibrium profit equals:

$$\pi_i^d = \left\{ \begin{array}{ccc} \frac{t}{2} + \frac{\lambda^2}{54t} & if & t \geq \frac{\lambda}{3} \\ \frac{(3t+\lambda)^3}{108\lambda t} & if & t \leq \frac{\lambda}{3} \end{array} \right\}. \tag{12}$$

[6] For a detailed proof of Proposition 2 see the longer version of the current paper (Esteves (2008)).

When firms can observe each consumer's brand loyalty degree they price high to those consumers who prefer their brand name and price low to consumers who prefer the rival's brand. As expected, when consumers have different brand preferences but see the firms' products as perfect substitutes, i.e. $t = 0$, as in Thisse and Vives (1988) firm A's price is equal to c to all consumers with $l > \frac{1}{2}$. Here, in contrast, for other values of t, firm A's price to a strong loyal consumer to firm B (with $l = 1$) is $c + t - \frac{\lambda}{3}$, greater than c whenever $t > \frac{\lambda}{3}$.

Price discrimination based on product preferences Here firms observe a consumer product taste θ but not l and set their prices accordingly. Given the similarity between this case and the previous one, it is straightforward to deduce that in this case the equilibrium results are simply obtained by interchanging t and λ.

5 Profit Effects

This section compares each firm's equilibrium profit in the three different informational regimes (see table 1). One where the firms do not know anything about a given consumer location (no disc.), one where the firms have information about each consumer location in the brand direction (disc. based on l) and the one where the information is about each consumer location in the product direction (disc. based on θ). Profits are measured on the basis of λ.

Table 1: Equilibrium Profits

	No Disc.	Disc. based on l	Disc. based on θ
$t < \frac{\lambda}{3}$	$\pi_i^* = 0.5\lambda$	$\pi_i^d < 0.22(2)\lambda$	$\pi_i^d > 0.502\lambda$
$\frac{\lambda}{3} \leq t < \lambda$	$\pi_i^* = 0.5\lambda$	$0.22(2)\lambda \leq \pi_i^d < 0.518\lambda$	$0.502\lambda \leq \pi_i^d < 0.518\lambda$
$\lambda \leq t < 3\lambda$	$0.5\lambda < \pi_i^* < 1.5\lambda$	$0.518\lambda \leq \pi_i^d < 1.506\lambda$	$0.518\lambda \leq \pi_i^d < 0.66(6)\lambda$
$t \geq 3\lambda$	$\pi_i^* \geq 1.5\lambda$	$\pi_i^d \geq 1.506\lambda$	$\pi_i^d \leq 0.66(6)\lambda$

Proposition 3. *If the degree of differentiation along each of the two dimensions is sufficiently different, then price discrimination can boost firm profits when (i) firms have information about the location of consumers in the less differentiated dimension while (ii) they remain ignorant about their preferences in the more differentiated dimension.*

An important contribution of this note is to show that competitive price discrimination need not necessarily lead to the prisoners' dilemma result that generally follows in markets that exhibit best-response asymmetry. Table 1 shows that the profitability of price discrimination is strongly dependent on the kind of information available to firms. When t is sufficiently low in comparison to λ, firms are better off when they have the required information to price discriminate on the basis of a consumer's product preference. Conversely, when t is higher than λ, discrimination can raise profits if firms have access to information about a consumer's brand loyalty. In contrast, if firms can observe the brand loyalty degree of individual consumers but $\lambda > t$ (i.e., if firms have information about the location of consumers in the more differentiated dimension) they are better off under the uniform pricing policy. (The same happens when firms observe a consumer taste θ and $t > \lambda$.[7])

[7]Some papers have investigated the location choices of firms in two-dimensional models (e.g. Tabuchi (1994) and Boom (2001)). Tabuchi (1994) shows that firms choose maximum differentiation in the more important dimension and minimum differentiation in the less important one. Boom (2001) shows that when firms decide to provide incompatible components, they choose maximum differentiation in one dimension and minimum differentiation in the other one. When firms choose their product specification, two effects are relevant. While the price competition effect is relaxed when firms locate far apart, firms benefit from a central location in each characteristics segment because a higher demand arises there. With two dimensions, firms can relax price competition by differentiating their products in one characteristic while they benefit from more central location in the other one. In a sense, the intuition behind Proposition 3 has a similar flavour. Firms may benefit from price discrimination if they have information about the consumer's preferences in the less important dimension while price competition is relaxed if they remain ignorant about the consumers' preferences in the more important one.

6 Concluding Remarks

This note has shown that competitive price discrimination need not necessarily lead to the prisoners' dilemma result that generally follows in markets that exhibit best-response asymmetry. Price discrimination can boost industry profit (i) if firms have access to the right kind of information about consumer preferences (i.e. if they know the location of consumers in the less differentiated dimension) and (ii) if firms have partial information about consumer preferences. In other words, price discrimination can increase industry profit if firms have information about the location of consumers in the less important differentiation dimension while they remain ignorant of their preferences in the more differentiated dimension.[8] While some information might benefit firms, ignorance acts to help competing firms to use price discrimination in a profitable way.

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[8] A natural and interesting extension for a future research would be to look at the firms' incentives to acquire information about consumer preferences. One possibility would be to investigate the equilibrium choices if each firm had to focus its effort on finding out about either brand or product preference. I thank a referee for raising this point.

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