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# Strategic entry deterrence through spatial price discrimination

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**Abstract**

This paper explores the strategic properties of pricing rules. We show that spatial price discrimination may be used for entry deterrence purposes, while f.o.b. pricing policies are better to accommodate entry. Commitment to a pricing policy changes the form of competition in the post-entry game. Discriminatory pricing makes the incumbent 'tough' whereas f.o.b. makes the incumbent 'soft' and is the optimal policy when entry has to be accommodated. When there is no commitment to a pricing policy, under asymmetric information, the existing firm may use delivered pricing policies to deter entry. © 1998 Elsevier Science B.V.

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## 1. Introduction

In a spatial market, when there are costs of transporting goods from one location to another, the sellers may set different prices for goods delivered at different locations. A pricing rule is defined as a function $p(x)$, where $x$ is the location of the consumer.

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If the pricing policy is f.o.b. (free on board) consumers may pick up the product at the mill, paying the mill price and incurring the freight cost. Delivered pricing policies are pricing rules that are not based on consumers picking up the product at the mill. The most common delivered pricing rules are basing-point pricing and uniform delivered pricing. In a uniform delivered pricing system each firm quotes the same price to all consumers, regardless of distance. In a basing-point pricing system, firms decide on the location of a base point and a price at that location (the base price); the price at any other location is calculated as the base price plus transportation charges from the base point.[1] We define a delivered pricing rule as any price function different from f.o.b. Note that a delivered pricing policy entails spatial price discrimination.[2]

The existence of non-negligible transportation costs can also be interpreted in terms of product differentiation.[3] In this context, f.o.b. pricing corresponds to a firm producing a single variety of the good and the consumer having to adapt the product to his preferences (the transportation costs represent the utility loss for not consuming the most preferred variety). On the other hand, a delivered price schedule corresponds to a firm producing several varieties of the product and being able to price discriminate among consumers (sell the different varieties at prices that do not reflect the different transportation costs).

In this paper, we show that spatial price discrimination may be a useful strategy to deter entry, while f.o.b. is preferable when the incumbent has to accommodate a new firm. The reason is that f.o.b. pricing makes the existing firm 'soft'[4] and this is better when entry has to be accommodated, since the best response of the entrant is also f.o.b. pricing and post-entry competition is relaxed. Under asymmetric information, delivered pricing may be used as an entry deterring strategy by an established firm that would rather price according to f.o.b. in the absence of the entry threat. This happens because an incumbent which is not 'flexible' enough to produce the whole set of varieties (his transportation costs are high) prefers f.o.b., and it wants this information not to be revealed to the entrant. Thus, in a pooling equilibrium of the game, the 'less flexible' incumbent is using delivered pricing to deter entry.

Thisse and Vives (1988) analyze the strategic choice of spatial pricing policy in a duopoly market with homogeneous product and inelastic demand; they conclude that f.o.b. is not an equilibrium pricing system and firms will choose discriminating pricing policies. De Fraja and Norman (1993) obtain an asymmetric equilib-

[1] In some markets delivered pricing policies have been widely used. Examples of basing-point pricing policies are the Pittsburgh Plus system used in the steel industry and the Portland Plus system used for plywood. See Machlup (1949); Scherer (1980); Phlips (1983).

[2] There is price discrimination whenever the difference in the final price at any two locations does not fully reflect the differences in transportation costs; in other words, when the net price (delivered price minus freight costs) is not constant.

[3] Hotelling (1929).

[4] See the taxonomy in Fudenberg and Tirole (1984).

rium in which one firm prices according to f.o.b. and the other price discriminates in a model with differentiated goods and elastic demand. There is a related literature on product line rivalry. Martinez-Giralt and Neven (1988) analyze a model where firms sell two spatially differentiated products; the result is that in equilibrium each firm produces only one variety. Our work generalizes that finding in the sense that even when firms are allowed to produce a continuum of varieties they still prefer to compete with only one, to avoid the more intense price competition. De Fraja (1993) studies the choice of product lines in a spatial context; he shows that firms either cluster at the center of the market and supply different products, or select different locations and supply identical product pairs. In a model where products are differentiated by both quality and brand name, Gilbert and Matutes (1993) show that when firms can commit themselves to restricting the number of varieties, they specialize if the degree of brand differentiation is small, and produce a full product line if brand differentiation is large. Models where brand proliferation is used as an entry deterring strategy are those of Hay (1976); Schmalensee (1978); Judd (1985); Bonanno (1987); Shaked and Sutton (1990), among others.

In Section 3, we study the problem under the assumption that firms can commit themselves to a pricing policy (although not to the price level), to illustrate how the possibility of commitment to a pricing policy changes the form of competition in the post-entry game. If the pricing schedule chosen by the incumbent makes it 'soft', then the best response of the entrant is to become 'soft' and post-entry profits are higher for incumbent and entrant. However, when exogenous entry barriers (measured here by the fixed cost) are high, then the incumbent chooses pricing policies that make it 'tough'[5] and do not allow entry.

In Section 4, we assume that commitment to a pricing policy is not possible, and there is asymmetric information. The entrant is not certain about the transportation cost of the existing firm (interpreted as the degree of flexibility required to produce multiple varieties). With this specification, we show that the incumbent may use delivered pricing policies to deter entry.

## 2. A model of entry in Hotelling's line

Consumers are distributed uniformly along the unit interval [0, 1]. The location of a consumer is denoted $x$ and defined as the distance to the left endpoint of the market. The preferences are as follows: each consumer has a reservation value, $R$, for the good, and buys precisely one unit per period of time, from the firm that has the lowest final (delivered) price, as long as his total payment does not exceed his reservation value, and buys nothing otherwise. When several firms have the same

[5] Fudenberg and Tirole (1984).

delivered price at a given location the consumer chooses the supplier with the lowest transportation cost.[6] The good cannot be stored.

There are two firms that may produce a homogeneous good in the spatial market [0, 1]. Firm I is the incumbent and E is a potential entrant. The location of firm I is $a = 0$, $a$ being the distance from the firm to the left endpoint of the market, and the entrant can choose any location in the interval [0, 1]. The location of the entrant will be denoted by $b$, the distance to the right endpoint of the interval. Entry has a cost $f_E$. Marginal costs of production are constant and identical for both firms; for the sake of notational simplicity prices are expressed net of marginal cost.

The cost of transporting one unit of the good is given by the function $t_I(d)$ for the incumbent, $t_E(d)$ for the entrant, and $t(d)$ for the consumers, where $d$ is the distance from the location of the consumer to the producer. We will assume that $R > 2t_i(1)$ ($i = \text{I, E}$). The reason for having different transportation costs for the incumbent, entrant and consumers is that we will interpret $t_i(d)$ ($i = \text{I, E}$) as the flexibility to produce multiple varieties, which may be different for incumbent and entrant;[7] $t(d)$ is interpreted as the cost for a consumer, in terms of utility loss, of not consuming the most preferred variety of the product, but a variety at a distance $d$.[8]

## 3. The choice of a pricing policy under commitment

In this section we will assume that firms can commit themselves to a given pricing rule. The commitment may derive from the high cost of announcing and implementing a pricing policy (which is presumably higher than the cost of announcing a price level); this cost may be high enough for the selection of a pricing policy to imply in fact a commitment. We can also provide a product differentiation interpretation of the switching cost. Since f.o.b. pricing corresponds to the production of one variety of the good, commitment to such a pricing policy is equivalent in this context to investment in a technology that allows the production of only one variety. Rather, if the firm chooses to invest in a technology that allows the production of a set of varieties, then the firm may or may not produce them, but it is not committed to a single variety.

The timing of the game is as follows:

[6] The assumption that price ties are broken in the socially efficient way is fairly standard in the literature. See, for example, Lederer and Hurter Jr. (1986) for a justification.

[7] Thisse and Vives (1988) interpret $t_i(d)$ as the cost for the firm of producing a variety at a distance $d$ from the 'standard' variety. Gronberg and Meyer (1981) study the choice of spatial price policies when firms and consumers have different transportation costs.

[8] We assume there is no arbitrage.

Stage 1. The incumbent chooses a pricing policy, f.o.b or delivered pricing. The entrant observes the pricing policy of the incumbent and its location. With this information, it decides whether to enter or not. If the entrant does not enter, the incumbent sets prices as a monopolist and the game ends. If there is entry, the new firm pays entry cost $f_E$ and decides simultaneously on location $b$ and on whether to have an f.o.b. policy or a delivered pricing policy.

Stage 2. Incumbent and entrant observe each other's pricing policies and location, and decide the price level simultaneously and independently.

In this section the difference in transportation costs between incumbent and entrant plays no part and therefore, we assume for the sake of simplicity that $t_E(d) = t_I(d) = t(d)$. We also assume that the freight costs from the production point to the consumer are convex: $t(d) = td^2$. This last assumption allows us to obtain the existence of an equilibrium (with linear transportation costs or linear–quadratic cost functions if the location $b$ is a decision variable, there is no equilibrium in pure strategies).[9]

The existing firm can commit itself at the first stage to a pricing policy, or if we choose the product differentiation interpretation, the incumbent either commits itself to a technology constrained to a single variety (f.o.b.) or selects a technology that enables it to produce the complete range of varieties (delivered pricing). We solve the game by backward induction to obtain the subgame perfect equilibria.

### *3.1. Second stage*

There are several cases depending on the outcome of the previous stage:

a) There has been entry, incumbent and entrant price according to f.o.b.
b) Entry, incumbent and entrant use delivered pricing.
c) Entry, incumbent is committed to f.o.b., entrant uses delivered pricing.
d) Entry, incumbent uses delivered pricing, entrant prices according to f.o.b.
e) No entry

### *3.2. Incumbent and entrant price according to f.o.b.*

If both firms have chosen f.o.b. policies, they will select mill prices simultaneously and independently. The demand for each firm is given by:

[9] See d'Aspremont et al. (1979); Gabszewicz and Thisse (1986). Another way to avoid equilibrium existence problems with linear transportation costs is to assume that the location of the entrant is fixed; solving the game under those assumptions, we get similar results.

$$D_I(b,\ p_I,\ p_E) = \begin{Bmatrix} 1 & \text{if } p_I \leq p_E - t(1-b^2) \\ \dfrac{(1-b)}{2} + \dfrac{p_E - p_I}{2(1-b)t} & \text{if } p_E + t(1-b)^2 > p_I > p_E - t(1-b^2) \\ 0 & \text{if } p_I \geq p_E + t(1-b)^2 \end{Bmatrix},$$

$$D_E(b,\ p_I,\ p_E) = \begin{Bmatrix} 1 & \text{if } p_E \leq p_I - t(1-b)^2 \\ b + \dfrac{(1-b)}{2} + \dfrac{p_I - p_E}{2(1-b)t} & \text{if } p_I + t(1-b^2) > p_E > p_I - t(1-b)^2 \\ 0 & \text{if } p_E \geq p_I + t(1-b^2) \end{Bmatrix},$$

The profit functions are $\Pi_I(b,\ p_I,\ p_E) = p_I D_I(b,\ p_I,\ p_E)$ and $\Pi_E(b,\ p_I,\ p_E) = p_E D_E(b,\ p_I,\ p_E)$. These profit functions are quasi-concave, ensuring the existence of a price equilibrium, whatever the location $b$ may be.[10] The equilibrium mill prices as functions of the entrant's location are given by (see Fig. 1):

$$p_I^*(b) = t(1-b)\,\frac{(3-b)}{3}, \quad p_E^*(b) = t(1-b)\,\frac{(3+b)}{3}.$$

It should be noted that the entrant correctly anticipates how its location decision affects price competition. The profit as a function of location is: $\Pi_E(b) = p_E^*(b) D_E[b,\ p_I^*(b),\ p_E^*(b)]$. The entrant chooses location, given that the incumbent is located at $a=0$, to maximize profits. We can write the total derivative of profits with respect to location as:

$$\frac{\mathrm{d}\Pi_E(b)}{\mathrm{d}b} = \frac{\partial \Pi_E}{\partial p_E}\,\frac{\mathrm{d}p_E^*}{\mathrm{d}b} + p_E^*\left(\frac{\partial D_E}{\partial b} + \frac{\partial D_E}{\partial p_I}\,\frac{\partial p_I^*}{\partial b}\right)$$

The first term $(\partial \Pi_E / \partial P_E) = 0$ (by the envelope theorem), since the entrant will choose price optimally. Thus, we can break down the derivative into two effects:

Demand effect (direct effect of $b$ on $\Pi_E$):

$$p_E^*\,\frac{\partial D_E}{\partial b} = \frac{1}{2}\,p_E^* + \frac{p_I^* - p_E^*}{2t(1-b)^2}\,p_E^* = p_E^*\,\frac{3-5b}{6(1-b)}.$$

Strategic effect (effect through the change in the incumbent's price):

$$p_E^*\frac{\partial D_E}{\partial p_I}\,\frac{\partial p_I^*}{\partial b} = p_E^*\,\frac{b-2}{3(1-b)} < 0.$$

When the demand effect is positive (for locations $b < (3/5)$), there is an incentive

[10] See d'Aspremont et al. (1979).

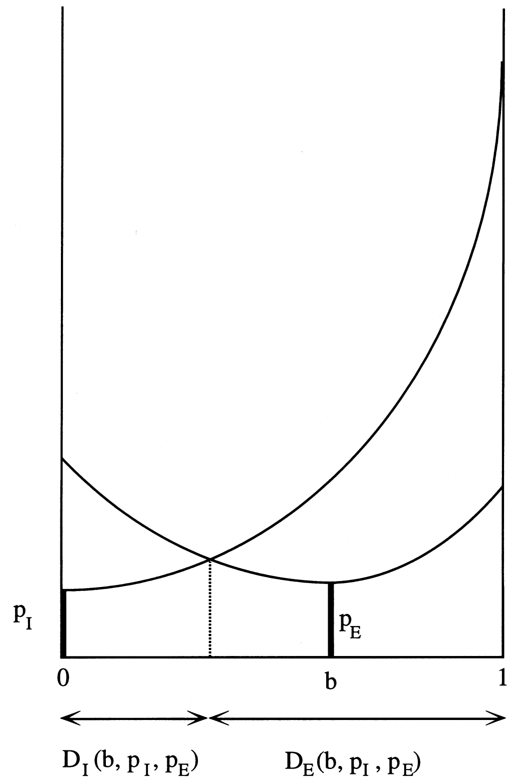


Fig. 1. Equilibrium f.o.b. prices and market areas.

for the entrant to move towards the incumbent. The strategic effect, however, is always negative; the closer to the incumbent the entrant is, the more intense the price competition will be and, hence, the lower the profits. It is easy to check that the strategic effect predominates over the demand effect, so that $(\mathrm{d}\Pi_{\mathrm{E}}(b)/\mathrm{d}b)<0$. Thus, the optimal location for the entrant is $b=0$ (see d'Aspremont et al., 1979). In equilibrium, each firm sells to half of the market, they have identical mill prices, $p_{\mathrm{I}}=p_{\mathrm{E}}=t$, and their profits are $\Pi_{\mathrm{I}}=(t/2)$ and $\Pi_{\mathrm{E}}=(t/2)-f_{\mathrm{E}}$, respectively.

### *3.3. Incumbent and entrant use delivered pricing*

Denote as $p_{\mathrm{I}}(x)$ and $p_{\mathrm{E}}(x)$ the incumbent and entrant's delivered prices at location $x$, $0\leq x\leq 1$. At a given location $x$, competition is à la Bertrand: with cost asymmetries if $x\neq(1-b/2)$ and with the same cost if $x=(1-b/2)$. When $x<(1-b/2)$, the incumbent's cost is lower than the entrant's. The opposite is true when $x > (1 - b/2)$.[11] This implies that in equilibrium the delivered price at $x$ will equal the transportation cost of the firm located further from $x$.

Given the previous argument,[12] when the entrant is located at $b$, the equilibrium pricing policies are given by: $p_I(x) = p_E(x) = p(x) = \max\{tx^2,\ t[(1-b)-x]^2\}$ for all $x \in [0,\ 1]$.[13]

In Fig. 2, the dark line represents the equilibrium delivered prices. The shaded area on the right measures the entrant's profits and the shaded area on the left the incumbent's profits. Given a location $b$ for the entrant, profits for the two firms are:

$$\Pi_I(b) = \int_0^{(1-b)/2} t\{[(1-b)-x]^2 - x^2\}\,dx = \frac{(1-b)^3}{4}\,t$$

$$\Pi_E(b) = \int_{(1-b)/2}^{1} t\{x^2 - [(1-b)-x]^2\}\,dx - f_E$$

$$= t\left\{(1-b) - (1-b)^2 + \frac{(1-b)^3}{4}\right\} - f_E.$$

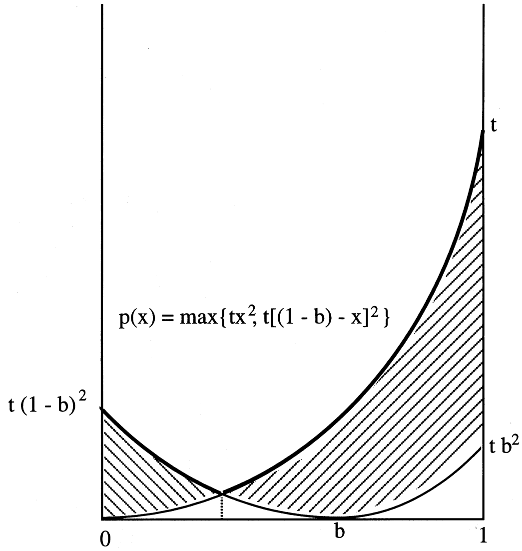


Fig. 2. Equilibrium price policy and firms' profits under delivered pricing.

[11] When firms price according to f.o.b., they are competing in the entire market with only one strategic variable: the mill price. However, under discriminatory pricing, firms compete at each location $x$ separately. In this situation, the stability of price competition is less difficult than under f.o.b. In fact, under price discrimination it would not be necessary to assume quadratic costs to get existence of equilibrium.

[12] See Lederer and Hurter Jr. (1986) for a formal proof.

[13] This subgame has additional Nash equilibria, which are Pareto inferior to the Nash equilibrium indicated in the text. See Thisse and Vives (1992) for a discussion on these equilibria.

In the incumbent's market area, the final price decreases with the distance to the firm, whereas the transportation costs increase with that distance: the net price is not constant. In the entrant's market area, the net price also varies with distance and there is price discrimination.

The location that maximizes the entrant's profits is $b=(1/3)$. It should be noted that the entrant chooses the socially optimal location given the restriction $a=0$; that is, the entrant selects $b$ to minimize the transportation cost in its market area.[14] In equilibrium, the incumbent gets a third of the market and the entrant sells to the rest of the consumers. The equilibrium profits are: $\Pi_{\mathrm{E}}=(8/27)t-f_{\mathrm{E}}$ and $\Pi_{I}=(2/27)t$.

### 3.4. Incumbent is committed to f.o.b., entrant uses delivered pricing

Given location $b$ for the entrant, the equilibrium mill price is $p_{\mathrm{I}}=0$ and the entrant's delivered pricing policy is $\{p_{\mathrm{E}}(x)=tx^2$, for all $x\in[0, 1]\}$. The incumbent sells in the market area $[0, (1-b/2)]$ and the entrant in the rest of the market. The equilibrium profits are:

$$\Pi_{\mathrm{E}}(b)=\int_{(1-b)/2}^{1} t\{x^2-[(1-b)-x]^2\}\,\mathrm{d}x-f_{\mathrm{E}}$$
$$=t\left\{(1-b)-(1-b)^2+\frac{(1-b)^3}{4}\right\}-f_{\mathrm{E}},\quad \Pi_{\mathrm{I}}(b)=0.$$

Note that a positive mill price for the existing firm cannot be sustained in equilibrium. If $p_{\mathrm{I}}>0$ the incumbent always has the incentive to reduce slightly its price and sell to the entire market.[15] The entrant cannot improve its profits by increasing or decreasing its price in any segment of the market (see Fig. 3). To maximize profits the entrant will choose a location $b=(1/3)$. The equilibrium profits for the entrant are: $\Pi_{\mathrm{E}}=(8/27)t-f_{\mathrm{E}}$.

### 3.5. Incumbent uses delivered pricing, the entrant follows f.o.b.

Given a location $b$ for the entrant, the equilibrium prices are: $p_{\mathrm{I}}(x)=t[(1-b)-x]^2$ for all $x\in[0, 1]$ and $p_{\mathrm{E}}=0$. This case is symmetric to the previous one. The established firm sells in the market area $[0, (1-b/2)]$ and the entrant in the rest of the market. The equilibrium profits are:

$$\Pi_{\mathrm{I}}(b)=\int_{0}^{(1-b)/2} t\{[(1-b)-x]^2-x^2\}\,\mathrm{d}x=\frac{(1-b)^3}{4}\,t,\quad \Pi_{\mathrm{E}}(b)=-f_{\mathrm{E}}.$$

[14] See Hurter Jr. and Lederer (1985).

[15] Thisse and Vives (1988) make the assumption that when firms are committed to different pricing policies, the firm committed to f.o.b. is the leader and the other firm is the follower. In that case it is possible to sustain in equilibrium a pricing rule with $p_{\mathrm{I}}>0$ and both firms would get higher profits.

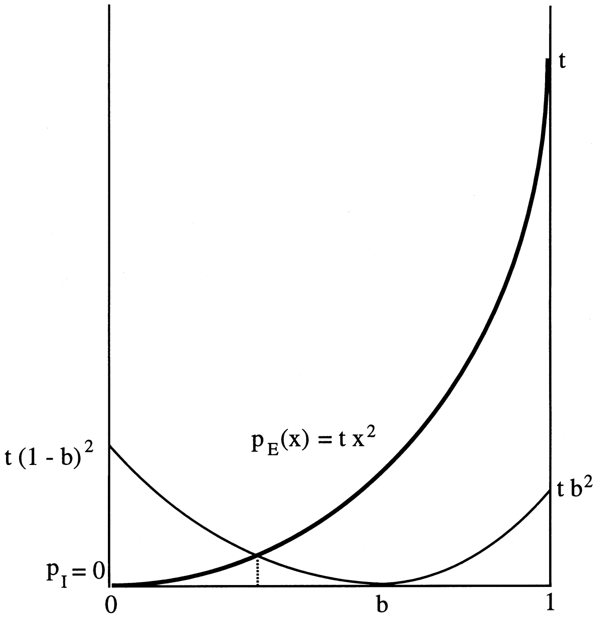


Fig. 3. Equilibrium price policy when the incumbent is committed to f.o.b. and the entrant uses delivered pricing.

Note that the entrant obtains the same profits, $\Pi_E = -f_E$, whatever the value of $b$; the entrant's location only affects the incumbent's profits.

### *3.6. No entry*

The best pricing policy for a monopoly is a uniform delivered price equal to $R$, the consumers' reservation value. Profits are:

$$\Pi_I = \int_0^1 (R - tx^2)\,\mathrm{d}x = R - \frac{t}{3}.$$

However, if constrained to f.o.b., the existing firm will choose a mill price $p_I = R - t$, so that the whole market is served. Profits in that case are $\Pi_I = R - t$.

Table 1 summarizes the possible outcomes of the second stage. If the incumbent is committed to f.o.b. the best response for the entrant is f.o.b. as well. If the incumbent has chosen to be flexible and produces all the varieties of the product, the entrant will also choose to be flexible. We can now state the main result of this section.

**Proposition 1.** *If entry cost is low,* $f_E \leq (8/27)t$, *the incumbent cannot deter entry and in the duopoly equilibrium firms price according to f.o.b. For intermediate*

Table 1
Summary of firms' profits

| | | No entry | Entry Entrant f.o.b. | d.p.p. |
|---|---|---|---|---|
| Incumbent | f.o.b. | $(R-t,\ 0)$ | $\left(\frac{t}{2}, \frac{t}{2} - f_E\right)$ | $\left(0, \frac{8t}{27} - f_E\right)$ |
| | d.p.p. | $\left(R - \frac{t}{3}, 0\right)$ | $\left(\frac{(1-b)^3 t}{4}, -f_E\right)$ | $\left(\frac{2t}{27}, \frac{8t}{27} - f_E\right)$ |

*values of* $f_E$, $(8/27)t<f_E<(t/2)$, *the incumbent uses a delivered pricing policy and deters entry. If* $f_E$ *is high,* $f_E \geq (t/2)$, *entry into this market is blockaded, and the incumbent will choose a delivered pricing policy.*

This result is quite simple to interpret. Delivered pricing makes the incumbent a tough competitor, so that entry is made more difficult. In other words, being able to produce all the varieties of the good and price discriminating among them makes the incumbent more aggressive in the post-entry game. For values of $f_E$ in the interval $((8t/27), (t/2))$, delivered pricing deters entry, although if the existing firm priced according to f.o.b., entry would be profitable. However, for lower entry costs, entry is unavoidable and therefore the best strategy for the incumbent is to adopt an f.o.b. pricing system to 'soften' the following period competition. In terms of product differentiation note that when entry cannot be deterred, competition between the firms makes both of them choose non-flexible technologies (only two varieties of the product are in the market), and consumers pay a cost in terms of utility loss. However, when the incumbent is able to deter entry it chooses to produce all the varieties.

In the next section we will show that when the incumbent cannot credibly commit itself to a pricing policy, under asymmetric information, discriminatory pricing may be useful to deter entry.

## 4. The choice of a pricing policy under incomplete information

In this section, we assume that the potential entrant has incomplete information about the transportation cost of the incumbent $t_I(d)$.[16] The entrant takes the pricing policy as a signal of the incumbent's freight costs. Anticipating this, the incumbent might try to use the price rule to deter entry. We keep the assumption of convex

[16] A model where the incumbent reveals information about costs through location is Boyer et al. (1994).

transportation costs:[17] $t(d)=td^2$, $t_I(d)=t_I d^2$ and $t_E(d)=td^2$. The entrant's prior beliefs are:

–with probability $\beta$ the incumbent's transportation cost parameter $t_I$ is high, $t_I=\bar{t}$ (the incumbent is not very flexible and can produce the whole range of products only at a high cost). We assume that $\bar{t}>3t$.

–with probability $(1-\beta)$ the transportation cost is low, $t_I=\underline{t}$ (the incumbent is very flexible and can produce the whole range of products at a low cost). We assume that $\underline{t}<t$.

We also assume that (i) $\underline{\Pi}_E^{bb}<0<\bar{\Pi}_E^{bb}$ and (ii) $\beta\bar{\Pi}_E^{bb}+(1-\beta)\underline{\Pi}_E^{bb}<0$, where $\underline{\Pi}_E^{bb}$ is the equilibrium profits for the entrant when the existing firm is low cost, and $\bar{\Pi}_E^{bb}$ when it is high cost.[18] The first condition implies that firm E only wishes to enter against the incumbent with high transportation costs and the second that with the prior information the expected profits are negative.

In this model there are two production periods. In the first one the price rule used by the incumbent may be a signal of its type; the entrant may try to infer some information from the pricing policy to make the entry decision.[19] The timing of the game is as follows.

*First period:* the incumbent chooses pricing policy and price level and sells in the market as a monopolist. At the end of the period, the entrant observes the incumbent's location and the pricing rule. Then, the entrant decides whether to enter or not in the following period.[20]

*Second period:* the incumbent's type (transportation cost) is made common knowledge and the entrant decides location. The incumbent observes the entrant's location. If there is entry, both firms choose pricing policy and price level simultaneously and independently; otherwise, the incumbent behaves as a monopolist. The existing firm discounts second period profits with a discount factor $\delta\in[0, 1]$.[21]

[17]Here, with linear transportation costs there is equilibrium in pure strategies in the post-entry price-location game (see Lederer and Hurter Jr., 1986). The results are similar to those with quadratic costs.

[18]See the entrant's equilibrium profits in Table 2.

[19]In the previous section we did not need two production periods, only the possibility of commitment in the first stage.

[20]The entrant may also observe the price level, but that level will not be informative. See Milgrom and Roberts (1982) for a model where the entrant may obtain information from the first period price level. On the other hand, in a context of standard third degree price discrimination with homogeneous product, Aguirre (1996) shows that a high demand incumbent can use uniform pricing to convey bad news to a potential entrant about its profitability in the market.

[21]If location is decided before the incumbent's type is known, then the incumbent has a further motive for signalling: to change the entrant's location.

We will characterize the perfect Bayesian equilibria. First, we obtain the equilibrium pricing policies of the second period game and the firms' profits.

### 4.1. Second period

The possibilities for the second period are: a) No Entry and b) Entry.

#### 4.1.1. No entry

Denote as $\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}}$ the monopoly profits for the high cost incumbent firm under a delivered pricing policy, and $\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$ the profits when the monopolist is constrained to an f.o.b. rule. The following two lemmas give us the preferred pricing policy for the 'flexible' incumbent (low cost) and for the 'less flexible' incumbent (high cost).

**Lemma 1.** *The high cost incumbent's optimal pricing policy is f.o.b.*: $\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} < \overline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$.

**Proof.** Under f.o.b. pricing, the incumbent would set a mill price $p = R - t$, and its profits would be: $\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} = R - t$. Under delivered pricing, the incumbent would set a delivered price $p(x) = R$; profits would be: $\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} = R - (\bar{t}/3)$. Since $\bar{t} > 3t$, $\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} < \overline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$. Q.E.D.

Lemma 1 simply states that when $\bar{t} > 3t$ the transportation costs of the type $\bar{t}$ incumbent are so high that it prefers the consumers to carry out the transportation of the goods.

**Lemma 2.** *The low cost incumbent prefers delivered pricing*: $\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} > \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$.

**Proof.** F.o.b. pricing would lead the incumbent to a mill price $p = R - t$, and profits would be: $\underline{\Pi}_{\mathrm{I}}^{\mathrm{f}} = R - t$. Under delivered pricing the incumbent would choose a delivered price $p(x) = R$, and profits would be: $\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} = R - (\underline{t}/3)$. Since $\underline{t} < t$, $\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} > \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$. Q.E.D.

Now it should be clear that the assumption $\underline{t} < t < (\bar{t}/3)$ serves to separate both types of incumbents, so that in the absence of an entry threat they would behave differently. This assumption could be relaxed considerably taking into account explicitly that delivered pricing may have higher implementation costs (a fixed cost of carrying out the transportation activity, insurance of the goods, . . . ). Thus, the separation between the two types of incumbent does not need to rely completely (as it does in this model) on the unit transportation cost.

#### 4.1.2. Entry

If there is entry, firms have to decide, simultaneously, pricing policy and price level (mill price and delivered price). The following lemma characterizes the second stage equilibrium.

**Lemma 3.** *A Nash equilibrium in pure strategies in the second period has both firms using delivered pricing, independently of the type of the incumbent.*

**Proof.** Lederer and Hurter Jr. (1986) or Thisse and Vives (1988).[22]

Table 2 gives the second period equilibrium pricing policy, the profits for the entrant as a function of location and the optimal location. After solving the second period game, we go back to the first period.

### 4.2. First period

The firm decides its pricing policy taking into account that the entrant may observe the price schedule and try to infer some information about the type of the incumbent. The high cost monopolist prefers f.o.b. and the low cost type delivered pricing, so that if the entrant observes f.o.b., it could infer that the incumbent is a high cost type and enter the market. This could make it worth it for a high cost monopolist to sacrifice short run profits and use a delivered price rule in order not to reveal that information to the entrant.

Note that, for the entrant, the incumbent's price level observed in the first period cannot be informative, since both types of incumbent firm prefer the same level:

Table 2
Post-entry equilibrium price schedules, entrant's location and profit

| | High-cost incumbent | Low-cost incumbent |
|---|---|---|
| Post-entry equilibrium price policy $p(x)$ | $\max\{\bar{t}x^2, t[(1-b)-x]^2\}$ | $\max\{\underline{t}x^2, t[(1-b)-x]^2\}$ |
| $\Pi_E(b)$ | $\int_{(1-b)\bar{A}}^{1} \{\bar{t}x^2 - t[(1-b)-x]^2\}\, dx - f_E$ | $\int_{(1-b)\underline{A}}^{1} \{\underline{t}x^2 - t[(1-b)-x]^2\}\, dx - f_E$ |
| Optimal location | $\dfrac{\sqrt{t(t-\bar{B})} - (t-\bar{B})}{\bar{B}}$ | $\dfrac{\sqrt{t(t-\underline{B})} - (t-\underline{B})}{\underline{B}}$ |

where $\underline{A} = \dfrac{t - \sqrt{t\underline{t}}}{t - \underline{t}}$; $\bar{A} = \dfrac{\sqrt{\bar{t}t} - t}{\bar{t} - t}$; $\underline{B} = \underline{A}[(t - \underline{t})\underline{A}^2 + 3t(1 - \underline{A})]$; $\bar{B} = \bar{A}[-(\bar{t} - t)\bar{A}^2 + 3t(1 - \bar{A})]$.

[22] See footnote 13.

$p(x) = R$ in the case of a delivered pricing policy and a mill price of $R - t$ in the case of f.o.b. In this model, only the pricing rule can contain any information about the type of the incumbent. The perfect Bayesian equilibria may be separating or pooling.

In a separating equilibrium, each type of incumbent behaves differently in the first period and, therefore, reveals its type to the entrant. Define $\underline{\delta} = (\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} - \overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} / \overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} - \overline{\Pi}_{\mathrm{I}}^{\mathrm{bb}})$, where $\overline{\Pi}_{\mathrm{I}}^{\mathrm{bb}}$ denotes the incumbent's duopoly profits when both firms use delivered pricing; $\underline{\delta} < 1$, since $\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} > \overline{\Pi}_{\mathrm{I}}^{\mathrm{b}}$ by Lemma 1 and $\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} > \overline{\Pi}_{\mathrm{I}}^{\mathrm{bb}}$ (duopoly and monopoly profits, respectively, under the same pricing policy). The following proposition states our first result in this section.

**Proposition 2.** *If $\delta > \underline{\delta}$, there is no separating perfect Bayesian equilibrium.*

**Proof.** The posterior beliefs (once the signal has been observed) in a separating equilibrium must be: $\mathrm{pr}(\overline{t}/\text{f.o.b.}) = 1$ and $\mathrm{pr}(\underline{t}/\text{delivered pricing}) = 1$. Thus, the potential entrant enters if it observes f.o.b. and stays out if it observes delivered pricing. The incentive compatibility condition for the high cost type must be satisfied:

$$\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} + \delta\overline{\Pi}_{\mathrm{I}}^{\mathrm{bb}} \geq \overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} + \delta\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}}.$$

Assuming $\delta > \underline{\delta}$, the inequality cannot hold. Q.E.D.

For small values of the discount factor, $\delta \leq \underline{\delta}$, the future is not very important for the incumbent and it prices to maximize short run profits. In that case the unique perfect Bayesian equilibrium is separating: the low cost firm price discriminates and the high cost one prices according to f.o.b.

We now look at the pooling equilibria (both types of incumbent firms use the same pricing policy in the first stage of the game). If $\beta$ is the prior probability (prior beliefs) that the incumbent is high cost and $(1-\beta)$ the prior probability of low cost, the posterior beliefs in a pooling equilibrium are the same. For the existence of a pooling equilibrium the condition $\beta\, \overline{\Pi}_{\mathrm{E}}^{\mathrm{bb}} + (1-\beta)\underline{\Pi}_{\mathrm{E}}^{\mathrm{bb}} < 0$, i.e., that the expected profits of the entrant given its prior beliefs, must be negative, is crucial. The following proposition states our main result of this section.

**Proposition 3.** *If $\delta > \underline{\delta}$, in a pooling perfect Bayesian equilibrium high cost and low cost incumbents use a delivered pricing rule in the first period and there is no entry.*

**Proof**. The conditions that must be satisfied in a pooling equilibrium are:

$$\overline{\Pi}_{\mathrm{I}}^{\mathrm{b}} + \delta\overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} \geq \overline{\Pi}_{\mathrm{I}}^{\mathrm{f}} + \delta\overline{\Pi}_{\mathrm{I}}^{\mathrm{bb}}, \quad \underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} + \delta\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} \geq \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}} + \delta\underline{\Pi}_{\mathrm{I}}^{\mathrm{bb}}.$$

The first inequality holds for $\delta > \underline{\delta}$ and the second inequality holds for any $\delta$, since

$\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} > \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}}$ by Lemma 2, and $\underline{\Pi}_{\mathrm{I}}^{\mathrm{bb}} < \underline{\Pi}_{\mathrm{I}}^{\mathrm{b}}$ (duopoly and monopoly profits, respectively, under the same pricing policy). On the other hand, the entrant's best response is not to enter, given our assumption $\beta\, \overline{\Pi}_{\mathrm{E}}^{\mathrm{bb}} + (1-\beta)\underline{\Pi}_{\mathrm{E}}^{\mathrm{bb}} > 0$, and its beliefs are correct in equilibrium. Q.E.D.

There is another pooling equilibrium with both incumbents using f.o.b. and no entry. The condition is: $\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} + \delta\underline{\Pi}_{\mathrm{I}}^{\mathrm{bb}} \leq \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}} + \delta\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}}$, which holds if $\delta \geq (\underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} - \underline{\Pi}_{\mathrm{I}}^{\mathrm{f}} / \underline{\Pi}_{\mathrm{I}}^{\mathrm{b}} - \underline{\Pi}_{\mathrm{I}}^{\mathrm{bb}})$. In this equilibrium, the beliefs are such that if a firm deviates from f.o.b. to delivered pricing the potential entrant will associate probability one to the fact that the established firm has a high cost (although the high cost firm prefers f.o.b., see Lemma 1). This perfect Bayesian equilibrium does not satisfy any of the usual refinements in the signaling literature, in particular the intuitive criterion of Cho and Kreps (1987).[23] Therefore, for $\delta > \underline{\delta}$ the only perfect Bayesian equilibrium satisfying the intuitive criterion is a pooling equilibrium with price discrimination: the high cost firm prefers delivered pricing (although in the absence of the potential entrant f.o.b. is better), so that no new information is revealed prior to the entry decision. For low values of the discount factor, $\delta \leq \underline{\delta}$, the future is less important and the monopolist prefers to use the pricing policy that maximizes short run profits and allow entry in the following period.

## 5. Concluding remarks

We have explored some of the strategic properties of spatial pricing rules. Delivered pricing policies are more aggressive and therefore tend to discourage entry by new firms. When entry is unavoidable, the incumbent may be interested in committing itself to an f.o.b. pricing rule to soften the post-entry competition. Under asymmetric information, delivered pricing may be used by an inefficient incumbent in order not to reveal information about its costs to the entrant (even though this type of incumbent would rather price according to f.o.b.) and deter entry. In terms of product differentiation, flexibility to produce the whole range of varieties is a more aggressive course of action for an incumbent than choosing a technology restricted to producing just one variety, and discourages entry. However, when there is entry, competition causes the number of varieties to decrease to one per firm in the market. Under asymmetric information we find that incumbents that would rather produce only one variety in the absence of an entry

[23]The reasoning is as follows. Fix the pooling equilibrium with both types of incumbent using f.o.b. pricing and consider the message delivered pricing out of the equilibrium path. The deviation to delivered pricing is dominated for the high-cost incumbent who makes a lower first period profit pricing f.o.b. and cannot increase its second period profit. Hence, posterior beliefs after delivered pricing should be pr ($\underline{t}$/delivered pricing) = 1 and entry is deterred. But then the low-cost incumbent would have incentives to deviate to delivered pricing.

threat, may be producing all the varieties to hide their inefficiency to the prospective entrant.

Extensions and generalizations of this work could come in many areas. Our analysis has been restricted to price competition and inelastic demands, although firms could compete à la Cournot in the post-entry game and demands could be elastic at any point in the market. In the context of spatial discrimination under Cournot oligopoly see, for example, Greenhut and Greenhut (1975); Hamilton et al. (1989); Anderson and Neven (1991).[24]

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## References

Aguirre, I., 1996. Uniform pricing: good or bad news about market profitability? SEEDS D.P. 149.

al-Nowaihi, A., Norman, G., 1992. Spatial competition by quantity setting firms: a comparison of simultaneous and two-stage quantity–location games. University of Leicester, Discussion Papers in Economics, no 92/19.

Anderson, S.P., Neven, D.J., 1991. Cournot competition yields spatial agglomeration. International Economic Review 32, 793–808.

d'Aspremont, C., Gabszewicz, J.J., Thisse, J-F., 1979. On Hotelling's stability in competition. Econometrica 47 (5), 1145–1150.

Bonanno, J., 1987. Location choice, product proliferation and entry deterrence. The Review of Economic Studies 54, 37–45.

Boyer, M., Laffont, J-J., Mahenc, P., Moreaux, M., 1994. Location distortions under incomplete information. Regional Science and Urban Economics 24, 409–440.

Cho, I., Kreps, D., 1987. Signaling games and stable equilibria. The Quarterly Journal of Economics 102, 179–221.

De Fraja, G., Norman, G., 1993. Product differentiation, pricing policy and equilibrium. Journal of Regional Science 33, 343–363.

De Fraja, G., 1993. Relaxing spatial competition through product line choice (or vice versa). Regional Science an Urban Economics 23, 461–486.

Fudenberg, D., Tirole, J., 1984. The fat cat effect, the puppy dog ploy, and the lean and hungry look. The American Economic Review 74, 361–366.

Gabszewicz, J.J., Thisse, J-F., 1986. On the nature of competition with differentiated products. The Economic Journal 96, 160–172.

Gilbert, R.J., Matutes, C., 1993. Product line rivalry with brand differentiation. The Journal of Industrial Economics 41, 223–240.

Greenhut, J.G., Greenhut, M.L., 1975. Spatial price discrimination, competition and location effects. Economica 42, 401–419.

[24] al-Nowaihi and Norman (1992) consider Cournot competition under mill-pricing.

Gronberg, T., Meyer, J., 1981. Transport inefficiency and the choice of spatial pricing mode. Journal of Regional Science 21, 541–549.

Hamilton, J.H., Thisse, J-F., Weskamp, A., 1989. Spatial discrimination: Bertrand vs. Cournot in a model of location choice. Regional Science and Urban Economics 19, 87–102.

Hay, D., 1976. Sequential entry and entry-deterring strategies in spatial competition. Oxford Economic Papers 28, 240–257.

Hotelling, H., 1929. Stability in competition. The Economic Journal 39, 41–57.

Hurter, Jr. A.P., Lederer, P.J., 1985. Spatial duopoly with discriminatory pricing. Regional Science and Urban Economics 15, 541–553.

Judd, K., 1985. Credible spatial preemption. Rand Journal of Economics 16, 153–166.

Lederer, P.J., Hurter, Jr. A.P., 1986. Competition of firms: discriminatory pricing and location. Econometrica 54 (3), 623–640.

Machlup, F., 1949. The Basing point system. Blakiston, Philadelphia, PA.

Martinez-Giralt, X., Neven, D.J., 1988. Can price competition dominate market segmentation?. The Journal of Industrial Economics 4, 431–442.

Milgrom, P., Roberts, J., 1982. Limit pricing and entry under incomplete information: an equilibrium analysis. Econometrica 50, 443–460.

Phlips, L., 1983. The economics of price discrimination. Cambridge University Press, Cambridge.

Scherer, F.M., 1980. Industrial Market Structure and Economic Performance, 2nd ed. Rand McNally, Chicago.

Schmalensee, R., 1978. Entry deterrence in the ready-to-eat breakfast cereal industry. The Bell Journal of Economics 9, 305–327.

Shaked, A., Sutton, J., 1990. Multimarket firms and market structure. Rand Journal of Economics 21, 45–62.

Thisse, J-F., Vives, X., 1988. On the strategic choice of spatial price policy. The American Economic Review 78, 122–137.

Thisse, J-F., Vives, X., 1992. Basing point pricing: competition versus collusion. The Journal of Industrial Economics XL, 248–260.