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Abstract

In this note we analyze two-dimensional product differentiation in competition between nonprofit firms. Unlike for-profit settings, which finds maximal differentiation in the characteristic most salient to consumers and minimal differentiation in the other dimension, we show that the presence of at least one nonprofit firm leads to minimal differentiation in both dimensions. We extend the analysis to mixed competition between a nonprofit and for-profit firm.

Keywords: Product differentiation, dominant dimension, nonprofit, for-profit.
JEL classification: L1, L3, R3.

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1 Introduction

Fifty years after Hotelling (1929) concluded that competing firms were insufficiently differentiated, in what came to be known as "the principle of minimum differentiation", D'Aspermont, Gaszewicz and Thisse (1979) showed no pure strategy equilibrium existed in the Hotelling framework. Replacing Hotelling's linear penalty for a firm's output not meeting the consumer's ideal with a quadratic penalty, they found, in contrast to Hotelling, firms will maximally differentiate. In an extension to that result, Irmen and Thisse (1998) showed that, in multi-characteristic spaces, two competing firms choose to maximize differentiation in a characteristic of dominant importance to consumers, and to minimize differentiation in all other characteristics.

In this note we analyze product differentiation in competition between nonprofit and for-profit firms. After replicating Irmen and Thisse's result, we show that when all firms are nonprofit, firms minimize differentiation both in dominant and dominated dimensions. As a consequence, firms' products look alike and split the market equally. We extend the analysis to asymmetric firms, one nonprofit and another for-profit. We show that, when at least one firm is nonprofit, differentiation becomes nil in the dominant domain under all parameter values. Our results help explain, for instance, the competition between nonprofit and for-profit hospitals, where their prices, types and quality of care they offer, or lenght of stay, are extremely similar.[1]

2 Model

Our model is a two-dimensional variant of the Irmen and Thisse framework. Consumers are continuously distributed uniformly over a unit square $[0,1]^2$ in a configuration commonly known as a "Hotelling city." Each point on the square, as defined by its location (z_1, z_2), indicates the preferred product characteristics of the consumer there located. Two firms, A and B, produce a good, with the product characteristics defined by the firms locations, so the characteristics of the good produced by firm A are given by the pair $a = (a_1, a_2)$ and likewise the product from firm B is defined by $b = (b_1, b_2)$. Firms are identical except for product location (characteristics). There is a constant marginal cost of production, which for simplicity is set equal to zero, and is independent of the product characteristics chosen by the firm. There are no fixed costs. Every firm j's objective function is

$$\theta_j \pi_j + (1 - \theta_j) D_j \text{ where } j = \{A, B\}$$

Parameter $\theta_j \in [0,1]$ denotes the weight that this firm assigns to its profit, π_j, rather than

[1] Plante (2009) examined differences between the types of patients nonprofit and for-profit hospitals treat and the length of time it took to treat them. The results indicated no significant difference between the variables used as indicators of patient type, including Medicare percentage, Medicaid percentage, or case-mix index. Similarly, a 1999 study of 43 hospitals that converted to for-profit, for example, found that, on average, there were not statistically significant differences in prices, the levels of uncompensated care provided or the provision of unprofitable services like trauma care, burn care and substance abuse treatment; see Becker (2014). Last, forprofit and nonprofit hospitals adopted more similar technologies, as shown by Robinson and Luft (1985).

on demand D_j.[2] When firms are nonprofit, $\theta_j = 0$, they seek to maximize market share. In contrast, when firms only care about profits, $\theta_j = 1$, our objective function coincides with that in Irmen and Thisse. Our approach allows firms to be symmetric in the weight they assign to profits, $\theta_A = \theta_B = \theta$, or asymmetric if $\theta_A \neq \theta_B$.

Consumers buy one unit of the good, either from firm A or B. If consumer in location (z_1, z_2) buys from firm A, she derives a net utility of

$$u_A(z_1, z_2) = S - p_A - t_1(z_1 - a_1)^2 - t_2(z_2 - a_2)^2$$

where $S > 0$ denotes surplus, which is assumed to be sufficiently large to ensure that consumers buy from one seller or the other, p_A is the price she pays for the good, and transportation costs t_1 and t_2 define how important each characteristic is to consumers. Following Irmen and Thisse, we assume that characteristic 2 dominates characteristic 1, $t_2 > t_1$.[3] An analogous expression holds if the consumer buys from firm B instead.

The time structure of the game is the following: first, firms simultaneously and independently choose location; second, firms select prices; and finally consumers choose which firm to buy from. We solve the model by applying backward induction.

3 Equilibrium analysis

3.1 Third stage

Following Irmen and Thisse (assuming $b \geq a$) the demand for firm A is given by

$$D_A = \frac{p_B - p_A + t_1(b_1^2 - a_1^2) + t_2(b_2^2 - a_2^2) - t_1(b_1 - a_1)}{2t_2(b_2 - a_2)}$$

and that of firm B is $D_B = 1 - D_A$.

3.2 Second stage

Anticipating the above demand functions D_A and D_B, every firm j chooses its price p_j to solve

$$\max_{p_j} \theta_j \pi_j + (1 - \theta_j) D_j$$

where profits $\pi_j = p_j D_j$ since production costs are zero by definition. Differentiating with respect to p_j, we obtain firm A's best response function

$$p_A(p_B) = \begin{cases} \frac{\theta_A(M_1+M_2)-1}{2\theta_A} + \frac{1}{2}p_B \text{ if } p_B \geq \frac{\theta_A(M_2-M_1)+1}{\theta_A} \\ 0 \text{ otherwise.} \end{cases}$$

[2] Thompson (1994) provides empirical evidence showing that nonprofit hospitals in the U.S. compete for market share.

[3] With only two characteristics, we are restricting ourselves to what Irmen and Thisse call "strong dominance".

where $M_1 \equiv t_1(b_1 - a_1)(b_1 + a_1 - 1) + 1$, and $M_2 \equiv t_2(b_2^2 - a_2^2)$. Hence, p_A increases in its rival's price, p_B, as in standard models on horizontally differentiated products; and its vertical intercept increases in the weight that firm A assigns to profits, θ_A.[4] When firm A assigns a low weight to profits, the ratio $\frac{\theta_A(M_2-M_1)+1}{\theta_A}$ becomes high, entailing that most prices p_B lie below $\frac{\theta_A(M_2-M_1)+1}{\theta_A}$, ultimately inducing firm A to respond with a zero price. This setting includes the case in which firm A is a non-profit, $\theta_A = 0$, whereby its best response function collapses to $p_A(p_B) = 0$ for all p_B. That is, when a firm is non-profit, practicing average cost pricing[5] becomes a weakly dominant strategy, as it is unaffected by its rival's price. If, in contrast, firm A is for-profit, $\theta_A = 1$, its best response function simplifies to $p_A(p_B) = \frac{M_1+M_2-1}{2} + \frac{1}{2}p_B$, which is positive if $p_B > 1 - M_1 - M_2$; a condition is more likely to hold when the good is more differentiated in the dimension that consumers regard as dominant.[6] A similar, although not symmetric, best response function applies to firm B.

Using the best response functions to simultaneously solve for equilibrium prices (p_A^*, p_B^*) for firms A and B in the second stage, we obtain that (1) if both firms are nonprofit, $\theta_A = \theta_B = 0$, equilibrium prices are $p_A^* = p_B^* = 0$; (2) if only firm A is non-profit, $\theta_A = 0$, equilibrium prices are

$$\begin{aligned} p_A^* &= 0 \text{ when } \theta_A = 0, \text{ and} \\ p_B^* &= \begin{cases} \frac{\theta_B[M_1 - t_2(b_2-a_2)(b_2+a_2-2)]-1}{2\theta_B} & \text{if } \theta_B > \overline{\theta}_B \\ 0 \text{ otherwise} \end{cases} \end{aligned}$$

where $\overline{\theta}_B \equiv \frac{1}{M_1 - t_2(a_2-b_2)(b_2+a_2-2)}$; (3) if only firm B is non-profit, $\theta_B = 0$, equilibrium prices are

$$\begin{aligned} p_B^* &= 0 \text{ when } \theta_B = 0, \text{ and} \\ p_A^* &= \begin{cases} \frac{\theta_A(M_1+M_2)-1}{2\theta_A} & \text{if } \theta_A > \overline{\theta}_A \\ 0 \text{ otherwise} \end{cases} \end{aligned}$$

where $\overline{\theta}_A \equiv \frac{1}{M_1+M_2}$; and (4) when $\theta_A, \theta_B > 0$, equilibrium prices become

$$p_A^* = \begin{cases} \frac{\theta_A\theta_B[3+M_1+t_2(b_2-a_2)(b_2+a_2+2)]-2\theta_B}{3\theta_A\theta_B} & \text{if } \theta_A > \widehat{\theta}_A \\ 0 \text{ otherwise} \end{cases}$$

[4] Since we allow for $\theta_A \in [0,1]$, this vertical intercept is only positive if weight θ_A is high enough, i.e., $\theta_A > \frac{1}{M_1+M_2}$. In this setting, price p_A is positive for all p_B. Otherwise, p_A is defined by this formula only if p_B is sufficiently high, i.e., $p_B \geq \frac{\theta_A(M_2-M_1)+1}{\theta_A}$.

[5] A nonprofit firm constrained to not making losses maximizes sales by setting its price equal to average cost. Since in our set-up average and marginal costs are zero, the firm sets its price at zero.

[6] This result is consistent with Irmen and Thisse. In a context where all firms are for-profit, $\theta_A = \theta_B = 1$, they show that differentiation is nil in the dominated dimension, $a_1 = b_1$, but maximal in the dominant dimension, $b_2 = 1$ and $a_2 = 0$. Inserting these equilibrium locations, we obtain $M_2 = t_2$ and $M_1 = 1$, thus yielding a best response function of $p_A(p_B) = \frac{t_2}{2} + \frac{1}{2}p_B$ for firm A; and similarly for firm B. Simultaneously solving for these two best response functions, we obtain equilibrium prices of $p_A^* = p_B^* = t_2$, which coincide with those in Irmen and Thisse.

and

$$p_B^* = \begin{cases} \frac{\theta_A\theta_B[t_2(b_2-a_2)(4-b_2-a_2)-M_1]-\theta_B}{3\theta_A\theta_B} & \text{if } \theta_B > \widehat{\theta}_B \\ 0 \text{ otherwise} \end{cases}$$

where $\widehat{\theta}_A \equiv \frac{2\theta_B}{\theta_B[3+M_1+t_2(b_2-a_2)(b_2+a_2+2)]-1}$ and $\widehat{\theta}_B \equiv \frac{2\theta_A}{\theta_A[3-M_1-t_2(b_2-a_2)(b_2+a_2+2)]-1}$.

In words, when both firms are nonprofit, both set a price equal to average cost (zero) to maximize sales while not incurring losses. When only firm j is nonprofit, it sets a zero price while its rival $k \neq j$ sets a monopoly price if its own weight on profits is sufficiently high, i.e., $\theta_k > \overline{\theta}_k$. Otherwise, both firms practice average cost pricing even if one of the two firms assigns a positive (but small) weight on profits, i.e., $\theta_k \leq \overline{\theta}_k$. The monopoly price that firm k charges is only positive when products are strongly differentiated; otherwise, the effect of firm j setting a zero price for a relatively homogeneous good forces the for-profit firm k to practice average cost pricing as well.[7] This conclusion has important implications for mixed competition. Lakdawalla and Philipson (2006) argue that for-profit firms cannot compete with nonprofit providers if there is sufficient nonprofit preferences among the suppliers of a good, and mixed competition is possible only when there is "insufficient" nonprofit goals. Our results suggest that, without substantial product differentiation, for-profit firms can compete only by acting like their nonprofit competitors. Finally, if both firms are for-profit, every firm j sets a positive price if it assigns a sufficient weight on profits, $\theta_j > \widehat{\theta}_j$, and if products are relatively differentiated.

3.3 First stage

Anticipating the equilibrium behavior that ensues in all subsequent stages, every firm j chooses its location pair (j_1, j_2) to solve

$$\max_{j_1,j_2} \theta_j \pi_j(p_j^*, p_k^*) + (1-\theta_j)\, D_j(p_j^*, p_k^*)$$

where both profits and consumer surplus are evaluated at equilibrium prices (p_j^*, p_k^*). It is straightforward to show that equilibrium locations are $a_1^* = b_1^* = 1/2$ in the dominated dimension; a result that holds independently on its own weight on profits, θ_j, and its rival's, θ_k. This result hence extends Irmen and Thisse's finding to contexts in which one or both firms are nonprofit.

We next examine optimal locations in the dominant dimension j_2. For simplicity, we focus on three industry settings: (i) both firms are for-profit, $\theta_A = \theta_B = 1$; (ii) both firms are non-profits, $\theta_A = \theta_B = 0$; and (iii) one firm is nonprofit while its rival is for-profit, $\theta_j = 0$ and $\theta_k = 1$.

1. **Two for-profits.** Inserting $\theta_A = \theta_B = 1$ in the above program, its equilibrium prices

[7] For instance, when $\theta_A = 0$ and $\theta_B > 0$, prices p_A^* and p_B^* become zero for all values of θ_B if the product is undifferentiated in both dimensions, $a_1 = b_1$ and $a_2 = b_2$. A similar argument applies when $\theta_B = 0$ and $\theta_A > 0$, whereby prices p_A^* and p_B^* are also zero for all values of θ_A.

$p_A^* = p_B^* = 0$, and using equilibrium location $a_1^* = b_1^* = 1/2$,[8] firm A solves

$$\max_{a_2} \pi_A(p_A^*, p_B^*) = \frac{t_2(b_2 - a_2)(b_2 + a_2 + 2)^2}{18}$$

The above program yields best response function $a_2(b_2) = -\frac{2}{3} + \frac{1}{3}b_2$, which is negative for all admissible values of $b_2 \in [0, 1]$. Hence, firm A's best response function collapses to a flat line $a_2(b_2) = 0$ for all b_2. Operating similarly for firm B, we obtain

$$\max_{b_2} \pi_B(p_A^*, p_B^*) = \frac{t_2(b_2 - a_2)(b_2 + a_2 - 4)^2}{18}$$

with best response function $b_2(a_2) = \frac{4}{3} + \frac{1}{3}a_2$, which is positive for all values of a_2. Simultaneously solving for a_2 and b_2, and using the constraint that $b_2, a_2 \in [0, 1]$, we obtain equilibrium locations $a_2^* = 0$ and $b_2^* = 1$. Therefore, when both firms are for-profit $\theta_A = \theta_B = 1$, product differentiation in the dominant dimension is maximal; as found by Irmen and Thisse (1998).

2. **Two nonprofit.** Following a similar approach as above, firm A's program reduces to

$$\max_{a_2} D_A(p_A^*, p_B^*) = \frac{a_2 + b_2}{2}$$

which, differentiating with respect to a_2, yields 1/2, i.e., increasing location a_2 is a weakly dominant strategy for firm A. Similarly, firm B's program simplifies to

$$\max_{b_2} D_B(p_A^*, p_B^*) = \frac{2 - a_2 - b_2}{2}$$

After differentiating with respect to b_2, we obtain $-1/2$, i.e., decreasing location b_2 is a weakly dominant strategy for firm B. Intuitively, firm A (B) has monotonic incentives to increase (decrease) its location, which is only compatible with the initial assumption $b \geq a$ if a_2 converges to b_2 from below, ultimately entailing $a_2^* = b_2^*$. In words, a continuum of equilibria emerges in this setting with locations satisfying $a_2^* = b_2^* \in [0, 1]$. As a result, firms do not differentiate in any dimension.[9]

3. **Only one firm is nonprofit.** Following a similar approach as in cases 1 and 2, the nonprofit firm A's program becomes

$$\max_{a_2} D_A(p_A^*, p_B^*) = \frac{(b_2 + a_2 + 2)}{4}$$

[8] Inserting $a_1^* = b_1^* = 1/2$ in the firm A's objective function is equivalent to inserting it after taking first-order conditions with respect to choice variable a_2 since $a_1^* = b_1^* = 1/2$ is not a function of a_2. Otherwise, the optimal location a_2^* would not coincide using the first or second approach.

[9] Among the continuum of equilibria that can be supported in this scenario, social conventions could help select the equilibrium in which both firms locate at the center, $a_2^* = b_2^* = 1/2$. Regardless of which equilibrium emerges, all equilibria in this setting yield nil product differentiation, as opposed to those in Irmen and Thisse.

which, differentiating with respect to a_2, yields $1/4$, i.e., increasing location a_2 is a weakly dominant strategy for firm A. In contrast, the for-profit firm B's program simplifies to

$$\max_{b_2} \pi_B(p_A^*, p_B^*) = \frac{t_2(b_2 - a_2)(b_2 + a_2 - 2)^2}{8}$$

with best response function $b_2(a_2) = \frac{2}{3} + \frac{1}{3}a_2$. Inserting $a_2^* = 1$ into this function, yields $b_2^* = 1$ entailing that, when only one of the firms is nonprofit, nil product differentiation emerges.[10]

4 Discussion

D'Aspermont, Gaszewicz and Thisse (1979) identified two countervailing incentives from firm location. First, to maximize market share, firms want to locate in the center of the demand field; and, second, to create market power and essentially become a local monopoly, firms seek to be apart. Irmen and Thisse show, in a setting with multiple dimensions, that the first incentive dominates for profit-maximizing firms, driving them to maximal differentiation in the dominant domain. We show that the second incentive dominates for nonprofit, inducing firms to compete for the center yielding nil product differentiation. Importantly, this result holds even if only one of the two firms is nonprofit.

Overall, our findings suggest that Irmen and Thisse's minimal differentiation result in the dominated dimension extends to settings in which one or both firms are nonprofit. However, their maximal differentiation outcome in the dominant dimension breaks down if at least one of the firms is nonprofit. As suggested in our discussion of equilibrium prices, the presence of nil differentiation induces even for-profit firms to practice average cost pricing under large parameter conditions. Our results, hence, suggest that the presence of at least one nonprofit firms leads to minimal differentiation in products and services, subsequently strengthening price competition.

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[10] A similar outcome applies when firm B is the only nonprofit, $\theta_B = 0$ and $\theta_A = 1$, whereby firm B chooses $b_2^* = 0$ for all a_2. Since $b \geq a$ by definition, firm A must choose a location $a_2^* = 0$, yielding nil product differentiation in this case too.

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