Advertising and strategic entry deterrence in pharmaceutical markets

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July 16, 2008

1 Introduction

Structure, conduct and performance of the pharmaceutical market may change substantially after the entry of new pharmaceuticals. From the societal perspective, the entry of generic and/or therapeutic substitutes is considered desirable, because entry increases the number of treatment alternatives, may introduce new and better treatments with lower side-effects for patients, and fosters price competition in monopolistic markets. From the perspective of incumbent producers, entry may not look so desirable because the firms simply have to adjust themselves to a more competitive environment with lower prices and profitability. Therefore, it may be in the interest of incumbent firms to take actions which reduce the likelihood of entry. In this article we examine firms' incentives to use advertising in entry prevention in pharmaceutical markets.

Empirical work on pharmaceutical markets has addressed the question whether advertising is a barrier to entry in pharmaceutical markets. Scott Morton (2000) studied the impact of advertising of branded pharmaceuticals on the number of generic pharmaceuticals. She finds that brand advertising has no significant influence on the number of generic pharmaceuticals and concludes that advertising is not a barrier to entry. In their study of 30 branded pharmaceuticals, Caves et. al (1991) observed that brand advertising is reduced prior to patient expiration. Without committing to either persuasive or informative view of advertising, the authors conclude that brand advertising does not limit generic competition after patents of branded pharmaceuticals expire.

Reduction in advertising expenditures prior to the entry of new goods does not necessarily imply that the incumbent firm accommodates to the entry of new goods. If advertising expands the market and has public good properties, the incumbent firm may be willing to reduce advertising for strategic reasons. In such circumstances, an increase in brand advertising prior to entry expands the market and increases the demand and profitability of the entering firm. Brand advertising may then increase the likelihood of entry, and, for strategic reasons, the incumbent firm may be willing to reduce advertising in order to deter entry. Such arguments may be particularly relevant in pharmaceutical markets, because empirical evidence shows that direct-to-consumer advertising of pharmaceuticals is a market-expanding public good (Iizuka and Jin, 2005, Rosenthal et. al, 2003).

Theoretical work on informative advertising and strategic entry deterrence gives partial support for the above type of argument. Schmalensee (1983) developed a model where the incumbent firm may use informative advertising to deter entry. The incumbent and the entrant compete in quantities in the post-entry equilibrium. Schmalensee (1983) showed that the incumbent firm distorts its advertising downwards from the monopoly advertising to deter entry. The assumption that firms compete in quantities is critical in the Schmalensee's model as the later work by Iishigaki (2000) has shown. Iishigaki shows that when the firms compete in prices instead of quantities the Schmalensee-type model has no equilibrium in which the incumbent firm deters entry.

Our goal is to contribute to relatively small theoretical literature studying advertising, pricing and entry in pharmaceutical markets. Brekke and Kuhn (2006), Brekke et. al (2007) have studied pricing and advertising in pharmaceutical markets using theoretical models. Brekke and Kuhn (2006) analyze advertising and pricing decisions of pharmaceutical firms when firms use both consumer- and physician-advertising in sales promotion. The authors do not address the question whether advertising prevents entry. Brekke et. al (2008) examine reference pricing using a model with endogenously determined entry, but the model does not contain advertising that the incumbent might use strategically to prevent entry.

Königbauer (2007) comes closest to our work. She examines the role of physician-oriented advertising as an entry-deterring devise in pharmaceutical markets. She studies a two-stage model, where the incumbent chooses price and advertising expenditures in the first stage, and entry and pricing decisions are made in the second stage. Königbauer derives a post-entry price equilibrium in which the branded pharmaceutical is priced higher than the generic pharmaceutical. Given complexity of the model, she examines brand advertising and welfare using numerical analysis. One of the conclusions is that the probability of entry is not affected by the advertising cost.

Our work complements Königbauer's (2007) results. We examine a model in which the entrant can choose both advertising and price. We show that the entry of a potential entrant can either be blockaded, deterred or accommodated in an equilibrium and derive conditions for all these three cases. Unlike Königbauer (2007), we find that the cost of advertising has an impact on the market equilibrium. The higher is the advertising cost, more likely it is that the incumbent firm accommodates to the entry of a new pharmaceutical. Basic intuition of the result is straightforward. A high advertising cost means that it is costly to use advertising to deter or blockade entry and, therefore, the incumbent firm is better off adjusting to the market entry of new pharmaceuticals.

From the perspective of empirical work it is also important to have clear predictions on what kind of advertising behavior of the incumbent firm indicates that the firm aims at deterring or accommodating to entry. According to our results, the incumbent firm deters (accommodates to) entry by distorting advertising upwards (downwards) from the monopoly advertising. Empirical observation that branded pharmaceuticals reduce their advertising prior to the expiration of patents (Caves et. al, 1991) would then indicate that firms accommodate to the entry of generic pharmaceuticals.

The rest of the article is organized as follows. The following section displays the economic model. Section 3 examines the monopoly equilibrium. Section 4 studies the entry model and presents the main results of this article. Section 5 concludes the paper.

2 The model

Consider a pharmaceutical market with an incumbent firm (firm 1) and a potential entrant (firm 2). The incumbent firm is the firm producing a branded pharmaceutical. The entrant can be a producer of another branded pharmaceutical or a the producer of a generic pharmaceutical. The entrant selling a branded pharmaceutical may enter the market before the patent of the incumbent firm has expired, but generic entry is possible only after the patent of pharmaceutical 1 has expired.

We examine an extensive form which is typically used in the literature of strategic entry deterrence (see Schmalensee, 1983, Ishigaki, 2000). The strategic game between the two firms begins (Stage 1) when firm 1 chooses its (real) advertising a_1. We analyze advertising with durable effects (Schmalensee, 1983). Berndt et al. (1995) provide empirical evidence from pharmaceutical market which supports this assumption. Because of these features, advertising can also be used to deter entry.

Once decided, advertising of firm 1 becomes commonly known. In the second stage, the entrant decides whether or not to enter the pharmaceutical market. Let $e \in \{0, 1\}$ denote the entry decision of the entrant, where $e = 1$ indicates that the firm enters the market. The entry cost of firm 2 is $ef_2 > 0$, where f_2 is a fixed setup cost of the entrant. If the entrant chooses to enter, the firm also selects advertising expenditure a_2.

Post-entry prices are announced in Stage 3. If entrant has not entered the pharmaceutical market, the incumbent firm chooses the price p_1. If the entrant has entered the market, price competition between the firms takes place and they simultaneously choose prices $p \equiv (p_1, p_2)$. We analyze sub-game perfect Nash equilibrium points of this extensive-form game.

We consider a patient population with size n. Health state θ is assumed to be $U(0, 1)$-distributed with total mass n.[1] A patient at health state θ obtains health benefit $v - td(\theta, l_i)$ by consuming pharmaceutical i. The parameter v denotes the maximum health benefit that patients may obtain from the consumption of a pharmaceutical. The side-effects of pharmaceutical i are measured by the term $td(\theta, l_i)$, where $t > 0$ measures the strength of side-effects and l_i is the location of pharmaceutical i in the unit interval. Side effects are zero if $d(\theta, l_i) = 0$ and the patient ends up consuming pharmaceutical i that perfectly matches the patient's health state. In terms of the locations, we assume maximum product differentiation, that is, pharmaceutical 1 is located at $l_1 = 0$ and pharmaceutical 2 at the location $l_2 = 1$. We apply the linear distance function $d(\theta, l_i) = \mid \theta - l_i \mid$.

A patient at health state θ obtains utility

$$U(i, p_i, a_i; \theta) = v + \alpha a_i - td(\theta, l_i) - \lambda p_i + b, \tag{1}$$

if prescribed pharmaceutical $i = 1, 2$.[2] The parameter λ denotes the copayment rate. If the patient is prescribed an outside option with instructions on health, diet and exercise, he obtains a fixed reservation utility which is normalized to zero.

All patients visit a physician, to whom prescription decisions are delegated. The parameter b denotes the net surplus that a visiting patient derives from the physician visit. The physician is paid a regulated net payment f per each visiting patient. We assume that the physician observes the health state of a visiting patient[3] and knows the health benefit

[1] The size of the economy increases by replication of patients.

[2] The utility function has been used in the quality competition literature. The model was first used by Economides (1984). Later Ma and Burgess (1993), Barros and Martines-Xiralt (2002), Brekke et. al (2006), and Miraldo (2007) have applied the model to examine location, quality and price competition of duopoly firms in both regulated and unregulated markets.

[3] The physician may have to diagnose the patient in order to learn θ. We assume that any costs due to diagnosis are fixed and accounted for in the net payment f.

$v - td(\theta, l_i)$ and the out-of-pocket payment λp_i of pharmaceutical $i = 1, 2$. The physician-oriented advertising causes the physician, either correctly or incorrectly, to re-value the effectiveness of pharmaceutical treatments upwards. Empirical results by Iizuka and Jin (2005) show that physician-oriented advertising significantly affects prescription decisions.

When deciding about the treatment, the physician compares the three treatment alternatives with each other and chooses the treatment that provides the highest utility. The physician obtains utility

$$V(i, p_i, a_i, \theta) = f + v + a_i - td(\theta, l_i) - \lambda p_i, \tag{2}$$

if she prescribes pharmaceutical $i = 1, 2$ to a patient at health state θ, and utility f if she prescribes the outside option.

The parameter $\alpha \in \{0, 1\}$ in the utility function (1) measures the effectiveness of the physician-oriented advertising on the utility of patients. We allow physician-oriented advertising to be either persuasive (Dixit and Norman, 1978) or complementary (Stigler and Becker, 1977). Persuasive advertising creates spurious product differentiation but it has not real welfare effects (see e.g. Bagwell, 2007). We say that physician-oriented advertising is persuasive, if $\alpha = 0$. Complementary advertising has positive welfare effects (see Stigler and Becker, 1977), because advertising is used to produce final goods. In our case, final goods are health benefits, which are produced with pharmaceuticals and advertising that contains useful information about the use of pharmaceuticals. We say that the physician-oriented advertising is complementary, if $\alpha = 1$.

Pharmaceuticals are produced at constant marginal cost which is assumed to be zero. The fixed setup cost of firm 1 is f_1. Assuming no discounting, the profit functions of the incumbent and the entrant are

$$\pi_1(p, a, e) = ep_1 D_1(p, a) + (1 - e)p_1 D(p_1, a_1) - \gamma c(a_1) - f_1 \tag{3}$$

and

$$\pi_2(p, a, e) = e(p_2 D_2(p, a) - \gamma c(a_2) - f_2), \tag{4}$$

respectively. Here $a \equiv (a_1, a_2)$ denotes advertising strategies of the two firms. The function $D_i(p, a)$ is the demand function of pharmaceutical i in case the entrant has entered the market, and $D(p_1, a_1)$ is the demand for pharmaceutical 1 if the entrant has not entered the market.

The cost of real advertising a_i is $\gamma c(a_i)$ with $\gamma > 0$. We assume throughout that $c(a)$ is a continuously differentiable, strictly increasing and strictly convex function with $c'(0) = 0$.

In search for sub-game perfect Nash equilibrium points, we also utilize the quadratic form $c(a) = (1/2)a^2$.

3 Monopoly equilibrium

Following Schmalensee (1984) and Iischigaki (2000), we begin the analysis of the model by first analyzing the price and advertising behavior of firm 1 not threatened by entry. We provide the full analysis of the monopoly equilibrium in a sequential setting similar to that of the entry model. The monopoly firm first selects advertising expenditures a_1 and, subsequent to that, the firm sets the price of pharmaceutical 1. The sequential analysis of the monopoly market is an essential part of the entry model, which will be analyzed in the next section.

In the monopoly market, the prescribing physician faces a choice between pharmaceutical 1 and the outside option. Because the physician income does not depend on the prescribed treatment, the objective of the physician can be defined as

$$\max_{\{1,0\}}\{v + a_1 - t\theta - \lambda p_1, 0\}. \tag{5}$$

Physician prescribes pharmaceutical 1 to patients in the worst health states. The fraction of patients prescribed pharmaceutical 1 is

$$\sigma^1(p_1, a_1) = (1/t)(v + a_1 - \lambda p_1), \tag{6}$$

if the price of the pharmaceutical satisfies the condition $(1/\lambda)(v-t+a_1) < p_1 < (1/\lambda)(v+a_1)$. If the price of pharmaceutical 1 is high and the condition $p_1 \geq (1/\lambda)(v + a_1)$ holds true, the physician opts for the outside option and the demand for the incumbent pharmaceutical is zero. On the other hand, if the price of pharmaceutical 1 is sufficiently low and $p_1 \leq (1/\lambda)(v - t + a_1)$, the physician prescribes pharmaceutical 1 to all patients. The demand for the incumbent pharmaceutical can be defined as

$$D(p_1, a_1) = \begin{cases} n, & \text{if } p_1 \leq (1/\lambda)(v - t + a_1) \\ n\sigma^1(p_1, a_1), & \text{if } (1/\lambda)(v - t + a_1) < p_1 < (1/\lambda)(v + a_1) \\ 0, & \text{otherwise.} \end{cases} \tag{7}$$

The profit function of firm 1 is $\pi_1(p_1, a_1) = p_1 D(p_1, a_1) - \gamma c(a_1) - f_1$.

Let us first consider the determination of the monopoly price, denoted $p_1^m(a_1)$. The profit function of firm 1 is a strictly concave function in the interval $(1/\lambda)(v - t + a_1) < p_1 <$

$(1/\lambda)(v + a_1)$. Assuming that the monopoly price belongs to that interval, the first-order condition

$$\sigma^1(p_1, a_1) + p_1 \frac{\partial \sigma^1(p_1, a_1)}{\partial p_1} = 0 \tag{8}$$

can be solved to obtain the monopoly price $p_1^m(a_1) = (1/(2\lambda))(v + a_1)$. The monopoly price falls into the assumed interval if $p_1^m(a_1) > (1/\lambda)(v - t + a_1)$. This condition is satisfied when the physician-oriented advertising of the incumbent firm is sufficiently low and $a_1 < 2t - v$. In that case firm 1 prices its pharmaceutical so that the physician prescribes the outside option to some patients at the highest health states. The outside option is a better treatment than pharmaceutical 1 for these patients, because the side-effects of pharmaceutical 1 causes the treatment utility of pharmaceutical 1 to be negative. In other words, firm 1 does not serve the whole market and market is not covered.

When advertising of firm 1 is high and $a_1 \geq 2t - v$, the market is covered at the price $p_1^m(a_1)$. The incumbent firm is now better off increasing its price upwards from $p_1^m(a_1)$, because the profit $p_1 n - \gamma c(a_1)$ is linearly increasing in price p_1 for all price levels below $(1/\lambda)(v - t + a_1)$. For prices higher than the threshold value $(1/\lambda)(v - t + a_1)$, the profit of firm 1 is strictly decreasing in price p_1, because the condition $a_1 \geq 2t - v$ implies that $p_1^m(a_1) \leq (1/\lambda)(v - t + a_1)$. Therefore, the monopoly price is $p_1^m(a_1) = (1/\lambda)(v - t + a_1)$ for all levels of advertising of firm 1 such that $a_1 \geq 2t - v$.

To sum up the above analysis, the monopoly price is

$$p_1^m(a_1) = \begin{cases} (\frac{1}{2\lambda})(v + a_1), & \text{if } a_1 < 2t - v \\ (\frac{1}{\lambda})(v - t + a_1), & \text{otherwise.} \end{cases} \tag{9}$$

The incumbent pharmaceutical is consumed by the fraction $\sigma^1(p_1^m(a_1), a_1) = (1/(2t))(v + a_1)$ of patients if $a < 2t - v$, and the market is covered if $a_1 \geq 2t - v$. The corresponding maximum profit of firm 1 is

$$\tilde{\pi}_1^m(a_1) \equiv \pi_1(p_1^m(a_1), a_1) = \begin{cases} (\frac{n}{4\lambda t})(v + a_1)^2 - \gamma c(a_1) - f_1, & \text{if } a_1 < 2t - v \\ (\frac{n}{\lambda})(v - t + a_1) - \gamma c(a_1) - f_1, & \text{otherwise.} \end{cases} \tag{10}$$

Let us then consider the determination of advertising in the monopoly market. If the monopoly advertising, denoted a_1^m, satisfies the condition $a_1^m < 2t - v$ and the first part of the profit is a concave function in advertising, the monopoly advertising must satisfy the first-order condition

$$(\frac{n}{2\lambda t})(v+a_1) - \gamma c'(a_1) = 0. \tag{11}$$

In this case, the market is not covered in the monopoly equilibrium. On the other hand, if the monopoly advertising is sufficiently large and satisfies the condition $a_1^m \geq 2t - v$, it can be solved from the first-order condition

$$(\frac{n}{\lambda}) - \gamma c'(a_1) = 0. \tag{12}$$

In this case the market is covered in the monopoly equilibrium.

We next utilize the quadratic advertising cost function and give a detailed characterization of the monopoly advertising in Proposition 1 below. The results show that for combinations of low maximum health benefit and high advertising cost, monopoly advertising can be found as a solution of the first-order condition (11) but when the maximum health benefit increases and/or the cost of advertising decreases the monopoly advertising is determined as the solution of the first-order condition (12).

Proposition 1 *Suppose that $c(a_1) = (1/2)a_1^2$. If the conditions $0 < v < (2t)[(2\lambda t\gamma - n)/(2\lambda t\gamma)]$ and $\gamma > (n/(2\lambda t))$ hold true, the market is not covered in the monopoly equilibrium, and monopoly advertising and profit are $a_1^m = (vn)/(2\lambda t\gamma - n)$ and $\pi_1^m(a_1^m) = (v^2 n\gamma)/(2\lambda t\gamma - n) - f_1$, respectively. Otherwise, the market is covered in the monopoly equilibrium, and monopoly advertising and profit are $a_1^m = n/(\lambda\gamma)$ and $\pi_1^m(a_1^m) = (v-t)(n/\lambda) + (1/(2\gamma))(n/\lambda)^2 - f_1$, respectively.*

Proof. See Appendix.

4 Entry model

We next examine subgame-perfect Nash equilibrium (SPNE) points of the entry model introduced in Section 2. We begin from the end of the model, first analyzing the pricing decisions of the firms.

4.1 Price setting after entry

If firm 2 does not enter the market, we can use the results from the above section 3. The equilibrium price in the monopoly equilibrium is $\tilde{p}_1(a_1) = p_1^m(a_1)$ as defined in (9), and the equilibrium profit of firm 1 is the monopoly profit $\tilde{\pi}_1(a_1) = \pi_1^m(a_1)$ given by equation (10).

More interesting is the sub-game, which begins after the entrant has entered the market and chosen advertising. In this sub-game the two firms engage in price competition. Advertising choices of the two firms have been made previously. Let us denote the advertising difference between firm 1 and firm 2 $\Delta \equiv a_1 - a_2$. In order to derive Nash equilibrium prices for each possible pair of advertising strategies $(a_1, a_2) \in R_+^2$, we first consider the cases where the incumbent firm advertises more than the entrant and $a_1 \geq a_2 \geq 0$. The remaining cases where the entrant advertises more and $a_2 > a_1 \geq 0$ will be considered below.

The prescribing physician now faces the problem

$$\max_{\{1,2,0\}} \{v + a_1 - t\theta - \lambda p_1, v + a_2 - t(1-\theta) - \lambda p_2, 0\}. \tag{13}$$

Let θ_{st} be the value of the health state which makes the physician indifferent between treatments s and t. The relevant values are given as:

$$\theta_{12} = (\frac{1}{2t})(\Delta - \lambda(p_1 - p_2) + t), \tag{14}$$

$$\theta_{01} = (\frac{1}{t})(v + a_1 - \lambda p_1), \tag{15}$$

and

$$\theta_{02} = (\frac{1}{t})(\lambda p_2 + t - v - a_2). \tag{16}$$

Assuming that each patient is prescribed either one of the pharmaceuticals and the market is divided between the two pharmaceuticals, the fraction $\sigma^1(p, a) = \theta_{12}$ of patients end up consuming pharmaceutical 1 and the fraction $\sigma^2(p, a) = 1 - \theta_{12}$ of the patients consume pharmaceutical 2. The demand for pharmaceutical $i = 1, 2$ is $D_i(p, q, a) = n\sigma^i(p, a)$, and the profit function of firm i is

$$\pi^i(p, a) = p_i D_i(p, a) - \gamma c(a_i) - f_i. \tag{17}$$

The two assumptions that the market is covered and served by the two firms need not hold true. An increase in the price of pharmaceutical 1, for example, may first lead to a situation in which the physician the chooses the outside option for patients in the worst health states and, finally, to a situation in which only the entrant has a positive market share. A priori, we do not assume either of these conditions to hold true in equilibrium but derive the best-response functions and Nash equilibrium points in price competition between the two firms. Lemma 1, below, displays the Nash equilibrium points of the price game and also the conditions under which the market is covered in an equilibrium.

Lemma 1 *Assume $v > 3t$ and $a_1 \geq a_2$. Then Nash equilibrium equilibrium prices are profits are*

$$\tilde{p}_i(a) = (\frac{1}{3\lambda})(3t - (-1)^i\Delta) \tag{18}$$

$$\tilde{\pi}_i(a) = (\frac{n}{18\lambda t})(3t - (-1)^i\Delta)^2 - \gamma c(a_i) - f_i \tag{19}$$

for $i = 1, 2$ if $0 \leq \Delta < 3t$, and Nash equilibrium prices and profits are

$$\tilde{p}_i(a) = (2 - i)(1/\lambda)(\Delta - t) \tag{20}$$

$$\tilde{\pi}_i(a) = (2 - i)(\frac{n}{\lambda})(\Delta - t) - \gamma c(a_i) - f_i \tag{21}$$

for $i = 1, 2$ if $3t \leq \Delta$. In both equilibrium points the market is covered.

Proof. See Appendix.

The symmetry of the problem implies that, in case firm 2 was the firm selling the more-advertised pharmaceutical and $a_2 \geq a_1$, Nash equilibrium prices and profits are

$$\tilde{p}_i(a) = (\frac{1}{3\lambda})(3t - (-1)^i\Delta) \tag{22}$$

$$\tilde{\pi}_i(a) = (\frac{n}{18\lambda t})(3t - (-1)^i\Delta)^2 - \gamma c(a_i) - f_i \tag{23}$$

for $i = 1, 2$ if $0 \leq -\Delta < 3t$, and Nash equilibrium prices and profits are

$$\tilde{p}_i(a) = (i - 1)(1/\lambda)(-\Delta - t) \tag{24}$$

$$\tilde{\pi}_i(a) = (i - 1)n(1/\lambda)(-\Delta - t) - \gamma c(a_i) - f_i \tag{25}$$

for $i = 1, 2$ if $3t \leq -\Delta$.

In both Nash equilibrium points the pharmaceutical market is covered, which follows from a sufficiently high maximum health benefit. The first equilibrium point is an interior equilibrium in which both firms have strictly positive market shares. The prices of the two pharmaceuticals differ from each other if there are differences in the firms' advertising. In the second equilibrium, the difference in physician-oriented advertising between the two pharmaceuticals is so high that only the highly-advertised pharmaceutical is prescribed.

Throughout the following analysis, we will assume that the condition $v > 3t$ holds true. This condition is sufficient to ensure that the market is covered in a duopoly equilibrium. In addition, the condition can also be given another interpretation. The condition places an upper bound for product differentiation in the following sense. When $v > 3t$, the ratio of minimum and maximum health benefit $(v-t)/v$ must be at least 2/3. Clearly, product differentiation bounded from above. This condition allows us to interpret the model also as a strategic interaction between branded and generic pharmaceuticals.

4.2 Entrant's advertising and entry

Let us then examine decision-making of the entrant who has entered the market and is considering how much to spend on physician-oriented advertising. The Stage 2 profit function of the entrant, conditional on entry, is

$$\tilde{\pi}_2(a) =$$
$$\begin{cases} (\frac{n}{\lambda})(-\Delta - t) - \gamma c(a_2) - f_2, & \text{if } a_2 \geq a_1 + 3t \\ (\frac{n}{18\lambda t})(3t-\Delta)^2 - \gamma c(a_2) - f_2, & \text{if } \max\{0, a_1 - 3t\} < a_2 < a_1 + 3t \\ -\gamma c(a_2) - f_2, & \text{otherwise.} \end{cases} \tag{26}$$

If advertising of the generic entrant is low relative to that of the incumbent firm, the entrant has zero market share in price competition between the two firms. Equivalently, if advertising of the entrant is high relative to advertising of firm 1, the entering firm becomes the monopoly firm in price competition. For intermediate levels of advertising of the entrant, that is when $\max\{0, a_1 - 3t\} < a_2 < a_1 + 3t$, both firms have strictly positive market shares in the ensuing price competition.

Sufficiently high cost of advertising guarantees that the entrant is not willing to launch an aggressive advertising campaign which leaves no demand for pharmaceutical 1 when firms engage in price competition. The following Lemma displays a condition for this to take place and also characterizes the best response function and the corresponding maximum profit of the entrant. Later, we use the quadratic cost function and derive the best response function of the generic firm also in cases where the aggressive advertising campaign is a desirable option for the entering firm.

Lemma 2 *Suppose that the condition $\gamma \geq n/(c'(3t)\lambda)$ holds true and the second part of the firm 2's profit function is a concave function in firm 2's advertising. If $a_1 < 3t$, the best response of the entrant, denoted $a_2(a_1)$, satisfies the first-order condition*

$$(\frac{n}{9\lambda t})(3t + a_2 - a_1) - \gamma c'(a_2) = 0$$

and, if $a_1 \geq 3t$, the best response of the entrant is not to advertise and $a_2(a_1) = 0$. The maximum profit of the entrant

$$\tilde{\pi}_2(a_1, a_2(a_1)) = \frac{n}{18\lambda t}(3t + a_2(a_1) - a_1)^2 - \gamma c(a_2(a_1)) - f_2$$

is strictly decreasing in a_1 for all $a_1 < 3t$, and the maximum profit is $-f_2$ for all $a_1 \geq 3t$.

Proof. See Appendix.

Having determined the maximum profit of the entrant, we can then analyze the entry decision of the entering firm. If $a_1 \geq 3t$, firm 2 does not enter the market, because the firm earns a strictly negative profit. Advertising of firm 1 must be below $3t$ for entry to occur. On the other extreme, firm 2 never enters, if the firm earns negative profit when firm 1 does not advertise. To rule out this possibility, we assume $\tilde{\pi}_2(0, a_2(0)) > 0$. Then it is possible to conclude that there is a limit-advertising strategy of firm 1, denoted a_1^l,[4] such that the maximum profit of the entrant is (strictly) positive for all $a_1 < a_1^l$ and the maximum profit is negative for $a_1 \geq a_1^l$. The entrant enters if and only if $a_1 < a_1^l$.

When the advertising cost is quadratic, the condition of Lemma 2 holds true when $\gamma \geq n/(3\lambda t)$. This is also a sufficient condition to ensure that the profit function of firm 2 is a strictly concave function in the firm 2's advertising. From the first-order condition in Lemma 2 we obtain the best-response function $a_2(a_1) = (n(3t - a_1)/(9\lambda t\gamma - n))$ for all $a_1 < 3t$. The best response of firm 2 is $a_2(a_1) = 0$ for all $a_1 \geq 3t$. The maximum profit of firm 2 is given as

$$\tilde{\pi}_2(a_1, a_2(a_1)) = (\frac{n\gamma}{2})\frac{(3t - a_1)^2}{(9\lambda t\gamma - n)} - f_2 \tag{27}$$

for all $a_1 < 3t$, and the maximum profit is $\tilde{\pi}_2(a_1, a_2(a_1)) = -f_2$, otherwise. The limit-advertising strategy a_1^l is now given by

$$a_1^l = 3t - (\frac{1}{n\gamma})\sqrt{2f_2(n\gamma)(9\lambda t\gamma - n)}. \tag{28}$$

The entrant enters the market if and only if advertising of firm 1 is less than the limit-advertising. To keep the model interesting, we assume that $f_2 < ((3t)^2 n\gamma)/[2(9\lambda t\gamma - n)] \equiv f_2^0$. If the condition did not hold true, firm 2 would earn negative profit for any advertising of firm 1 and, hence, the firm would not enter the market in any circumstances.

[4]By Lemma 2 the maximum profit is a strictly decreasing function in a_1. Firm 2 earns strictly positive profit at $a_1 = 0$ and the profit of firm 2 is strictly negative at $a_1 = 3t$. Continuity of the maximum profit follows from the maximum theorem (when finding the value of a_2 which maximizes the profit of firm 2, the objective function is a continuous function and the feasible set $[0, 3t + a_1]$ (without loss one can concentrate even on the set $[0, 3t]$) is a compact set for all $0 \leq a_1 \leq 3t$. Therefore $a_2(a_1)$ is continuous.

With quadratic advertising cost we can extend the result of Lemma 2 for all γ's. Results of Lemma 2 apply for the cases where $\gamma > n/(3\lambda t)$. Proof of Lemma 3 demonstrates that, if $\gamma \leq n/(8\lambda t)$, the best response of firm 2 is the monopoly advertising $n/(\gamma\lambda)$[5] for low levels of firm 1 advertising and no-advertising strategy for high levels of firm 1 advertising. Proof of Lemma 3 also demonstrates that, if $n/(8\lambda t) < \gamma \leq [(11+\sqrt{13})/(54)](n/(\lambda t))$, the best response of firm 2 is defined in three parts. For low levels of firm 1 advertising, the best response of firm 2 is $n/(\gamma\lambda)$ and, for intermediate levels of firm 1 advertising, the best response is $(n(3t - a_1))/(9\lambda t\gamma - n)$, and, finally, for high levels of firm 1 advertising, the optimal response of firm 2 is not to advertise.

Lemma 3, below, displays the case in which $\gamma \leq n/(8\lambda t)$. This result will be used in the following section together with the above-examined case of costly advertising to study the incentives of firm 1 to deter entry of firm 2.

Lemma 3 *Suppose that $\gamma \leq n/(8\lambda t)$. Then the best response function of firm 2 is*

$$a_2(a_1) = \begin{cases} n/(\lambda\gamma), & \text{if } 0 \leq a_1 \leq n/(2\lambda\gamma) - t \\ 0, & \text{otherwise} \end{cases}$$

The maximum profit of firm 2 is $\tilde{\pi}_2(a_1, a_2(a_1)) = (n/\lambda)[(n/2\lambda\gamma) - t - a_1] - f_2$, if $a_1 \leq (n - 2\lambda t\gamma)/(2\lambda\gamma)$, and $\tilde{\pi}_2(a_1, a_2(a_1)) = -f_2$ otherwise.

Proof. See Appendix.

For the low-cost advertising, the limit-advertising is given by

$$a_1^l = \frac{n}{2\lambda\gamma} - t - (\frac{\lambda}{n})f_2. \tag{29}$$

As above, we assume that the fixed entry cost is sufficiently low, that is $f_2 \leq (n/\lambda)[(n - 2\lambda t\gamma)/(2\lambda\gamma)]$, so that firm 2 has some possibilities to enter the market.

4.3 Advertising of the incumbent firm

Our main interest in this section is to analyze advertising choices of the incumbent firm. Is the firm willing to deter the entry of firm 2 or should we rather observe that the incumbent firm accommodates to entry. We analyze these questions first concentrating on the case of costly advertising.

[5]This advertising is obtained by maximizing the profit of firm 2 $(1/\lambda)(a_2 - a_1 - t) - (\gamma/2)a_2^2$, which is the monopoly profit of firm 2 when the difference $a_2 - a_1$ is sufficiently large.

4.3.1 Costly advertising

We first concentrate on the situation in which the cost of advertising is so high that the entering firm 2 is not willing to engage in aggressive advertising campaign. To ensure this we assume that the condition $\gamma > n/(3\lambda t)$ holds true.

The reduced-form profit function of firm 1 is defined as

$$\tilde{\pi}_1(a_1, a_2(a_1)) = \begin{cases} (\frac{n}{18\lambda t})(3t + a_1 - a_2(a_1))^2 - \gamma c(a_1) - f_1, & \text{if } a_1 < a_1^l \\ (\frac{n}{\lambda})(v - t + a_1) - \gamma c(a_1) - f_1, & \text{if } a_1 \geq a_1^l. \end{cases} \tag{30}$$

If the incumbent firm chooses advertising which satisfies the condition $a_1 < a_1^l$, firm 2 earns strictly positive profit and enters the market. The profit function that corresponds to such advertising levels is denoted $\tilde{\pi}_1^s(a_1, a_2(a_1))$ and is called duopoly profit function.[6] If the equilibrium advertising of firm 1 is lower than the limit-advertising, the incumbent firm accommodates to the entry of firm 2. The second part of the firm 1's profit, denoted $\tilde{\pi}_1^m(a_1)$ and called the monopoly profit function, corresponds to those levels of firm 1 advertising which keep the entrant out of the market. If the equilibrium advertising of firm 1 exceeds the limit-advertising, the firm either blockades or deters the entry of firm 2.

Section 3 provided a thorough analysis of the monopoly profit function. If the monopoly profit is maximized without the constraint $a_1 \geq a_1^l$, the unconstrained maximum of the monopoly profit function is obtained at the monopoly advertising $a_1^m = n/(\lambda\gamma)$, and the corresponding monopoly profit is $\tilde{\pi}_1^m(a_1^m)$ (See Proposition 1).

Let us then analyze the duopoly profit function. We first ignore the constraint $a_1 < a_1^l$ and analyze the unconstrained maximum of the duopoly profit function. The best response function of firm 2 is $a_2(a_1) = (n(3t - a_1))/(9\lambda t\gamma - n)$ under the quadratic advertising cost. The duopoly profit function can then be written as follows:

$$\tilde{\pi}_1^s(a_1, a_2(a_1)) =$$
$$(\frac{n}{18\lambda t})[(\frac{3t(9\lambda t\gamma - 2n)}{9\lambda t\gamma - n}) + (\frac{9\lambda t\gamma}{9\lambda t\gamma - n})a_1]^2 - (\gamma/2)a_1^2 - f_1. \tag{31}$$

Assuming that the duopoly profit function is a strictly concave function in firm 1 advertising, the unconstrained maximum of the duopoly profit function can be derived. The first-order condition for duopoly advertising, denoted a_1^s, is

$$(\frac{n\gamma}{(9\lambda t\gamma - n)^2})[3t(9\lambda t\gamma - 2n) + (9\lambda t\gamma)a_1] - \gamma a_1 = 0, \tag{32}$$

[6]Superscript s refers to the Stackelberg leader.

from which we obtain

$$a_1^s = \frac{(3t)n(9\lambda t\gamma - 2n)}{(9\lambda t\gamma - n)^2 - n(9\lambda t\gamma)}. \tag{33}$$

The maximum profit that firm 1 earns by choosing the advertising strategy a_1^s is

$$\tilde{\pi}_1^s(a_1^s, a_2(a_1^s)) = (\frac{n}{18\lambda t})\frac{(3t)^2(9\lambda t\gamma - 2n)^2}{(9\lambda t\gamma - n)^2 - n(9\lambda t\gamma)} - f_1. \tag{34}$$

To provide incentives for the incumbent firm not to exit the market, we assume throughout that the fixed setup cost of firm 1 is so low that the profit (34) is strictly positive.

The following lemma shows that when advertising is costly and $\gamma > n/(3\lambda t)$, the duopoly profit function is a strictly concave function in the firm 1's advertising. Under the same condition, it also holds true that the monopoly advertising exceeds the duopoly advertising. This property will be useful in the following analysis on strategic entry deterrence.

Lemma 4 *Duopoly profit function* $\tilde{\pi}_1^s(a_1, a_2(a_1))$ *is a strictly concave function in advertising* a_1 *and* $a_1^s < a_1^m$, *if* $\gamma > n/(3\lambda t)$.

Proof. See Appendix.

The comparison of the monopoly and duopoly profit functions reveals that for high values of firm 1 advertising the duopoly profit exceeds the monopoly profit. This is because the duopoly revenue is convex and increasing in the firm 1's advertising but the monopoly revenue is linear and increasing in advertising a_1. Lemma 5, below, shows that for relevant values of firm 1 advertising the desirable ranking between the monopoly and duopoly profits prevails. Again, this ranking will be used in the following analysis on strategic entry deterrence.

Lemma 5 $\tilde{\pi}_1^m(a_1) > \tilde{\pi}_1^s(a_1, a_2(a_1))$ *for all* $0 \leq a_1 \leq 3t$.

Proof. See Appendix.

Monopoly advertising is the best strategy for the incumbent firm if it keeps keeps the entrant out of the market. If that happens, the entry is said to be blockaded. Entry is blockaded by the monopoly advertising, if and only if the monopoly advertising exceeds the limit-advertising a_1^l. The following Proposition presents conditions for entry to be blockaded by the monopoly advertising. Entry is blockaded by the monopoly advertising, if the entry cost of firm 2 exceeds the threshold value displayed in the proposition.

Proposition 2 *Suppose that* $\gamma > n/(3\lambda t)$. *Then the entry of firm 2 is blockaded by the monopoly advertising, if*

$$f_2 \geq \frac{n(3\lambda t\gamma - n)^2}{2\lambda^2\gamma(9\lambda t\gamma - n)} \equiv f_2^1.$$

Proof. See Appendix.

If the monopoly advertising is lower than the limit-advertising strategy, the monopoly advertising induces firm 2 to enter the market. Now, the optimal strategy of firm 1 is either to adopt the limit-advertising strategy and deter the entry of firm 2 or accommodate to the entry of firm 2. The entry-deterrence strategy yields firm 1 the profit

$$\tilde{\pi}_1^m(a_1^l) = (\frac{n}{\lambda})(v + 2t - (\frac{1}{n\gamma})\sqrt{2\gamma f_2 n(9\lambda t\gamma - n)})$$
$$-(\frac{\gamma}{2})(3t - (\frac{1}{n\gamma})\sqrt{2\gamma f_2 n(9\lambda t\gamma - n)})^2. \quad (35)$$

On the other hand, firm 1 earns the maximum duopoly profit (34) by accommodating to the entry. The comparison of these two profit levels determines whether entry is deterred or accommodated. The following Proposition displays the precise conditions for these two cases to happen.

Proposition 3 *Suppose that* $\gamma > n/(3\lambda t)$ *and entry is not blockaded. Then*

1. *Firm 1 deters the entry of firm 2 by the limit-advertising strategy* a_1^l,
   (a) *if* $n/(3\lambda t) < \gamma \leq \gamma^1$ *and* $0 \leq f_2 < f_2^1$, *where* γ^1 *makes firm 1 indifferent between the strategy* $a_1 = 3t$ *and the strategy* a_1^s, *or*
   (b) *if* $\gamma > \gamma^1$ *and* $f_2^2 \leq f_2 < f_2^1$, *where* f_2^2 *makes firm 1 indifferent between the strategies* a_1^l *and* a_1^s.
2. *Firm 1 accommodates to the entry of firm 2 by choosing* a_1^s, *if* $\gamma > \gamma^1$ *and* $0 \leq f_2 < f_2^2$.

Proof. See Appendix.

Propositions 2 and 3 characterize the conditions under which the entry of firm 2 is either blockaded, deterred or accommodated by firm 1. The results suggest that the strategic behavior of firm 1 depends of the cost of advertising and the cost of entry in a sensible way. First, if the setup cost of firm 2 is high and satisfies the condition presented in Proposition 2, the entry of firm 2 is blockaded by the monopoly advertising of firm 1. For intermediate values of the entry cost, that is when $f_2^2 < f_2 < f_2^1$, firm 1 either deters or blockades the entry of firm 2 (see Proposition 3). And finally, for low levels of entry cost f_2, entry is either blockaded, deterred or accommodated by advertising of firm 1 (see Proposition 3). In this case, firm 1 accommodates to the entry of firm 2 if the cost of advertising is sufficiently high.

Let us then describe the equilibrium behavior of the firms in the entry game. If the entry of firm 2 is blockaded in equilibrium, the incumbent firm advertises and prices similarly as the firm would do without a threat from an entering firm. The incumbent firm chooses monopoly advertising $\tilde{a}_1^m$, the entrant decides not the enter the market, and the monopoly firm charges the monopoly price $p_1^m(\tilde{a}_1^m)$. In the blockaded entry case, the incumbent firm earns the monopoly profit $\tilde{\pi}_1^m(\tilde{a}_1^m)$, and the equilibrium profit of the entrant is zero.

Let us then consider the equilibrium in which entry is deterred. The incumbent firm uses the limit-advertising strategy $\tilde{a}_1^l$ of equation (28), the entrant responds optimally by not entering the market, and the incumbent firm charges the limit-price

$$p_1^m(\tilde{a}_1^l) = (\frac{1}{2\lambda})(v + 3t - (\frac{1}{n\gamma})\sqrt{2f_2(n\gamma)(9\lambda t\gamma - n)}). \tag{36}$$

Whenever used, the limit-advertising strategy $\tilde{a}_1^l$ exceeds the monopoly advertising a_1^m (see the proof of Proposition 3). Therefore, the equilibrium limit-price must also exceed the monopoly price. In the deterred-entry equilibrium, the incumbent firm earns the profit $\tilde{\pi}_1^m(\tilde{a}_1^l)$, which is lower than the monopoly profit. It is worth observing, however, that firm 1 never chooses an entry-deterrence strategy which yields the firm a negative profit, because firm 1 can always switch to the strategy a_1^s and earn the profit $\tilde{\pi}_1^s(a_1^s, a_2(a_1^s)) > 0$. Equilibrium profit of the entrant is again zero.

In the case of accommodated entry, the incumbent firm chooses duopoly advertising $\tilde{a}_1^s$ as defined in (33), the entrant responds optimally by entering the market and chooses advertising

$$\tilde{a}_2^s = a_2(\tilde{a}_1^s) = \frac{(3t)n(9\lambda t\gamma - 3n)}{(9\lambda t\gamma - n)^2 - n(9\lambda t\gamma)}. \tag{37}$$

When firm 1 accommodates to the entry of firm 2, the firm distorts its advertising downwards from the monopoly advertising (see Proposition 3). However, as the first-mover, the incumbent has a higher equilibrium advertising than the entrant. The two firms charge equilibrium prices $p_1(\tilde{a}_1^s, \tilde{a}_2^s) = (1/(3\lambda))(3t + \tilde{a}_1^s - \tilde{a}_2^s)$ and $p_1(\tilde{a}_1^s, \tilde{a}_2^s) = (1/(3\lambda))(3t + \tilde{a}_1^s - \tilde{a}_2^s)$. Because $\tilde{a}_1^s > \tilde{a}_2^s$, the equilibrium price of the incumbent is higher than the equilibrium price of the entrant. In equilibrium, firm 1 earns the profit (34), and the profit of firm 2 is

$$\tilde{\pi}_2^s(\tilde{a}_1^s, a_2(\tilde{a}_1^s)) = (\frac{n}{18\lambda t})\frac{(3t)^2(9\lambda t\gamma - 2n)^2\Gamma}{(9\lambda t\gamma - n)^2 - n(9\lambda t\gamma)} - f_2 \quad (38)$$

where

$$\Gamma = \frac{(9\lambda t\gamma - 3n)^2(9\lambda t\gamma)(9\lambda t\gamma - n)}{(9\lambda t\gamma - 2n)^2[(9\lambda t\gamma - n)^2 - n(9\lambda t\gamma)]}. \quad (39)$$

Now, it holds true that, for all $n/(3\lambda t) < \gamma < \infty$, the parameter Γ is increasing in γ, $\Gamma < 1$ and, moreover, $\Gamma \rightarrow 1$ when γ approaches infinity. Therefore, for all finite γ such that $n/(3\lambda t) < \gamma$ the entrant's profit net of entry cost is lower than the profit of the incumbent firm net of fixed setup cost.

Caves et. al (1991) find that brand advertising is reduced prior to patent expiration and conclude that brand advertising does not limit generic competition in pharmaceutical markets. The predictions of the current model are consistent with this empirical finding. When entry is accommodated by the incumbent firm, the firm distorts advertising downwards from the monopoly advertising.

Empirical studies also report that the prices of generic pharmaceuticals are lower than the prices of branded pharmaceuticals after the entry of generic pharmaceuticals (see Frank and Salkever, 1997 and Scherer, 2000). Moreover, branded firms may even raise their prices after the entry of generic firms, which has been called Generic Paradox. The above analysis suggests that differences in advertising and prices are due to first-mover advantage of the incumbent firm and product differentiation that this advantage creates.

4.3.2 Low-cost advertising

The above analysis has assumed a sufficiently high advertising cost. We relax this assumption now and examine the cases where the advertising cost is low. Low-cost advertising gives the entrant an incentive to use advertising which causes the market share of firm 1 to vanish but, on the other hand, low-cost advertising also gives the incumbent firm a cheap instrument which can be used to deter of blockade entry. Next, we show that the incumbent firm always blockades entry if the cost of advertising is low.

Let us first assume that $[(11+\sqrt{13})/(54)](n/(\lambda t)) < \gamma \leq n/(3\lambda t)$. The best response function of firm 2 is the same as that in the case of costly advertising (see Proof of Lemma 3) and, therefore, the results of Lemma 2 apply to the entrant. The condition $\gamma \leq n/(3\lambda t)$ implies that $a_1^m = n/(3\lambda t) \geq 3t$. But since the limit-advertising (29) is always less than $3t$, the monopoly advertising keeps the entrant out of the market. The entry is blockaded.

Let us next examine the case where $n/(8\lambda t) < \gamma \leq [(11+\sqrt{13})/(54)](n/(\lambda t))$. According to Lemma 3, firm 2 has the best response $a_2^1(a_1) = n/(\lambda\gamma)$ if $0 \leq a_1 \leq a_1^+$, where

$$a_1^+ = \frac{n - 6\lambda t\gamma + \sqrt{\lambda t\gamma(9\lambda t\gamma - n)}}{\lambda\gamma}, \tag{40}$$

and the best response $a_2^2(a_1) = (n(3t - a_1))/(9\lambda t\gamma - n)$ if $a_1^+ < a_1 < 3t$. If $a_1 \geq 3t$, firm 2 does not advertise. The limit advertising level of firm 2 may fall into the range $[0, a_1^+]$ or the range $[a_1^+, 3t]$ and is defined accordingly either by (27) or (29). In any case, the limit-advertising must fall into the range $[0, 3t]$, because for advertising $a_1 = 3t$ firm 2 earns strictly negative profit and for advertising $a_1 = 0$ the profit of firm 2 is strictly positive. The condition $\gamma < n/(3\lambda t)$ implies that $a_1^m > 3t$ and, again, it holds true that $a_1^l < a_1^m$. Similarly as above, entry is blockaded.

Let us finally consider the cases $\gamma \leq n/(8\lambda t)$. Lemma 3 displays the best response of the entrant. Firm 1 faces the profit function

$$\tilde{\pi}_1(a_1, a_2(a_1)) = \begin{cases} -\gamma c(a_1), & \text{if } a_1 < a_1^l \\ (\frac{n}{\lambda})(v - t + a_1) - \gamma c(a_1), & \text{if } a_1 \geq a_1^l, \end{cases} \tag{41}$$

where the limit advertising a_1^l is given by the equation (29).

If firm 2 enters the market, the best response of firm 2 is to launch an aggressive advertising campaign which drives the market share of firm 1 to zero in the following market competition. The best firm 1 can do in that case is to earn zero profit (net of any fixed costs) by not advertising. However, low-cost advertising affects positively firm 1 too, because the monopoly advertising of firm 1 is large. In fact, for all entry costs f_2

$$a_1^m = \frac{n}{\lambda\gamma} > \frac{n}{2\lambda\gamma} - t - (\frac{\lambda}{n})f_2 = a_1^l \tag{42}$$

and the entry of firm 2 is blockaded by the monopoly advertising. To summarize the above analysis, entry is blockaded when $\gamma \leq n/(3\lambda t)$.

5 Conclusions

The loss of monopoly position gives pharmaceutical firms an incentive to take actions which reduce the likelihood and profitability of entry. In this article we have examined whether incumbent producers in pharmaceutical markets use physician-oriented advertising as a strategic instrument to deter entry of new pharmaceuticals.

Results of our theoretical analysis suggest that the entry of new pharmaceuticals can be blockaded, deterred or accommodated in the market equilibrium. The incumbent firm accommodates to entry if the cost of advertising is high and the fixed setup cost, entry cost, of the entrant is low. If the advertising cost is low and the entry cost is high, the incumbent firm either deters or blockades the entry of a new pharmaceutical.

We also find that the monopoly advertising and pricing of the incumbent firm keep the entrant out of the market in the blockaded equilibrium. If the incumbent uses advertising to deter entry, the firm distorts its advertising and price upwards from the monopoly advertising and price. If the incumbent firm accommodates to the entry of a new pharmaceuticals, the firm distorts its advertising (and also price) downwards from the monopoly advertising. This last finding is consisted with empirical observations from the pharmaceutical markets.

Future research could examine two questions at the minimum. First, it would be important to examine pricing behavior of the two firms in a market that is not covered. In such a situation, entry of a new pharmaceutical might imply that some patients who were not consuming incumbent pharmaceutical (perhaps because of the monopoly price) might consume the entering pharmaceutical in the post-entry equilibrium. Welfare implications of such an equilibrium might be different from the welfare implications of a covered-market equilibrium. Secondly, one might also examine the welfare rankings of the blockaded, deterred and accommodated equilibrium points.

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