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STRAUME

PATENTS: INCENTIVES FOR R&D  
OR MARKETING?



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# Patents: Incentives for R&D or Marketing?\*

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## Abstract

We analyse how a patent-holding (incumbent) firm may strategically use advertising ex ante to affect the R&D investments in new (differentiated) products, and thus the ex post market structure in the industry. We derive exact conditions for advertising and R&D being substitute strategies for an incumbent firm and show that it may over-invest in advertising to reduce the incentive for an entrant to invest in R&D, thereby reducing the probability of a new product on the market. In this case, a more generous patent policy implies that a larger share of the patent rent is spent on marketing, relative to R&D. Our model, which is particularly fitted to the pharmaceutical industry, is analysed both within a general framework and in a more specific setting of informative advertising.

*Keywords:* Marketing; Research & Development; Pharmaceuticals

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# 1 Introduction

A patent protects the patent-holder from firms copying its product. In other words, patents restrict entry of homogeneous (identical) products for a given period, and thus provide the holder with some market power. It is important to notice, though, that patents seldom imply a complete monopolisation of a market. In most cases, it just implies that competing products must be sufficiently differentiated. Markets with patented products are thus typically characterised as oligopolistic markets with differentiated products.

The rationale behind patents is to stimulate firms to undertake R&D investments to discover new products by granting some degree of market power and thus returns on the investments. A generous patent system is likely to stimulate innovation strongly. However, there may be a flip-side of the coin. A generous patent system may also enable patent-holding firms to exhibit market power in a potentially detrimental way. In this paper, we analyse in detail how a patent-holding firm may strategically use advertising *ex ante* to affect the R&D investments in new products, and thus the *ex post* market structure in the industry. In particular, we show that a firm may over-invest in advertising to reduce the incentive for an entrant to invest in R&D and thus the probability of a new product on the market.

To analyse the interaction between advertising and R&D, we consider a market with potentially two horizontally differentiated products. We assume that one of the products – the ‘breakthrough’ product – has already been developed by a firm, which is thus a monopolist in the market. The second product in the market may or may not be discovered, depending on the amount of R&D investments incurred. In the R&D race there are two competitors: the incumbent monopolist and a potential entrant. We use a two-period model, where the breakthrough product is sold in both periods and the new product – if it is discovered – is sold in the second period only. Thus, we have potentially three different *ex post* market structures: (i) single-product monopoly if neither firm discovers the second product; (ii) multi-product monopoly if the incumbent wins the R&D race; and (iii) a duopoly if the entrant wins the R&D race. The game is analysed using both general functions and within a

standard informative advertising framework.

We focus attention towards markets where non-price competition is a key feature. Abstracting from pricing strategies enables us to focus closely on the relationship between advertising and R&D within a model where firms interact strategically.<sup>1</sup> Non-price competition is highly relevant for markets where prices are not set unilaterally by the seller, but instead regulated by (or negotiated with) a third-party. It is also important in markets where consumers pay only a small amount of the price due to (social or private) insurance coverage, welfare benefits, etc. Finally, non-price competition may also be relevant for markets characterised as semi-cartels (or by semi-collusion), where firms reach agreements (or collude) on price, but compete fiercely along other dimensions, like advertising, R&D or quality.

A prime example, which we use throughout the paper, is the pharmaceutical market. In this market patents of chemical compounds play a crucial role in terms of stimulating developments of new and more efficient drugs. Consequently, the pharmaceutical industry is very R&D-intensive. However, this industry is also one of the most advertising-intensive industries (Scherer and Ross, 1990). Marketing expenditures typically amount to 20-40 percent of sales revenues, often exceeding R&D expenditures. According to Schweitzer (1997) the marketing expenses for three of the largest US pharmaceutical companies – Merck, Pfizer, and Eli Lilly – ranged from 21 to 40% of annual sales revenues, while the R&D expenses varied between 11 and 15%.<sup>2</sup> The importance of the non-price strategies in the pharmaceutical market may be explained by the fact that most countries exert some sort of price control either directly by regulating the prices or indirectly via the reimbursement system. In addition, the demand for pharmaceuticals is quite price inelastic, which is mainly due to health insurance and/or physicians' ignorance of price in the prescription choice.

Our paper focuses on innovations of competing products (non-drastic innovations), and not on innovations of completely new products (drastic in-

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<sup>1</sup>There are several papers on patents that abstract from pricing strategies, see, e.g., Needham (1976), Waterson (1990), Langinier (2004).

<sup>2</sup>Similar figures are reported from Novartis and Aventis, the largest pharmaceutical companies in Europe. See also Zweifel and Breyer (1997) for figures in Germany and Switzerland.

novations). In the pharmaceutical industry a patent is granted for a drug's novel chemical composition rather than its therapeutic properties. Many new pharmaceuticals receive patents despite their being functionally similar to existing drugs. As such, their introduction expands physicians' choices and can pose a competitive threat to established drugs with the same or similar indications. Lu and Comanor (1998) find that all but 13 of 148 new branded chemical entities introduced in the US between 1978-87 had at least one fairly close substitute; the average number of substitutes being 1.86. Scherer (2000) reports that the number of drugs per symptom group ranged from 1 to 50, with a median of 5 drugs and a mean of 6.04. Thus, empirical evidence clearly demonstrates the importance of non-drastring product innovations.

We analyse in detail the incentives of the incumbent firm to use advertising, not only to increase the returns from innovations, but also to *strategically* reduce a potential entrant's incentive to invest in R&D to develop a competing product. The key mechanism in the relationship between advertising and R&D incentives is the incumbent's ability to influence ex post payoffs of the potential entrant through first-period advertising of the existing product.<sup>3</sup> Within a quite general framework we provide the conditions for advertising and R&D to be *substitute strategies* for the incumbent firm. We also identify the conditions for when over-investment in advertising by the incumbent firm occurs as an equilibrium outcome. Specialising the model to a standard informative advertising framework, as introduced by Butters (1977), we show that advertising and R&D are always substitute strategies for the incumbent firm. We also present numerical simulations to show that a more generous patent system tends to stimulate marketing incentives to a larger degree than R&D incentives.

Finally, we discuss some welfare and policy implications. In particular, we analyse welfare effects of a stricter regulation on advertising and a more generous patent system. These issues are especially relevant for the pharmaceutical industry, since most countries impose regulations on both marketing

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<sup>3</sup>This mechanism was observed by Needham (1976), who argued that an incumbent's pre-entry advertising influences the entry decision only if there is some link between pre-entry advertising and the entrant's post-entry expected profits.

and prices of prescription drugs. Applying the informative advertising model, we take the most positive view of advertising.<sup>4</sup> Our results suggest that strict regulation of advertising and strict price regulation (or a less generous patent system) are policy substitutes. This means that a strict price regulation (or patent) system should be matched with lenient regulation of advertising, and vice versa.

Our paper is related to the literature on advertising and entry. In his seminal paper, Schmalensee (1983) considers a homogenous-product market served by an incumbent with a potential entrant. He analyses the following three-stage game: at stage 1 the incumbent sends out ads to consumers; at stage 2 the entrant decides whether or not to enter, and if entry occurs, the entrant sends out its own ads. Finally, at stage 3 active firms play some simultaneous-move oligopoly game.<sup>5</sup> The main result is that the incumbent can deter entry, but it does so by strategically *under-investing* in advertising.

Another seminal paper is Fudenberg and Tirole (1984). They assume products to be differentiated, and analyse the following two-period model: in the first (pre-entry) period, the incumbent chooses a fraction of consumers to inform, which becomes the incumbent's captive market. In the second period, the incumbent and the entrant compete for the non-captive market through price competition. They find that the incumbent will under-invest in advertising ('lean and hungry look') if it chooses to deter entry, because this establishes a credible threat to cut prices in the event of entry. Conversely, if the established firm chooses to allow entry, it will advertise heavily and become a 'fat cat' in order to soften the entrant's pricing behaviour.

Together, these papers suggest the following striking conclusion: the incumbent does not deter entry by investing more in advertising than it would if there were no threat of entry.<sup>6</sup> Thus, there is no formal support for strategic

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<sup>4</sup>If we assumed advertising to be purely persuasive, a complete ban on advertising is more likely to be socially beneficial. In most cases, including pharmaceutical marketing, advertising contains elements of both persuasion and information.

<sup>5</sup>Schmalensee (1983) observes that if entry occurs and firms set prices, then a pure-strategy Nash equilibrium does not exist. Accordingly, he assumes that firms compete in quantities. Ishigaki (2000) characterises the mixed-strategy pricing equilibria induced by entry, and finds that entry is either blockaded or accommodated.

<sup>6</sup>Despite several similarities, this result is contrary to the production capacity literature.

over-investment in advertising by the incumbent firm. Notice that the incumbent can credibly threaten not to *decrease* its investment since such reductions are infeasible. In these models, advertising is a durable investment since buyers never forget the ads they receive. However, the incumbent can always *increase* its advertising ex post if this is profitable. This rises a concern whether the incumbent can *credibly* commit to under-investing in advertising. Schmalensee (1983) observes this problem, but avoids it by making restrictions on the incumbent's advertising choices.<sup>7</sup> Fudenberg and Tirole (1984) also avoids this problem simply by making second-period advertising *exogenous*.

The present paper differs from the above mentioned contributions in several different respects. Our model is not an entry model as such, but entry is one possible outcome of an R&D contest. Furthermore, by focusing on non-price competition we establish incentives for *over-investment* in advertising by the incumbent firm, which contrasts with results for entry deterrence under price competition, as previously discussed. In doing so, we also enforce dynamic consistency by allowing the incumbent to re-optimize its advertising investment ex post (post-entry). More precisely, if it is profitable for the incumbent to advertise more heavily if entry occurs than if not, then it is never credible for the incumbent to under-invest in advertising ex ante. The potential entrant will foresee this and base its decision on the ex post advertising level.

Our paper also relates to more specific studies of pharmaceutical markets. In this field, the issue of advertising and entry has received considerable attention for a long period, especially from empirical studies, see, e.g., Hurwitz and Caves (1988), Grabowski and Vernon (1992), Caves et al. (1991), and Scott Morton (2000).<sup>8</sup> A common finding is that there is no evidence of entry deterring behaviour on the part of incumbents. However, all these papers are

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For instance, Dixit (1980) shows that the incumbent strategically overinvests in capacity in order to deter entry.

<sup>7</sup>The assumption that the incumbent can credibly commit not to increase its advertising after entry, is justified by Schmalensee (1983) as follows: "Under some conditions, destruction of the materials necessary to print more leaflets may serve to accomplish this" (p. 647). This is hardly very convincing.

<sup>8</sup>There are also two recent theoretical papers on advertising in the generic market, namely Cabrales (2004) and Königbauer (2004). Both model competition between branded and generic firms using a vertical product differentiation model. The latter explicitly analyses the entry decision, providing support for entry accommodating behaviour by the incumbent.



concerned about branded vs. generic competition, which means that they are considering competition between homogenous products or ‘artificially’ vertically differentiated products. To our best knowledge, there is no study that analyses advertising as device for restricting competition between branded (or patented) products, nor the effect of advertising on R&D investments.

Finally, our paper relates to the literature on patent races, and especially, that on monopoly persistence. The issue – which has been addressed by Gilbert and Newberry (1982) and Reinganum (1983), among others – is whether a monopolist in the product market is more likely to innovate than an entrant. The basic result from this literature is two-fold: (i) if the innovation is drastic, then it is more likely with entry into the product market; (ii) if innovation is non-drastic, then it is more likely for the monopoly to persist.<sup>9</sup> This literature is mainly on process innovations. Since we consider non-drastic product innovations, the parallels are not straightforward. However, in a loose sense, our paper contributes to this literature by providing an alternative explanation for monopoly persistence, namely that the incumbent can use advertising to reduce the entrant’s incentive to spend resources on R&D.

The rest of the paper is organised as follows. In section 2 we present the general framework in the context of a pharmaceutical market, and derive the equilibrium advertising and R&D investments. In section 3 we illustrate our model by analysing a standard informative advertising model. In section 4 we discuss briefly some welfare and policy implications from our analysis. Finally, in section 5 the paper is concluded.

## 2 A general model

Consider a therapeutic market with potentially two horizontally differentiated patented products (prescription drugs). Assume that one of the products – the ‘breakthrough’ drug – has already been developed by firm 1, which is thus a monopolist in the market. The second (horizontally differentiated) product may or may not be discovered, depending on the amount of R&D investments incurred. We assume that firm 1 faces competition from an entrant (firm 2)

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<sup>9</sup>A related paper is Langinier (2004) who examines the role of patents – or more precisely patent renewals – as strategic barriers to entry, depending on the information structure.

in the race to discover the new drug. In correspondence with the practice in most European countries, we assume that drug prices are regulated<sup>10</sup>, so firms can only influence sales through marketing. In line with the specific features of the pharmaceutical industry – where marginal production costs are very low – we also disregard the possibility of capacity constraints, and assume that firms will always supply the quantity demanded, as long as the price covers marginal production costs. We consider a two-period model with the following sequence of events:

Stage 1a: The incumbent advertises and sells the ‘breakthrough’ drug.

Stage 1b: The incumbent and the potential entrant simultaneously invest in R&D to develop a new product.

Stage 2: The new product – if it is discovered – is advertised by the patent holder and sold in the market alongside the old product.

Stages 1a and 1b constitute the first period, where the incumbent is a monopolist in the market. Thus, the breakthrough drug is sold in both periods, whereas the new drug is sold in the second period only. The two periods are not necessarily equal in length, though, and we will generally work with the assumption that the second period is the most important one. Whereas the first-period is a single-product monopoly phase, in the second period there may be three different market structures: (i) single-product monopoly if neither firm discovers the second product; (ii) multi-product monopoly if the incumbent wins the R&D race; and (iii) a duopoly if the entrant wins the R&D race.

## 2.1 Some preliminaries

Due to the extensive prevalence of third-party payment for prescription drugs in most countries, we make the assumption that demand for a particular drug depends only on the amounts of advertising for the existing drugs within the therapeutic market.<sup>11</sup> More specifically, the demand for drug  $i$  in the second

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<sup>10</sup>See Mossialos (1998) for an overview.

<sup>11</sup>The pharmaceutical market is characterised by a low price-elasticity, see e.g., Rizzo (1999) and Scherer (2000).

period is given by  $D_i(A_i, A_j)$ , where  $A_i$  ( $A_j$ ) is the amount of advertising for drug  $i$  ( $j$ ), where  $\partial D_i/\partial A_i > 0$ ,  $\partial^2 D_i/\partial A_i^2 \leq 0$  and  $\partial D_i/\partial A_j < 0$ . These assumptions on  $D_i$  imply that advertising has both a *market expanding* and a *business stealing* effect. In the first (monopoly) period, demand for the ‘breakthrough’ drug (product 1) is given by  $\theta D_1(A_1, 0)$ , where  $\theta \leq 1$  reflects the importance (length) of the first period, relative to the second.

A key assumption of the analysis is that the effects of advertising persist over time. As is common in the literature on strategic advertising, we take this assumption to the extreme by letting the effects of advertising on demand be infinitely durable. Firm  $i$  can invest in an advertising stock of  $A_i$  at a cost  $K(A_i)$ , where  $\partial K/\partial A_i > 0$  and  $\partial^2 K/\partial A_i^2 > 0$ . We assume that both firms possess the same advertising technology.

We abstract from production costs once a new drug has been developed, implying that all costs of the pharmaceutical firms are related to marketing and R&D. The regulated price,  $p$ , is assumed to be equal for both drugs and constant over time. We can also loosely think of  $p$  as the ‘generosity of the patent system’, including patent length.

### 2.1.1 Ex post advertising

Let us first consider ex post advertising incentives in the case of entry of a new product in the market. The introduction of a new product gives rise to one of potentially two new market structures, depending on which firm develops the new product.

#### Duopoly

The profit of firm 2 (the entrant) is given by

$$pD_2(A_1, A_2) - K(A_2), \quad (1)$$

with the first-order condition for optimal advertising of the new product given by

$$p \frac{\partial D_2(A_1, A_2)}{\partial A_2} - \frac{\partial K(A_2)}{\partial A_2} = 0. \quad (2)$$

Let  $A_2^D(A_1)$  define the best response of the entrant in the duopoly case, given by the solution to (2). By total differentiation of (2), we can easily obtain

$$\frac{\partial A_2^D(A_1)}{\partial A_1} = - \left[ \frac{p(\partial^2 D_2 / \partial A_1 \partial A_2)}{p(\partial^2 D_2 / \partial A_2^2) - \partial^2 K / \partial A_2^2} \right]. \quad (3)$$

Applying the second-order condition, we see that

$$\partial A_2^D(A_1) / \partial A_1 < 0 \text{ if } \partial^2 D_2 / \partial A_1 \partial A_2 < 0.$$

In this case the decision variables are *strategic substitutes*<sup>12</sup>, implying that increased ex ante advertising by the incumbent will reduce the optimal ex post advertising by the entrant.

### Monopoly

If the new product is developed by the incumbent, ex post profit for firm 1 is given by

$$p[D_1(A_1, A_2) + D_2(A_1, A_2)] - K(A_2). \quad (4)$$

The first-order condition for optimal advertising of the new product is then

$$p \left( \frac{\partial D_1(A_1, A_2)}{\partial A_2} + \frac{\partial D_2(A_1, A_2)}{\partial A_2} \right) - \frac{\partial K(A_2)}{\partial A_2} = 0, \quad (5)$$

which defines a best response function  $A_2^M(A_1)$ . Comparing (2) and (5), we see that the multi-product monopolist internalises the business-stealing effect of advertising, implying that  $A_2^M(A_1) < A_2^D(A_1)$ . Once more, by total differentiation of (5) we derive

$$\frac{\partial A_2^M(A_1)}{\partial A_1} = - \left[ \frac{p(\partial^2 D_1 / \partial A_1 \partial A_2 + \partial^2 D_2 / \partial A_1 \partial A_2)}{p(\partial^2 D_1^2 / \partial A_2^2 + \partial^2 D_2 / \partial A_2^2) - \partial^2 K / \partial A_2^2} \right]. \quad (6)$$

Equivalent to the duopoly case, we see that

$$\partial A_2^M(A_1) / \partial A_1 < 0 \text{ if } \partial^2 D_i / \partial A_i \partial A_j < 0.$$

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<sup>12</sup>See Bulow et al. (1985).

For the remainder of the analysis, we will make the assumption that  $\partial^2 D_i / \partial A_i \partial A_j \leq 0$ , which implies that advertising investments are strategic substitutes for the firms.

### 2.1.2 Ex post payoffs

We can use the preceding analysis to characterise a key mechanism of the model, namely how second-period payoffs are affected by first-period advertising by the incumbent. Inserting the equilibrium levels of ex post advertising, second-period payoffs are defined as follows:<sup>13</sup>

Single-product monopoly:

$$V_1^S(A_1) := pD_1(A_1, 0). \quad (7)$$

Multi-product monopoly:

$$V_1^M(A_1) := p[D_1(A_1, A_2^M(A_1)) + D_2(A_1, A_2^M(A_1))] - K(A_2^M(A_1)). \quad (8)$$

Duopoly:

$$V_1^D(A_1) := pD_1(A_1, A_2^D(A_1)), \quad (9)$$

$$V_2^D(A_1) := pD_2(A_1, A_2^D(A_1)) - K(A_2^D(A_1)). \quad (10)$$

Entirely plausible assumptions on the demand functions would ensure that  $V_1^M(A_1) > V_1^S(A_1) > V_1^D(A_1)$ . Applying the Envelope Theorem, the effects of first-period advertising on second-period profits are easily derived:

$$\frac{\partial V_1^S(A_1)}{\partial A_1} = p \frac{\partial D_1(A_1, 0)}{\partial A_1} > 0, \quad (11)$$

$$\frac{\partial V_1^M(A_1)}{\partial A_1} = p \left[ \frac{\partial D_1(A_1, A_2^M(A_1))}{\partial A_1} + \frac{\partial D_2(A_1, A_2^M(A_1))}{\partial A_1} \right] > 0, \quad (12)$$

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<sup>13</sup>We use the following notation:  $V_i^z$  denotes second-period payoffs for firm  $i$  in market structure  $z$ , where  $i = 1, 2$  and  $z = S$ (ingle-product monopoly),  $M$ (ulti-product monopoly),  $D$ (uopoly).

$$\frac{\partial V_1^D(A_1)}{\partial A_1} = p \left[ \frac{\partial D_1(A_1, A_2^D(A_1))}{\partial A_1} + \frac{\partial D_1(A_1, A_2^D(A_1))}{\partial A_2} \frac{\partial A_2^D(A_1)}{\partial A_1} \right] > 0, \quad (13)$$

$$\frac{\partial V_2^D(A_1)}{\partial A_1} = p \frac{\partial D_2(A_1, A_2^D(A_1))}{\partial A_1} < 0. \quad (14)$$

The key mechanism in the relationship between advertising and R&D incentives is the incumbent's ability to influence ex post payoffs of the potential entrant through first-period advertising of the existing product. As we observe from (14), such advertising directly reduces the second-period payoff of the entrant. In addition, if advertising decisions are strategic substitutes, the incumbent has a strategic first-mover advantage which enables him to shift second period duopoly rents from the possible entrant through first-period advertising. This effect is reflected in the second term of (13).

For later analysis, it is also useful to establish the ranking of the marginal effects of first-period advertising on second-period payoff in the different possible market structures. From  $\partial D_j / \partial A_i < 0$  and  $\partial^2 D_i / \partial A_i \partial A_j \leq 0$ , it follows that

$$\frac{\partial V_1^S(A_1)}{\partial A_1} \geq \frac{\partial V_1^D(A_1)}{\partial A_1} > \frac{\partial V_1^M(A_1)}{\partial A_1},$$

the latter inequality implying that first-period investments have a larger positive effect on the incumbent's second-period profits in duopoly than in multi-product monopoly. This follows from the internalisation of the business-stealing effect in multi-product monopoly and the first-mover advantage vis-à-vis the entrant in duopoly.

## 2.2 R&D competition

During the monopoly phase, the incumbent and a potential entrant compete in terms of R&D to develop a new (horizontally differentiated) drug in the market. Technically, we assume that R&D investments are made simultaneously (and non-cooperatively) after the incumbent has sunk his advertising investments. The probability of success for firm  $i$  in the R&D contest is given by  $z_i(x_i, x_j)$ , where  $x_i$  ( $x_j$ ) is the R&D investment undertaken by firm  $i$  ( $j$ ). By 'success' we mean that firm  $i$  will develop and obtain a patent for the new drug. We assume that  $z_1 + z_2 \leq 1$ , accommodating the possibility that the

new drug will not be developed. We assume that

$$\begin{aligned} \partial z_i / \partial x_i > 0, \quad \partial z_i / \partial x_j < 0, \quad \partial^2 z_i / \partial x_i^2 \leq 0, \\ \partial^2 z_i / \partial x_j^2 \geq 0, \quad \partial z_i / \partial x_i > |\partial z_i / \partial x_j|. \end{aligned}$$

The last assumption essentially means that increased R&D effort by either firm will always increase the overall probability that a new drug is developed. The cost of exerting an R&D effort of  $x_i$  is given by  $C(x_i)$ , where  $\partial C / \partial x_i > 0$  and  $\partial^2 C / \partial x_i^2 > 0$ .

For a given level of advertising by the incumbent, each firm chooses the level of R&D that maximises expected second-period payoffs, anticipating the equilibrium ex post advertising outcome. The expected second-period payoff for firm 1 (the incumbent), denoted  $B_1$ , is given by

$$B_1 = [1 - z_1(x_1, x_2) - z_2(x_1, x_2)] V_1^S + z_1(x_1, x_2) V_1^M + z_2(x_1, x_2) V_1^D - C(x_1), \quad (15)$$

which can be re-arranged to

$$B_1 = V_1^S + z_1(x_1, x_2) \underbrace{[V_1^M - V_1^S]}_{\text{Gain of winning}} - z_2(x_1, x_2) \underbrace{[V_1^S - V_1^D]}_{\text{Loss of losing}} - C(x_1).$$

The expected second-period profit for the possible entrant is given by

$$B_2 = z_2(x_1, x_2) V_2^D - C(x_2). \quad (16)$$

Equilibrium R&D efforts by the two firms are given by the solution to the following pair of first-order conditions:

$$\frac{\partial B_1}{\partial x_1} = \frac{\partial z_1}{\partial x_1} (V_1^M - V_1^S) - \frac{\partial z_2}{\partial x_1} (V_1^S - V_1^D) - \frac{\partial C}{\partial x_1} = 0, \quad (17)$$

$$\frac{\partial B_2}{\partial x_2} = \frac{\partial z_2}{\partial x_2} V_2^D - \frac{\partial C}{\partial x_2} = 0. \quad (18)$$

Our assumptions on  $z_i(\cdot)$  and  $C(\cdot)$  ensure that the second-order conditions

are met.<sup>14</sup> We also assume that the determinant of the Jacobian matrix

$$J = \begin{bmatrix} \partial^2 B_1 / \partial x_1^2 & \partial^2 B_1 / \partial x_1 \partial x_2 \\ \partial^2 B_2 / \partial x_2 \partial x_1 & \partial^2 B_2 / \partial x_2^2 \end{bmatrix}$$

is positive, guaranteeing uniqueness of the equilibrium.<sup>15</sup>

### 2.2.1 The effect of first-period advertising on R&D incentives

The first-order conditions implicitly define the optimal R&D efforts as functions of the first-period investment level by the incumbent:  $x_1^*(A_1)$  and  $x_2^*(A_1)$ , respectively. How do R&D incentives depend on first-period advertising? By the Implicit Function Theorem we can derive the expressions for  $\partial x_1^* / \partial A_1$  and  $\partial x_2^* / \partial A_1$  from the first-order conditions of the R&D game, using Cramer's Rule:

$$\frac{\partial x_1^*}{\partial A_1} = \frac{\begin{vmatrix} -\partial^2 B_1 / \partial A_1 \partial x_1 & \partial^2 B_1 / \partial x_1 \partial x_2 \\ -\partial^2 B_2 / \partial A_1 \partial x_2 & \partial^2 B_2 / \partial x_2^2 \end{vmatrix}}{|J|}, \quad (19)$$

$$\frac{\partial x_2^*}{\partial A_1} = \frac{\begin{vmatrix} \partial^2 B_1 / \partial x_1^2 & -\partial^2 B_1 / \partial A_1 \partial x_1 \\ \partial^2 B_2 / \partial x_2 \partial x_1 & -\partial^2 B_2 / \partial A_1 \partial x_2 \end{vmatrix}}{|J|}. \quad (20)$$

From  $|J| > 0$ , it follows that

$$\text{sign} \left( \frac{\partial x_1^*}{\partial A_1} \right) = \text{sign} \left\{ -\Omega \left( \underbrace{\frac{\partial^2 z_2}{\partial x_2^2} V_2^D - \frac{\partial^2 C}{\partial x_2^2}}_{<0} \right) + \Phi \left( \underbrace{\frac{\partial z_2}{\partial x_2} \frac{\partial V_2^D}{\partial A_1}}_{<0} \right) \right\} \quad (21)$$

<sup>14</sup>The second-order conditions are given by

$$\begin{aligned} \frac{\partial^2 B_1}{\partial x_1^2} &= \frac{\partial^2 z_1}{\partial x_1^2} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_1^2} (V_1^S - V_1^D) - \frac{\partial^2 C}{\partial x_1^2} < 0, \\ \frac{\partial^2 B_2}{\partial x_2^2} &= \frac{\partial^2 z_2}{\partial x_2^2} V_2^D - \frac{\partial^2 C}{\partial x_2^2} < 0. \end{aligned}$$

<sup>15</sup>See Appendix A for the explicit expression of  $|J|$ , with the corresponding condition for  $|J| > 0$ .



and

$$\text{sign} \left( \frac{\partial x_2^*}{\partial A_1} \right) = \text{sign} \left\{ -\Psi \underbrace{\left( \frac{\partial z_2}{\partial x_2} \frac{\partial V_2^D}{\partial A_1} \right)}_{<0} + \Omega \underbrace{\left( \frac{\partial^2 z_2}{\partial x_1 \partial x_2} V_2^D \right)}_{\leq 0} \right\}, \quad (22)$$

where

$$\begin{aligned} \Omega &:= \frac{\partial z_1}{\partial x_1} \left( \frac{\partial V_1^M}{\partial A_1} - \frac{\partial V_1^S}{\partial A_1} \right) - \frac{\partial z_2}{\partial x_1} \left( \frac{\partial V_1^S}{\partial A_1} - \frac{\partial V_1^D}{\partial A_1} \right) < 0, \\ \Phi &:= \frac{\partial^2 z_1}{\partial x_2 \partial x_1} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_2 \partial x_1} (V_1^S - V_1^D) \leq 0, \\ \Psi &:= \frac{\partial^2 z_1}{\partial x_1^2} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_1^2} (V_1^S - V_1^D) - \frac{\partial^2 C}{\partial x_1^2} < 0. \end{aligned}$$

An increase in ex ante advertising by the incumbent has a direct and (potentially) an indirect effect on R&D efforts of both firms, and we see that the sign of the overall effect is generally ambiguous in both cases. The direct effects of increased advertising are reflected in the first term on the right-hand side of both equations, and are unambiguously negative with respect to R&D efforts for both firms. Increased advertising by the incumbent directly reduces the ex post payoff of firm 2 – as can be seen from (14) – and thus reduces the incentives for this firm to exert effort in the R&D contest. This effect is reflected in the first term of (22). Increased advertising for the old product also directly reduces the incentives to invest in R&D for the incumbent, because such advertising reduces the gain of winning the contest while not reducing the loss of losing. This follows from the fact that  $\partial V_1^S / \partial A_1 \geq \partial V_1^D / \partial A_1 > \partial V_1^M / \partial A_1$ , and is reflected in the first term of (21). Note that the relative sizes of these marginal effects together with  $\partial z_i / \partial x_i > |\partial z_i / \partial x_j|$  ensure that  $\Omega < 0$ .

If  $\partial^2 z_i / \partial x_i \partial x_j = 0$ , the direct effects unambiguously ensure that increased advertising of the breakthrough product will reduce the R&D incentives for both firms. However, if  $\partial^2 z_i / \partial x_i \partial x_j \neq 0$  there are additional indirect effects that could work in the opposite direction. The second (and last) terms of (21) and (22) reflect that a lower amount of R&D by firm  $i$  could – ceteris paribus – spur increased R&D investment by firm  $j$  if R&D efforts are strategic substi-

tutes; that is, if  $\partial^2 z_i / \partial x_i \partial x_j < 0$ . Thus, if the second-order cross derivatives of the probability functions are either zero or sufficiently small in absolute value (which is also, in qualitative terms, the condition for  $|J| > 0$ ), we have that  $\partial x_1^* / \partial A_1 < 0$  and  $\partial x_1^* / \partial A_2 < 0$ . This result has two interesting implications. First, *advertising and R&D are substitute strategies* for the incumbent firm. Second, *increased advertising will reduce overall investments in R&D*, thereby reducing the probability that a new product will be introduced on the market.

### 2.3 First-period advertising

At the outset of the game, the incumbent chooses the optimal level of advertising for the existing patented product by maximising expected present-value profits over the two periods, anticipating the outcome of the R&D game and the subsequent market equilibria in the second period. For simplicity, we abstract from discounting. The incumbent firm's expected ex ante profits, denoted  $\Pi_1$ , are then given by

$$\Pi_1(A_1) = \theta V_1^S(A_1) + B_1(x_1^*(A_1), x_2^*(A_1), A_1) - K(A_1). \quad (23)$$

As a benchmark for comparison, we start out by considering the case of exogenous probabilities of second-period market structures. In this case, the first-order condition for optimal advertising is given by

$$(1 + \theta) \frac{\partial V_1^S}{\partial A_1} + z_1 \left( \frac{\partial V_1^M}{\partial A_1} - \frac{\partial V_1^S}{\partial A_1} \right) + z_2 \left( \frac{\partial V_1^D}{\partial A_1} - \frac{\partial V_1^S}{\partial A_1} \right) - \frac{\partial K}{\partial A_1} = 0. \quad (24)$$

When deciding the optimal level of first-period advertising, the incumbent has to consider the marginal second-period benefits of increased advertising in the different market structures, and weigh these net benefits with the relevant probabilities. Compared with the case of certain single-product monopoly in both periods (i.e.,  $z_1 = z_2 = 0$ ), we see that the possibility of entry of a new product in the market means that the optimal level of advertising is lower, due to the lower marginal second-period benefits of advertising in multi-product monopoly or duopoly.

Let us now turn to the case of endogenous probabilities, determined by

the absolute and relative R&D efforts of the firms. We perform the analysis under the assumption of dynamic consistency, i.e., that the incumbent has no incentive to increase advertising of the original product ex post. In general, a sufficiently high value of  $\theta$  will always ensure that this is indeed the case.

Anticipating  $x_1^*(A_1)$  and  $x_2^*(A_1)$  the incumbent sets  $A_1$  to maximise (23). The first-order condition for an optimal level of advertising can be conceptualised and expressed as follows:

$$\frac{\partial \Pi_1(A_1)}{\partial A_1} = \text{Direct rent effect} + \text{Strategic R\&D effect} = 0, \quad (25)$$

where the *Direct rent effect* is equal to the right-hand side of (24), whereas the *Strategic R&D effect* is given by

$$\begin{aligned} & \left( \frac{\partial z_1}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} + \frac{\partial z_1}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} \right) (V_1^M - V_1^S) \\ & + \left( \frac{\partial z_2}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} + \frac{\partial z_2}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} \right) (V_1^D - V_1^S) \\ & - \frac{\partial C}{\partial x_1} \frac{\partial x_1^*}{\partial A_1}. \end{aligned} \quad (26)$$

We can quickly establish that the sign of this effect is generally ambiguous. In other words, compared with the case of exogenous probabilities of entry in the second-period, it is unclear – in a model of this generality – whether the incumbent has incentives to over-invest or under-invest in advertising in order to influence the amount of R&D that is undertaken by potential rivals. Under the assumptions that  $\partial x_2^*/\partial A_1 < 0$  and  $\partial x_1^*/\partial A_1 < 0$ , as discussed in Section 2.2.1, we will subsequently discuss each of the three terms that constitute the *Strategic R&D effect*.

The first term reflects the effect of advertising on the incumbent's expected gain of winning the contest. By increasing first-period advertising, the incumbent can reduce the rival's R&D investments, thereby increasing the probability of winning the contest. At the same time, though, increased advertising also reduces the incumbent's incentives to win, resulting in lower R&D effort by this firm as well. If the effect that works through the rival's R&D response

is the dominant one – that is, if  $\frac{\partial z_1}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} > \left| \frac{\partial z_1}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} \right|$  – the first term of (26) will contribute in the direction of over-investment by the incumbent firm.

The second term reflects the effect of advertising on the incumbent’s expected loss of losing the contest. The incumbent can reduce the rival firm’s R&D efforts by advertising the existing product more intensely, thereby reducing the probability of losing the contest. On the other hand, though, increased advertising reduces also the incumbent’s R&D efforts. Once more, if the first effect is dominating – that is, if  $\left| \frac{\partial z_2}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} \right| > \frac{\partial z_2}{\partial x_1} \frac{\partial x_1^*}{\partial A_1}$  – the second term of (26) will also contribute in the direction of over-investment by the incumbent firm.

The third term unambiguously contribute to higher first-period investment, and simply reflects the cost effect of advertising and R&D being substitute strategies for the incumbent firm. Higher advertising reduces R&D incentives and thus R&D costs, which – all else equal – gives the incumbent firm an added incentive to advertise the existing product more intensely.

### 3 An example: Informative advertising

In this Section we illustrate our model by analysing a standard specific advertising model that fits the assumptions of the general model. We consider an informative advertising model with an information technology that follows Butters (1977).<sup>16</sup> There is a unit mass of potential consumers that are ex ante uninformed about the existence of the products in the market, and rely on advertising to become informed. If a consumer receives one or more ads for a particular product, she knows about the existence and attributes of this product. We assume unit demand, implying that informed consumers buy one unit of one of the products in the market.<sup>17</sup> With two products in the market, consumers who are informed about both products buy either of the products with probability  $\frac{1}{2}$ .<sup>18</sup> If a fraction  $A_i$  ( $A_j$ ) of consumers are informed about

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<sup>16</sup>This approach has been widely used in the advertising literature. See e.g., Schmalensee (1983), Grossman and Shapiro (1984), Fudenberg and Tirole (1984), Ishigaki (2000), etc.

<sup>17</sup>More specifically, we assume that consumers buy one unit in the second period and  $\theta \leq 1$  units in the first period.

<sup>18</sup>We can interpret this as a Hotelling model with uniform distribution of consumers, symmetric location of products and ads reaching consumers randomly.

drug  $i$  ( $j$ ), second-period demand for drug  $i$  is given by

$$D_i(A_i, A_j) = A_i(1 - A_j) + \frac{A_i A_j}{2}, \quad i, j = 1, 2; \quad i \neq j. \quad (27)$$

Note that  $\partial^2 D_i / \partial A_i \partial A_j = -\frac{1}{2}$ , implying that advertising choices are strategic substitutes for the firms. We assume that a firm can inform a fraction  $A_i$  of the consumers about the existence and attributes of product  $i$  by incurring a cost of  $K(A_i) = \frac{k}{2} A_i^2$ ,  $A_i \in [0, 1]$ .

We can now use the parameterised demand and cost functions to calculate second-period payoffs in the different market structures. Straightforward calculations yield

$$V_1^S(A_1) = pA_1, \quad (28)$$

$$V_1^M(A_1) = p \left[ A_1 + \frac{p}{2k} (1 - A_1)^2 \right], \quad (29)$$

$$V_1^D(A_1) = pA_1 \left[ 1 - \frac{p}{4k} (2 - A_1) \right], \quad (30)$$

$$V_2^D(A_1) = \frac{p^2}{8k} (2 - A_1)^2. \quad (31)$$

In order to obtain analytical solutions in the R&D contest, we construct the success functions in the following way. Let  $x_i \in [0, 1]$  denote the probability that firm  $i$  discovers the new product. If the product is only discovered by firm  $i$ , this firm will be granted a patent for the product. However, if both firms discover the product, the patent will be granted to either of the firms with probability  $\frac{1}{2}$ . This yields the following success functions:<sup>19</sup>

$$z_i(x_i, x_j) = x_i(1 - x_j) + \frac{x_i x_j}{2}, \quad i, j = 1, 2; \quad i \neq j.$$

We assume that firm  $i$  can obtain a probability  $z_i$  of discovery by undertaking an R&D investment of  $C(x_i) = \frac{c}{2} x_i^2$ ,  $x_i \in [0, 1]$ .

We can now insert these functional expressions into (15) and (16), and

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<sup>19</sup>This particular success function has the following properties:  $\partial z_i / \partial x_i > 0$ ,  $\partial z_i / \partial x_j < 0$ ,  $\partial^2 z_i / \partial x_i^2 = \partial^2 z_i / \partial x_j^2 = 0$  and  $\partial^2 z_i / \partial x_i \partial x_j < 0$ .

solve for the optimal values of  $x_i$  in the R&D competition:

$$x_1^*(A_1) = \frac{2p^2 [32ck(1 - A_1)^2 - p^2 [2 - 3A_1(2 - A_1)](2 - A_1)^2]}{128c^2k^2 - p^4 [2 - 3A_1(2 - A_1)](2 - A_1)^2}, \quad (32)$$

$$x_2^*(A_1) = \frac{4p^2(2 - A_1)^2 [4ck - p^2(1 - A_1)^2]}{128c^2k^2 - p^4 [2 - 3A_1(2 - A_1)](2 - A_1)^2}. \quad (33)$$

An interior solution requires a lower bound on the cost parameter  $c$ . It is relatively straightforward to verify that  $c > \underline{c} := p^2/4k$  is a sufficient condition for  $x_1^*(A_1), x_2^*(A_1) \in (0, 1)$  for all  $A_1 \in [0, 1]$ . For  $c > \underline{c}$ , it can also be verified that

$$\frac{\partial x_1^*(A_1)}{\partial A_1} < 0 \text{ and } \frac{\partial x_2^*(A_1)}{\partial A_1} < 0 \text{ for all } A_1 \in [0, 1]. \quad (34)$$

Thus, in the informative advertising model, marketing and R&D are always substitute strategies for the incumbent, and a lower level of first-period advertising will increase overall R&D expenditures. A formal proof of this is given in Appendix B.

Turning now to the first-period advertising decision and the equilibrium outcome of the full game, the complexity of the model makes analytical solutions infeasible. Instead, we present the results in the form of numerical examples where we set  $\theta = \frac{1}{10}$ .<sup>20</sup> Tables 1-5 report equilibrium values of first-period advertising and R&D investments for different values of the key parameters  $k$ ,  $c$  and  $p$ . In table 6, we present measures of the incumbent's incentives to use advertising *strategically* in order to affect R&D expenditures. We do so by evaluating the *strategic R&D effect* defined by (26) in equilibrium. A positive value implies that the incumbent strategically *over-invests* in first-period advertising in order to reduce the potential entrant's R&D efforts. Table 6 reveals that the incentives for over-investment are increasing in  $p$  and decreasing in  $k$  and  $c$ . For this numerical example it is also straightforward to verify that the model is dynamically consistent in the sense that the incumbent firm has no incentive to increase advertising ex post.

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<sup>20</sup>The effect of a higher value of  $\theta$  is essentially to increase first-period advertising and reduce R&D incentives.

Table 1: Equilibrium values of  $A_1$ .

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.217	0.137	0.219	0.137
2	0.426	0.267	0.435	0.272
3	0.656	0.393	0.662	0.406
4	0.977	0.522	0.918	0.543

Table 2: Equilibrium values of  $A_2^M$ .

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.157	0.108	0.156	0.108
2	0.230	0.183	0.226	0.182
3	0.206	0.273	0.203	0.223
4	0.002	0.239	0.066	0.229

Table 3: Equilibrium values of  $A_2^D$ .

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.178	0.116	0.178	0.116
2	0.315	0.217	0.313	0.216
3	0.403	0.324	0.401	0.299
4	0.401	0.370	0.433	0.364

Table 4: Equilibrium values of  $x_1$ .

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.060	0.046	0.020	0.015
2	0.132	0.128	0.043	0.043
3	0.161	0.203	0.041	0.066
4	0.155	0.266	0.024	0.075

Table 5: Equilibrium values of  $x_2$ .

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.077	0.053	0.026	0.018
2	0.231	0.176	0.080	0.061
3	0.374	0.327	0.132	0.115
4	0.386	0.473	0.154	0.170

Table 6: *Strategic R&D effect.*

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.002	0	0.001	0
2	0.033	0.011	0.013	0.004
3	0.169	0.057	0.072	0.024
4	0.506	0.169	0.217	0.081

Although we restrict ourselves to a relatively small set of numerical examples, several regularities can be identified that shed some light on the mechanisms of the model. We concentrate here on the effects of prices and costs on first-period advertising and R&D expenditures. Consider first the effects of an increase in *advertising costs* ( $k$ ). This always leads to a reduction of first-period advertising, through the direct cost effect. R&D efforts are ambiguously affected, though, due to an interaction of two opposing effects. On

the one hand, reduced first-period advertising – *ceteris paribus* – increases R&D incentives, as we have analysed in great detail in Section 2.2.1. On the other hand, higher advertising costs also reduce ex post payoffs, since the new product has to be advertised. This will – all else equal – reduce R&D incentives. From our numerical examples, we observe that the first effect dominates only for relatively high values of  $p$ .

The effect of increased *R&D costs* ( $c$ ) reduces R&D efforts directly, but the effect on first-period advertising is ambiguous. We see that, for most of the reported parameter values, advertising investments will increase (although by quite small amounts). In our examples, the exception is for the combination of high price and low advertising costs. In this case the incumbent has very strong incentives to advertise in order to protect his monopoly position (which is very profitable due to the high price), and these incentives are particularly strong for low R&D costs, which (all else equal) increases the probability that a competitor will enter the market.

More interesting, perhaps, are the effects of a higher *regulated price* ( $p$ ). An increase in the price (which can also be interpreted as increased patent length) will increase first-period advertising simply because it makes the monopoly position more valuable for the incumbent patent holder. Consequently, the incumbent will have stronger incentives to use advertising strategically in order to protect his monopoly rent. Nevertheless, the potential entrant will react to a higher price by increasing his R&D efforts. This is due to the fact that a higher price not only increases the value of the existent patent, it also increases the value of obtaining the second patent in the market. Thus, the increased advertising efforts by the incumbent have only a dampening effect on the competitor's R&D expenditures. The effect of a higher price on the *incumbent's* R&D efforts is ambiguous, though. *Ceteris paribus*, more advertising of the existing product will reduce the incumbent's incentives for R&D. However, a higher  $p$  also increases the value of the contested prize, which – all else equal – leads to increased R&D efforts by both firms. From Table 4 we see that the second effect dominates when advertising costs are high, implying that it is more costly to use advertising as a means to reduce R&D investments. For lower advertising costs, on the other hand, there appears to be a hump-shaped



relationship between  $p$  and  $x_1^*$ . For a sufficiently high price, a further price increase will trigger an increase in advertising that is sufficiently strong to reduce the incumbent's R&D investments.

In our numerical examples, although the incumbent's R&D efforts may decrease, *aggregate* R&D expenditures always increase as a result of a higher price. This is confirmed by comparing Tables 4 and 5. However, a higher price (or, generally, a more generous patent policy) implies that a larger share of the patent rent is spent on marketing, relative to R&D. This is a key result. Indeed, we see from Tables 4 and 5 that raising  $p$  above a certain level hardly stimulates aggregate R&D expenditures at all, while incentives for advertising increase considerably.

## 4 Welfare and policy implications

In most countries there exists a wide set of restrictions on drug marketing. For instance, direct-to-consumer advertising of prescription drugs is prohibited in most countries (except for the US and New Zealand). Moreover, there exist ethical guidelines regulating the interaction between medical doctors and sales representatives from the pharmaceutical companies. Health authorities also usually require that a disclaimer stating the effectiveness, side-effects, contraindications, etc., is printed along with an advertisement of a drug. In this Section, we use our model to discuss if and when strict regulation of drug advertising is justified from a viewpoint of social welfare.

Advertising and welfare is often a methodologically complicated issue, in particular if advertising contains elements of persuasion, which may potentially change individuals' preferences. In most cases, advertising contains elements of both information and persuasion. In the pharmaceutical market, for instance, sales representatives may inform the physician about the existence and the characteristics of a new drug, but at the same time sponsor conference trips, offer gifts, free samples, etc., which may be of a more persuasive nature. From a viewpoint of social welfare, *informational* advertising brings an obvious social benefit in the sense that a larger fraction of consumers becomes aware of a product that may yield a positive net utility if consumed. On the other hand, the potential for socially beneficial *persuasive* advertising is far less

obvious. In the subsequent analysis, we will assume that advertising is purely informational and ask whether restrictions on advertising can be beneficial for social welfare even in this case.

When evaluating welfare effects, we place equal weights on consumers' and producers' surplus. Furthermore, we specify a social welfare function that is independent of drug prices. This follows from the assumption of inelastic demand if consumers pay the full price out-of-pocket. In the presence of third-party payment by a governmental agency, we need the additional assumption that the government can raise the necessary funds in a non-distortionary manner. Social welfare is thus given by aggregate consumer utility net of R&D and marketing costs. Since the outcome of the R&D competition is uncertain, the relevant measure of social welfare is in expected terms. Denoting aggregate consumer utility by  $U$ , expected welfare, in general form, is given by

$$\begin{aligned}
 W = & \theta U(A_1, 0) + [1 - z_1(x_1, x_2) - z_2(x_1, x_2)] U(A_1, 0) \\
 & + z_1(x_1, x_2) [U(A_1, A_2^M) - K(A_2^M)] \\
 & + z_2(x_1, x_2) [U(A_1, A_2^D) - K(A_2^D)] \\
 & - C(x_1) - C(x_2) - K(A_1)
 \end{aligned} \tag{35}$$

In the following, we apply the informative advertising model that was introduced in Section 3. We use the Hotelling interpretation of the model, with linear transportation costs, where the two drugs are located at the endpoints of the Hotelling line. Let  $v$  denote the gross utility of consuming a product, while  $t$  is the cost per unit distance between the actual product and the consumer's 'ideal' product. Considering pharmaceuticals,  $v$  can be interpreted as the effectiveness of the drug treatment and  $t$  as a measure of potential side-effects, contraindications, etc. We also assume full market coverage, i.e., no consumers refrain from buying the existing product(s). Assuming that consumers pay a fraction  $\alpha \in [0, 1]$  of the price, this is equivalent to imposing a restriction  $v - \alpha p - t \geq 0$ .

It is now straightforward to derive the expressions for ex post consumer utility in the different potential market structures. In the single-product case, where neither firm succeed in developing the new drug, aggregate consumer

utility is given by

$$U(A_1, 0) = A_1 \int_0^1 (v - ty) dy = A_1 \left( v - \frac{t}{2} \right). \quad (36)$$

In the multi-product case, where either the incumbent or the entrant discovers the new product, aggregate consumer utility is given by

$$\begin{aligned} U(A_1, A_2) &= A_1(1 - A_2) \int_0^1 (v - ty) dy + A_2(1 - A_1) \int_0^1 (v - t(1 - y)) dy \\ &+ A_1A_2 \left( \int_0^{\frac{1}{2}} (v - ty) dy + \int_{\frac{1}{2}}^1 (v - t(1 - y)) dy \right) \\ &= [A_1 + A_2 - 2A_1A_2] \left( v - \frac{t}{2} \right) + A_1A_2 \left( v - \frac{t}{4} \right). \end{aligned} \quad (37)$$

Observe that aggregate utility is constituted by two qualitatively different segments; the fraction of partially informed consumers, i.e.,  $A_i(1 - A_j)$ , and the fraction of fully informed consumers, i.e.,  $A_1A_2$ . Partially informed consumers buy the only drug that they are aware of, with the corresponding aggregate mismatch costs  $t/2$ , while fully informed consumers choose the most ‘suitable’ drug treatment, generating aggregate mismatch costs equal to  $t/4$ . It clearly follows that the social benefit of developing a second drug in the market is monotonically increasing in  $t$ .

Using the same cost and success functions as in the previous Section, an explicit expression for expected social welfare can now be found by inserting these, along with (36) and (37), into (35). In order to evaluate the welfare effect of a strict governmental policy towards pharmaceutical marketing, our strategy is to evaluate social welfare, as given by (35), for the numerically derived equilibrium levels of R&D and marketing in Section 3. In doing so, we interpret the advertising cost parameter  $k$  as a measure of the extent of marketing regulation. This parameter measures the cost of reaching a certain fraction of the consumer population through advertising. It seems reasonable, then, to interpret a high (low) value of  $k$  as reflecting extensive (few) restrictions on advertising. All else equal (i.e., for given levels of marketing and R&D), a

higher value of  $k$  will of course reduce welfare, since informing a given fraction of consumers becomes more costly. The question, though, is whether the firms' marketing and R&D decisions might be influenced in a way that leads to an overall increase in social welfare. A numerical example is provided in Table 7.

Table 7: Social welfare.

$p$	$c = 1$		$c = 3$	
	$k = 5$	$k = 8$	$k = 5$	$k = 8$
1	0.254	0.158	0.246	0.153
2	0.237	0.152	0.240	0.152
3	-0.117	-0.057	-0.048	-0.021
4	-0.969	-0.477	-0.676	-0.375

Assumptions:  $\theta = 1/10$ ,  $v = 3$ ,  $t = 1$

A clear pattern emerges from this example. The social loss of imposing more restrictions on drug marketing (i.e., increasing  $k$  from 5 to 8 in this example) is larger when drug prices are low. If  $p$  becomes sufficiently high, increased marketing restrictions is actually beneficial for social welfare, even if advertising is purely informational. In other words, strict restrictions on advertising are desirable only in health care systems with very generous price regulation (or patent protection).

Generous price regulation (high  $p$ ) strongly increases advertising incentives, relative to R&D incentives. This leads to higher expected mismatch costs in equilibrium. Increasing the restrictions on advertising might in this situation improve welfare by directly reducing the incumbent's incentives to advertise, and indirectly spurring R&D incentives. This is clearly observed for the cases of  $p = 3, 4$  in Table 7. It should be noted, though, that these cases are only valid if there is a sufficiently degree of third-party payment for prescription drugs (i.e., the participation constraint  $v - \alpha p - t \geq 0$  can only be met if  $\alpha < 1$ ). Several numerical simulations with different parameter values produce similar results.

In terms of policy recommendations, our exercise suggests that a generous price regulation (or patent) system should be matched with strict regulation

on advertising, and vice versa, that a strict price regulation (or patent) system should be matched with lenient regulation of advertising.

## 5 Concluding remarks

In this paper we have analysed how a patent-holding firm may strategically use advertising *ex ante* to affect the R&D investments in new products, and thus the *ex post* market structure in the industry. We have considered a market with potentially two horizontally differentiated products, assuming one of the products has already been developed by a firm. The second product may or may not be discovered, depending on the amount of R&D investments incurred by the incumbent and a potential entrant. We have used a two-period model, where the breakthrough product is sold in both periods and the new product - if it is discovered - is sold in the second period only.

Within a general framework, we have provided the conditions for advertising and R&D to be *substitute strategies* for the incumbent firm. We have also presented the general conditions for *strategic over-investment* by the incumbent to occur as an equilibrium outcome. A key result of the paper is that a generous patent system tends to stimulate marketing incentives, relative to R&D incentives, which may have important implications for public policy and welfare.

We have focused on non-drastic innovations. A natural extension of the model would be to allow the firms also to choose drastic innovations (i.e., discovery of completely new products) and analyse the choice between drastic and non-drastic innovations. This is a topic for further research.

## Appendix A. The Jacobian from the R&D game

From (17) and (18), we can derive

$$\begin{aligned}
|J| &= \left( \underbrace{\frac{\partial^2 z_1}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_2^2} - \frac{\partial^2 z_1}{\partial x_2 \partial x_1} \frac{\partial^2 z_2}{\partial x_1 \partial x_2}}_{\leq 0} \right) \left( \underbrace{V_1^M - V_1^S}_{> 0} \right) V_2^D \\
&\quad - \left( \underbrace{\frac{\partial^2 z_2}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_2^2} - \left( \frac{\partial^2 z_2}{\partial x_1 \partial x_2} \right)^2}_{< 0} \right) \left( \underbrace{V_1^S - V_1^D}_{> 0} \right) V_2^D - \underbrace{\frac{\partial^2 C}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_2^2}}_{< 0} V_2^D \\
&\quad - \frac{\partial^2 C}{\partial x_2^2} \left( \underbrace{\frac{\partial^2 z_1}{\partial x_1^2} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_1^2} (V_1^S - V_1^D) - \frac{\partial^2 C}{\partial x_1^2}}_{< 0} \right).
\end{aligned}$$

We see that  $|J| > 0$  provided that the first term is either non-negative or sufficiently small in absolute value.

## Appendix B. Comparative statics in the informative advertising model

From (32) and (33) we derive

$$\frac{\partial x_1^* (A_1)}{\partial A_1} = - \frac{128p^2ck(4kc\mu - \sigma)}{(128c^2k^2 - p^4(2 - 3A_1(2 - A_1))(2 - A_1)^2)^2} \quad (\text{B.1})$$

and

$$\frac{\partial x_2^* (A_1)}{\partial A_1} = - \frac{8p^2(2 - A_1)(128c^2k^2\psi + \phi)}{(128c^2k^2 - p^4(2 - 3A_1(2 - A_1))(2 - A_1)^2)^2}, \quad (\text{B.2})$$

where

$$\mu := 32ck(1 - A_1) - p^2(2 - A_1)(8 - 3A_1(5 - 2A_1)),$$

$$\sigma := p^4(1 - A_1)(2 - A_1)(3A_1(3 + A_1(A_1 - 3)) - 4),$$

$$\psi := 4ck - p^2(1 - A_1)(3 - 2A_1),$$

$$\phi := p^4 (1 - A_1) (2 - A_1)^3 (12ck - p^2).$$

We observe that  $\partial x_1^*(A_1)/\partial A_1 < 0$  and  $\partial x_2^*(A_1)/\partial A_1 < 0$  if the numerators are positive in (B.1) and (B.2), respectively. Since the values of both numerators are increasing in  $c$ , it suffices to make an evaluation at the limit  $c \rightarrow \underline{c}$ . Straightforward computation yields

$$\lim_{c \rightarrow \underline{c}} (4kc\mu - \sigma) = p^4 A_1^2 (22 - 36A_1 + 18A_1^2 - 3A_1^3) > 0 \text{ for } A_1 \in [0, 1]$$

and

$$\lim_{c \rightarrow \underline{c}} (128c^2 k^2 \psi + \phi) = 2p^6 A_1^2 (2 - A_1) (5 - A_1) > 0 \text{ for } A_1 \in [0, 1].$$

It follows that  $\partial x_1^*(A_1)/\partial A_1 < 0$  and  $\partial x_2^*(A_1)/\partial A_1 < 0$  for  $c > \underline{c}$  and  $A_1 \in [0, 1]$ .

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