Pharmaceutical Patents: Incentives for R&D or Marketing?

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Abstract

We analyse how a patent-holding pharmaceutical firm may strategically use advertising of existing drugs to affect R&D investments in new (differentiated) drugs, and thereby affect the probability distribution of future market structures in the industry. Within a fairly general model framework, we derive exact conditions for advertising and R&D being substitute strategies for the incumbent firm and show that it may overinvest 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 a more specific setting of informative advertising, we show that such overinvestment incentives are always present, and that more generous patent protection implies that a larger share of the patent rent is spent on marketing, relative to R&D.

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1 Introduction

A patent protects the patent-holder from firms copying its product for a given period. In other words, patents restrict entry of homogeneous (identical) products during the patent period. However, patents rarely lead to a complete monopolisation of a market. In most cases, a patent just requires that new products must be sufficiently differentiated, implying some degree of competition in the market.

The rationale behind patents is to stimulate firms to undertake R&D investments to discover new products by granting 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 induce patent-holding firms to exhibit market power in a potentially detrimental way. This is the basic idea explored in this paper. In a model framework designed to fit the pharmaceutical industry, we analyse how a patent-holding firm may *strategically* use advertising ex ante to affect the R&D investments in new products, and thereby reducing the probability of increased future competition.

The relationship between innovation and marketing is of special interest for the pharmaceutical industry. This industry is highly R&D-intensive and patents of chemical compounds play a crucial role in terms of stimulating developments of new drugs. The pharmaceutical 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%.[1]

The basic structure of our model is as follows. We consider a therapeutic market with potentially two (horizontally) differentiated drugs, where one of the drugs is already discovered – the breakthrough drug – and under patent protection. The incumbent is thus

[1] Similar figures are reported from Novartis and Aventis, the largest pharmaceutical companies in Europe. See also Zweifel and Breyer (1997) for figures for Germany and Switzerland.

a monopolist and advertises the drug, taking into account the possibility of future entry of new competing products. A new competing product may or may not be discovered, depending on the amount of R&D investments incurred by the incumbent and a potential entrant. If the incumbent is successful, he becomes multi-product monopolist, a situation often referred to as brand-proliferation. On the other hand, if the new drug is discovered by the potential entrant, there is a duopoly, where the incumbent and the entrant advertise accordingly to capture market shares. Finally, if none of the firms are successful, the incumbent remains a single-product monopolist in the market.

This modelling set-up builds on two empirical observations:[2] first, the vast majority of pharmaceutical innovations are follow-on drugs rather than completely new medical treatments. 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. Second, there is a large variation in the degree of competition across therapeutic markets. Some therapeutic fields are monopolised by a dominant pharmaceutical company, often having several related drugs on the market, while other therapeutic fields are highly competitive with several pharmaceutical firms offering different products that can cure the same disease (Scherer, 2000). Thus, our set-up applies to a wide set of therapeutic markets, and offers explanations for market structure variation across therapeutic markets.

In line with the specific features of pharmaceutical markets, we restrict attention to non-price strategies – innovation and marketing – by assuming that firms face exogenous (regulated) drug prices.[3] The importance of non-price strategies in the pharmaceutical market can be explained by the fact that most countries exert some sort of price control

[2] There are also many examples that may illustrate this particular set-up. For instance, in the class of anti-ulcer drugs called H2-antagonists, SmithKline introduced the breakthrough drug Tagamet in 1977. Tagamet was heavily advertised and it took six years before Glaxo, which then was a rival firm, entered the market with a new, competing drug, Zantac. Similar patterns can be found for cholesterol-reducing medicines, high-blood pressure medicines, etc.

[3] Although this assumption is most appropriate in pharmaceutical markets, there are several papers on patents with a more general applicability that abstract from pricing strategies, see, e.g., Needham (1976), Waterson (1990) and Langinier (2004).

either directly by regulating the prices or indirectly via the reimbursement system.[4] In addition, the demand for pharmaceuticals is highly price inelastic, mainly due to health insurance and/or physicians' ignorance of price in the prescription choice.[5]

In a fairly general framework, we obtain two main results. First, we show that advertising and R&D are *substitute strategies* for the incumbent firm – implying that more advertising will, all else equal, induce the incumbent to spend less on R&D – if the following two conditions are met, in equilibrium: (i) the second-order cross derivatives of demand with respect to advertising expenditures are negative (implying that advertising expenditures are strategic substitutes), and (ii) the second-order cross derivatives of the innovation success functions are sufficiently small in absolute value.[6]

Second, under these general conditions, we show that the incumbent has an incentive to *strategically overinvest* in advertising in order to negatively affect R&D investments and thereby protect its existing patent rent. 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 ex ante advertising of the existing product.[7] If drug marketing has a business-stealing effect, advertising may serve as a rent-shifting device, reducing the R&D incentives of the potential entrant.[8]

We also derive a general condition for identifying under which circumstances the incumbent has incentives to invest *too much* in advertising from a social welfare perspective. We conclude that, under reasonable assumptions, socially excessive advertising is more likely to occur if there is a stronger persuasive element to advertising, and/or if the patent rent is higher (due to either longer patent periods or a higher regulated drug price). Naturally,

[4] Kanavos (2001) provides a comprehensive overview of pharmaceutical regulation practices in 14 EU countries. See also Danzon (1997) for an overview of theory and practices of pharmaceutical price regulation.

[5] See Newhouse (1993), Scherer (2000) and Rizzo (1999).

[6] Obviously, advertising and R&D can be substitutes for financial reasons: the patent-holder has to decide whether to spend more on advertising or on research, but cannot spend as much on both because of financial constraints. In this paper, we abstract from financial constraints and focus exclusively on the potential *strategic relationship* between the advertising and R&D.

[7] 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.

[8] The empirical study by Berndt et al. (1995) of the H_2-antagonist market shows that drug marketing is neither purely business-stealing nor purely market-expanding, but somewhere in between.

a divergence between private and social advertising incentives opens for a discussion of relevant policy measures, like restrictions on drug marketing and the generosity of the patent system. These issues are especially relevant for the pharmaceutical industry, since most countries impose regulations on both marketing and prices of prescription drugs. Our analysis suggests that strict regulation of advertising and strict price regulation (or, equivalently, a less generous patent system) are *policy substitutes*, implying that a generous patent (or price regulation) system should be matched with strict regulation on advertising, and vice versa.

Applying the general framework to a standard *informative advertising* model (see e.g., Butters, 1977; Grossman and Shapiro, 1984), we show that advertising and R&D are substitute strategies and that the incumbent always has an incentive to strategically overinvest in advertising in order to reduce the probability for a new product being developed by the potential entrant. Using numerical simulations, we also demonstrate that a generous patent system (equivalently, generous drug prices) tends to stimulate marketing incentives relative to R&D incentives, and, finally, that our conclusions from the general welfare analysis about the relationship between patent rent and advertising incentives are strongly confirmed, even in a setting where advertising is purely informative.

We find these results interesting for several reasons: first, the potentially negative impact of a more generous patent protection on R&D incentives runs counter to the general presumption in most theoretical papers on optimal patent design (see, e.g., Denicolo, 1996). On the other hand, the results seem to be in line with the recent, though scarce, empirical studies on this topic. For instance, Sakakibara and Branstetter (2001) find no evidence of an increase in either R&D spending or innovative output due to the Japanese patent law reform, strengthening the patent protection in Japan. In addition, Jaffe (2000) documents several studies from the US, which offer indirect evidence that calls the value of stronger patents into questions. Our paper provides one possible answer to this puzzle, namely that a patent enables the patent-holder to exploit market power – in our case by means of marketing – to reduce incentives for R&D innovations of new, competing products. The

market power effect can be viewed as a negative, indirect effect counteracting any positive, direct effects of patents on innovation.

The general insight that advertising can strategically preempt R&D is of course not entirely novel. Although there are, to our knowledge, no previous studies of the strategic link between advertising and R&D,[9] our paper is clearly related to the literature on advertising and entry (see, e.g., Schmalensee, 1983, Fudenberg and Tirole, 1984, Ishigaki, 2000). A striking conclusion from this literature is that the incumbent can deter entry by strategically *under-investing* in advertising, a result that runs counter to the related literature on production capacities.[10] Advertising is assumed to be a durable investment, but the incumbent can always increase the advertising stock ex post if this is profitable. This raises a concern whether the incumbent can *credibly* commit to under-invest in advertising. Schmalensee (1983) observes this problem, but avoids it by making restrictions on the incumbent's advertising choices.[11] Fudenberg and Tirole (1984) also avoids this problem simply by making second-period advertising *exogenous*.

In our model, entry only occurs with a certain probability, depending on the amount of R&D incurred by the contestants. 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 or quantity competition, as previously discussed. In doing so, we also enforce dynamic consistency by allowing the incumbent to re-optimise its advertising investment ex post. 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.

[9] The theoretical section in Ellison and Ellison (2007) is perhaps an exception, if we interprete the uncertain entry cost as R&D investments. However, the effect of patent protection on marketing and R&D incentives is not an issue. Furthermore, another main difference to our study is that they do not allow the entrant to advertise its product. This assumption may be justified by the fact that they are concerned with generic entry. Our interest is in entry of therapeutic competitors, which are typically heavily advertised. As our analysis shows, this changes the incumbent's ex ante (pre-entry) advertising incentives substantially.

[10] For instance, Dixit (1980) shows that an incumbent strategically *overinvests* in capacity in order to deter entry from a potential entrant.

[11] 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 justification is certainly debatable.

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), Caves et al. (1991), Grabowski and Vernon (1992), and Scott Morton (2000).[12] A common finding is that there is no evidence of entry deterring behaviour on the part of incumbents. However, all these papers are concerned about branded vs. generic competition, which means that they are considering competition between homogenous or 'artificially' vertically differentiated products.[13] To our best knowledge, there is no study that analyses advertising as a device for restricting competition between branded (or patented) products, nor the effect of advertising on R&D investments.

The rest of the paper is organised as follows. We present the general model framework in Section 2 and derive the equilibrium in terms of advertising and R&D investments in Section 3. Some welfare properties of the equilibrium are analysed in Section 4, with a discussion of corresponding policy implications. In Section 5 we illustrate our model by analysing a standard (parameterised) informative advertising model. Finally, the paper is concluded in Section 6.

2 A general model

Consider a therapeutic market with potentially two horizontally differentiated patented products (prescription drugs). One of the products – the 'breakthrough' drug – has already been developed by firm 1. 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 a potential entrant – firm 2 – in the race to discover the new drug.

[12] Another related study is Matraves (1999), who provides a detailed description of the relationships between advertising, R&D and market concentration in the pharmaceutical industry.

[13] Generic drugs are chemically identical products to the original brand-name drug. However, all the mentioned empirical studies strongly suggest that generics are not *de facto* perfect substitutes to the original brand-name drug. It turns out that a vertical differentiation model, where the generics are perceived to be of lower quality than the brand-name drug, produces results that fit the empirical observations well (see, e.g., Cabrales, 2003, Königbauer, 2007, Brekke et al., 2007).

We consider a two-period model with the following sequence of events:

Stage 1a: The incumbent advertises and sells the existing drug.

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

Stage 2: The new drug – if discovered – is advertised by the patent holder and sold in the market alongside the already existing drug.

Stages 1a and 1b constitute the first period, where the incumbent is a monopolist in the market. The breakthrough product (drug 1) is sold in both periods, whereas the new product (drug 2) – if discovered – is sold in the second period only. Thus, while the first-period is a single-product monopoly phase, the second period is characterised by one of three different market structures: (i) a single-product monopoly if neither firm discovers the second product; (ii) a multi-product monopoly if the incumbent wins the R&D race; and (iii) a duopoly if the entrant wins the R&D race.

Drug demand

Demand for prescription drugs is typically highly price-inelastic, mainly due to third-party payment (i.e., insurance) for drug consumption.[14] We make the assumption that drug demand is perfectly price-inelastic and depends only on the amounts of advertising for the existing drugs within the therapeutic market. Let A_i denote the amount of advertising for drug i. The demand for this drug in the *second period* is given by a function $D_i(A_i, A_j)$, where $\partial D_i/\partial A_i > 0$, $\partial^2 D_i/\partial A_i^2 \leq 0$, $\partial D_i/\partial A_j < 0$, and $\partial D_i/\partial A_i > |\partial D_j/\partial A_i|$.[15] These assumptions on the demand function imply that advertising has both a *market expanding*

[14] Patients often pay a fixed deductible or a flat fee per prescription irrespective of which prescription drug they choose. Even if they pay coinsurance, the rate is very low, resulting in low price elasticity. Moreover, the physicians may also be ignorant of prices when prescribing drugs. As a result, demand for prescription drugs is highly price inelastic. For empirical evidence on price elasticities, see, e.g., Newhouse (1993), Rizzo (1999) and Scherer (2000).

[15] Demand can be positive even without any advertising, i.e., $D(0) = \overline{D}$, where $\overline{D}$ reflects a fixed baseline demand. The size of $\overline{D}$ does not matter for the analysis; the important assumption is that advertising is the only instrument the firms can use to influence demand.

and a *business stealing* effect.[16,17] For simplicity, we assume that demand is equal in both periods, implying that first-period demand is given by $D_1(A_1, 0)$.

Advertising

A key assumption in our 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.[18] The firm producing drug i can invest in an advertising stock A_i for this product at a cost $K(A_i)$, where $K'(A_i) > 0$, $K''(A_i) > 0$ and $K(0) = 0$. Thus, we assume that both firms possess the same advertising technology.

R&D

During the monopoly phase, the incumbent and the potential entrant compete in terms of R&D to develop a new (horizontally differentiated) drug in the market. Game-theoretically, we assume that R&D investments are made simultaneously and non-cooperatively. If we denote the amount of R&D investment of firm i by x_i, the probability of success for firm i in the R&D contest is given by a function $z_i(x_i, x_j)$. 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. The R&D success function is assumed to have the following general properties: $\partial z_i/\partial x_i > 0$, $\partial z_i/\partial x_j < 0$, $\partial^2 z_i/\partial x_i^2 \leq 0$, $\partial^2 z_i/\partial x_j^2 \geq 0$ and $\partial z_i/\partial x_i > |\partial z_i/\partial x_j|$. The last assumption essentially means that increased R&D effort by either firm will always increase the overall probabil-

[16] This is in line with the empirical study by Berndt et al. (1995) of the H_2-antagonist market, showing that drug marketing is neither purely business-stealing nor purely market-expanding, but somewhere in between.

[17] The strategic effect of advertising is related to the business-stealing effect. If $\partial D_i/\partial A_j = 0$, then the incumbent cannot affect the ex post profits of the entrant, and advertising has no strategic effect. Thus, advertising has a pure (non-strategic) demand effect, i.e., $\partial D_i/\partial A_i > 0$, and strategic effect, i.e., $\partial D_i/\partial A_j < 0$.

[18] See, e.g., Schmalensee (1983), Fudenberg and Tirole (1984), Grossman and Shapiro (1984), etc. See also Brekke and Kuhn (2006) for an application to the pharmaceutical industry. As will be discussed in Section 6, our results only need some degree of advertising persistence. The assumption of infinite durability is just a simplification, making the analysis more tractable.

ity that a new drug is developed. The cost of exerting an R&D effort of x_i is given by a function $C(x_i)$, where $C'(x_i) > 0$, $C''(x_i) > 0$ and $C(0) = 0$.

Profits

As already mentioned, markets for prescription drugs are predominantly characterised by highly price inelastic demand, mainly due to extensive third-party payment and highly asymmetric information in the physician-patient relationship. As a consequence, prescription drugs are, in most countries, subject to some kind of price regulation. In the present model, we therefore make the assumption that the firms face exogenous drug prices, which seems a reasonable approximation to the above mentioned particular features. More specifically, we assume that the firms face a regulated drug price p, which – for simplicity – is assumed to be equal for both drugs.[19] Notice that, since demand is insensitive to price changes, a price increase is equivalent to a demand increase. Thus, an increase in p can also be interpreted as being equivalent to an increase in the patent length. Whether we use this interpretation, or explicitly acknowledge that the regulated drug price is an integral part of patent protection for pharmaceuticals, we can think of p as representing the 'generosity' of the patent system.

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. 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 (i.e., $p \geq 0$).

Second period profits for firm i in market structure t is denoted V_i^t, where $i = 1, 2$, and $t = S$(ingle-product monopoly), M(ulti-product monopoly), D(uopoly). Assuming dynamic consistency, i.e., that the incumbent has no incentive to increase advertising of

[19] Equal prices for both drugs might be a reasonable assumption in the case of horizontally differentiated drugs with equivalent therapeutic benefits. In the last section of the paper, we briefly discuss how different drug prices might affect our results.

the original product ex post, second period profits are given by[20]

$$V_1^S = pD_1(A_1, 0), \tag{1}$$

$$V_1^M = p[D_1(A_1, A_2) + D_2(A_1, A_2)] - K(A_2), \tag{2}$$

$$V_1^D = pD_1(A_1, A_2), \tag{3}$$

$$V_2^D = pD_2(A_1, A_2) - K(A_2). \tag{4}$$

Since the market structure in the second period depends on the outcome of the R&D contest, *expected second period profits* for firm i, denoted B_i, are given by

$$B_1 = [1 - z_1(x_1, x_2) - z_2(x_1, x_2)] V_1^S + z_1(x_1, x_2) V_1^M + z_2(x_1, x_2) V_1^D - C(x_1), \tag{5}$$

$$B_2 = z_2(x_1, x_2) V_2^D - C(x_2). \tag{6}$$

Abstracting from discounting, *expected present-value profits* for the incumbent firm at the outset of the game, denoted Π_1, are consequently given by[21]

$$\Pi_1 = V_1^S + B_1 - K(A_1). \tag{7}$$

3 Analysis

We look for the subgame-perfect Nash equilibrium of the above described game, solving the model by backwards induction. We start, then, by analysing second-period advertising of the new product: drug 2.

[20] In this model, dynamic consistency is always satisfied under reasonable assumption. We qualify this claim in Section 4, when discussing optimal first-period advertising incentives.

[21] We could have introduced a discount factor $\delta \in [0, 1]$ on second-period profits, but this only complicates the analysis, without providing any qualitatively different results. For simplicity, we therefore assume $\delta = 1$.

3.1 Second-period advertising

The introduction of a new product gives rise to one of potentially two new market structures, depending on which firm develops the new product:[22]

Duopoly

If the entrant obtains the patent for the new product, it chooses a level of advertising, A_2^D, that maximises profits for firm 2, given by (4). The first-order condition for optimal advertising of the new product defines a best response function $A_2^D(A_1)$. It is straightforward to derive that $\partial A_2^D(A_1)/\partial A_1 < 0$ if $\partial^2 D_2/\partial A_1 \partial A_2 < 0$. In this case the decision variables are *strategic substitutes*[23], implying that increased first-period advertising by the incumbent will reduce the optimal second-period advertising by the entrant.

Monopoly

If the new product is developed by the incumbent, the optimal level of advertising for this product, A_2^M, maximises the incumbent's second-period profits, given by (2). The first-order condition defines a best response function $A_2^M(A_1)$. It is straightforward to verify that the multi-product monopolist internalises the business-stealing effect of advertising, implying that $A_2^M(A_1) < A_2^D(A_1)$. Furthermore, as in the duopoly case, we find that $\partial A_2^M(A_1)/\partial A_1 < 0$ if $\partial^2 D_i/\partial A_i \partial A_j < 0$.

For the remainder of the analysis, we will generally assume that advertising investments are strategic substitutes for the firms.

3.2 The effects of first-period advertising on second-period profits

By inserting the equilibrium levels of second-period advertising in the second-period profit expressions, (1)-(4), we derive equilibrium second-period profits for firm i in market structure t as a function of first-period advertising for the incumbent product; $V_i^t(A_1)$. The properties of the demand functions – where advertising has both a market expanding

[22] Details of the calculations in this subsection are given in the Appendix.
[23] See Bulow et al. (1985).

and a business-stealing effect – implies the following ranking of equilibrium second-period profits:

$$V_1^M(A_1) > V_1^S(A_1) > V_1^D(A_1). \tag{8}$$

In words: for any level of first-period advertising, the introduction of a new drug in the therapeutic market is beneficial for the incumbent if the drug is developed by the incumbent himself, but detrimental for the incumbent if the drug is developed by a new entrant.

A key mechanism of the model is that first-period advertising by the incumbent affects second-period profits for both firms. It is relatively straightforward to verify that[24]

$$\frac{\partial V_1^S(A_1)}{\partial A_1} > 0, \quad \frac{\partial V_1^M(A_1)}{\partial A_1} > 0, \quad \frac{\partial V_1^D(A_1)}{\partial A_1} > 0, \quad \frac{\partial V_2^D(A_1)}{\partial A_1} < 0. \tag{9}$$

First-period advertising by the incumbent 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.

With the assumptions of $\partial D_i/\partial A_j < 0$ and $\partial^2 D_i/\partial A_i \partial A_j < 0$, we can also show that

$$\frac{\partial V_1^S(A_1)}{\partial A_1} > \frac{\partial V_1^M(A_1)}{\partial A_1}; \quad \frac{\partial V_1^D(A_1)}{\partial A_1} > \frac{\partial V_1^M(A_1)}{\partial A_1}. \tag{10}$$

The latter inequality implies that first-period advertising has 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 (i.e., $\partial D_i/\partial A_j < 0$) and the first-mover advantage vis-à-vis the entrant in duopoly (i.e., $\partial A_2^D/\partial A_1 < 0$). This particular relationship between the marginal second-period effects of first-period advertising will prove crucial in the subsequent analysis.

[24] See the Appendix for details.

3.3 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. 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 second-period outcome. Expected second-period profits are given by (5) and (6). For illustrative purposes, it may be useful to re-arrange the expression for the incumbent's expected second-period profits in the following way:

$$B_1 = V_1^S + z_1(x_1, x_2) \underbrace{\left[V_1^M - V_1^S\right]}_{\text{Gain of winning}} - z_2(x_1, x_2) \underbrace{\left[V_1^S - V_1^D\right]}_{\text{Loss of losing}} - C(x_1). \tag{11}$$

Thus, the incentive for the incumbent to undertake R&D investments can be decomposed into two different factors: (i) the profit gain derived from winning the R&D competition, and (ii) the profit loss of losing the R&D competition.[25]

From (6) and (11), equilibrium R&D efforts by the two firms are given by the solution to the following pair of first-order conditions:

$$\frac{\partial B_1}{\partial x_1} = \frac{\partial z_1}{\partial x_1}\left(V_1^M - V_1^S\right) - \frac{\partial z_2}{\partial x_1}\left(V_1^S - V_1^D\right) - \frac{\partial C}{\partial x_1} = 0, \tag{12}$$

$$\frac{\partial B_2}{\partial x_2} = \frac{\partial z_2}{\partial x_2} V_2^D - \frac{\partial C}{\partial x_2} = 0. \tag{13}$$

Our assumptions on $z_i(\cdot)$ and $C(\cdot)$ ensure that the second-order conditions are met. We also assume that the determinant of the Jacobian matrix is positive, guaranteeing uniqueness of the equilibrium.[26]

[25] Beath et al. (1989) label the first effect as the 'profit incentive' and the second effect as the 'competitive threat'. These also correspond to the 'replacement effect' and the 'efficiency effect' in Gilbert and Newberry (1982) and Reinganum (1983).

[26] See the Appendix for details.

3.4 The effects of first-period advertising on R&D incentives

The first-order conditions (12)-(13) implicitly define the optimal R&D efforts of firm 1 and 2 as functions of the first-period investment level by the incumbent: $x_1^*(A_1)$ and $x_2^*(A_1)$, respectively. The relationship between first-period advertising and R&D incentives is characterised as follows:

Proposition 1 *Assume that advertising investments are strategic substitutes for the firms;* $\frac{\partial^2 D_i(A_i,A_j)}{\partial A_i \partial A_j} < 0$. *Then the following results obtain:*

(i) $\frac{\partial x_1^*}{\partial A_1} < 0$ *if* $\left| \frac{\partial^2 z_i(x_i^*,x_j^*)}{\partial x_i \partial x_j} \right|$ *is sufficiently small.*

(ii) $\frac{\partial x_2^*}{\partial A_1} < 0$ *if* $\frac{\partial^2 z_i(x_i^*,x_j^*)}{\partial x_i \partial x_j} \geq 0$ *or* $\left| \frac{\partial^2 z_i(x_i^*,x_j^*)}{\partial x_i \partial x_j} \right|$ *is sufficiently small.*

A proof is given in the Appendix.

The first part of the proposition establishes the conditions for *advertising and R&D being substitute strategies* for the incumbent firm, implying that more resources spent on advertising will lead to less resources spent on R&D. This will be the case if advertising investments are strategic substitutes and the second-order cross derivatives of the innovation success functions are sufficiently small in absolute value in equilibrium.[27] If these conditions are met, increased advertising by the incumbent will also dampen the potential entrant's R&D incentives, as confirmed by the second part of the proposition.

The intuition for these results follow from a combination of direct and indirect effects. An increase in first-period advertising by the incumbent has a direct and (potentially) an indirect effect on R&D efforts of both firms, and the sign of the overall effect is generally ambiguous in both cases. The direct effects of increased advertising are unambiguously negative with respect to R&D efforts for both firms. Increased advertising by the incumbent directly reduces the second-period payoff of firm 2 and thus reduces the incentives for the potential entrant to exert effort in the R&D contest. Increased advertising for the existing product also directly reduces the incentives to invest in R&D for the incumbent,

[27] Notice that this is also the condition, in qualitative terms, for a positive Jacobian determinant. See the Appendix for further details.

because such advertising reduces the gain of winning the contest by more than a potential increase in the loss of losing.[28]

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. A lower amount of R&D by firm i could – ceteris paribus – spur increased R&D investments by firm j if R&D efforts are strategic substitutes; that is, if $\partial^2 z_i/\partial x_i \partial x_j < 0$.

Since the condition for the second part of the proposition is less restrictive than for the first part, the following implication also holds:

Corollary 1 *Increased first-period advertising by the incumbent reduces the probability that a new product is developed and introduced on the market if* $\partial^2 D_i/\partial A_i \partial A_j < 0$ *and* $\left|\partial^2 z_i/\partial x_i \partial x_j\right|$ *is sufficiently small.*

3.5 First-period advertising

At the outset of the game, the incumbent chooses the optimal level of advertising for the existing patented drug by maximising expected present-value profits over the two periods, given by (7), anticipating the outcome of the R&D game and the subsequent market equilibria in the second period. Thus, optimal first-period advertising is given by

$$A_1^* = \arg\max \left\{ \Pi_1 (A_1) = V_1^S (A_1) + B_1 \left(x_1^* (A_1), x_2^* (A_1), A_1\right) - K (A_1) \right\}. \tag{14}$$

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

$$2\frac{\partial V_1^S}{\partial A_1} - z_1 \left(\frac{\partial V_1^S}{\partial A_1} - \frac{\partial V_1^M}{\partial A_1} \right) - z_2 \left(\frac{\partial V_1^S}{\partial A_1} - \frac{\partial V_1^D}{\partial A_1} \right) - \frac{\partial K}{\partial A_1} = 0. \tag{15}$$

When deciding the optimal level of first-period advertising, the incumbent has to consider

[28] This follows from (10).

the marginal second-period benefits of increased advertising in the different market structures, and weigh these net benefits with the relevant probabilities. Here we see what it takes to ensure dynamic consistency. Since the effect of advertising is (by assumption) infinitely durable, and since the incumbent's returns from advertising occur over two periods, the optimal level of first-period advertising will, under reasonable asssumptions, be such that the incumbent has no incentive to increase advertising of drug 1 in the second-period. This holds true unless advertising incentives in duopoly (given by $\partial V_1^D/A_1$) are extremely strong, implying that $\partial^2 D_i/\partial A_i \partial A_j$ is very large in absolute value.[29]

In the following, we define *overinvestment* in advertising as an advertising level in excess of the level given by the above benchmark. In other words, we say that an incumbent firm overinvests in advertising if it advertises more than it would have done if advertising and R&D decisions were unrelated, implying that the R&D probabilities (z_1 and z_2) were exogenous with respect to the first-period advertising decision.

Let us now turn to the case of endogenous probabilities, determined by the absolute and relative R&D efforts of the firms. From (14), the first-order condition for an optimal level of first-period advertising can be conceptualised and expressed as follows:

$$\frac{\partial \Pi_1 (A_1)}{\partial A_1} = \textit{Direct rent effect} + \textit{Strategic R\&D effect} = 0, \tag{16}$$

where the *Direct rent effect* is equal to the left-hand side of (15), whereas the *Strategic R&D effect* can, by using (12), be expressed as

$$\left[\frac{\partial z_1}{\partial x_2}\left(V_1^M - V_1^S\right) - \frac{\partial z_2}{\partial x_2}\left(V_1^S - V_1^D\right)\right]\frac{\partial x_2^*}{\partial A_1}. \tag{17}$$

Since the expression in square brackets is unambiguously negative, it follows that the *Strategic R&D effect* is positive if and only if $\partial x_2^*/\partial A_1 < 0$. Since our definition of *overinvestment* is equivalent to a positive *Strategic R&D effect*, the following result follows immediately:

[29] In the parametric example presented in the next section, dynamic consistency is ensured by a wide margin.

Proposition 2 *The incumbent firm optimally overinvests in advertising if and only if such advertising reduces the R&D effort of the potential entrant.*

As we can see from (17), the gain for the incumbent of inducing a lower R&D effort from the potential entrant – which provides the incentives for overinvestment – is constituted by two parts. A lower value of x_2^* implies that the incumbent's expected gain of winning the contest, $z_1\left(V_1^M - V_1^S\right)$, is increased, while the expected loss of losing, $z_2\left(V_1^S - V_1^D\right)$, is reduced. Thus, as long as first-period advertising by the incumbent reduces R&D efforts by the potential entrant, with the relevant conditions given in Proposition 1, incentives for overinvestment are present.

4 Some welfare and policy implications

In this section of the paper, we assess the welfare properties of the equilibrium derived above. We restrict attention to the first-period advertising decision and ask how the incumbent's advertising incentives correspond to the ones of a social planner, taking the subsequent R&D decisions as given, and under which circumstances restrictions on marketing activities might be justified.[30]

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 (physicians) becomes aware

[30] 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 almost every western country, 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.

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.

When evaluating welfare effects, we make use of the standard welfare measure: the sum of consumers' and producers' surplus net of third party payments. Assuming that third-party funds can be raised in a non-distortionary manner, the social welfare function simplifies to (gross) 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.

Let $U^t(A_1)$ denote aggregate consumer utility in market structure $t = S, M, D$. Furthermore, we define $\widehat{U}^D(A_1) := U^D(A_1) - K\left(A_2^D(A_1)\right)$ and $\widehat{U}^M(A_1) := U^M(A_1) - K\left(A_2^M(A_1)\right)$ as aggregate utility net of second-period advertising costs in the market structures with successful innovation. Expected social welfare, as a function of first-period advertising, is then given by[31]

$$\begin{aligned} W(A_1) &= U^S(A_1) + [1 - z_1(A_1) - z_2(A_1)]\, U^S(A_1) + z_1(A_1)\,\widehat{U}^M(A_1) \\ &\quad + z_2(A_1)\,\widehat{U}^D(A_1) - C(x_1(A_1)) - C_2(x_1(A_1)) - K(A_1). \end{aligned} \tag{18}$$

In the subsequent analysis, we make the following assumptions:

1. The conditions stated in Proposition 1 are satisfied; i.e., $\partial x_1^*/\partial A_1 < 0$ and $\partial x_2^*/\partial A_1 < 0$.

2. Aggregate consumer utility is weakly increasing in advertising, and is always higher with two drugs on the market; i.e., $\partial U^t/\partial A_1 \geq 0$ for $t = S, M, D$, and $U^t > U^S$ for $t = M, D$.

3. The welfare function is concave in A_1.

Let us first characterise the socially optimal (second-best) level of first-period advertising, taking into account the subsequent effects on R&D investments and (possible)

[31] Notice that, to save notation, we write $z_i(A_1) := z_i(x_1(A_1), x_2(A_1))$, $i = 1, 2$.

second-period advertising of the new drug. Taking the first-order derivative of W with respect to A_1 yields

$$\begin{aligned}\frac{\partial W(A_1)}{\partial A_1} &= (2-z_1-z_2)\frac{\partial U^S}{\partial A_1}+z_1\frac{\partial \widehat{U}^M}{\partial A_1}+z_2\frac{\partial \widehat{U}^D}{\partial A_1}-\frac{\partial K}{\partial A_1} \\ &+\left(\frac{\partial z_1}{\partial x_2}\left(\widehat{U}^M-U^S\right)+\frac{\partial z_2}{\partial x_2}\left(\widehat{U}^D-U^S\right)-\frac{\partial C}{\partial x_2}\right)\frac{\partial x_2^*}{\partial A_1} \\ &+\left(\frac{\partial z_1}{\partial x_1}\left(\widehat{U}^M-U^S\right)+\frac{\partial z_2}{\partial x_1}\left(\widehat{U}^D-U^S\right)-\frac{\partial C}{\partial x_1}\right)\frac{\partial x_1^*}{\partial A_1}.\end{aligned} \tag{19}$$

The interpretation of this expression, consisting of six terms, is reasonably straightforward. The first four terms represent the effect of increased advertising on consumer utility (net of advertising costs) in each possible market structure, weighted by the respective probabilities. The next two terms represent the expected utility loss, net of R&D costs (and second-period advertising costs), of a lower probability of drug innovation, due to the adverse effect of advertising on R&D effort. This effect would be zero at the point where R&D investment are at the socially optimal (first-best) level. The socially optimal (second-best) level of advertising balances these effects to the point where $\partial W(A_1)/\partial A_1 = 0$.

In order to assess the welfare properties of the equilibrium derived in the previous section, we can evaluate the above expression at the equilibrium, A_1^*, which is implicitly given by (15)-(17). By substituting for $\partial K/\partial A_1$ at the optimal level A_1^*, and rearranging, we obtain the following expression:[32]

$$\begin{aligned}\frac{\partial W(A_1^*)}{\partial A_1} &= (2-z_1-z_2)\left(\frac{\partial U^S}{\partial A_1}-\frac{\partial V_1^S}{\partial A_1}\right)+z_1\left(\frac{\partial \widehat{U}^M}{\partial A_1}-\frac{\partial V_1^M}{\partial A_1}\right)+z_2\left(\frac{\partial \widehat{U}^D}{\partial A_1}-\frac{\partial V_1^D}{\partial A_1}\right) \\ &+\left(\frac{\partial z_1}{\partial x_2}\left(\widehat{U}^M-U^S\right)+\frac{\partial z_2}{\partial x_2}\left(\widehat{U}^D-U^S\right)-\frac{\partial C}{\partial x_2}\right)\frac{\partial x_2^*}{\partial A_1} \\ &+\left(\frac{\partial z_1}{\partial x_1}\left(\widehat{U}^M-U^S\right)+\frac{\partial z_2}{\partial x_1}\left(\widehat{U}^D-U^S\right)-\frac{\partial C}{\partial x_1}\right)\frac{\partial x_1^*}{\partial A_1} \\ &-\left[\frac{\partial z_1}{\partial x_2}\left(V_1^M-V_1^S\right)-\frac{\partial z_2}{\partial x_2}\left(V_1^S-V_1^D\right)\right]\frac{\partial x_2^*}{\partial A_1}\end{aligned} \tag{20}$$

[32] We use the notational shorthand $\frac{\partial W(A_1^*)}{\partial A_1}$ for $\left.\frac{\partial W(A_1)}{\partial A_1}\right|_{A_1=A_1^*}$.

This expression gives the difference between social and private marketing incentives (in a second-best context). If $\partial W\left(A_1^*\right)/\partial A_1 < 0$ the incumbent invest too much in advertising, while the opposite holds true if $\partial W\left(A_1^*\right)/\partial A_1 > 0$. The difference between social and private incentives is essentially made up of three different components. The first three terms in (20) represent the difference between marginal consumer utility and marginal second-period profits in each of the possible market structures, weighted by probabilities. The subsequent two terms have been discussed before, while the final term is what we have dubbed the *Strategic R&D effect* of the incumbent.

Under which circumstances will the incumbent advertise more than the socially optimal level? In other words, when is $\partial W\left(A_1\right)/\partial A_1|_{A_1=A_1^*} < 0$? One key factor is the extent to which advertising is persuasive (as opposed to informative). If we take an "objective welfare" perspective, the degree of persuasiveness should be reflected in the size of the marginal utility of advertising; $\partial U^t/\partial A_1$. From the first three terms of (20) we see that the less informative advertising is (i.e., the lower the marginal utility of advertising is), the more likely it is that the whole expression is negative, implying a socially excessive level of advertising in equilibrium.

Another key factor is the strength of patent protection, measured by the parameter p. This enters directly in the first three terms, and in the last term, of (20). It is straightforward to verify that an increase in p increases the marginal profit gain of advertising, $\partial V^t/\partial A_1$, $t = S, M, D$, and also increases the profit differentials $\left(V_1^M - V_1^S\right)$ and $\left(V_1^S - V_1^D\right)$. In other words, stronger patent protection not only increases advertising incentives for given R&D levels (first three terms), it also increases incentives for strategic advertising to reduce R&D investments (last term). A change in p has also indirect effects through changes in $\partial x_1^*/\partial A_1$ and $\partial x_2^*/\partial A_1$, which are generally difficult to characterise. However, under the assumption that the first-order effects dominate the second-order ones, we see that – all else equal – stronger patent protection increases the likelihood of advertising being at a socially excessive level in equilibrium. This conclusion implies that stricter regulation of drug marketing (i.e., reducing A_1^*) and a less generous patent policy/stricter

price regulation (i.e., reducing p) are policy substitutes.

5 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).[33] 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, where informed consumers buy one unit in each period. With two products in the market, consumers who are informed about both products buy either product with probability 1/2.[34] If a fraction A_i (A_j) of consumers are informed about drug i (j), second-period demand for drug i is given by

$$D_i(A_i, A_j) = A_i(1 - A_j) + \frac{A_i A_j}{2}, \qquad i, j = 1, 2; \quad i \neq j. \tag{21}$$

Notice that $\partial^2 D_i / \partial A_i \partial A_j = -1/2$, 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 drug i by incurring a cost of $K(A_i) = \frac{k}{2} A_i^2$, $A_i \in [0, 1]$. We can now use these parameterised demand and cost functions to calculate second-period payoffs in the different market structures.[35]

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

[33] This approach has been widely used in the advertising literature. See, e.g., Schmalensee (1983), Fudenberg and Tirole (1984), Grossman and Shapiro (1984), Ishigaki (2000), Brekke and Kuhn (2006).

[34] We can interpret this as a Hotelling model with uniform distribution of consumers, symmetric location of products and ads reaching consumers randomly.

[35] The explicit expressions are given in the Appendix.

granted to either firm with probability $\frac{1}{2}$. This yields the following success functions:[36]

$$z_i(x_i, x_j) = x_i(1 - x_j) + \frac{x_i x_j}{2}, \qquad i, j = 1, 2; \quad i \neq j. \tag{22}$$

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

5.1 Equilibrium analysis

We can insert these functional expressions into (6) and (11), and solve for the optimal values of x_i in the R&D competition:

$$x_1^*(A_1) = \frac{2p^2\left[32ck(1 - A_1)^2 - p^2[2 - 3A_1(2 - A_1)](2 - A_1)^2\right]}{128c^2k^2 - p^4[2 - 3A_1(2 - A_1)](2 - A_1)^2}, \tag{23}$$

$$x_2^*(A_1) = \frac{4p^2(2 - A_1)^2\left[4ck - p^2(1 - A_1)^2\right]}{128c^2k^2 - p^4[2 - 3A_1(2 - A_1)](2 - A_1)^2}. \tag{24}$$

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 $A_1 \in [0, 1]$. From (23)-(24) we derive:

Proposition 3 *In the informative advertising model, given that $c > \underline{c}$, then*

(i) $x_1^* = x_2^*$ if $A_1 = 0$,

(ii) $x_1^* < x_2^*$ if $A_1 > 0$, and

(iii) $\frac{\partial x_i^*}{\partial A_1} < 0$ for any $A_1 \in [0, 1]$ and $i = 1, 2$.

A proof is given in the Appendix.

Proposition 3 shows that the incumbent will invest less aggressively in R&D than the potential entrant. While the entrant's R&D incentives are determined by the possibility of duopoly profit only, the incumbent balances the profit gain of winning the R&D competition against the profit loss of losing the R&D competition. Since the incumbent has

[36] 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 $\partial^2 z_i/\partial x_i \partial x_j < 0$.

already secured some profits, due to being a single-product monopolist in the first period, the net gain of winning the R&D competition is lower than for the entrant. However, in the extreme case of no first-period advertising, both firms will invest equally much in R&D. The reason is simply that for $A_1 = 0$, single-product monopoly profits are also zero, implying that the incumbent and the entrant face identical expected profit gains from winning from the R&D competition.

The proposition also confirms that the general conditions given in Proposition 1 are always satisfied in the informative advertising model, implying that marketing and R&D are substitute strategies for the incumbent, and a lower level of first-period advertising will increase overall R&D expenditures. By combining Propositions 2 and 3, we also see that the informative advertising model yields strategic overinvestment in advertising by the incumbent.

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.[37] Tables 1–3 report equilibrium values of first-period advertising and R&D investments for different values of the key parameters k, c and p. In Table 4, 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 (17), in equilibrium, which measures the degree of overinvestment in first-period advertising. Table 4 reveals that the incentives for overinvestment are increasing in p and decreasing in k and c.

[37] It is straightforward to verify that the model is dynamically consistent. In the informative advertising model, the incumbent has no incentives to increase advertising of drug 1 in the second period if $A_1^* \geq \frac{p}{k}$. From Table 1 we see that this condition is always satisfied.

Table 1: A_1^*.

	$c = \frac{1}{2}$		$c = 1$	
p	$k = 10$	$k = 15$	$k = 10$	$k = 15$
1	0.200	0.133	0.200	0.133
2	0.396	0.264	0.398	0.265
3	0.596	0.394	0.599	0.397
4	0.811	0.525	0.809	0.529

Table 2: x_1^*.

	$c = \frac{1}{2}$		$c = 1$	
p	$k = 10$	$k = 15$	$k = 10$	$k = 15$
1	0.062	0.049	0.032	0.025
2	0.144	0.137	0.072	0.070
3	0.193	0.215	0.085	0.108
4	0.235	0.283	0.078	0.130

Table 3: x_2^*.

	$c = \frac{1}{2}$		$c = 1$	
p	$k = 10$	$k = 15$	$k = 10$	$k = 15$
1	0.079	0.057	0.040	0.029
2	0.239	0.187	0.124	0.097
3	0.401	0.345	0.212	0.182
4	0.499	0.498	0.273	0.270

Table 4: *Strategic R&D effect*.

	$c = \frac{1}{2}$		$c = 1$	
p	$k = 10$	$k = 15$	$k = 10$	$k = 15$
1	0.001	0.000	0.000	0.000
2	0.018	0.007	0.010	0.003
3	0.086	0.036	0.051	0.021
4	0.234	0.105	0.156	0.067

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.[38] 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 *marketing 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. *Ceteris paribus*, reduced first-period advertising increases R&D incentives, as we have analysed in great detail in Section 4.4. However, higher advertising costs also reduce second-period profits, 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, and with respect to the incumbent's R&D incentives.

[38] Other simulations with different parameter values yield a qualitatively similar picture.

Increased *R&D costs* (c) reduce 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 *drug price* (p). A price increase 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 2 we see that the second effect always dominates when advertising costs are high, implying that it is more costly to use advertising as a means to reduce R&D investments. On the other hand, for the combination of low advertising costs and high R&D costs, there is 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 2 and 3. However, a higher price – or, generally, a more generous patent protection – 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 2 and 3 that raising p above a certain level has a very modest effect on aggregate R&D expenditures, while incentives for advertising increase considerably.

5.2 Welfare implications

We can derive welfare implications from the informative advertising example by using 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 drug, while τ is the cost per unit distance between the actually consumed drug and the consumer's 'ideal' drug. Whereas v can be interpreted as the effectiveness of the drug treatment, τ can be interpreted as a measure of potential side-effects and contraindications. We also assume full market coverage, i.e., no consumers refrain from buying the existing product(s).

It is now straightforward to derive the expressions for ex post consumer utility in the different potential market structures.[39] For simplicity, we assume full third-party payment of drugs.[40,41]

[39] The explicit expressions are given in the Appendix.

[40] Since social welfare does not depend on prices, the assumption of full third-party payment makes the exposition easier without affecting the result.

[41] With full third-party payment, the assumption of full market coverage is equivalent to imposing a restriction $v - \tau \geq 0$.

Table 5: The socially optimal level of A_1

	$c = \frac{1}{2}$		$c = 1$	
p	$k = 10$	$k = 15$	$k = 10$	$k = 15$
1	0.498	0.332	0.499	0.333
2	0.490	0.328	0.495	0.331
3	0.491	0.328	0.495	0.330
4	0.511	0.338	0.511	0.338
Other parameter values: $v = 3$, $\tau = 1$				

The socially optimal level of first-period advertising is reported in Table 5, for different numerical values of the key parameters. The numerical values are identical to the ones previously chosen, so that we can make a straightforward comparison between the equilibrium values of advertising (Table 1) and the socially optimal ones (Table 5). The only general picture that appears from this numerical example is that the socially optimal level of advertising is inversely proportional to the direct advertising costs. The parameters p and c have minimal influence on the socially optimal level of advertising. In relation to the general discussion of private versus social advertising incentives in Section 4, this confirms that any second-order effects of an increase in p (through changes in $\partial x_1^*/\partial A_1$ and $\partial x_2^*/\partial A_1$) is by far outweighed by the first-order effects through the incumbent's increased profit incentives for advertising; i.e., the increase in $\partial V^t/\partial A_1$, $\left(V_1^M - V_1^S\right)$ and $\left(V_1^S - V_1^D\right)$. Thus, when comparing Table 1 and Table 5, the picture is very clear: In equilibrium, first-period advertising is excessively high for sufficiently high values of p, regardless of advertising or R&D costs. This confirms our conclusion that stricter regulation of drug marketing and a stricter patent policy are policy substitutes. In other words, even in a setting where advertising is purely informational, our results suggest that a generous patent (or price regulation) system should be matched with strict regulation on advertising, and vice versa.

6 Concluding remarks

In this paper we have analysed how a patent-holding pharmaceutical firm may strategically use advertising ex ante to affect R&D investments in new drugs, and thereby change the probability distribution of future market structures. In doing so, we have explored the basic idea that a generous patent system may provide incentives for patent-holding firms not only to spend resources on R&D to obtain new patents, but also to spend resources on marketing to protect existing patents. In this final section of the paper, we will not recapitulate our results in detail, but instead provide some discussion of a couple of key assumptions.

While the assumption of drug demand being insensitive to prices is appropriate for most pharmaceutical markets, the additional simplifying assumption that the price is equal for the old and new drug in the therapeutic market is not so obvious. However, while a relaxation of this assumption is likely to affect the relative strength of R&D and marketing incentives, it does not affect the main mechanisms of the model. A higher expected price for the new drug will – all else equal – stimulate R&D incentives for both firms. This suggests that it might be relatively less important for the incumbent to spend resources on marketing in order to protect the existing patent rent. However, a higher price for the new product also means that a potential entrant – if successful in obtaining the new patent – will advertise this drug more heavily in the second-period duopoly, which, in turn, increases the incumbent's loss in case of entry. Consequently, this gives the incumbent a stronger incentive – all else equal – to use first-period advertising as a strategic instrument in order to reduce the probability of incurring such a loss. The relative strength of these effects is a priori uncertain.

The analysis rests on the crucial assumption that the effect of advertising persists over time. If this was not the case, there would be no demand-side link between marketing and R&D, and the two decision variables would be strategically independent. While the standard assumption in the strategic advertising literature – that the effect of advertising is infinitely durable – is obviously unrealistically strong when taken literally, it may

nevertheless be a useful simplification that captures an important aspect of advertising. In reality, the effects of advertising are neither completely instantaneous nor infinitely durable, but somewhere in between. The question is rather how strong the persistence effect is. The basic idea explored in our analysis only requires that there is, to a certain degree, a persistence effect. Obviously, the weaker this persistence effect is, the more costly it is for the incumbent firm to use first-period advertising strategically in order to affect R&D expenditures and thereby the probabilities of second-period market structures.

Finally, it should be mentioned that 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

The effects of first-period advertising on second-period profits

The first-order conditions for optimal second-period advertising in market structures D and M, respectively, are given by

$$p\frac{\partial D_2\left(A_1,A_2\right)}{\partial A_2}-\frac{\partial K\left(A_2\right)}{\partial A_2}=0 \tag{A1}$$

and

$$p\left(\frac{\partial D_1\left(A_1,A_2\right)}{\partial A_2}+\frac{\partial D_2\left(A_1,A_2\right)}{\partial A_2}\right)-\frac{\partial K\left(A_2\right)}{\partial A_2}=0. \tag{A2}$$

Comparing (A1) and (A2), it is clear that $A_2^M\left(A_1\right)<A_2^D\left(A_1\right)$. Totally differentiating these first-order conditions, and applying the Envelope Theorem, the effects of first-period advertising on second-period profits are given by

$$\frac{\partial V_1^S\left(A_1\right)}{\partial A_1}=p\frac{\partial D_1\left(A_1,0\right)}{\partial A_1}>0, \tag{A3}$$

$$\frac{\partial V_1^M\left(A_1\right)}{\partial A_1}=p[\frac{\partial D_1\left(A_1,A_2^M\right)}{\partial A_1}+\frac{\partial D_2\left(A_1,A_2^M\right)}{\partial A_1}]>0, \tag{A4}$$

$$\frac{\partial V_1^D\left(A_1\right)}{\partial A_1}=p\left[\frac{\partial D_1\left(A_1,A_2^D\right)}{\partial A_1}+\frac{\partial D_1\left(A_1,A_2^D\right)}{\partial A_2}\frac{\partial A_2^D}{\partial A_1}\right]>0, \tag{A5}$$

$$\frac{\partial V_2^D\left(A_1\right)}{\partial A_1}=p\frac{\partial D_2\left(A_1,A_2^D\right)}{\partial A_1}<0. \tag{A6}$$

The R&D game: Second-order conditions and the Jacobian

The second-order conditions for optimal R&D expenditures are given by

$$\frac{\partial^2 B_1}{\partial x_1^2}=\frac{\partial^2 z_1}{\partial x_1^2}\left(V_1^M-V_1^S\right)-\frac{\partial^2 z_2}{\partial x_1^2}\left(V_1^S-V_1^D\right)-\frac{\partial^2 C}{\partial x_1^2}<0 \tag{A7}$$

and

$$\frac{\partial^2 B_2}{\partial x_2^2}=\frac{\partial^2 z_2}{\partial x_2^2}V_2^D-\frac{\partial^2 C}{\partial x_1^2}<0. \tag{A8}$$

The Jacobian matrix is given by

$$J = \begin{bmatrix} \frac{\partial^2 B_1}{\partial x_1^2} & \frac{\partial^2 B_1}{\partial x_2 \partial x_1} \\ \frac{\partial^2 B_2}{\partial x_1 \partial x_2} & \frac{\partial^2 B_2}{\partial x_2^2} \end{bmatrix}. \tag{A9}$$

From (12) and (13), we derive

$$\begin{aligned} |J| \;=\; & \left(\underbrace{\frac{\partial^2 z_1}{\partial x_1^2}\frac{\partial^2 z_2}{\partial x_2^2} - \frac{\partial^2 z_1}{\partial x_2 \partial x_1}\frac{\partial^2 z_2}{\partial x_1 \partial x_2}}_{\leqslant 0} \right) \left(\underbrace{V_1^M - V_1^S}_{>0} \right) V_2^D \\ & - \left(\underbrace{\frac{\partial^2 z_2}{\partial x_1^2}\frac{\partial^2 z_2}{\partial x_2^2} - \left(\frac{\partial^2 z_2}{\partial x_1 \partial x_2} \right)^2}_{<0} \right) \left(\underbrace{V_1^S - V_1^D}_{>0} \right) V_2^D - \underbrace{\frac{\partial^2 C}{\partial x_1^2}\frac{\partial^2 z_2}{\partial x_2^2}}_{<0} V_2^D - \underbrace{\frac{\partial^2 C}{\partial x_2^2}\frac{\partial^2 B_1}{\partial x_1^2}}_{<0}. \end{aligned} \tag{A10}$$

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

Proof of Proposition 1.

From the first-order conditions of the R&D game, (12)-(13), applying Cramer's Rule and assuming $|J| > 0$, the signs of $\partial x_1^*/\partial A_1$ and $\partial x_2^*/\partial A_1$ are given by

$$sign\left(\frac{\partial x_1^*}{\partial A_1} \right) = sign \left\{ -\Omega \left(\underbrace{\frac{\partial^2 z_2}{\partial x_2^2} V_2^D - \frac{\partial^2 C}{\partial x_2^2}}_{<0} \right) + \Phi \underbrace{\frac{\partial z_2}{\partial x_2}\frac{\partial V_2^D}{\partial A_1}}_{<0} \right\} \tag{A11}$$

and

$$sign\left(\frac{\partial x_2^*}{\partial A_1} \right) = sign \left\{ \underbrace{-\frac{\partial^2 B_1}{\partial x_1^2}\frac{\partial z_2}{\partial x_2}\frac{\partial V_2^D}{\partial A_1}}_{>0} + \Omega \underbrace{\frac{\partial^2 z_2}{\partial x_1 \partial x_2} V_2^D}_{\leqslant 0} \right\}, \tag{A12}$$

where

$$\Omega := \frac{\partial z_1}{\partial x_1}\left(\frac{\partial V_1^M}{\partial A_1} - \frac{\partial V_1^S}{\partial A_1} \right) - \frac{\partial z_2}{\partial x_1}\left(\frac{\partial V_1^S}{\partial A_1} - \frac{\partial V_1^D}{\partial A_1} \right) < 0, \tag{A13}$$

$$\Phi := \frac{\partial^2 z_1}{\partial x_2 \partial x_1}\left(V_1^M - V_1^S\right) - \frac{\partial^2 z_2}{\partial x_2 \partial x_1}\left(V_1^S - V_1^D\right) \lesseqgtr 0. \tag{A14}$$

Notice that (10) together with $\partial z_i/\partial x_i > |\partial z_i/\partial x_j|$ ensure that $\Omega < 0$. In both (A11) and (A12), the first term is unambiguously negative. The second term, which can potentially be positive, will never offset the first term, in (A11) or (A12), if $\left|\partial^2 z_i\left(x_i^*, x_j^*\right)/\partial x_i \partial x_j\right|$ is sufficiently small. In (A12) the condition is weaker, since a sufficient condition for $\partial x_2^*/\partial A_1 < 0$ is that the second-order cross partial derivative of the success function is non-negative. *Q.E.D.*

Profits and utility in the informative advertising model

Using the demand and cost functions specified Section 5, second-period payoffs, as functions of first-period advertising, are given by

$$V_1^S(A_1) = pA_1, \tag{A15}$$

$$V_1^M(A_1) = p\left[A_1 + \frac{p}{2k}(1 - A_1)^2\right], \tag{A16}$$

$$V_1^D(A_1) = pA_1\left[1 - \frac{p}{4k}(2 - A_1)\right], \tag{A17}$$

$$V_2^D(A_1) = \frac{p^2}{8k}(2 - A_1)^2. \tag{A18}$$

Using the Hotelling interpretation of the model given in Section 5, we can derive aggregate consumer utility in each of the possible market structures. In the single-product case, where neither firm succeed in developing the new drug, aggregate consumer utility is given by

$$U^S(A_1) = A_1 \int_0^1 (v - \tau y)\, dy = A_1\left(v - \frac{\tau}{2}\right). \tag{A19}$$

In the multi-product case, where either the incumbent or the entrant discovers the new

product, aggregate consumer utility is given by

$$\begin{aligned} U^M(A_1, A_2) &= U^D(A_1, A_2) \qquad \text{(A20)} \\ &= A_1(1-A_2)\int_0^1 (v-\tau y)\,dy + A_2(1-A_1)\int_0^1 (v-\tau(1-y))\,dy \\ &\quad + A_1A_2\left(\int_0^{\frac{1}{2}} (v-\tau y)\,dy + \int_{\frac{1}{2}}^1 (v-\tau(1-y))\,dy\right) \\ &= [A_1 + A_2 - 2A_1A_2]\left(v-\frac{\tau}{2}\right) + A_1A_2\left(v-\frac{\tau}{4}\right) - \frac{k}{2}A_2^2. \end{aligned}$$

Inserting the optimal levels of second-period advertising, $A_2^D = \frac{p}{k}\left(1-\frac{A_1}{2}\right)$ and $A_2^M = \frac{p}{k}(1-A_1)$, yield aggregate utility as functions of first-period advertising: $U^M(A_1)$ and $U^D(A_1)$.

Proof of Proposition 3.

Part (i) and (ii): Since the denominators of (23) and (24) are equal, it is sufficient to compare the numerators to decide the ranking of $x_1^*(A_1)$ and $x_2^*(A_1)$.

$$x_2^*(A_1) - x_1^*(A_1) \geq 0$$

$$\Updownarrow$$

$$\Delta := 8A_1kc(4-3A_1) - p^2A_1(2-A_1)^3 \geq 0. \qquad \text{(A21)}$$

By inspection of (A21), it is easily verified that $\lim_{A_1\to 0}\Delta = 0$. This establishes part (i) of the proposition.

To prove part (ii) of the proposition, we evaluate Δ at the lower bound of c, i.e., $\underline{c} := p^2/4k$, yielding the following:

$$\lim_{c\to\underline{c}}\Delta = A_1^2p^2\left[6(1-A_1) + A_1^2\right] > 0 \text{ for any } A_1 > 0.$$

Since Δ is increasing in c, it must hold that $x_2^*(A_1) > x_1^*(A_1)$ for any $c > \underline{c}$ and $A_1 > 0$.

Part (iii): From (23) and (24) we derive:

$$\frac{\partial x_1^*(A_1)}{\partial A_1} = -\frac{128p^2ck\left(4kc\mu-\sigma\right)}{\left(128c^2k^2-p^4\left(2-3A_1\left(2-A_1\right)\right)\left(2-A_1\right)^2\right)^2} \tag{A22}$$

and

$$\frac{\partial x_2^*(A_1)}{\partial A_1} = -\frac{8p^2\left(2-A_1\right)\left(128c^2k^2\psi+\phi\right)}{\left(128c^2k^2-p^4\left(2-3A_1\left(2-A_1\right)\right)\left(2-A_1\right)^2\right)^2}, \tag{A23}$$

where

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

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

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

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

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 (A22) and (A23), respectively. Since the values of both numerators are increasing in c, it suffices to make an evaluation at the limit $c \to \underline{c}$. Straightforward computation yields

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

and $\lim_{c\to\underline{c}}\left(128c^2k^2\psi+\phi\right) = 2p^6A_1^2\left(2-A_1\right)\left(5-A_1\right) > 0$ for $A_1 \in [0,1]$ .It follows that $\partial x_1^*(A_1)/\partial A_1 < 0$ and $\partial x_1^*(A_1)/\partial A_1 < 0$ for $c > \underline{c}$ and $A_1 \in [0,1]$. *Q.E.D.*

References

[1] Beath, J., Katsoulacos, Y., Ulph, D., 1989. Strategic R&D policy. Economic Journal 99, 74–83.

[2] Berndt, E.R., Bui, L., Reiley, D.R., Urban, G.L., 1995. Information, marketing, and pricing in the US antiulcer drug market. American Economic Review Papers and Proceedings, 85, 100–105.

[3] Brekke, K.R., Kuhn, M., 2006. Direct to consumer advertising in pharmaceutical markets. Journal of Health Economics 25, 102–130.

[4] Brekke, K.R., Königbauer, I., Straume, O.R., 2007. Reference pricing of pharmaceuticals. Journal of Health Economics 26, 613–642.

[5] Bulow, J., Geanakoplos, J., Klemperer, P., 1985. Multimarket oligopoly: strategic substitutes and complements. Journal of Political Economy, 93, 488–511.

[6] Butters, G., 1977. Equilibrium distributions of sale and advertising prices. Review of Economic Studies, 44, 465–491.

[7] Cabrales, A., 2003. Pharmaceutical generics, vertical product differentiation, and public policy. Mimeo, Universitat Pompeu Fabra.

[8] Caves, R., Whinston, M.D., Hurwitz, M., 1991. Patent expiration, entry, and competition in the U.S. pharmaceutical industry. Brookings Papers on Economic Activity. Microeconomics, 1–66.

[9] Denicolo, V., 1996. Patent races and optimal patent breadth and length. Journal of Industrial Economics 44, 249–265.

[10] Dixit, A., 1980. The role of investment in entry deterrence. Economic Journal, 90, 95-106.

[11] Ellison, G., Ellison, S.F., 2007. Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration. NBER Working Paper 13069, National Bureau of Economic Research, Inc.

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

[13] Gilbert, R.J., Newberry, D., 1982. Pre-emptive patenting and the persistence of monopoly. American Economic Review, 72, 514–526.

[14] Grabowski, H.G., Vernon, J., 1992. Brand loyalty, entry, and price competition in pharmaceuticals after the 1984 Drug Act. Journal of Law and Economics, 35, 331–350.

[15] Grossman, G., Shapiro, C., 1984. Informative advertising with differentiated products. Review of Economic Studies, 51, 63–81.

[16] Hurwitz, M., Caves, R., 1988. Persuasion or information? Promotion and the shares of brand name and generic pharmaceuticals. Journal of Law and Economics, 31, 299–320.

[17] Ishigaki, H., 2000. Informative advertising and entry deterrence: a Bertrand model. Economic Letters, 67, 337–343.

[18] Jaffe, A.B., 2000. The U.S. patent system in transition: policy innovation and the innovation process. Research Policy, 29, 531–557.

[19] Kanavos, P., 2001. Overview of pharmaceutical pricing and reimbursement regulation in Europe. Commission of the European Communities, Dg Enterprise, November.

[20] Königbauer, I., 2007. Advertising and generic market entry. Journal of Health Economics, 26, 286–305.

[21] Langinier, C., 2004. Are patents strategic barriers to entry? Journal of Economics & Business, 56, 349–361.

[22] Lu, J.L., Comanor, W.S., 1998. Strategic pricing of new pharmaceuticals. Review of Economics and Statistics, 80, 108–118.

[23] Matraves, C., 1999. Market structure, R&D and advertising in the pharmaceutical industry. Journal of Industrial Economics, 47, 169–194.

[24] Needham, D., 1976. Entry barriers and non-price aspects of firms' behavior. Journal of Industrial Economics, 25, 29–43.

[25] Newhouse, J.P., 1993. Free for All? Lessons from the RAND Health Experiment. Cambridge, Mass.: Harvard University Press.

[26] Reinganum, J.F., 1983. Uncertain innovation and the persistence of monopoly. American Economic Review, 73, 741–778.

[27] Rizzo, J.A., 1999. Advertising and competition in the ethical pharmaceutical industry: The case of antihypertensive drugs. Journal of Law and Economics, 42, 89-116.

[28] Sakakibare, M., Branstetter, L., 2001. Do stronger patents induce more innovation? Evidence from the 1988 Japanese patent law reforms. RAND Journal of Economics, 32, 77–100.

[29] Schmalensee, R., 1983. Advertising and entry deterrence: an exploratory model. Journal of Political Economy, 91, 636–653.

[30] Scherer, F.M., Ross, D., 1990. Industrial Market Structure and Economic Performance. Houghton Mifflin Company, Boston, Chapter 16.

[31] Scherer, F.M., 2000. The pharmaceutical industry. In: Cuyler, A.J., Newhouse, J.P. (Eds.), Handbook of Health Economics. North Holland, Elsevier, Amsterdam, Chapter 25.

[32] Schweitzer, S.O., 1997. Pharmaceutical Economics and Policy. Oxford University Press, New York.

[33] Scott Morton, F.M., 2000. Barriers to entry, brand advertising, and generic entry in the US pharmaceutical industry. International Journal of Industrial Organization, 18, 1085–1104.

[34] Waterson, M., 1990. The Economics of Product Patents. American Economic Review, 80, 860-869.

[35] Zweifel, P., Breyer, F., 1997. Health Economics. Oxford University Press, New York.

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