Patents: Incentives for R&D or Marketing?

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Abstract

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. We consider a market with potentially two horizontally differentiated products. 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. We use a two-period model with the following sequence of events. First, the incumbent advertise and sells the “breakthrough” product. Second, the incumbent and the potential entrant simultaneously invest in R&D to develop a new product. Third, the new product – if it is discovered – is advertised by the patent holder and sold in the market alongside the old product. This game is analysed first within a general model pointing out the basic properties and trade-offs. Then we employ a standard informative advertising model to derive more explicit results and illustrate specific features of this type of market structure. A main finding is that the incumbent 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.

Keywords: Marketing; Research and 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 potential 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. We consider a two-period model with the following sequence of events. First, the incumbent advertises and sells the “breakthrough” product. Second, the incumbent and the potential entrant simultaneously invest in R&D to develop a new product. Third, the new product – if it is discovered – is advertised by the patent holder and sold in the market alongside the old product. The two first events constitute the first period, where the incumbent is the monopolist in the market. Thus, the breakthrough product is sold in both periods, whereas the new product is sold in the second period only. 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. This game is analysed first within a general model pointing out the basic properties and trade-offs. Then we employ a standard informative advertising model to derive more explicit results and illustrate specific
features of this type of market structure.

We restrict attention to 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. 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, 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, while the R&D expenses varied between 11 and 15%. The importance of the non-pricing 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 mainly is due to health insurance and/or physicians' ignorance of price in the prescription choice.

Our paper focus on innovations of competing (differentiated) products, and not on innovations of completely new treatments. 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

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1 There are several papers on patents that abstract from pricing strategies, see e.g., Langinier (2004), Waterson (1990),... 
2 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. 
3 This is likely to be the case in other industries as well.
and can pose a competitive threat to established drugs with the same or similar indications. Interestingly, 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. Moreover, 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 that the vast amount of innovations is developments of competing substitute drugs, rather than completely new drugs.

We analyse in detail the incentives of the incumbent firm to use advertising - not only to increase the returns in the monopoly period - but importantly also to \textit{strategically} reduce a potential entrant’s incentive to invest in R&\textit{D} to develop a competing product. The key mechanism in the relationship between advertising and R&\textit{D} incentives is the incumbent’s ability to influence ex post payoffs of the potential entrant through first-period advertising of the existing product (references of similar cases). We demonstrate that a necessary condition for strategic over-investment in advertising ex ante by the incumbent is that advertising decisions are strategic substitutes. If this is the case, then 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.

We also analyse how first-period advertising affects the R&\textit{D} incentives. We show that the effect of an increase in ex ante advertising by the incumbent involves a direct and (potentially) an indirect effect on R&\textit{D} investments, and that the sign is generally ambiguous. The direct effect is negative with respect to R&\textit{D} efforts by both firms. We provide conditions for ex ante advertising to reduce the level of R&\textit{D} effort. Two conditions: (i) Advertising must be strategic substitutes, in the Bulow, Klemperer sense. Otherwise, ex post rent-shifting is not possible. (ii) The success functions of the R&\textit{D} race must not be too strong strategic complements nor too strong strategic substitutes. The latter condition is clearly technical but we discuss the set of functional forms of which this may hold. Given these two conditions, two interesting implications arise. First, \textit{advertising and R&\textit{D} are substitute strategies} for the incumbent firm. Second, \textit{increased advertising will reduce overall investments in R&\textit{D}}, thereby reducing the probability that a new product will be introduced on the market. Finally, we show that optimal first-period advertising involves both a \textit{direct rent effect} and a \textit{strategic R&\textit{D} effect}. The former effect basically trades off the effect of ex ante advertising on first-period and second-period profits. The second effect is more complicated, and involves the effect of ex ante advertising on both
the incumbent’s and the potential entrant’s R&D incentives. We provide the exact conditions for over-investment in first-period advertising to occur.

As an example we use a standard informative advertising model, as introduced by Butters (1977), Grossman and Shapiro (1984), and others - though, assuming exogenous prices - to illustrate the basic features of the general model. This framework clearly proofs to satisfy the above mentioned conditions. Informative advertising serves as a device to shift ex post profits, inducing the incumbent to strategically over-invest in advertising in order to lower the probability of a new product to be developed.

Finally, we discuss some welfare and policy implications. In particular, we analyse welfare effects of a more strict regulation on advertising and a higher regulated price (or more generous patent system). These issues are especially relevant for the pharmaceutical industry, since most countries exhibit regulations on both marketing and prices of prescription drugs. By conducting the analysis within the informative advertising framework, we take the most positive view of advertising. In our setting advertising is potentially detrimental to welfare since it reduces R&D investments and the likelihood of ex post competition in the market. Obviously, if advertising were purely persuasive it would be optimal for the government to prohibit these activities. However, since advertising in general, and perhaps especially for the pharmaceutical market, also provides information, the welfare and policy implications are less clear-cut. This is also often the argument raised to defend promotional activities in the pharmaceutical market. Assuming the extreme case of advertising being purely informative, we analyse whether or not a strict regulation on advertising is optimal. Interestingly, we find that strict restrictions on advertising are desirable only for high (regulated) prices, while the opposite is true for low (regulated) prices. In terms of policy recommendations we conclude 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.

2 A general model

Consider a therapeutical market with potentially two horizontally differentiated patented products (prescription drugs). Assume that one

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4If we assumed advertising to be purely persuasive, then, obviously, the socially optimal solution would be to completely prohibit advertising. In most cases, including pharmaceutical marketing, advertising would contain elements of persuasion and information.
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) in the race to discover the new drug. In correspondence with the practice in most European countries, we assume that drug prices are regulated, 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 (firm 1) wins the R&D race; and (iii) a duopoly if the entrant (firm 2) 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 therapeutical market. More specifically, the demand for drug $i$ in the second 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.

\footnote{legg inn noen passende referanser om lav priselastisitet.}
In the first (monopoly) period, demand for the “breakthrough” drug (product 1) is given by \( D_1(A_1, 0) \), 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 \( \frac{\partial K}{\partial A_i} > 0 \) and \( \frac{\partial^2 K}{\partial A_i^2} > 0 \). We assume that all 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

\[
pD_2(A_1, A_2) - K(A_2),
\]

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

\[
p \frac{\partial D_2(A_1, A_2)}{\partial A_2} - \frac{\partial K(A_2)}{\partial A_2} = 0.
\]

Let \( A^P_2(A_1) \) define the best response of the entrant in the duopoly case, given by the solution to \( () \). By total differentiation of \( () \), we can easily obtain

\[
\frac{\partial A^P_2(A_1)}{\partial A_1} = -\frac{p (\partial^2 D_2/\partial A_1 \partial A_2)}{p (\partial^2 D_2/\partial A_2^2) - \partial^2 K/\partial A_2^2}.
\]

Applying the second-order condition, we see that \( \frac{\partial A^P_2(A_1)}{\partial A_1} < 0 \) if \( \partial^2 D_2/\partial A_1 \partial A_2 < 0 \). In this case the decision variables are strategic substitutes, 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 profits for firm 1 is given by
\[ p \left[ D_1 (A_1, A_2) + D_2 (A_1, A_2) \right] - K (A_2). \]
The first-order condition for optimal advertising of the new product is then
\[ p \left( \frac{\partial D_1 (A_1, A_2)}{\partial A_2} + \frac{\partial D_2 (A_1, A_2)}{\partial A_2} \right) - \frac{\partial K (A_2)}{\partial A_2} = 0, \]
which defines a best response function \( A_2^M (A_1) \). Comparing (1) and (2), 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 (1) we derive
\[ \frac{\partial A_2^M (A_1)}{\partial A_1} = \frac{p (\partial^2 D_1 / \partial A_1 \partial A_2 + \partial^2 D_2 / \partial A_1 \partial A_2)}{p (\partial^2 D_1^2 / \partial A_2^2 + \partial^2 D_2 / \partial A_2^2) - \partial^2 K / \partial A_2^2}. \]
Equivalent to the duopoly case, we see 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 make the assumption that \( \partial^2 D_i / \partial A_i \partial A_j \leq 0 \).

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:\(^6\)

Single-product monopoly:
\[ V_1^S (A_1) := p D_1 (A_1, 0). \]
Multi-product monopoly:
\[ V_1^M (A_1) := p \left[ D_1 (A_1, A_2^M (A_1)) + D_2 (A_1, A_2^M (A_1)) \right] - K (A_2^M (A_1)). \]
Duopoly:
\[ V_1^D (A_1) := p D_1 (A_1, A_2^D (A_1)), \quad V_2^D (A_1) := p D_2 (A_1, A_2^D (A_1)) - K (A_2^D (A_1)). \]

\(^6\) We use the following notation: \( V_i^z \) denotes second-period payoffs for firm \( i \) in market structure \( z \), where \( i = 1, 2 \) and \( z = S(\text{ingle-product monopoly}), M(\text{ulti-product monopoly}), D(\text{uopoly}). \)
Entirely plausible assumptions on the demand functions would ensure that $V^M_1 (A_1) > V^S_1 (A_1) > V^D_1 (A_1)$. Applying the Envelope Theorem, the effects of first-period advertising on second-period profits are easily derived:

$$\frac{\partial V^S_1 (A_1)}{\partial A_1} = p \frac{\partial D_1 (A_1, 0)}{\partial A_1} > 0,$$

$$\frac{\partial V^M_1 (A_1)}{\partial A_1} = p \left[ \frac{\partial D_1 (A_1, A^M_2 (A_1))}{\partial A_1} + \frac{\partial D_2 (A_1, A^M_2 (A_1))}{\partial A_1} \right] > 0,$$

$$\frac{\partial V^D_1 (A_1)}{\partial A_1} = p \left[ \frac{\partial D_1 (A_1, A^D_2 (A_1))}{\partial A_1} + \frac{\partial D_2 (A_1, A^D_2 (A_1))}{\partial A_2} \frac{\partial A^D_2 (A_1)}{\partial A_1} \right] > 0,$$

$$\frac{\partial V^2_1 (A_1)}{\partial A_1} = p \frac{\partial D_2 (A_1, A^D_2 (A_1))}{\partial A_1} < 0.$$ 

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 (1), 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 (1).

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 $\partial D_2 / \partial A_i < 0$ and $\partial^2 D_1 / \partial A_i \partial A_j \leq 0$, it follows that $\partial V^S_1 (A_1) / \partial A_1 \geq \partial V^D_1 (A_1) / \partial A_1 > \partial V^M_1 (A_1) / \partial A_1$, 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-á-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 \( \partial z_i / \partial x_i > 0, \partial z_i / \partial x_j < 0, \partial^2 z_i / \partial x_i^2 \leq 0, \partial^2 z_i / \partial x_j^2 \geq 0 \) 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 probability that a new drug will be 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

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

which can be re-arranged to

\[
B_1 = V_1^S + z_1(x_1, x_2) \left[ V_1^M - V_1^S \right] - z_2(x_1, x_2) \left[ V_1^S - V_1^D \right] - C(x_1).
\]

The expected second-period profit for the possible entrant (firm 2) is given by

\[
B_2 = z_2(x_1, x_2) V_2^D - C(x_2).
\]

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

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

\[
\frac{\partial B_2}{\partial x_2} = \frac{\partial z_2}{\partial x_2} V_2^D - \frac{\partial C}{\partial x_2} = 0.
\]

Our assumptions on \( z_i(\cdot) \) and \( C(\cdot) \) ensure that the second-order conditions are met.\(^7\) We also assume that the determinant of the Jacobian matrix \( J = \begin{bmatrix} \partial^2 B_1 / \partial x_1^2 & \partial^2 B_1 / \partial x_2 \partial x_1 \\ \partial^2 B_2 / \partial x_2 \partial x_1 & \partial^2 B_2 / \partial x_2^2 \end{bmatrix} \) is positive, guaranteeing uniqueness of the equilibrium.\(^8\)

\(^7\)The second-order conditions are given by

\[
\frac{\partial^2 B_1}{\partial x_i^2} = \frac{\partial^2 z_1}{\partial x_i^2} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_i^2} (V_1^S - V_1^D) - \frac{\partial^2 C}{\partial x_i^2} < 0,
\]

\[
\frac{\partial^2 B_2}{\partial x_2^2} = \frac{\partial^2 z_2}{\partial x_2^2} V_2^D - \frac{\partial^2 C}{\partial x_2^2} < 0.
\]

\(^8\)See Appendix A for the explicit expression of \(|J|\), with the corresponding condition for \(|J| > 0\).
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:

\[
\frac{\partial x_1^*}{\partial A_1} = \frac{-\partial^2 B_1 / \partial A_1 \partial x_1 \partial^2 B_1 / \partial x_1 \partial x_2}{-\partial^2 B_1 / \partial A_1 \partial x_2 \partial^2 B_2 / \partial x_2^2} \frac{|J|}{|J|}
\]

\[
\frac{\partial x_2^*}{\partial A_1} = \frac{-\partial^2 B_1 / \partial x_1^2 \partial x_2}{\partial^2 B_2 / \partial x_2 \partial x_1 - \partial^2 B_2 / \partial A_1 \partial x_2} \frac{|J|}{|J|}
\]

From \( |J| > 0 \), it follows that

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

and

\[
\text{sign} \left( \frac{\partial x_2^*}{\partial A_1} \right) = \text{sign} \left\{ -\Psi \left( \frac{\partial z_2}{\partial x_2} \frac{\partial V_2^D}{\partial A_1} \right) + \Omega \left( \frac{\partial^2 z_2}{\partial x_2 \partial x_1} V_2^D \right) \leq 0 \right\},
\]

where

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

\[
\Phi := \frac{\partial^2 z_1}{\partial x_2 \partial x_1} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_2 \partial x_1} (V_1^S - V_1^D) \leq 0,
\]

\[
\Psi := \frac{\partial^2 z_1}{\partial x_2^2} (V_1^M - V_1^S) - \frac{\partial^2 z_2}{\partial x_2^2} (V_1^S - V_1^D) - \frac{\partial^2 C}{\partial x_1^2} < 0.
\]

An increase in ex ante advertising by the incumbent has a direct and (potentially) an indirect effect on R&D efforts by 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 (–) – 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 (). 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 \( \frac{\partial V^S_1}{\partial A_1} \geq \frac{\partial V^D_1}{\partial A_1} > \frac{\partial V^M_1}{\partial A_1} \), and is 
reflected in the first term of (). Note that the relative sizes of these 
marginal effects together with \( \frac{\partial z_i}{\partial x_i} > \frac{\partial z_j}{\partial x_j} \) ensure that \( \Omega < 0 \).

If \( \frac{\partial^2 z_i}{\partial x_i \partial x_j} = 0 \), the direct effects unambiguously ensure that 
increased advertising of the old product will reduce the R&D incentives 
for both firms. However, if \( \frac{\partial^2 z_i}{\partial x_i \partial x_j} \neq 0 \) there are additional indirect 
effects that could work in the opposite direction. The second (and last) 
terms of (–) and () 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 substitutes; that is, if \( \frac{\partial^2 z_i}{\partial x_i \partial x_j} < 0 \). 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 \( \frac{\partial z_i}{\partial A_1} < 0 \) and \( \frac{\partial z_i}{\partial A_2} < 0 \). 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 pe-
riod. For simplicity, we abstract from discounting. The incumbent firm’s 
expected ex ante profits, denoted \( \Pi_1 \), are then given by

\[
\Pi_1 (A_1) = \theta V^S_1 (A_1) + B_1 (x^*_1 (A_1), x^*_2 (A_1), A_1) - K (A_1).
\]

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

\[
\frac{\partial \Pi_1 (A_1, z_1, z_2)}{\partial A_1} = (1 + \theta) \frac{\partial V^S_1}{\partial A_1} + z_1 \left( \frac{\partial V^M_1}{\partial A_1} - \frac{\partial V^S_1}{\partial A_1} \right) + z_2 \left( \frac{\partial V^D_1}{\partial A_1} - \frac{\partial V^S_1}{\partial A_1} \right) - \frac{\partial K}{\partial A_1} = 0.
\]

When deciding the optimal level of first-period advertising, the incum-
 bent 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. Anticipating \( x_1^* (A_1) \) and \( x_2^* (A_1) \) the incumbent sets \( A_1 \) to maximise (\( ) \)). The first-order condition for an optimal level of advertising can be conceptualised and expressed as follows:

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

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

\[
\left( \frac{\partial z_1}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} + \frac{\partial z_1}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} \right) (V_1^M - V_1^S) + \left( \frac{\partial z_2}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} + \frac{\partial z_2}{\partial x_2} \frac{\partial x_2^*}{\partial A_1} \right) (V_1^D - V_1^S) - \frac{\partial C}{\partial x_1} \frac{\partial x_1^*}{\partial A_1}.
\]

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 overinvest or underinvest in advertising in order to influence the amount of R&D that is undertaken by potential rivals. Under the assumptions that \( \frac{\partial x_2^*}{\partial A_1} < 0 \) and \( \frac{\partial x_1^*}{\partial A_1} < 0 \), 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 \( \frac{\partial z_1}{\partial x_2} \frac{\partial x_1^*}{\partial A_1} > \left| \frac{\partial z_1}{\partial x_1} \frac{\partial x_1^*}{\partial A_1} \right| \) – the first term of (\( ) \) will contribute in the direction of overinvestment 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

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9The dynamic consistency of the model requires that \( \theta \) is not too low. Otherwise, the incumbent firm might have an incentive to increase advertising of the old product ex post.
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 $\frac{\partial^2 z}{\partial x_2 \partial A_1} > \frac{\partial^2 z}{\partial x_1 \partial A_1}$ – the second term of (1) will also contribute in the direction of overinvestment 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).\(^{10}\) 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 of 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.\(^{11}\) With two products in the market, consumers who are informed about both products buy either of the products with probability $\frac{1}{2}$.\(^{12}\) If a fraction $A_i$ ($A_j$) of consumers are informed about drug $i$ ($j$), second-period demand for drug $i$ is given by

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

Note that $\frac{\partial^2 D_i}{\partial A_i \partial A_j} = -\frac{1}{2}$, 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. Straight-

---

\(^{10}\)This approach has been widely used in the advertising literature. See e.g., .......

\(^{11}\)More specifically, we assume that consumers buy one unit in the second period and $\theta \leq 1$ units in the first period.

\(^{12}\)We can interpret this as a Hotelling model with uniform distribution of consumers, symmetric location of products and ads reaching consumers randomly.
forward calculations yield

\[ V_1^S(A_1) = pA_1, \]
\[ V_1^M(A_1) = p \left[ A_1 + \frac{p}{2k} (1 - A_1)^2 \right], \]
\[ V_1^D(A_1) = pA_1 \left[ 1 - \frac{p}{4k} (2 - A_1) \right], \]
\[ V_2^D(A_1) = \frac{p^2}{8k} (2 - A_1)^2. \]

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:

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

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 \((\cdot)(\cdot)\), and solve for the optimal values of \( x_i \) in the R&D competition:

\[ x_1^*(A_1) = \frac{2p^2 \left[ 32ck(1 - A_1)^2 - p^2 \left[ 2 - 3A_1(2 - A_1) \right] (2 - A_1)^2 \right]}{128c^2k^2 - p^2 \left[ 2 - 3A_1(2 - A_1) \right] (2 - A_1)^2}, \]
\[ x_2^*(A_1) = \frac{4p^2 (2 - A_1)^2 \left[ 4ck - p^2 (1 - A_1)^2 \right]}{128c^2k^2 - p^2 \left[ 2 - 3A_1(2 - A_1) \right] (2 - A_1)^2}. \]

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

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

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 complicity of the model makes analytical solutions infeasible. Instead, we present the results in the form

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\(^{13}\)This particular success function has the following properties: \( \frac{\partial z_i}{\partial x_i} > 0, \frac{\partial z_i}{\partial x_j} < 0, \frac{\partial^2 z_i}{\partial x_i^2} = \frac{\partial^2 z_i}{\partial x_j^2} = 0 \) and \( \frac{\partial^2 z_i}{\partial x_i \partial x_j} < 0 \).
of numerical examples, where we choose to set $\theta = \frac{1}{10}$. Tables 1-3 report equilibrium values of first-period advertising and R&D investments for different values of the key parameters $k$, $c$ and $p$.

Table 1: Equilibrium values of $A_1$.

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

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

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Table 4: Equilibrium values of $x_1$.

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Table 5: Equilibrium values of $x_2$.

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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. 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 \( c \) 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), since higher R&D costs generally make advertising a more effective means of influencing R&D efforts. 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.

Finally, let us consider the effect 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 increase 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 has 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 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.

4 Welfare and policy implications

Advertising and welfare is quite often a complicated issue, in particular so if advertising contains elements of persuasion, which may potentially change individuals’ preferences. It is common to distinguish between informative and persuasive advertising. The social benefit of informative advertising is usually direct in the sense that a larger fraction of consumers becomes aware of the product and thus consumes this (given a non-negative utility). The social benefits of persuasive advertising, however, are usually indirect. For instance, persuasive advertising may accommodate entry and thus foster competition and a larger variety of products (some references). In our case, advertising has a potential negative indirect effect, namely that it lowers the incentive for an entrant to invest in R&D. Thus, purely persuasive advertising will indeed be detrimental to welfare and should thus be banned.

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. Obviously, this complicates welfare analysis of advertising even further. Below we therefore analyse welfare properties within the informative advertising approach.

Let us start with specifying the consumer surplus in the potential different ex post market structures. In the single-product case, where neither firm succeed in developing the new drug, consumer surplus is given by

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

where $v > t > 0$. As usual $v$ is 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 (mismatch costs). Considering pharmaceuticals $v$ can be interpreted as the effectiveness of the drug treatment and $t$ as a measure of potential side-effects, contradictions, etc.

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14 The demand function in () relies on the assumption that every consumer has a non-negative net utility from consuming either drug. It is easily checked that this is always true if $v > t$. 
In the multi-product case, where either the incumbent or the entrant discovers the new product, the consumer surplus is given by

\[ CS(A_1, A_2) = A_1 (1 - A_2) \int_0^1 (v - ty) \, dy + A_2 (1 - A_1) \int_0^1 (v - t (1 - y)) \, dy \]

\[ + A_1 A_2 \left( \int_0^{\frac{1}{2}} (v - ty) \, dy + \int_{\frac{1}{2}}^1 (v - t (1 - y)) \, dy \right) \]

\[ = [A_1 + A_2 - 2A_1 A_2] \left( v - \frac{t}{2} \right) + A_1 A_2 \left( v - \frac{t}{4} \right). \]

Observe that the consumer surplus is constituted by two qualitatively different segments; the fraction of partially informed physicians, i.e., \( A_i (1 - A_j) \), and the fraction of fully informed physicians, i.e., \( A_i A_j \). Partially informed physicians prescribe the drug they are aware, with the corresponding mismatch cost \( (v - t/2) \), while fully informed physicians trade off the two drug treatments, generating a mismatch cost equal to \( (v - t/4) \).

We can now derive the first-best levels of advertising and R&D. Assume first that the new drug (drug 2) is discovered. Total (ex post) welfare in the multi-product case is then given by:

\[ \Psi(A_1, A_2) = CS(A_1, A_2) - \frac{k}{2} A_2^2. \]

Maximising \( \Psi \) with respect to \( A_2 \), we obtain the first-best advertising level of the new drug:

\[ A_{2FB}^2 (A_1) = \frac{4v (1 - A_1) - t (2 - 3A_1)}{4k}. \]

Notably, the first-best advertising of drug 2 depends on \( v, t, k \) and \( A_1 \). For a given \( A_1 \), advertising of drug 2 is increasing in \( v \) and decreasing in \( k \), as one would intuitively expect. However, the effect of \( t \) depends on the initial level of \( A_1 \). If \( A_1 \) is less (more) than \( 2/3 \) for some reason (e.g., a high \( \theta \)), then \( A_2 \) is decreasing (increasing) in \( t \). By inspection, we see that \( A_{2FB}^2 \geq 0 \) for any \( A_1 \) due to the assumption of \( v > t \). However, we need to ensure that \( A_{2FB}^2 \leq 1 \), which is true if

\[ A_1 > \frac{4 (v - k) - 2t}{4v - 3t}. \]

Basically, this restriction is non-binding if assume that \( k \) is sufficiently high, i.e., \( k > v - t/2 \).
The socially optimal levels of R&D are derived by balancing the expected gain in consumer surplus against the investment costs of R&D. Expected welfare can be written as follows

\[ \Phi (A_1, x_1, x_2) = CS (A_1, x_1, x_2) - \frac{C}{2} (x_1^2 + x_2^2), \]

with

\[ CS (A_1, x_1, x_2) = \left[ 1 - z_1 (x_1, x_2) - z_2 (x_1, x_2) \right] A_1 \left( v - \frac{t}{2} \right) \]

\[ + \left[ z_1 (x_1, x_2) + z_2 (x_1, x_2) \right] \left\{ \left[ A_1 + A_2^{FB} - 2A_1A_2^{FB} \right] \left( v - \frac{t}{2} \right) + A_1A_2^{FB} \left( v - \frac{t}{4} \right) \right\}. \]

Maximising () with respect to \( x_1 \) and \( x_2 \) we get the following first-order conditions:

\[ \frac{\partial W}{\partial x_i} = \frac{[4v (1 - A_1) - t (2 - 3A_1)]^2}{16k} (1 - x_j) - cx_i = 0, \]

where \( i, j = 1, 2 \) and \( i \neq j \). As in the general set-up, first-best R&D should be identical. Imposing symmetry, i.e., \( x_i = x_j = x \), we derive the following expression of first-best R&D:

\[ x^{FB} (A_1) = \frac{[4v (1 - A_1) - t (2 - 3A_1)]^2}{[4v (1 - A_1) - t (2 - 3A_1)]^2 + 16ck}. \]

It is easily verified that if \( A_1 \) is high for some reason (e.g., a high \( \theta \)), then the R&D investments should be reduced. The reason is that a high \( A_1 \) implies a lower expected gain in consumer surplus from discovering drug 2. As expected \( x^{FB} \) is decreasing in \( c \). For a given level of \( A_1 \), it is also decreasing in \( k \), which is related to the level of \( A_2^{FB} \).

Finally, when deriving first-best advertising of the existing drug (drug 1), the social planner needs to take into account the length of the first-periode also, as measured by \( \theta \). Total (ex ante) welfare is thus given by

\[ W (A_1) = \theta CS^S (A_1, 0) + CS (A_1, 2x^{FB}) - c \left( x^{FB} \right)^2 - \frac{k}{2} A_1^2. \]

First-best is derived by maximised by () with respect to \( A_1 \).

\[ \frac{\partial W}{\partial A_1} = (1 + \theta) \left( v - \frac{t}{2} \right) - (z_1 + z_2) \left( \frac{4v - 3t}{8k} \right) \Omega - kA_1 = 0, \]
\[
\frac{\partial W}{\partial x_1} = \frac{1}{16k} (1 - x_2) \Omega^2 - cx_1 = 0, \\
\frac{\partial W}{\partial x_2} = \frac{1}{16k} (1 - x_1) \Omega^2 - cx_2 = 0,
\]

where \( \Omega \equiv 4v (1 - a_1) - t (2 - 3a_1) \).

In Table 6 we provide a numerical illustration of first-best R&D and advertising for different values of \( t \). We see that \( A_1 \) is decreasing in \( t \), while \( A_2, x_1 \) and \( x_2 \) are increasing in \( t \). The explanation is straightforward. When the mismatch costs are high (e.g., severe side-effects), it is socially desirable to spend much on R&D to discover a new substitute drug with different characteristics. Moreover, in this situation it is also desirable to equalise the spending of advertising of the two drugs so that the probability that a physician is fully informed - rather than partially informed - become higher. The convex advertising technology enforces this incentive. On the other hand, if \( t \) (e.g., weak side-effects) is small, there is little gain to discovering a new drug, and thus R&D investments should be small. In this case also the disutility of being prescribed a less suitable drug is small. Consequently, it is socially optimal to direct advertising spending toward the existing drug rather than a potential new drug.

<table>
<thead>
<tr>
<th>( t )</th>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>( x )</th>
<th>( W )</th>
<th>( CS )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.609</td>
<td>0.774</td>
<td>0.514</td>
<td>5.980</td>
<td>7.905</td>
</tr>
<tr>
<td>2</td>
<td>0.602</td>
<td>0.778</td>
<td>0.519</td>
<td>5.610</td>
<td>8.278</td>
</tr>
<tr>
<td>3</td>
<td>0.592</td>
<td>0.782</td>
<td>0.525</td>
<td>5.239</td>
<td>7.905</td>
</tr>
<tr>
<td>4</td>
<td>0.579</td>
<td>0.789</td>
<td>0.533</td>
<td>4.866</td>
<td>7.532</td>
</tr>
<tr>
<td>5</td>
<td>0.560</td>
<td>0.800</td>
<td>0.545</td>
<td>4.491</td>
<td>7.158</td>
</tr>
<tr>
<td>6</td>
<td>0.530</td>
<td>0.817</td>
<td>0.564</td>
<td>4.109</td>
<td>6.784</td>
</tr>
<tr>
<td>7</td>
<td>0.473</td>
<td>0.850</td>
<td>0.598</td>
<td>3.715</td>
<td>6.416</td>
</tr>
<tr>
<td>8</td>
<td>0.310</td>
<td>0.952</td>
<td>0.683</td>
<td>3.275</td>
<td>6.121</td>
</tr>
</tbody>
</table>

Assumptions: \( \theta = 1/10, k = 5, c = 1, v = 10. \)

Comparing first-best advertising and R&D with the equilibrium outcomes, it is evident that the rankings depend on the levels of \( p \) relative to \( t \) and \( v \). Table 1-5 illustrates the effect of changes in \( p \) on equilibrium advertising and R&D. Comparing this with the first-best values in Table 6, there are two interesting observations: First, if \( t \) is high and \( p \) is low, then there is a tendency of under-investment in R&D, \( x_i \), and advertising of the new drug, \( A_2 \). The reason is that a high \( t \) yields large social gains, while a low \( p \) yields low private gains, of discovering the new product. Second, if both \( t \) and \( p \) are high, there is a strong tendency of too much
advertising of the existing product. A high \( t \) implies that it is socially desirable to develop and advertise the new drug (almost) at the same scale as the existing product. However, a high \( p \) makes it very profitable for the incumbent firm to advertise the existing product. The reason for this is two-fold: Extensive advertising of the existing drug (i) increases the returns during the patent period, and (ii) limits the potential entrant’s incentive to invest in R&D and thus increases the probability that the incumbent remain a monopolist position.

Finally, let us briefly examine some policy implications with respect to regulation of drug marketing. Notably, in most countries there exist a wide set of restrictions on 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. Finally, health authorities require that the disclaimer stating the effectiveness, side-effects, contraindications, etc., is often required to be printed along with an advertisement.

An interesting question in this context is whether or not strict regulation on drug advertising is justified? To answer this question we need to evaluate the welfare function in \( f() \) for the equilibrium advertising and R&D, as derived in section 3. Moreover, we interpret the advertising cost parameter \( k \) as a measure of the extent of advertising regulation, with high (low) values of \( k \) reflecting extensive (few) restrictions. Once more we rely on numerical calculations, and Table 7 below provides total welfare for different values of \( k, c \) and \( p \).

<table>
<thead>
<tr>
<th>( c = 1 )</th>
<th>( c = 3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p )</td>
<td>( k = 5 )</td>
</tr>
<tr>
<td>1</td>
<td>0.254</td>
</tr>
<tr>
<td>2</td>
<td>0.237</td>
</tr>
<tr>
<td>3</td>
<td>-0.117</td>
</tr>
<tr>
<td>4</td>
<td>-0.969</td>
</tr>
</tbody>
</table>

Assumptions: \( \theta = 1/10, \, v = 2, \, t = 1 \)

Interestingly, we see that strict restrictions on advertising, i.e., a high \( k \), are desirable only in health care systems with very generous price regulation (or patent system), i.e., a high \( p \). The argument is that when \( p \) is high (relative to \( t \)) firms tend to overinvest in both advertising and R&D from a welfare perspective, as explained above. Increasing the restrictions on advertising in this situation improve welfare by directly reducing advertising and indirectly reducing the incentive to invest in R&D. This
is clearly observed for the cases of $p = 3, 4$ in table 7. However, under strict price regulation (or less generous patent system) more restrictions on advertising actually makes things worse. In this situation firms initially invest too little in advertising and R&D, and a higher $k$ will enforce the under-investment incentive. A similar pattern is observed for R&D costs, measured by $c$.

In terms of policy recommendations we can conclude from this exercise 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.

A The Jacobian from the R&D game

From (1)-(2), we can derive

$$|J| = \left( \frac{\partial^2 z_1}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_2^2} - \frac{\partial^2 z_1}{\partial x_2 \partial x_1} \frac{\partial^2 z_2}{\partial x_1 \partial x_2} \right) (V_1^M - V_1^S) V_2^D > 0$$

$$- \left( \frac{\partial^2 z_2}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_2^2} - \left( \frac{\partial^2 z_2}{\partial x_1 \partial x_2} \right)^2 \right) (V_1^S - V_1^D) V_2^D > 0$$

$$\frac{\partial^2 C}{\partial x_1^2} \frac{\partial^2 z_2}{\partial x_1^2} (V_2 - V_1) - \frac{\partial^2 z_2}{\partial x_1^2} (V_1 - V_3) - \frac{\partial^2 C}{\partial x_1^2} < 0$$

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

B Comparative statics in the informative advertising model

From (1) and (2) we derive

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

and

$$\frac{\partial x_2^* (A_1)}{\partial A_1} = - \frac{8p^2 (2 - A_1) (128c^2 k^2 \psi + \phi)}{(128c^2 k^2 - p^4 (2 - 3A_1 (2 - A_1)) (2 - A_1)^2)^2}.$$
where
\[
\begin{align*}
\mu & := 32ck (1 - A_1) - p^2 (2 - A_1) (8 - 3A_1 (5 - 2A_1)), \\
\sigma & := p^4 (1 - A_1) (2 - A_1) (3A_1 (3 + A_1 (A_1 - 3)) - 4), \\
\psi & := 4ck - p^2 (1 - A_1) (3 - 2A_1), \\
\phi & := p^4 (1 - A_1) (2 - A_1)^3 (12ck - p^2).
\end{align*}
\]
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 () and (), respectively. Since the values of both numerators are increasing in \(c\), it suffices to make an evaluation at the limit \(c \to \bar{c}\). Straightforward computation yields
\[
\lim_{c \to \bar{c}} (4ck\mu - \sigma) = p^4A_2^2 (22 - 36A_1 + 18A_1^2 - 3A_1^3) > 0 \text{ for } A_1 \in [0, 1]
\]
and
\[
\lim_{c \to \bar{c}} (128c^2k^2\psi + \phi) = 2p^6A_1^2 (2 - A_1) (5 - A_1) > 0 \text{ for } A_1 \in [0, 1].
\]
It follows that \(\partial x_1^*(A_1)/\partial A_1 < 0\) and \(\partial x_2^*(A_1)/\partial A_1 < 0\) for \(c > \bar{c}\) and \(A_1 \in [0, 1]\).

References


